Archaeology of Digital Environments
Tools, Methods, and Approaches

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Abstract

Digital archaeologists use digital tools for conducting archaeological work, but their potential also lies in applying archaeological thinking and methods to understanding digital built environments (i.e., software) as contemporary examples of human settlement, use, and abandonment. This thesis argues for digital spaces as archaeological artifacts, sites, and landscapes that can be investigated in both traditional and non-traditional ways. At the core of my research is the fundamental argument that human-occupied digital spaces can be studied archaeologically with existing and modified theory, tools, and methods to reveal that human occupation and use of synthetic worlds is similar to how people behave in the natural world. Working digitally adds new avenues of investigation into human behavior in relation to the things people make, modify, and inhabit. In order to investigate this argument, the thesis focuses on three video game case studies, each using different kinds of archaeology specifically chosen to help understand the software environments being researched: 1) epigraphy, stylometry, and text analysis for the code-artifact of *Colossal Cave Adventure*; 2) photogrammetry, 3D printing, GIS mapping, phenomenology, and landscape archaeology within the designed, digital heritage virtual reality game-site of *Skyrim VR*; 3) actual survey and excavation of 30 heritage sites for a community of displaced human players in the synthetic landscape of *No Man's Sky*. My conclusions include a blended approach to conducting future archaeological fieldwork in digital built environments, one that modifies traditional approaches to archaeological sites and material in a post/transhuman landscape. As humanity continues trending towards constant digital engagement, archaeologists need to be prepared to study how digital places are settled, used, and abandoned. This thesis takes a step in that direction using the vernacular of games as a starting point.

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I declare that this thesis is a presentation of original work and I am the sole author. This work has not been previously presented for an award at this, or any other university. All sources are acknowledged as References.

1

Introduction

"Archaeology is the science of new things."
–Gavin Lucas (2013)

1.1. Introduction

Video games can all too easily be dismissed as juvenile pursuits. Yet their ubiquitous presence on computers, smartphones, tablets, and gaming consoles, in print and online advertising, and in a controlling market share of media sales, driven by an industry more lucrative than Hollywood that employs tens of thousands of people, demands the attention of archaeologists. Not only that, but video games host online human cultures, the communities of which regularly spill out into the "real" world. These sites of digital interactive entertainment offer new avenues of digital archaeology and digital heritage to explore, where the archaeologist can conduct archaeology of digital things and places, and where heritage is itself born-digital, not merely a reconstruction or preservation of "real" heritage through digital tools and means. Players make video games their own through interaction, modification, and community-building, creating complex and often historical meanings involving digital material culture and digital heritage mediated through screens. Video games are human constructions built to facilitate human interaction in digital space. The research questions central to this thesis are therefore: can digital built environments be studied archaeologically, and if so, how, and to what ends?

This thesis attempts to demonstrate through three case studies that digital built environments (i.e., software applications) are artifacts, sites, and landscapes that can be investigated archaeologically using current and modified theory and tools. This chapter serves as a general introduction and literature review of the archaeology of digital things, specifically video games, which will prepare the field for excavation in Chapters 3 through 5. Readers will find a Glossary at the back of this thesis, which contains video game and technology terms with which some readers might be unfamiliar.

1.2. Archaeology of Digital Environments

Since 2002, video game archaeology has appeared in peer reviewed archaeological publications starting with Ethan Watrall's essay, "Interactive Entertainment as Public Archaeology," in the *SAA Archaeological Record*. Known more widely as "archaeogaming," this subdiscipline focuses on the archaeology both in and of video games. In blogs such as archaeogaming.com and playthepast.org, archaeologists and historians turn a critical eye to understanding video games within their broader context as interactive media featuring material culture, and to video games as examples of material culture in their own right. While much of the published literature over the past 15 years has focused more on the reception of archaeology and archaeologists by video game developers and players (see Holtorf 2005, 2007; Lowe 2013; Mol 2016), or on games that simulate historical places/events and provide digital reconstructions of real-world historical spaces (see Chapman 2016; Copplestone 2017a; Gardner 2007), it is my intent to study video games more as examples of "interactive digital built environments." As this thesis explains, video games are archaeological artifacts. They are also archaeological sites and even landscapes. Accordingly, this thesis considers born-digital, virtual spaces of agency and activity as the new frontier of 21st-century archaeology.

I am not the first person to approach digital spaces as places of human construction and interaction. Quentin Jones was the first to describe software as "settlements" (1997, n.p.). He defined these settlements via a set of four criteria: 1) a minimum level of interactivity; 2) a variety of communicators; 3) a minimum level of sustained membership; and 4) a virtual common-public-space where a significant portion of interactive group-CMCs [computer-mediated communications] occur. In the case of video games, I would update Jones' software "settlements" to "habitations" as will be described below. Jones' work pre-dated virtual worlds with graphical interfaces such as *Everquest* (1999), *Neverwinter Nights* (2002), and *Second Life* (2003), the last of which would ultimately contain human sites and settlements within a digital environment.

Jones' 1997 article also coined the term "cyber-archaeology" (which is also written as "cyberarchaeology"), differentiating it from the archaeology of non-digital places. Jones defines cyber-archaeology as "the systematic exploration of cyber-space at the level where cyber-material impacts on online behavior." In his conclusions, Jones also stressed that, "the research program of the cyber-archaeologist allows for the exploration of the basic building blocks of communication via empirical research into CMC." To Jones, communication between humans is central to understanding online settlements, and the interaction between humans in a digital environment could be studied archaeologically. Jones' work, however, stressed positivism/empiricism and processualism, all of which have been superseded in digital archaeology by more contemporary archaeological approaches such as post-processualism and new materialism, which get beyond quantification.

"Cyber-archaeology" would later mature and be co-opted by Maurizio Forte and colleagues. Forte's primary interests are in the digital visualization of cultural heritage and human communication facilitated by digital environments, as well as the kinds of archaeological data that can be retrieved through digital interaction (2016). These interests grew out of earlier projects including the now-defunct *Archaeopedia 3D* (Forte, 2009), an attempt at creating a networked space for teams of archaeologists and other heritage professionals to interact directly with each other inside a visualization of reconstructed cultural heritage. Forte and Kurillo (2010, p. 8) wrote that:

> we want to discuss if and how it is possible to use a cybernetic approach in the use of collaborative systems in archaeology in relation to a metaverse of social communities. The key idea is that the multi-vocality of the archaeological interpretation can be better expressed by a network of activities, as well as by a new hybrid communication between virtual worlds at different levels of detail and embodiment.

What the practitioners of cyberarchaeology failed to grasp, however, was that the communication, networking, and visualization technologies they sought to create from scratch already existed in video game engines (e.g., *Unity*) and networked online virtual worlds (e.g., *Second Life*) that continued to evolve side-by-side with networked communication platforms including *Slack* and *Discord*, not to mention *Skype* and *Google Hangouts*. Cyberarchaeology seems to get in its own way, focusing on creating new methods of team communication instead of using or modifying existing, more sophisticated technologies while documenting virtual reconstructions of built heritage. The preoccupation of cyberarchaeology with digital reconstructions of heritage neglects those born-digital heritage spaces created by people within digital environments—not to mention other forms of intangible and non-visual human practices—something this thesis addresses in its games-based case studies.

An alternative approach to understanding human heritage in digital spaces was first published in 2006 by Tom Boellstorff. He argued for ethnography to become a significant part of game studies, and he and his colleagues followed this up with the publication of the first handbook for virtual world ethnography (Boellstorff, et al., 2012). Boellstorff, et al. stated that:

> Ethnography, an approach for studying everyday life as lived by groups of people, provides powerful resources for the study of the cultures of virtual worlds. As ethnographers, what interests us about virtual worlds is not what is extraordinary about them, but what is ordinary. . . . We aim to study virtual worlds as valid venues for cultural practice, seeking to understand both how they resemble and how they differ from other forms of culture (2012, p. 1).

Boellstorff later argues that, "virtual worlds are forms of online socialities, which also include social network sites like Facebook, mobile phone apps, texting, blogs, e-mail, games, and streaming video" (2016, p. 394). He notices the wider context in which virtual worlds exist, and that they "leak" frequently into the natural world, blending the two. Boellstorff, et al. stated as much in 2012, writing:

> We want to make clear that we advocate that the study of virtual worlds be driven by research questions, no a priori methodological dogmas or preferences. . . . Our research will almost always include journeying to other online locales such as forums, blogs, and wikis. . . . Ethnography is a flexible, responsive methodology, sensitive to emergent phenomena and emergent research questions (2012, p. 6).

These synthetic spaces have crossover value in helping us understand the natural world: "virtual worlds can help broaden the conversation regarding what an enunciation of worlds might entail" (Boellstorff, 2016, p. 394). These digital hubs of human interaction persist; their human occupants shape the digital spaces they inhabit (Boellstorff, 2016, p. 395). While ethnography is anthropological, it can examine how people make, use, and discard things, and how they work within (and manipulate) dwellings, settlements, and landscapes. It is this principal that is the focus of this thesis: how have humans interacted with digital constructions over time?

Boellstorff's early work in *Second Life* (*SL*)[1] was advanced by Rodney Harrison (2009, pp. 75–106) who wanted to look at *SL* archaeologically: "I want to explore some of the ways in which *SL* not only allows those with an interest in material culture to explore issues of virtuality (in opposition to 'actuality'), but also to explore some issues

1. *Second Life* is not a game per se, but rather an online creative space for individuals and groups to occupy and use.

which emerge regarding the changing function of heritage within contemporary society" (2009, p. 78). In Harrison's view, digital heritage is no longer confined to digital space, but blends with the natural world through computer-mediated communication (CMC). His archaeological observations of heritage within *SL* show its early reception (Harrison, pp. 80–81), but as my case studies will show, these have changed over the past ten years. Games-based digital heritage is community-created, facilitated by the creation in-game of heritage spaces (which are later designated as such through community consensus), but are not necessarily concerned with origin myths or heritage focused on what Harrison calls the "ruling class" (2009, p. 80), favoring instead a democratization of a given platform. With the use of reddit and other platforms shared by online communities, there is now room for discussion and dissension on what constitutes heritage within a digital space. Heritage is no longer memorial-based, but now includes memories of past events as well as the preservation of player-constructed architecture in games such as *EVE: Online*, *Minecraft*, and *No Man's Sky*. Players also understand better that they live and create within a blended reality, making things in digital spaces while communicating about them outside of those spaces. Virtual communities later manifest in actual communities, which is the opposite of what Harrison described ten years ago (2009, p. 81). Despite the fact of Harrison claiming to "excavate" *Second Life*, however, he only observed heritage within that platform. "Practical" field archaeology had yet to occur in *SL* or in other online digital environments, but would as will be described below.

While Boellstorff's work focused largely on ethnography, and Harrison's work attempted to evaluate the material culture of the online community and platform of *Second Life*, Bonnie Nardi was one of the first researchers to attempt something similar within an actual video game, in her case the massively multi-player online role-playing game (MMORPG) *World of Warcraft* (aka *WoW*) (Nardi, 2010). Here she became a player-anthropologist contributing to the gameplay of her peers while also observing their behavior within this enormous play-space. Olivier Servais (2015) followed in Nardi's footsteps, bridging the gap between her work in *WoW* and Boellstorff's in *Second Life*. Servais cements the opinion that humans are at the center of their own digital universes, stating, "gamers are rarely passive users. Often, they create their own logic for the game, assigning to it meanings far exceeding those envisaged by the game's designers. Furthermore, they often integrate personal elements of their lives into the games, thus bringing new dimensions to the gaming experience" (2015, p. 368). People make spaces and places their own in the digital world just as they do in the natural. Helen Thornham's (2011) work serves as a bridge between Boellstorff's 2016 observation of an ontological turn and Nardi's 2009 game ethnography: "My central argument is that we need to incorporate an understanding of the lived relations of gaming into both the field of videogame theory, and this is possible through interpretive ethnography and an ontological narrative lens" (2011, p. 9). This conception of software as a lived-in environment is also central to my thinking on the archaeology of digital games. As explained below, these interactive digital built environments, while designed primarily for entertainment, intersect with "real"-world social behaviors, identities, and commerce.

None of the above forays into understanding human occupation of digital spaces extend beyond ethonography and note-taking, although the understanding of how humans interact with digital things and places can contribute to an archaeological narrative. Alan Meades (2015) notes at the end of his book on the concept of "counterplay" in games—bending the rules to do things in digital spaces unintended by their designers—that, "we have seen an ascetic approach to games, where the methodical, archaeological scrutiny, and deep reading of simulation and code expose a profound and unique understanding and enable the creation of identity" (2015, p. 183). Meades is one of the earliest scholars to research human and non-human interaction in games, and the human tendency to manipulate these environments as they do natural landscapes, in order to achieve a desired effect (albeit one not intentionally desired by a game's creator[s]). The idea of human and non-human interaction is not unique to video games, but is itself at the heart of archaeological discourse of any place or thing regardless of material.

1.3. Towards an Archaeology of Synthetic Spaces

In establishing an archaeology of digital interactive entertainment (and ultimately one of software generally), the issue of "real" and "virtual" must be addressed. These terms continue to confuse archaeological discourse about digital heritage. Boellstorff (2016, p. 387) addresses this, critiquing the new ontological turn, notes the opposition of the "digital" to the "real." He states, "this fundamentally misrepresents the relationship between the online and offline, in both directions. First, it flies in the face of the myriad ways that the online is real. Second (and just as problematically), it implies that everything physical is real." Economist Ed Castronova arrived at a similar conclusion years earlier when struggling with how to differentiate between the lived experience in the "real world" and that in the "virtual", opting for "natural" and "synthetic" (2005, p. 294). The natural world existed in the pre-digital era, and continues to persist in the digital one and needs no special hardware for it to be experienced. A synthetic world is one mediated by screens. "Natural" and "synethetic" do not succumb to the dichotomy decried by Boellstorff and allow for mutual existence with each crossing over into the other. Castronova validated the "reality" of synthetic spaces, writing that they, "host massive flows of real human intercourse—information, commerce, war, politics, society, and culture. . . . As such, these places are like real cities and fairy-tale cities at the same time" (2005, p. 1). Two years later, Castronova refined his argument, noting that, "virtual worlds are not cathedrals, but they do transport people to another plane. They have a compelling positive effect on visitors, an effect dramatically misunderstood by many of those who have never spent time there" (2007, p. 189). He makes a crucial addition to his argument here, noting the difficulty that people lacking digital literacy have when attempting to understand all of the human activity that goes on within digital spaces. This is a classic archaeological problem when the archaeologist attempts to publish information on a site that few readers have visited, or on artifacts that few readers have seen. Archaeological communication to both a specialist and a general readership is a pillar of an archaeologist's mission regardless of the project. I will return to this point in later chapters.

Castronova also notes one of the other significant benefits of conducting research in synthetic space: "we may well discover some new, exciting, and beneficial things about how our society works, and how it can make every one of us happier" (2007, p. 208). I agree with Boellstorff and Castronova that digital/synthetic environments are "real". Many humans interact with software and games minute-to-minute, which cost people "real" money and an investment of "real" time, often generating "real" emotions. An archaeology of the "real" has become an archaeology of the digital.

1.4. Towards an Archaeology of Digital Things

On his blog *Introspective Digital Archaeology*, Jeremy Huggett (2016) considers digital archaeology in all of its aspects. In "A Digital Detox for Digital Archaeology", he writes that, "digital Archaeology should be a means of rethinking archaeology, rather than simply a series of methodologies and techniques. It is not simply a matter of the technology driving these challenges – what is important are our ambitions for the subject, and only then the ways in which digital technology might be used to catalyse, support, develop, and enhance those innovations."[2] I would like to think that an archaeology of digital things, of software and the hardware that runs it, would qualify as a means for rethinking archaeology. So many people spend time, labor, and money in spaces mediated by screens that it is obvious that we have before us new dwellings (to borrow from Heidegger), new societies, new cultures, both human and non-human, constantly blending the natural with the synthetic. Shaw noted that, "the legacy of cultural studies on which video game studies should draw is not to study culture in games, though that is useful as well, but to investigate how video game culture is constructed. This is a critical, not descriptive practice" (2010, p. 16).

2. https://introspectivedigitalarchaeology.com/2016/04/08/a-digital-detox-for-digital-archaeology/ (accessed 2 September 2019).

Humans built these spaces and the things within them. It is the next logical step for archaeological investigation, and it should be conducted contemporaneously with the digital material being investigated. If archaeologists wait for something digital to get old, the potential is great that much data and context will be lost when compared to working with digital material as soon as it is produced, used, and discarded. For example, Geocities webpages were shut down by parent company Yahoo in 2009, leaving webmasters scrambling to find new homes for their sites in fear that their work would be lost permanently (Law and Morgan, 2014). While some Geocities sites were indeed lost forever, most we re-archived elsewhere online through other hosts (Law and Morgan, 2014, pp. 5–6). Webmasters were (and largely still are) responsible for preserving their own content, which can make it difficult for archaeologists to conduct online work after events such as the Geocities shutdown. On the more traditional digital archaeology side, the Archaeology Data Service maintains the Grey Literature Library (GLL) in an effort to preserve digitally those unpublished archaeological sites in the natural world. In this instance, it is not the site that is in danger of disappearing, but rather its data and the interpretation of that data. Conducting digital archaeology temporally closer to the source helps ensure that as much data as possible can be preserved before things such as bit/link rot decay digital data beyond recognition and discovery.

Each of my case studies demonstrates that software, like sites and landscapes, always changes, and these changes occur much more quickly with digital things. Olivier warns that we should "envisage an archaeology of the short term. This particular approach should, on the one hand, take account of the specific investigations linked to our temporal proximity to this near past but it should also, on the other, develop problematics adapted to historical dynamics of very short scale, varying from a few hours to a few generations. For the most part, this new archaeological domain has yet to be engendered" (2001, p. 179). An archaeology of the digital must be an archaeology of the present.

The 2003 UNESCO Charter on the Preservation of Digital Heritage[3] provides an official *terminus post quem* for digital heritage and, by association, the archaeology of digital things. The charter agrees with the assessments above about technology's accelerated chronology, and that some of the things created digitally merit special attention for preservation as examples of meaningful heritage. Article 3 states that "the world's digital heritage is at risk of being lost to posterity. Contributing factors include the rapid obsolescence of the hardware and software which brings it to life, uncertainties about resources, responsibility and methods for maintenance and preservation, and the lack of supportive legislation." Article 4 warns, "Unless the prevailing threats are ad-

3. http://portal.unesco.org/en/ev.php-URL_ID=17721&URL_DO=DO_TOPIC&URL_SECTION=201.html (published in 2004, accessed 15 September 2019).

dressed, the loss of the digital heritage will be rapid and inevitable." Article 1 acknowledges that, "Where resources are 'born digital', there is no other format but the digital object." It is possible that one day an example of video game heritage will be designated as a "UNESCO World Digital Heritage Site." It may be more likely that something like the Internet Archive or Archaeology Data Service will receive that designation first.[4]

1.5. Towards an Archaeology of Digital Affinity Spaces

Digital interactive entertainment serves as an introduction to the wider understanding of all software as digital built environments for people to use, share, and "inhabit." As the corporeal and incorporeal continue to blend for people by virtue of increasingly affordable, omnipresent digital technology, we progressively descend into our own entertainment. Internationally, the time spent playing video games by adults rose 20% between 2018 and 2019 (Anderton, 2019). Data show a continued rise in time playing video games, too: 5.1 hours/week in 2011, 5.6 hours/week in 2012, 6.3 hours/week in 2013 (Aamoth, 2014). Reasons for the continual uptick in adults playing these games may be because players gain instant satisfaction of fundamental human needs of making and exploring (Yee, 2006). The feedback is immediate and increasingly haptic thanks to things like controllers that vibrate (such as when a player is close to solving a code-puzzle in *Shadow of the Tomb Raider*). Digital games continue to provide an interactive outlet to people who create and explore, whether these games are set in a real or imagined past on Earth or elsewhere.

Over the past 45 years and with the production billions of copies of thousands upon thousands of commercial games since the creation of the first publicly available video game, *Computer Space* (Nutting Associates, 1972), entire economies and gaming cultures have evolved (King and Borland, 2004). At this writing, there are five times more players of the massively multi-player online role-playing game *World of Warcraft* (Blizzard Entertainment, 2004) than ever lived and died in the City of Rome when it was the sole capital of the Roman Empire at its height.[5] Video games comprise a larger share of the entertainment market than movies, music, and books, with global sales exceeding US$100B in 2017.[6] Players invest hundreds of dollars a year in game subscriptions and purchases of standalone titles. Popular games engender huge followings of players and fans, and create their own subcultures outside of the game. Within some

4.archive.org and archaeologydataservice.ac.uk respectively.

5. 5.03 million players actively subscribe to *World of Warcraft* in 2019 (https://www.statista.com/statistics/276601/number-of-world-of-warcraft-subscribers-by-quarter/, accessed 2 September 2019). Greater Rome at the height of Empire (third century AD) housed ca. 1 million people (Storey, 1997, p. 976).

6. Luke Graham, "Digital games market to see sales worth $100 billion this year: Research," https://www.cnbc.com/2017/02/15/digital-games-market-to-see-sales-worth-100-billion-this-year-research.html (accessed 24 October 2019).

games, in-game cultures thrive, both real (e.g., guilds/groups of human players) and imagined (races and lore created by the developer to assist in creating a rich world and to propel the game-narrative). This is something that Champion (2016, p. 64) calls "cultural presence": "a feeling in a virtual environment that people with a different cultural perspective occupy or have occupied that virtual environment as a place." Video games can also be classed as "affinity spaces", which Gee and Hayes (2012, p. 129) define as "environments dedicated to supporting a shared passion among the participants." Listening to some of these players recount their adventures and explorations of far-flung, fantastic worlds, describing cities and monuments and history in exquisite detail is not unlike hearing a Romantic recounting of a first visit to Rome, or hearing an archaeologist explain the finer points of Dressel amphora types to a captive conference audience.

Games have long graduated from being the sole province of young people (they arguably never were).[7] They are serious business, and are taken seriously by both players and creators something that can most easily be seen in the rise of popularity and profitability in e-sports (competitive video gaming often waged before a live and online international audience) (Taylor, 2012). It makes sense then to treat video games as interactive digital built environments, to see them archaeologically, and to begin to understand their entanglements with the past and present, the real and virtual, the social and economic, as well as with each other within a wider context. With the advent of new video games that can create their own environments without direct human intervention,[8] we now have the chance to witness the birth of a question not yet asked: what does a culture look like when it is created independently of human intervention?

1.6. Digital Culture

The concept of "culture" is tricky to define, and its definition continues to evolve especially within the context of archaeology. In the twenty-first century, archaeology blends the human and the non-human together both in the natural and synthetic world. Humanity is part of a complex assemblage of landscape, site, and artifact, and human and non-human agents (Denning, 2011; Harris 2013; DeLanda, 2016; Haraway 2016). As archaeology seeks to understand humanity through material evidence and context, an individual culture can be defined by "the transformative relationships between individuals, groups, and material forms in the practice of everyday life . . . in the past and the present. By acknowledging the active role of objects in everyday life, historical archaeologists avoid the limitations of rigid classificatory schema that segregate objects

7. In 2019, 79% of regular video game players were over the age of 18 (https://www.statista.com/statistics/189582/age-of-us-video-game-players-since-2010/). A 2006 report published by the Entertainment Software Association noted that 69% of people who played video games regularly were over 18 with an average age of 33.

8. See the Glossary entry for "procedural generation", and Chapter 5 for a case study example.

from people" (Cochran and Beaudry, 2006, p. 203). Agbe-Davies (2010, p. 385) adds the concept of community to the cultural mix, noting that "community" is a process, that it is ever-changing, continually constituted, and non-homogenized. Harris (2013) widens the scope of community and culture to include everything human and non-human within a given area, all contributing actively to the ecology of a place.

These non-traditional approaches to defining "culture" all apply to synthetic environments, especially games because of the interaction and interdependence of human players and a game's active environment, a space designed to react to the presence of one or more players. But even if a player experiences a game alone at home, those experiences map onto those of others who have also played. What develops is a culture of lived and remembered experiences shared in a specific locality by a group of people. That locality is not restricted to earthly geography, but can be tied to a shared software application. This definition fits human populations within digital environments because the locality is the software itself, or even segments within a software application. For example, in *World of Warcraft*, I can identify with others who play the game, who can remember earlier versions of it as well as various in-game events over the years, and I can go one level deeper to identify with either Alliance or Horde major factions, drilling down to associating with players of a game-race (e.g., orcs, gnomes, etc.) or even within a guild (a group or team of players who regularly go adventuring together). Players (and the archaeologists among them) create what Brittain (2013, p. 258) calls a "life-world", an "archaeological topology of place." This concept of culture within a digital space, a shared locality from a geographically diverse human population, dips into the field of human geography. By way of definition, Mark Boyle (2015, p. 6) writes that, "the mission of Human Geography is to describe and explain how and why human beings locate themselves and their activities unevenly over the earth's surface, create distinctive places, generate various kinds of ecological footprints, connect places into webs and networks, and invent regions of various scales." Cultures are tied to places and/or localities and produce both tangible and intangible manifestations for representatives of those cultures to use. As my case studies show, each video game begets its own culture of users who both adopt and adapt these digital spaces and create human culture and lore while engaging with synthetic cultures that have been designed for human interaction. It is perhaps too soon to see mature cultures created solely through algorithms, yet algorithms are often used to generate the landscapes inhabited by human players, affect their actions and interactions in the world (see Chapters 3 and 4).

1.7. Heritage and the Digital

Archaeology of/within digital environments has yet to become mainstream, which places it as an archaeological outlier, a position it shares with other archaeological projects set either in the recent past or in the present.[9] In such a position, archaeology of digital environments—including video games—benefits from considering all perspectives as it searches for a framework in which to operate. It will be helpful to consider several definitions of "heritage", tying different, modern perspectives together where they apply to understanding digital things and places.

Harrison (2013, p. 14) provides a starting point with the traditional, "operational" definition of "heritage" stemming from the mid-nineteenth century as "the series of mechanisms by which objects, buildings, and landscapes are set apart from the 'everyday' and conserved for their aesthetic, historic, scientific, social or recreational values." In this interpretation, heritage is something to be triggered, but the definition ignores more personal and emotive meanings to places and objects. This definition is one of "official" Heritage (Harrison, 2013, p. 15), separate from unofficial heritage that exists under the surface within homes, families, and smaller affinity groups including those who adopt video games as their own.

Modernizing the definition of "heritage," Laurajane Smith (2006, p. 1) considers it to be a "process of engagement, an act of communication, and an act of making meaning in and for the present." As Agbe-Davies did when considering culture (2010), Smith does not separate artifacts from their human context, nor does she fetishize them. Instead, the objects are memory-catalysts, vehicles for personal stories from the past that anticipate the future of those who receive these stories (p. 2). To Smith, all heritage is intangible. While she acknowledges that places, and objects exist, and can be identifiable sites of heritage, she notes that they have no value in and of themselves: it is the performance of heritage that includes them that gives them value and meaning (p. 3).

Smith's definition can be applied to digital heritage as well. In considering video games as sites of human occupation, they lend themselves to nostalgia and memory. Because most games are finite (i.e., their creators stop updating them after a period of months or years), players migrate from game to game, occasionally returning to relive their initial play-experiences. The games become invested with memory and human history, some of which make the jump from player-culture within and around a game to becoming household names and part of the material culture and cultural heritage of everyday people, even those who do not identify as gamers. The Video Game Hall of Fame, curated by the National Museum of Play, identifies the best examples of these games to preserve, which then feed back into the community. Examples of "heritage"

9. For example, see Kiddey's 2017 book, *Homeless Heritage: Cooperative Social Archaeology as Therapeutic Practice*.

games as identified by the National Museum of Play include *Tomb Raider*, *Colossal Cave Adventure* (see my case study in Chapter 3), *World of Warcraft*, and many others each with their own communities. With games, however, it is also possible to have specific, personal artifacts imbued with meaning. To anyone, a copy of the disk containing *King's Quest V* is only important because it facilitates access to the popular 1990 game. To me, however, this copy of *King's Quest V* was my brother's favorite game, and he always talked about it. When I play it, I think of the game, but also of my brother.

These ideas of migration, the process of heritage, and a rapidly changing cultural environment is also supported by Schofield and Szymanski (2016, pp. 1–10). They note the need for archaeologists to attempt to understand why certain things in the recent past are valued and retained, and the difficulty in preserving heritage in a migratory culture whose very definition of home is also in flux. With digital material culture and digital heritage, these digital places sort themselves out over time, preserved either by individuals (e.g., Sander Slootweg who collects everything related to the Nintendo gaming system), hobbyist collectives (e.g., the Atari Museum), museums (e.g., Vigamus, in Rome), or by games companies themselves (e.g., Blizzard Entertainment). My case studies focus on the digital heritage identified by player communities, those who have adopted their games as second homes, and who work to preserve their memories through communicating with each other and by sharing their heritage with the wider world. These communities blend what Sharon MacDonald calls "social memory" and "cultural memory" (2013, p. 15), the social memory of a thing being communicated by word of mouth, while the cultural memory is transmitted through media. In the archaeology of digital heritage, video games perhaps best exemplify MacDonald's definitions: the game media is a cultural artifact, and its cultural value manifests socially through online forums such as reddit, YouTube, and social media.

Heritage is not only tied to objects and people, but also to places. Graham et al. (2010, p. 4) propose that, "heritage is inherently a spatial phenomenon." To them, heritage is based on distribution, and scale, where "location is someone's heritage, and thus inseparable from people, even if constructed from non-human elements, but not all heritage is bound to specific places." Regarding distribution, "heritage can be moved across space." As for scale, "places have a heritage at local, regional, national, continental, and international scale, and a particular heritage artifact can function at a variety of scales" (2010, p. 4). Taking a digital heritage example, the game *No Man's Sky* features an ad hoc human community known as the "Galactic Hub" (see Chapter 5). This community was displaced by a catastrophic event, forced to relocate elsewhere in the digital environment. The community remained intact, and their heritage retains memory for and nostalgia of their previous settlements as the human players built new homes far away from their original location. Two years after the 2017 event, the Hub community has more than doubled in size, but the heritage is shared by everyone and is taught to newcomers by way of the game community's wiki and reddit pages.

This brief review of "heritage" shows how various definitions can include video games as examples of cultural artifacts of the contemporary and recent past. Games (and their players) are migratory. Games themselves are localities offering a space for people to share experiences and memories. Some games become tagged as official heritage while others retain an unofficial status in their respective player-communities. Games evoke memory and discussion in person and online, as well as emotional responses in individuals. These memories and emotions are tied to digital environments, which become heritage spaces.

1.8. Digital Material Culture of the Recent Past

The case studies presented in Chapters 3–5 are examples of archaeology of the recent past. In the case of video games in 2019, nothing is older than 50 years, yet these can still be addressed archaeologically. Buchli and Lucas (2001, p. 3) write that, "by focusing attention on the nature of archaeological methods and data, in particular on the fact that, as archaeologists, we deal primarily with material culture, the whole issue of how recent the subject matter of archaeology should be, becomes irrelevant." Media archaeologist Jussi Parikka (2015, p. 6) sees the archaeology of media (which includes the digital) as being of deep (or geological) time, which includes the long-term environmental impact of new media. Just as with standing stones in the United Kingdom, these ancient artifacts persist into the present day and intrude upon and coexist with modern places. In video game culture, *Pac-Man*, *Pong*, *Tetris*, and myriad other classic games exist (and can still be played) side-by-side with their photorealistic, narrative-driven contemporaries, making it easy to compare and contrast past and present, to identify influences and genealogies all within the wider context of use and abandonment, of where these games were made and played and by whom. Even though these new media are "non-traditional" when compared with stones-and-bones forebears, the big questions we ask of the material remain the same. Space-archaeologist Kathryn Denning (2014, p. 95) states as much when considering the possibility of an archaeology of the non-human: the questions "What do Others know of their worlds? What do They do there? How can We learn about Them?—are the same. It is not surprising, therefore, that anthropology, archaeology, and SETI share certain core issues".

This idea of an archaeology of the non-human introduces a final issue about culture which, while not unique to an archaeology of digital things, is particularly suited to it. With software, humans may not even need to be present in its creation anymore, with algorithms taking over the duties of writing routines to resolve issues. The farther we get into the twenty-first century, the more possibilities there are of exploring not only how humans interact with non-human things (e.g., computers, software, etc.), but how non-human things interact with other non-human things. All of a sudden, the archaeologist is the only human in the equation. Per Object Oriented Ontology (OOO), humans no longer occupy the center of archaeological investigation by default. Bjørnar Olsen (2010, p. 11) writes that, "In order to understand how society works—and thus is made possible—we have to become more liberal and inclusive and to acknowledge that far more constructive entities than humans (and their thoughts, knowledge, and skills) are woven into its fabric. In other words, we have to take into account that societies consist of myriads of real and co-working entities composed of both humans and non-humans." Lucas (2013, p. 15) echoes this sentiment, stating, "archaeology is post-humanist. Humans remain part of the story, but they are not *the* story." Humans occupy a part of the ecology in which they occupy, and at times affect an undue amount of influence on their non-human counterparts, yet those non-human entities are present, adding to a system's complexity.

With this complexity in digital environments caused by the confluence of a human player (or players), non-human agents, digital things and landscapes, and underlying code and algorithms, comes emergent behavior, which occasionally gives rise to glitches, crashes, and other unintended consequences. But the construction of those digital built environments in whatever form they take is underscored by the archaeological principle of the formation process. Martin Bell (2015, p. 44) writes that, "archaeology is . . . the study of the past and its material remains. . . . Formation processes should be as central to the study of archaeology as source criticism is to the classicist or historian." Digital environments can be designed, but they are also affected by other features around them, just as landscapes are. Human agents within these spaces can modify them. Other software procedures can alter them. Environmental issues in the natural world can destroy them. Although digital, software behaves like a landscape as will be demonstrated in Chapter 4, but it requires human intervention in order to operate as a landscape. It is impossible to separate the human from the digital.

1.9. Rationale

This thesis is the first formal attempt to understand digital games archaeologically as sites to be surveyed and excavated. There have been attempts by archaeologists conducting the archaeology of digital things: Moshenska's USB drive excavation (2014); Perry and Morgan's hard drive excavation (2015); Aycock and Reinhard's reverse engineering of software copy protection (2017); Aycock, Reinhard, and Therriens' reverse engineering of video included on games CDs (2019), Aycock and Copplestone's code-excavation of an Atari 2600 game (2018). None of these investigations, however, treats the code-generated environment—the screen-mediated world—as its own archaeological space. Further, none conducts code epigraphy and stylometry to attempt to understand how these worlds were built or how they changed over time based on inscription evidence. Finally, none attempts to allow readers to better visualize the data under discussion. This thesis and its case studies fill this gap of fieldwork conducted within synthetic, digital space itself.

Games, unlike all other media counterparts (i.e., printed material, audio, images, and film), allow for complete action and interaction by people (players) in fully immersive spaces. Games are built environments, constructed like houses, designed, planned, and built, featuring later additions and occasional modifications made by the player-inhabitants. Games sprawl like cities as well, often spilling out from their tidy plans into a wider landscape to be explored and interacted with (as seen in open world games, e.g., *Skyrim* and *No Man's Sky*, Chapters 4 and 5 in this thesis), which allow people to wander where they will, occasionally allowing them to build for themselves, or to find evidence of past cultures (or past human players). In building a community of practice, video game archaeologists create their own media culture. As media archaeologist Huhtamo (2016, p. 123) explains, "media forms and their uses are constantly negotiated, tested, and contested. Material applications meet discursive ideas." We are finding our way to describe this new-ish medium through archaeological practice. Chateau and Moure (2016, p. 15) agree in their research on screen-mediated experiences: "We need a new vocabulary with which we can fully account for the various levels according to which the filmic universe can be defined." Here we might substitute "filmic" with "gaming," and Brittain (2013, p. 258) concurs: "We must explore new ways to appropriately articulate a 'lifeworld,'" meaning that researchers do not yet have a standardized vocabulary for describing what in this case is a digital environment populated by human and non-human agents.

Games occupy real-time and contain their own time(s) and chronologies within them. A game such as *Raiders of the Lost Ark* (Atari 1982) has its own specific date of creation, which places it in an absolute chronology of digital games. It post-dates *Adventure* (Atari 1979) and pre-dates *Joust* (Atari 1983), which helps one observe the evolution of coding, game art and sound, and an understanding of both gameplay and the commercial audience for that game when compared to games created before, during, and after 1982. It is of a specific type—an Atari 2600 cartridge—made of plastic and a silicon wafer. The game encoded on the wafer is also of a specific type: an "action RPG."[10] Games are played for a year or two after their release, the most popular of

10. There is an industry and community-accepted typology of video games of which RPGs (role-playing games) is a part. "Action RPGs" are a subtype.

which entertain millions of people, prior to a precipitous drop in interest as new games come to market.[11] The games, however, do not disappear; they *perdure* (to borrow a phrase of Ingold's [2012, p. 439]), continuing to be games whether or not they are being played. Thirty-five years after the fact, one can revisit these old games, which respond as they were programmed—provided one has the appropriate hardware on which to run them—as if no time had passed at all. Other time is at work within digital games as well, where "years" can pass during normal play. Players can observe changes in the landscape within a game, can see cultures rise and fall, and can have a direct hand in the success or failure of empires, centuries reeling off in a matter of real-world hours or days.

These virtual environments are largely simulations in which players interact with things explicitly placed by the game's maker(s). As such, they can be used for modeling human behavior, for visualizing structures or landscapes and how people interact with them. Most games include artificial intelligence (AI), which is designed to interact with players as they proceed through the game's environment. The AI in more recent games also includes machine learning, where the game, through observing the player, adapts to player-behavior. Game-controlled elements (typically opponents or non-player characters), react in new and unexpected ways to player agency/action, which makes the game more interesting and more challenging to the player. A story unfolds in play, adding to the internal history of the game, and in some instances, becoming part of history outside of the game as well.

The interaction of player and digital space is not unlike the interaction of a person in a corporeal space. Both spaces and interactions are governed by rules, whether they be mundane laws of physics or more complicated social constructs (Schell, 2008, pp. 228–33). As people interact with their environments, new/different behaviors emerge. This emergent behavior is a residue of complexity, a product of rules-based behavior (Johansson, 2012). In a game, a player's interaction with the internal environment gives rise to other in-game actions. Borrowing Ingold's analogy in his book *Making* (Ingold, 2013, p. 61) regarding how a site is "made," in the construction of a game by the game's maker(s), digital materials are manipulated in such a way as to create a visual space in which players can operate. In the natural world, a carpenter works with wood in order to frame a house within which occupants can live. In either case, virtual or real, space is constructed for others to inhabit (including archaeologists). The spaces, Ingold argues, are created in movement; they are "performed" (Ingold 2013, p. 85). Elsewhere Ingold

11. For example, the number of copies of *Uncharted 4* sold internationally in its first month of release (May 2016) was 2.1M. Ten months after release, nearly 92,000 new copies sold. http://www.vgchartz.com/game/77189/uncharted-4-a-thiefs-end/sales (accessed 16 September 2019). As for playtime data, the number of active, concurrent players of *Skyrim* on 16 September 2019 was 12,043 on the Steam platform, compared to launch-day (11 November 2011) number of 230,000 (https://steamspy.com/app/72850).

states that, "the practice of archaeology is itself a form of dwelling" (1993, p. 152). Players certainly perform within the games they play.

The archaeological study of digital games, however, takes a new step in understanding built environments. Ingold wondered: "Could certain practices of art, for example, suggest new ways of doing anthropology? Could not works of art be regarded as forms of anthropology, albeit 'written' in non-verbal media?" (Ingold, 2013, p. 8). Video game design certainly speaks to these questions. This study is post-materialist, especially when compared with excavating the foundations of a house built in the natural. In the natural world, the archaeologist finds evidence of stone, a material with which a builder created foundations, the base of walls. With the digital, one deals with a single "material": the pixel, which is triggered by an instantiation of code. The pixel itself is not a material, per se, but is instead the product of electricity, light, and thought. One material transforms into an infinite number of other materials in the creation of new, incorporeal spaces. This issue of materials returns us to the consideration of the natural and the synthetic, and how the two blend to create human-inhabited space mediated by screens.

There is a dialogue between humans and materials, and also between materials and other materials, and it is up to the archaeologist to decode what that conversation is about. Diana Coole discusses this within the context of "new materialisms":

> . . . if everything is material inasmuch as it is composed of physiochemical processes, nothing is reducible to such processes, at least as conventionally understood. For materiality is always something more than "mere" matter: an excess, force, vitality, relationality, or difference that renders matter active, self-creative, productive, unpredictable. In sum, new materialists are rediscovering a materiality that materializes, evincing immanent modes of self-transformation that compel us to think of causation in far more complex terms; to recognize that phenomena are caught in a multitude of interlocking systems and forces and to consider anew the location and nature of capacities for agency (2010, p. 9).

Coole goes on to explain this archaeologically:

> Human artifacts and natural objects are generally just treated as the taken-for-granted material background and paraphernalia of our everyday lives. We rarely pause to consider the contingent processes through which our familiar, visible world comes into being, not only through the hard labor of production and the economic hierarchies that structure

> it, but also via the creative contingencies of perception. Art can help us suspend these naturalist and humanistic habits by encouraging us to observe the very 'fabric of brute meaning' as it takes shape (2010, p. 104).

Digital archaeologists must therefore follow Coole's advice and not only attend to what they observe in a synthetic environment, but also what factors caused the environment to come into being. When investigating digital constructions as an archaeologist, many entanglements are in play, caused first by the construction of the physical artifacts mediating the digital experience, the natural and human resources needed to create the digital experience, and the human and non-human agents within the digital experience comprised on one side as flesh and on the other as rule-based pixels. This leads us to a definition created by Joohan Kim to define that interstitial being, the flesh-and-blood person who interfaces with a digital environment and the entities within: the "digital being" or "*res digitalis*" (2001, p. 87). Kim makes a unique distinction not considered by Castronova, Coole, or others when attempting to understand the co-existence of the natural and the synthetic: "the fundamental difference between physical things and digital-beings: while every physical thing is here or there, a digital-being is here and there" (Kim, p. 98).

As software users we are both here and there, a living paradox. We inhabit the room in which we then inhabit the computer in which we then inhabit the "immaterial" constructed space. The room is built heritage, as is the computer, as is the software application. Archaeologists can study each level discretely, or together. This thesis focuses on the digital constructs, the "immaterial" things and spaces, but also addresses wider archaeological contexts of use as well as the hardware needed to conduct investigations. For example, in Chapter 3, the game *Colossal Cave Adventure* is reviewed as a cultural artifact, but is then broken down into a complex genealogy of versions created by a community of hobbyist coders, most of whom created their editions of the game on different examples of hardware and operating systems. The archaeological matrix of code, authorship, hardware, and narrative is borne out of the evidence of both primary and secondary sources. The case study observes the immateriality of the game created by keying code onto the material of paper punchcards. The natural and synthetic worlds blend together for the digital archaeologist to evaluate, each world affecting the other.

Each video game, therefore, is an archaeological site of discovery. Edgeworth (2014, p. 44) observes that "the term 'site of discovery' might usefully be taken to refer to virtual on-screen realities as well as off-screen ones." Archaeologists discover things in the data as well as in the ground. In his assessment, "the virtual landscape can potentially yield an almost infinite number of new discoveries, each one giving rise to further paths of exploration that can be followed towards further discoveries and insights" (2014, p. 59).

This thesis serves as version 1.0 in how to arrive at those discoveries and insights, through surveying, excavating, and documenting interactive digital built environments (i.e., games).

1.10. Method

In the following chapters I apply established archaeological tools, methods, and theories to interactive digital built environments in three case studies. The detailed reasoning behind the selection of the games studied here opens each of the case studies' chapters; I chose to work with established theory/method at first to create a baseline for my work, modifying them for my needs in digital space as the work progressed. The first case study (*Colossal Cave Adventure*), Chapter 3, applies the ideas of Classical epigraphy (Bodel [2001] and Cooley [2012]) and stylometric analysis of computer code (Frantzeskou et al. [2006] and Caliskan-Islam [2015b]) within a digital archaeological context. Landscape archaeology and phenomenology of digital spaces features in Chapter 4, the second case study, following work in landscapes as described by Ingold (1993), Agbe-Davies (2010), Battle-Baptiste (2011), Kiddey and Schofield (2011), Johnson (2012), Gillings (2012), Cochran and Beaudry (2014), and Tilley and Daum (2017). A baseline case study of *No Man's Sky*, Chapter 5, follows largely the guidelines for excavation and its planning and publication as established by Martin Carver (2009) and Steve Roskams (2001), as well as Hodder (2005), Johnson (2010), Raab and Goodyear (1984), Renfrew and Bahn (1991), and Trigger (2006), but ported to the digital environment. These methods have been field-tested by the above authors in the natural world, and are applied formally for the first time in synthetic spaces occupied by humans. The third case study incorporates digital publication of surveyed and excavated media and site reports into the Archaeology Data Service as a testbed project for archiving archaeological fieldwork conducted within a digital environment.

With this thesis, I am attempting to give a voice to a handful of digitally mediated human communities through the lens of archaeology and cultural heritage. Archaeology of the digital begins at the margins of the discipline, which is strange because the materials being studied are in front of billions of faces every minute. Its archaeology should be front-and-center. As a researcher, I have taken lessons from other archaeologists working in non-traditional spaces, spaces that have for various social, economic, and privileged reasons been overlooked.

For example, from Whitney Battle-Baptiste (2011), I know that I can approach my brand of archaeology by first reading and evaluating primary sources, then examining a wider history and context in which to place my work both within and against that already published, as has been shown above. She writes (p. 51), "when we actively acknowledge where we stand when we enter the arena of archaeological interpretation, we will begin to create a space that initially may seem uncomfortable, but will allow us to use an inclusive and inquiring approach to the sites we are excavating." Her description of black feminist archaeology (p. 72) can be applied to archaeology of digital environments: "all these factors revolve around home, material, and cultural choice, factors that can directly be seen accompanying other disciplines and contemporary issues of historical memory and a collective understanding of the past."

In their archaeological work with Bristol's homeless population, Kiddey and Schofield (2011, p. 5) came to similar conclusions: "[archaeology's] close attention to material culture and place, and to interpreting traces of evidence for past human behaviour, embraces the full range of human experiences, from the deep past to the very latest depositions, and is inclusive of everyone in society." The inclusion of communities by archaeologists makes the work better and adds depth to the results, "improving the archaeological, but also with intellectual content" (Kiddey and Schofield, 2011, p. 5).[12] I found this to be the case with the *No Man's Sky* community (see Chapter 5), and would encourage the inclusion of affinity groups associated with any video game under archaeological investigation.

1.11. Chapter Outline

This thesis is divided into six chapters (including this introduction), which gradually make the case for the archaeology of interactive digital built environments, and how to do fieldwork in them.

Chapter Two conducts a needs assessment for the archaeology of video games. What questions should be asked? What hypotheses do archaeologists have for studying games? Why should games be considered as built environments, and what do archaeologists hope to answer through their study? As Lucas (2013, p. 374) writes, "What new entities can archaeology propose? What does archaeology show us that we did not know already?"

This chapter considers games-as-archaeology both theoretically and practically, discussing further the nature of digital material and materiality, the false dichotomy between "natural" and "synthetic", and how to approach digital fieldwork. Video games embody the relatively recent anthropological phenomenon of the "ontological turn." The archaeologist is situated in the middle, observing the physical and virtual melting together. Because games are interactive and are built for human habitation (if only for

12. For an in-depth look at public archaeology and digital heritage, see Lorna Richardson's 2014 UCL PhD thesis, *Public Archaeology in a Digital Age* (http://discovery.ucl.ac.uk/1436367/).

a few moments or hours), one must also consider human needs vs. code needs within the overarching context of the game itself. As the case studies below will show, one aspect of the archaeology of video games is in understanding how the code environment serves the narrative environment of the game-space and its human inhabitants, and how humans adapt and modify both to create their own stories.

Chapter Three contains the first case study: code epigraphy and archaeology in *Colossal Cave Adventure*, the first digital interactive text adventure (1975). This game inspired Mary Ann Buckles' 1985 PhD thesis, which helped create the games studies academic discipline. It also created the commercially successful genre of adventure computer games, as well as generations of coders and communities of interactive fiction authors. The case study does two things: it uses epigraphy to better understand inscriptional evidence within a digital archaeological and social context, and also utilizes stylometric analysis to follow how the original set of game-code influenced dozens of future versions. *Colossal Cave Adventure* can be considered to be an archaeological artifact, a discrete set of code with its own biography and history of use within a wider context of digital gaming and material culture.

Chapter Four contains the second case study, *The Elder Scrolls V: Skyrim VR*. With this case study, we move from a text-only artifact to a three-dimensional, engineered visual world containing manufactured cultural and built heritage. This open world video game affords a wide canvas to explore theoretical questions of landscape archaeology, phenomenology, heritage reception, and virtual reality, as well as practical experiments in GIS-mapping of digital environments, communicating 3D experiences through affordable means, and 3D printing digital artifacts. *Skyrim VR* can be considered to be an archaeological site containing several artifacts and examples of built heritage within its sprawling, digital geography.

Chapter Five contains the third and final case study, an archaeological survey and excavation of 30 abandoned human settlements in the digital universe of *No Man's Sky*. This case study follows the lead set by Çatalhöyük, which includes daily reflexive methodology in support of efficient workflow and record-keeping, including both text and visualization data (Berggren 2015, p. 443), and ensuring that all data are made available via the project database as quickly as possible: contextual metadata, photos, diaries, and videos from the excavations (Farid 2015, p. 74). The case study also conducts exercises in photogrammetry for understanding site history as well as in producing models of human-created architecture for 3D printing. A new type of time-based map is also created. *No Man's Sky* can be considered to be a landscape populated by dozens of archaeological sites that can each be taken as isolated units while also being connected to a wider human community.

Chapter Six offers a suite of conclusions based, first, on lessons learned from the three case studies, and then on archaeological trends shared by these projects. Several ideas for future digital archaeology projects are also presented along with proposed applications of this kind of digital archaeology to projects undertaken in the natural world.

1.12. Conclusion

Video game archaeology is post-material and post-human, a discipline that not only intersects past and present, but that also uses the screen as the sole method of accessing new archaeological spaces. These spaces are made by people (facilitated by machines) for other people to use, and are invested with creativity and examples of material culture. They are kinetic and also kinesthetic. They contain their own space-time. Each game is its own discrete entity, its own site. At the same time, each game exists in multiple, identical copies, circumventing the problem of the "unrepeatable experiment" of total excavation. They pose both classic and new questions to the archaeologist who operates in both the natural and the synthetic simultaneously, using archaeological craft. Drawing on Edgeworth (2014, p. 54), "[The archaeologist] has no direct contact with that [archaeological] evidence, which cannot be physically touched. Yet in another sense she displays all the attributes of a craft practitioner, demonstrating embodied skills of computer use alongside intellectual reasoning in the ongoing investigation . . . ". Archaeologists must adapt their tools and how they operate within digital sites.

The precipitate of this work within digital built environments is the creation of what Champion (2016, p. 64) calls "virtual heritage": "the attempt to convey not just the appearance but also the meaning and significance of cultural artefacts and the associated social agency that designed and used them, through the use of interactive and immersive digital media." In his article, Champion speaks about these interactive and immersive digital media intersecting with real-world cultural artifacts. I would argue that the same media will be used at some point in the not-too-distant future for conveying the meaning and significance of purely synthetic artifacts, events, and sites. Already there are brick-and-mortar and online video game museums (e.g., Vigamus, Rome's video game museum, and atarihistorymuseum.com), and in-game memorials (e.g., Leonard Nimoy statues erected in *Star Trek Online*). It is not a question of what but of when. The potential for artificial life to emerge from new and future games is the stuff of science fiction, yet has already been seen on a smaller scale.[13] Machine-created material culture, however, is already here, and is becoming more complex and harder to distinguish from those objects, artworks, and buildings purpose-built by design-

13. See John Horton Conway's *Game of Life* (1970), which shows rules-based emergence of cellular automata in heretofore-unseen combinations.

ers. At the same time, it is possible that machine-created culture (MCC) will generate something completely alien based on the rules used to program the procedural generation of new, digital artifacts. Will people be able to recognize that new material culture for what it is, something that resonates with machine-logic far removed from human pots and pans?

Digital archaeology exists now in two branches: 1) the use of digital tools to undertake archaeological projects and to answer archaeological questions, and 2) the archaeological investigation of digital things. The former branch currently speaks the loudest in the literature with journals such as the *Journal for Computer Applications in Archaeology* and *Digital Applications in Archaeology and Cultural Heritage*. Collectives such as Computer Applications in Archaeology, the Theoretical Archaeology Group, the Society for American Archaeology, the European Association of Archaeologists, and the journals *Internet Archaeology* and *Advances in Archaeological Practice* have welcomed the latter type of digital archaeology. One goal of digital archaeology is to appear side-by-side in publications containing more traditional articles from natural sites, and its inclusion by these groups and their journals is an encouraging step in that direction.

Huggett (2018b) proposed four suggestions to flesh out digital archaeology to "give it real identity and purpose into the future."[14] This thesis embodies his four suggestions, as will be evidenced by the following case studies:

1. Digital archaeologists need to do digital research as well as research digitally.

"Archaeogaming" has been formalized as a methodology starting in 2013 and later codified with its publication as a monograph in 2018 (Reinhard 2013; 2018c). Articles by Aycock (2018 with Copplestone; 2019 with Reinhard and Therrien), Copplestone (2017; 2019), and others, not to mention two special issues of *SAA's Archaeological Record* (2016; 2017) and two multi-author volumes on the subject published by the University of Leiden (2017; forthcoming), demonstrate a recent, robust community of practice for the archaeological investigation of interactive digital entertainment. This thesis includes an archaeology of code as its first case study, an archaeology of digital design and digital environments as its second case study, not to mention an archaeology of a human civilization within a digital settlement as its third case study.

2. Digital archaeologists need to build digital things.

My first case study allowed me to repurpose digital statistical tools and the R coding language to run stylometric analysis on sets of game-code. My second case study

14. "Who Watches the Digital?" 26 March 2018. https://introspectivedigitalarchaeology.com/2018/03/26/who-watches-the-digital/ (accessed 2 September 2019).

taught me how to 3D-print 2D digital artifacts from within a digital environment, and also taught me how to map a synthetic world using *QGIS*. My third case study enabled me to create a new kind of time-based map, and also encouraged photogrammetry for understanding the extent of ruined settlements in a digital environment. As we build a community of practice, it is imperative that more tools are used, analyzed, modified, or are built from scratch.

3. Digital archaeologists need to develop studies of digital practice.

The work in this thesis has been informed by the physical digital archaeology of Aycock, Copplestone, Morgan, Moshenska, and Perry, the theory of virtual world ethnography by Boellstorff (and supported by Nardi and Pearce), the notions of materiality by Ingold and Latour, the exploration of the similarities and differences of the natural v. the synthetic as published by Castronova, the object oriented ontology approach by Olson and Pétursdottír, the phenomenology of Heidegger and Husserl, the notions of landscape by Tilley, and the excavation methodologies of Carver and Roskams among others. Perry's work on digital archaeology and its communication to a wider audience has been crucial to how I present my work, and the digital ethics of Dennis (2019) informs how I approach what I do. Huggett's reflections on digital archaeology have also proved helpful to me in my ruminations on how to proceed with my case studies. Everyone currently involved in the archaeology of digital things curates a community of practice that continues to work towards a shared vocabulary, ethical guidelines, and method.

4. Digital archaeologists need to resist and critique the digital.

This thesis critiques the digital tools used within the case studies in order to identify bias and subjective use. Each case study features reflexive writing on the success and failure of my tools and methods. My general conclusions include several ideas on what projects to do next with digital things.

It is my hope that the case studies that follow show a blended approach of existing methods and theory without being too conservative in their application to digital spaces, yet also without being too freewheeling as to be cavalier in their approach to ways of understanding new materials and landscapes archaeologically.

Archaeology contributes to cultural survival. Per Bauer (2009, p. 83), firstly it "provides a long-term culture history for a region, which can serve as a kind of 'baseline' of change against which current dynamics may be evaluated", and secondly it "offers a long-term perspective on local *terroir* that may help both to moderate presentist biases and to temper fears about the threats of modernity on cultural diversity and tradition."

In Chapter 5 my research intersects with Bauer's points: the site reports and recorded media from my investigation into the abandoned settlements of the old Galactic Hub are now present on the Archaeology Data Service platform, which can now be referenced freely by the player community. The Hub culture can continue to persist in part because of the preserved memory of space and place made possible through archaeology.

I was able to do something similar with my first case study (see Chapter 3), which analyzed a history of evolving (and preserved) code for *Colossal Cave Adventure*. Here I was able both to preserve and illuminate code sets and coding trends shared between members of a community tied to one game but separated by earthly geography as well as decades between the initial version of the game and its current iterations. My work, posted on Github, is freely available to anyone interested in the history of this game who wants to review what changed and what stayed the same in this most historic example of digital interactive fiction.

These tools and efforts to study, archive, and publish my results intersect the two threads of digital archaeology. I conduct archaeological research within digital environments using digital tools, ultimately publishing and archiving on digital platforms.

2

Archaeology of Digital Environments: Video Games

2.1. Introduction: Digital Archaeology of the Recent Past

Archaeology is uniquely qualified as a discipline to document the human experience through its materiality. Although historically understood as dealing with the deep past, over the past 15–20 years archaeologists have plied their trade on the near-immediate. Since 2003, annual meetings of the CHAT group (Contemporary and Historical Archaeology in Theory) have met and published on the recent past featuring work by Ema Dwyer, Louise Fowler, Laura McAtackney, Sarah May, Hilary Orange, Angela Piccini, Joshua Pollard, Sefryn Penrose, and scores of others. Since 2013, results of contemporary archaeological projects can be found by multiple researchers in the *Journal of Contemporary Archaeology*. Bill Caraher's team (Kostis Kourelis, Richard Rothaus, Bret Weber) conducted an archaeology of "man camps" in the Bakken Oil Fields in 2016, creating a topology of temporary and semi-permanent settlements in an active community of laborers (Caraher et al., 2017). Going even farther afield, Alice Gorman stands at the forefront of space archaeology, studying everything from satellites and orbital debris to lunar-based archaeological sites and artifacts (Gorman, 2019). There is a logic to this uptick in interest in the archaeology of the contemporary: in the pre-Industrial past, technological innovation evolved much more slowly than it does in 2019. Upon understanding and exploiting electricity for the purposes of labor, the pace of science, technology, and innovations in manufacturing and creative media increased exponentially. As a result, the planet is besieged by new and discarded products. This phenomenon of exponential rates of technological change now is called formally the Law of Accelerating Returns, first published by Ray Kurzweil in 1999.

Archaeologists of the contemporary must scramble to keep pace with planned obsolescence and annual seriation/typologies on a volume and scale requiring Big Data to make sense of a globalized market of billions of people, all of whom continue to create, consume, and discard things. Archaeologists of the contemporary have already accepted the challenge in a diverse suite of research incorporating the archaeological data of entire cities and populations while making sure that historically under-represented people and subjects finally get their archaeological due. For example, Whitney Battle-Baptiste publishes on black feminist archaeology (2011), community-based archaeology as a tool for social justice (forthcoming), and colonial and postcolonial identity (2010). Costis Dallas stands at the intersection of digital archaeology and information science, publishing on digital curation (2009, 2015a), as well as offering insight into how archaeologists can manage data workflow in the twenty-first century (2015b). Sarah De Nardi researches on landscape, memory, and World War II and the Italian civil war, specifically on those non-combatants displaced and otherwise affected by the fighting (2015). Rebecca S. Graff's most recent work (forthcoming, 2020) uses contemporary methods to focus on the archaeology of garbage and consumerism during Chicago's 1893 World's Fair. Rebecca L. Hearne (2019) explores the extent to which archaeology can be used as a tool for advocacy, activism, social change, and mental health recovery. Jeremy Huggett has also published on the issues of heritage and Big Data (2014a, 2018a; Huggett et al., 2018). Uzma Z. Rizvi publishes on colonialism (2016), postcolonial topics (2016, with Jane Lydon), and decolonizing archaeology, as a discipline (2015). Alfredo González-Ruibal addresses the physical remains of modern manufacturing, destruction, and waste (2018a, 2018b), keeping up with what he calls the "vanishing present" (2007). Krysta Ryzewski focuses on contemporary archaeology of cities and their transformation, ruination, and use by people, as well as themes of creativity, colonialism, and risk (2017, with Laura McAtackney). New work on the archaeology of digital things fits within this diverse tapestry of current research, how they affect their human makers and consumers, and their potential uses as vehicles for environmental damage as well as colonialism, and markers of privilege and elite status.

Digital built environments are the new products of manufacturing, disposable architecture of the late 20th and early 21st centuries, yet they serve as second homes for people privileged enough to own computer/gaming hardware and discretionary time to spend in the networked environments this hardware supports. Mol (2016, pp. 148–51). makes this argument in his analysis of the games *Lord of the Rings Online*, *DayZ*, and *Diablo III*, exploring how systems of human networks and material culture are interdependent and create new online social networks and in-game events based on supply and demand. These games influence both human player and market behavior, each affecting the other. There is humanity behind the game mechanics and shiny user interfaces as well. "Computer games are a not just a technical product; they are a form of material culture which can be examined through archaeological lenses . . . drilling down into the material remains of . . . code to expose artifacts of the human process of programming" (Aycock and Copplestone, 2018, p. 22). Just because the environments are synthetic does not mean that they can be kept separate from humanity. Digital archaeology can be deployed to understand the connections between people and the technologies they adopt, use, modify, and discard.

Many of the digital spaces created in the past 40 years fall under the rubric of interactive digital entertainment (video games), although any software application could be considered to be a digital space. Of those games that use Earth as a setting, many deploy cultural tropes and iconography to communicate by visual shorthand that players are in ancient Greece (e.g., *Assassin's Creed: Odyssey*), or Imperial Rome (e.g., *Ryse: Son of Rome*), the old American West (e.g., *Red Dead Redemption* 1 and 2, see Wright, 2019), or the entire history of the World (e.g., *Civilization* VI, see Mol et al., 2017). These games use archaeological/heritage visuals, interpretations of the past by development teams that revise the world for audience engagement. These games remix physical, historical reality and create new stories from it. Archaeologists behave similarly when interpreting the past as they have found it based on data retrieved from the archaeological record.[1] Archaeology and storytelling can at times be at odds with one another as the discipline faces the issue of how to report on what it finds through survey, excavation, and other ways of extrapolating meaning from data. Praetzellis (2014) makes the case for archaeological storytelling for education. Ring (2008, pp. 3–5) describes archaeological storytelling as a collaboration between archaeologists, material culture, and exhibition designers to create a public narrative space. Given (2009) attempts to translate the archaeology of two sites in Scotland and Cyprus into stories that fall into the literary genre of speculative fiction, plausible narratives based on a close, critical reading of context and culture. Mickel (2015, p. 81) describes archaeological reportage as exhibiting "emplotment", using evidence-based narrative to support answers to research questions. Hodder (1989, p. 268) describes the changing nature of archaeological site reports, turning from nineteenth-century diarist-style entries to the hyper-sterile, facts-only reporting in the late twentieth century. Digital spaces allow for another dimension of archaeological storytelling and reporting based on immersive visuals and even sound design (Watterson, 2018), something above and beyond what traditional paper reports can convey. Humans can create digital built environments within which people can interact and learn; the spaces create an emotional and aesthetic response,

1. See the special forum in *Historical Archaeology* 34:2 (2000, pp. 1–24) dedicated to storytelling in archaeology. An entire session on archaeological storytelling was featured in 2017's annual meeting of the Society for American Archaeology (2019).

something arguably equally as valid as data-focused reports.[2] Each of the three case studies in this thesis merge many types of archaeological narratives (namely history, speculative reconstruction, and reporting) into a single—but multi-threaded—story.

This chapter builds the bridge between digital archaeology and that of digital environments, specifically video games, which can be studied as artifacts, sites, and landscapes. The chapter reports on the state of the subfield of archaeogaming and its future, how it fits within other archaeological theory, and concludes with an introduction to the three case studies, which form the heart of this thesis.

2.2. Archaeogaming as Archaeology

"Archaeogaming" (Reinhard, 2018c) is the literal interpretation of games as artifacts, sites, and landscapes, similar to any thing or place on Earth that has been manipulated, managed, and transformed by people past and present. I coined the portmanteau in 2013, yet the idea of video game archaeology has been incubating since at least 2002 with its first formal publication appearing in the Society for American Archaeology's *Archaeological Record* in an article by Ethan Watrall (2002). The article focused on "interactive entertainment" as a form of public archaeology, using the medium of video games to engage with the wider public on the reception of history and archaeology. Other authors—most notably Jeremiah McCall (2011) and Adam Chapman (2016)—would echo this theme in their books on the reception of events in world history by video games, their developers and players, and the educational potential of using historical video games as talking points in the classroom.

This period (2002–2013) also saw the growth of media archaeology, most notably published by Huhtamo and Parikka (2011) in their primer to the discipline, which sought to interpret material remains of communications media (e.g., typewriters) as sites of archaeological inquiry. Research on contemporary archaeology was also on the rise in the early and mid-2000s supported by groups such as CHAT and various Theoretical Archaeological Groups (TAGs). And 2013 saw the launch of journals such as the *Journal of Contemporary Archaeology* and *Advances in Archaeological* Practice. This period also witnessed growth in the field of digital ethnographies of virtual worlds (almost exclusively *Second Life*) by Boellstorff (2008), and video games (Nardi, 2010, in *World of Warcraft*), which culminated in the publication of a handbook of ethnographic methods for use in virtual worlds (Boellstorff et al., 2012). Video games, however, were largely absent from the conversations and publications in contemporary and digital archaeology with the occasional exception of using video game engines (e.g., *Unity*) to create digital reconstructions of ancient monuments (see for example Morgan, 2009).

2. See the Emotive Project (emotiveproject.eu) directed by Sara Perry, which focuses on emotive storytelling and how people experience heritage sites.

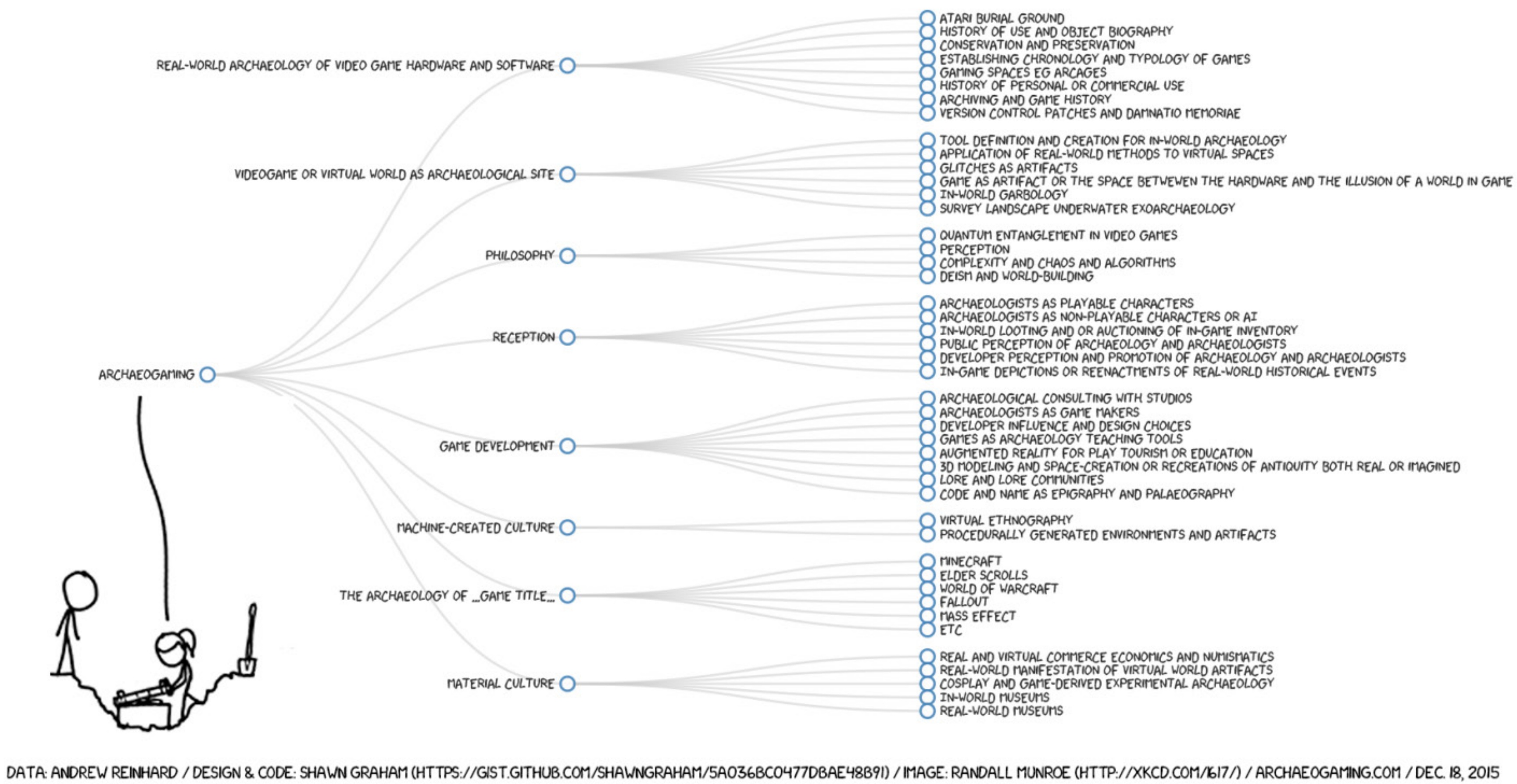


Figure 2.1. Map of archaeogaming research areas.

All of the above marks the digital turn in archaeology (Morgan and Eve, 2012), preparing the ground for a new discipline of archaeogaming to emerge.

I launched the *Archaeogaming* blog (archaeogaming.com) in June 2013 as a way for me to write informally about the intersection of video games and archaeology, complementing other, older blogs focused on historical reception in video games such as *Play the Past* (playthepast.org), and monographs on pedagogy and historical video games such as *Gaming the Past: Using Video Games to Teach Secondary History* (McCall, 2011), and historical and archaeological reception in articles such as "The Past as Playground: The Ancient World in Video Game Representation" (Gardner, 2007). I was at first interested in manufactured histories (aka "lore") and landscapes created by games developers for players to explore (see Lowe, 2012, for his research into born-ruined architecture in games), and was also curious about how archaeology and archaeologists were portrayed in games media (see Holtorf, 2005 and 2007). The blog's launch unintentionally corresponded with the 28th May announcement that Canadian entertainment company Fuel Industries had been granted permission to create a documentary about the excavation of the "Atari Burial Ground", an urban legend surrounding the 1983 burial of "the worst video game in history", *E.T.: The Extra-Terrestrial.*[3] The idea that hundreds of thousands of video game cartridges had become e-waste invested with mythology and nostalgia led me to think that games and games media are contemporary examples of built, cultural, and digital heritage, something physical containing something metaphysical. I eventually led the team of archaeologists in the excavation of those buried Atari games in April 2014 and observed the convergence of pop culture, nostalgia, and the ability to turn the excavation into a public archaeology event (Reinhard, 2015).

The presence of the *Archaeogaming* blog and related Twitter account (@archaeogaming) from 2013 onwards became a major hub in a growing, international community of practice. This community would see the independent creation of the VALUE Project in 2015 (now the VALUE Foundation [value-foundation.org]), by archaeology postgraduates at the University of Leiden, who organized the very first archaeogaming conference, *The Interactive Past* (TIPC), in April 2016. Before this, however, in March 2015, the *Challenge the Past* conference in Gothenburg featured several presentations on video games, history, and archaeology. It was a prelude to TIPC and to dedicated annual conference sessions at the Society for American Archaeology (2017), Society for Historical Archaeology (2017), American Society for Oriental Research (2018), and European Association for Archaeology (2018).

3. The documentary describing the mythology of the Atari dump and eventual excavation, *Atari: Game Over*, was released in 2014 by Lightbox Entertainment after securing the rights for filming from Fuel Industries.

After noticing several different threads emerging from this community of scholars, on 18 December 2015, I posted an archaeogaming map (Fig. 2.1) listing eight branches of investigation that could be (or already were being) undertaken: real-world archaeology of video game hardware and software (e.g., the Atari excavation), video games and virtual worlds as archaeological sites, philosophy (e.g., perception, entanglement, materialism, etc.), reception of history and archaeology by games, game development, machine-created culture (e.g., procedural generation, human cultures created within games), archaeology of individual game titles (e.g., the *Civilization* series), and material culture (e.g., cosplay, museums, virtual and actual artifacts). I codified archaeogaming in my book (Reinhard, 2018c) as an introduction to pursuing these various archaeological threads, but between 2015 and 2018, many of the video game archaeology publications focused not on games as examples of modern material culture and digital heritage, or even as built heritage ripe for survey and excavation, but rather on reception and education (see below), hardly evolving from Watrall's 2002 call to action.

In a 2016 conference presentation, Tara Copplestone (2016) delineated three archaeogaming strands: external, applied, and reflexive. "External" refers mostly to how archaeology is received by game-playing audiences. "Applied" (i.e., practical archaeogaming) concerns conducting archaeological work on/in games. "Reflexive" examines the ethics and methods behind the archaeology of interactive digital entertainment. External archaeogaming claims the lion's share of peer-reviewed publications, three examples being Meyers Emery and Reinhard (2016) on how archaeology is portrayed in games, Westin and Hedlund (2016) on how the past is represented in *Assassin's Creed* games, and Holtorf (2005; 2009) on archaeologist representation in games. These publications reflect one's initial thinking when hearing about archaeogaming for the first time: characters such as Lara Croft (*Tomb Raider*) and depictions of antiquity and even prehistory in games as imagined by their designers (e.g., *Horizon Zero Dawn*). In 2016 Colleen Morgan served as guest editor for two issues of the SAA's *Archaeological Record* containing 10 archaeogaming articles. While a breakthrough for the subdiscipline to garner such attention in a general archaeological publication, over half of the work presented therein centered on the reception of archaeology in/of games by developers, players, and archaeologists, further consolidating one thread of archaeogaming as perhaps the most approachable.

The SAA issue did, however, present the first publication of the ethical aspects of video game archaeology (Dennis, 2016), which was followed by Dennis's collaboration with Catherine Flick and myself in Flick et al. (2017) as we published on the reasoning behind creating a Code of Ethics for archaeological fieldwork in video games (especially those where an environment is shared between many human players), and the articulation of her ideas in long-form within her PhD thesis (2019). Similar themes are addressed in *The Interactive Past* book (Mol et al., 2017) of conference papers, which led with a section on "Ethical Approaches to Heritage and Video Games" concerning not only ethical gameplay (Fothergill and Flick), but also cultural appropriation by video games (Hughes), and indigenous game development (Cook Inlet Tribal Council). The book also addressed game design (Copplestone), archaeological investigation of games-as-sites (Reinhard), and the use of games for agent-based-modeling in order to answer questions about actual antiquity (Graham). Already in 2017, then, archaeogaming had begun to diversify and seriously address a suite of archaeological issues surrounding digital interactive entertainment. *The Interactive Past* 2 conference followed in October 2018, this time featuring themes on game development and reception, education, and applied archaeogaming focusing largely on synthetic landscapes, and education.

Applied/practical archaeogaming has also been published on its own, most of it by John Aycock, a computer scientist at the University of Calgary who wrote the book *Retrogame Archaeology* (2016) and collaborative articles with archaeologists (Aycock and Copplestone, 2018; Aycock and Reinhard, 2017 and 2019; Aycock and Biittner, (2019). The published work hinges around reverse-engineering software, which is only one part of the applied archaeogaming thread. Archaeology awaits the publication of other practical work.

It is worth noting that Aycock and Biittner (2019) and Aycock and Reinhard (2019) have been published in journals not dedicated to games, virtual worlds, or computer programming: *Open Archaeology* and the *Journal for Contemporary Archaeology*. My own work on the software Harris Matrix for video game versions appeared in *Advances in Archaeological Practice* (2018a), and my collaborative work with Aycock on the artifact of copy protection in the game *Jet Set Willy* appeared in *Internet Archaeology* (2017). It would appear that archaeogaming is gaining acceptance in the wider archaeological world with its now-frequent appearances in publications and at conferences.[4]

These peer-reviewed publications on video game archaeology[5] have been supplemented by public outreach, most frequently in the form of podcasts and blogs. Copplestone, Dennis, and I hosted the *8 Bit Test Pit* podcast from 2016–2017[6] to discuss archaeology and video games informally. Other podcasts including *ArchaeoFantasies*, *History Respawned*, *First Person Scholar*, *Spark* (for CBC radio), and *Culture File* (Irish public radio) have featured archaeogaming topics. Active international blogs on ar-

4. For example, the Computer Applications in Archaeology group's annual meeting have evolved to include games research in archaeology, largely involving the use of game engines by archaeologists for use in 3D reconstructions (CAA 2013 and 2015), game design by archaeologists (CAA 2017), and digital games as spaces for archaeological work of various types (CAA 2018).

5. A working bibliography of peer-reviewed archaeogaming publications may be found here: https://archaeogaming.com/bibliography/ (accessed 26 September 2019).

6. https://www.archaeologypodcastnetwork.com/gaming/0 (accessed 27 October 2019).

chaeology, history, and video games include *Archaeogaming*, *Play the Past* (playthepast.org), and personal blogs by Shawn Graham (Canada, electricarchaeology.ca), Florence Smith Nicholls (UK, florencesmithnicholls.com), and Camíla de Avila (Brazil, camiladeavila.com.br), among others.

Digital/games archaeologists are perhaps better positioned to connect with the public (many of whom play digital games) about what archaeologists are and what we do, transferring lessons learned in-game to sites and projects in the natural world, beginning with the common vocabulary of play, leading eventually to disparate interests in what happens outside of the computer or console.

Archaeogaming continues to expand globally, finally reaching Japan in 2019 with presentations by Erik Champion and Florence Smith Nicholls at the annual meeting of the Digital Games Research Association (DiGRA).[7] Not only diverse geographically and linguistically, archaeologists in the archaeogaming community also fall across the LBGTQ+ and cisgendered spectrum. Despite male-dominated computer culture and the continued presence of online hate, homo/transphobia, and misogyny within gaming culture at large, archaeogaming reflects the opposite by being an accessible and inclusive safe space for serious research. The diversity of voices within this subdiscipline of digital archaeology hopefully is indicative of broader changes happening within the whole of archaeological scholarship itself. More perspectives brought to bear on archaeological problems cannot help but improve the quality and variety of answers into how twenty-first century researchers understand and communicate the past, both distant and recent.

Looking to the current needs assessment of archaeogaming, there remain many unresearched and unpublished spots on my 2015 map. Underserved (for now) areas include, 1) investigating video game phenomenology and materialism as archaeological spaces to be experienced, 2) understanding complexity, emergent behavior, and actor-network theory in game-spaces occupied by people, 3) seeing video games as cultural artifacts and examples of built heritage, which require archaeological research questions to answer, and 4) learning what the effects of creating digital environments are on their human creators and on natural resources needed to produce this media. This thesis addresses a few of these lacunae in Chapters 3–5. Chapter 6 offers additional conclusions for video game archaeology and for the greater archaeology of digital things.

7. DiGRA 2019 was hosted by Ritsumeikan University in Kyoto established its Center for Game Studies in 2011, which remains the only center of its kind in Japan. As of this writing, no scholarly publications about video game archaeology (reception or otherwise) have appeared in either in Japanese, or in English by Japanese researchers.

2.3. Archaeogaming and Archaeological Theory

One question about archaeogaming is whether or not it really is archaeology as opposed to playing at archaeology. Is it grounded in any kind of theory? Since 2013, archaeogaming has been finding its way, taking a catholic approach as this section will demonstrate. According to Renfrew and Bahn, archaeology "involves the study of the human past through its material remains" (2012, p. 576). Archaeogaming fits within that rubric, as games are part of the material culture of the recent past (within 50 years of the present). For any archaeologist (digital or otherwise), archaeology must also attempt to interpret things as they were (reconstructing patterns of cultural descent) while proposing and testing explanations for the forces that have shaped such patterns (Shennan 2012: 23). Archaeologists typically ask what caused changes in shape and function and then reverse-engineer the thinking behind these design decisions. In this respect, archaeogaming is a kind of cognitive archaeology as most fully described by Colin Renfrew (1994), an attempt at understanding the minds behind the creation of the things they built.

In New Archaeology, archaeologists tend to emphasize cultural evolution and look for generalities and emphasize systems thinking (Johnson, 2010, p. 23). With archaeogaming, one can consider rules-based systems in computer code that creates new worlds in which humans can operate, creating new in-game cultures that spill over into the natural world via social media and online groups (often called "fandoms"). The archaeogamer can then ask how gaming cultures evolved within certain game series, or with the changes in online, networked communication and "always-on" digital entertainment. Are there similarities in video game cultures between different kinds of games and players, and how do those translate into the natural world?

Such an approach follows on from the culture historical approach of the 1960s, most notably associated with Lewis Binford, and refined in 1972 by James Deetz, who sought to apply a scientific method to archaeology while also focusing on the cultural process(es) behind the creation of an artifact to arrive at purely objective facts. The "why" of an artifact finds precedence over the "when." With archaeogaming, there really is no objectivity behind the game-as-designed and the game-as-played. Code is written by people and as such cannot be objective, nor is the archaeologist an objective observer. One can document what one sees from inside a digital environment, yet one must acknowledge one's own biases when doing so.

Archaeogaming also invites object-oriented ontology (OOO), posthumanism, and new materialism as mentioned in Chapter 1 in relation to the archaeology of digital things. With video games, it is difficult to decentralize the role of people within the gameplay environment, breaking with the work of Olson, Péttursdottír, Haraway, and E. Harris, who take "things" on their own terms, independent of direct human agency once discarded and set adrift. Human interaction is always present with games, from their design, development, and deployment, to the necessity of human agency in order to trigger functions and code routines within games. Even e-waste[8] from discarded games is a byproduct of human entanglement with both the natural and synthetic worlds, and human-driven creation and abandonment of games ultimately affects the environment of which humans are an integral part. Archaeogaming perhaps has more in common with post-humanism (Díaz-Guardamino and Morgan, 2019) and new materialism (Bennett, 2009), both of which blend multiple environments and embodiments, which accurately describe a person's digital experience. Investigating video games can provide answers to hardware-mediated embodiment, machine-driven heritage feedback, and new ways of studying traditional archaeological material through pixel-manipulation via the manipulation of digital assets or development of code.

The issue of time frequently enters into archaeological research, and archaeogaming is no different. Video game development (as well as the creation of virtual worlds) is iterative, with time interacting with the landscape of the game itself. This follows Ingold, who wrote, "only through such recognition, by temporalizing the landscape, can we move beyond the division that has afflicted most inquiries up to now, between the 'scientific' study of an atemporalized nature, and the 'humanistic' study of a dematerialized history. And no discipline is better placed to take this step than archaeology" (1993, p. 172). Tilley also takes this approach in understanding landscapes (of which video games are an example as explained below), stating, "the experience of space is always shot through with temporalities, as spaces are always created, reproduced, and transformed in relation to previously constructed spaces provided and established from the past. Spaces are intimately related to the formation of biographies and social relationships" (1994, p. 11). Even with video games that appear to be finite (e.g., one can play a maximum number of boards in *Pac-Man* before the game ends), the games, like any archaeological site or landscape, persist. They have a life and an afterlife (Guins, 2014).

Returning to longer-standing theoretical paradigms, archaeogaming breaks with post-processual archaeology posited by Margaret Conkey, Ian Hodder, Rosemary Joyce, Daniel Miller, Christopher Tilley, and Peter Ucko (where archaeological interpretations are subjective) by maintaining a positivistic distinction between material and data,[9] but also takes post-processualism further by acknowledging three actors (developer, player, and avatar) and three intertwined contexts (game media, player environment, and gamespace itself). This connectivity does something strange when attempting to

8. Electronic products at (or near) the end of their primary use, which will then either be refurbished, recycled, discarded, or reused.

9. Digital games are designed sets of coded rules affecting what appears through a graphical user interface, yet the data produced from the action and interaction of these rules are open to myriad interpretations.

fit within a representational context: it seems to speak to both a representational and non-representational co-existence. When sensorily experiencing digital material culture, one sees a representation of something, which is mediated through the veil of the screen, yet at the same time, the viewer understands that what is being viewed is quite literally a representation of something that could manifest in the natural world. Archaeogaming allows this paradox to happen, to see and recognize something both as it is presented and knowing also that it is a representation of a thing, both of which can be acted upon by the viewer. Archaeogaming also accepts the paradox of materialism and non-materialism co-existing in a digital space, with the assumption that an electrically activated pixel is quark-like in its state of quantum superposition,[10] being both material and non-material simultaneously. By this I mean digital environments with any kind of graphical user interface operate in a liminal space where the disposition of a pixel is dependent on human agency and is neither on nor off until observed by the user.

People also interact through the materials of physical media to access non-physical materials, with the possibility (as demonstrated in my second and third case studies) of transmuting non-material objects from digital spaces into the natural, material world. This transmutation might fall under the definition of intermodal representationalism, which states that, "phenomenal characters of experiences are determined by their contents together with their intentional modes or manners of representation, which are nonrepresentational features corresponding roughly to the sensory modalities" (Bourget, 2017, p. 251). Archaeogaming could also be sited within the new materialism of Bennett (2003) with its focus on both human and non-human actors, the vibrancy of matter/material (which can include activated pixels), and a turning away of either/or false dichotomies (see Chapter 1 above) in real versus virtual, instead taking a blended approach where both humans and non-humans occupy natural and synthetic worlds simultaneously. In 2019, everything on Earth exists somewhere on a digital spectrum under the hyperobject of 802.11.[11] All of the above is important to archaeology of digital environments, which seeks to understand the relationships between people and materials and the possibility spaces they create for human and non-human interactions in ways not yet seen with traditional artifacts, sites, and landscapes. This is the core tenet of behavioral archaeology, which "redefines archaeology as a discipline that studies relationships between people and things in all times and all places . . . ." (Johnson, 2010, p. 65). While archaeogaming does not redefine archaeology, it expands on its definition by providing new materials and new places to study.

Heidegger stated in 1973 that, "humans are situated in and inseparable from the

10. The principle of quantum superposition states that if a physical system may be in one of many configurations—arrangements of particles or fields—then the most general state is a combination of all of these possibilities. Direct human observation forces one of these possible configurations to appear.

11. 802.11 is a wireless networking protocol that comes in different flavors depending on indoor or outdoor use and blankets the entire planet without the consent or even knowledge of its existence by most people.

world that is around them and into which they are thrown and dwell." Video games are a large part of contemporary culture and as such merit archaeological study. Dennis (2016, p. 18) reminds us that:

> archaeogaming requires treating a game world, a world bounded and defined by the limitations of its hardware, software, and coding choices, as both a closed universe and as an extension of the external culture that created it. Everything that goes into the immaterial space comes from its external cultural source in one way or another. Because of this, we see the same problems in studying culture in games as in studying culture in the material world.

Digital technology in a blended environment yields new research questions, which pull archaeology into the future.

2.4. Video Games as Artifacts

The term "Artifact" requires several definitions when being used for video games. From archaeology, an artifact is anything produced, used, modified, and discarded by a human that can then be used as archaeological material evidence to reconstruct or understand past behavior. An artifact does not occur naturally and requires human interaction. Video games fit that archaeological definition. The physical game-artifact was created by at least one person with the help of machines. This collaboration resulted in a distributed thing that contains within its production a history of creation, possible inscription, and has a find spot (or more than one find spot as its biography grows). The artifact of the game provides the heart of the game-space, as well as metadata, its developer-created information, a mobile inscription, and a container of text-and-image.

From computer science, artifacts are discrete assets created by people when developing software applications (e.g., DLL library files, executable files, even text files, etc., that combine to form a software assemblage, as well as game assets such as objects, characters, structures, etc.). In video game design, artifacts are also playable areas within a digital environment as well as code-routines written to create areas and events with which human players interact (Leino, 2012). These artifacts are contained within the site of the game as defined in section 2.5 below.

Archaeogaming adds additional ways that "artifact" can be applied to digital environments. First, most video games are now available as digital downloads, which accounted for 83% of sales in 2018, compared to 17% of games purchased on CD or DVD.[12] This means that moving forward there will be fewer physical artifacts of games

12. https://www.statista.com/statistics/190225/digital-and-physical-game-sales-in-the-us-since-2009/ (accessed 26 September 2019).

media and more digital examples accessed through the artifacts of networked hardware so long as a network connection is present and the game has not been withdrawn by its rightsholder. In the future it is likely that digital archaeologists will find indirect evidence of games through online images, videos, and posts, but not the games themselves.

Video game environments also produce their own artifacts as observed by humans: glitches (Reinhard, 2018c, pp. 148–55). These glitches—breaks-in-presence—are products of code-complexity and human agency. When reported by players, these glitch-artifacts get patched, which erases them from the archaeological record, leaving evidence only through digital documentation such as images, video, and text descriptions. Glitches are temporary software artifacts, perhaps comparable to fugitive materials such as textiles or paint from antiquity. Video games are thus artifacts, and they contain artifacts. These digital environments are also archaeological sites, as explained below.

2.5. Video Games as Archaeological Sites

It is easy to understand a video game as an artifact, something produced by one or more people and is representative of contemporary material culture. The artifact of a game disk is portable, can be used for game installation and play, and can be discarded. For manufactured games, a game disk is but one of many identical artifacts widely distributed to a network of consumers. In other instances, someone might create their own game, save the coded files and other assets (audio, art, animation) to a disk, which is unique, a single, personal expression of human creativity.

Video games are not merely artifacts of encoded plastic and metal; they are also archaeological sites. To understand this claim, one first needs to understand the definition(s) of what constitutes an archaeological site and then see how those definitions can be applied to examples of digital interactive entertainment. The simplest definition comes from Carver (2009, p. 89): "an area of ground in need of investigation." Archaeological sites have been generally understood as "a place where human activity occurred and material remains were deposited" (West Virginia Department of Arts, Culture and History, 2019). Archaeological sites may contain artifacts and features, artifacts defined as "any portable object made and/or used by humans" (e.g., pottery, coins, worked flint, etc.), and features being "non-portable evidence of past human behavior, activity, and technology," (e.g., foundations, fire pits, postholes, etc.) (Jones, 1996). These artifacts and features may be either above or below ground, and are typically concentrated within a locality, the definition of which varies from site to site.

To take a natural world example, I worked at the Etruscan site of Poggio Civitate. By stating the site's name, others know exactly what (and where) the site is (or can look it up). The site tops a hill near the village of Vescovado di Murlo, and is famous for its terracotta "cowboy" statues as well as the remains of a massive, timbered complex completely destroyed by fire in the sixth century BCE (Phillips, 1993). These artifacts and features are localized to a hilltop and show evidence of material remains and human activity. So it is with games.

Starting from this traditional baseline, one can now contemplate how examples of software (video games in this thesis), fit the definition of "archaeological site." I first considered this idea in *Archaeogaming* (Reinhard, 2018c, pp. 88–95), determining three ways of interpreting games-as-sites: 1) installation media; 2) installation location; and 3) the game environment.

For the first example, installation media-as-site, an initial surface survey of the single installation CD for *Diablo* (Blizzard Entertainment, 1997), contains a collected assemblage of five directories and 12 loose files. The loose files include a few with which players can directly interact: install.exe and autorun.exe (for installation), and readme.txt, modem.doc, network.doc, and serial.doc, which contain information about the game and how to configure it. The executable files (known as "artifacts" in software development) call out to other loose files (e.g., the smackw32.dll and dinkw32.dll library files, and the 493MB diabdat.mpq file containing all of the audio, art, animation, and code files that build the game on a player's computer), as well as a few of the directories containing assets needed for the game to run (e.g., directx7, which contains the files for establishing a Microsoft Windows environment in which the game can operate). The MPQ file is a file type proprietary to Blizzard Entertainment used for compressing and encrypting files as a level of digital rights management (DRM). One can unpack an MPQ file using open source utilities such as *MPQ Extractor* (Macintosh) and *MPQ Editor* (Windows). The CD contains artifacts (files) as well as features (directories) within the locality of the CD. The digital artifacts and features are deposited material remains, evidence of human activity, thereby warranting archaeological investigation.

The second example, installation location-as-site, defines sites by where game-files are installed on a local computer. To continue with the *Diablo* example, the game installs to (on my computer) the "Diablo" directory, which is located in "Program Files (x86)" on the local hard drive ("C"). This directory contains DLL (library) files, an executable to run the game ("Diablo.exe"), along with simple TXT (text) files for installation and license information. *Diablo* was designed to be played with the CD in the computer, which explains the small installation footprint on my PC. The locality of the installation confines 21 files within one directory, an assemblage of deposited (installed) material remains. The site also shows evidence of past human activity through the date- and time-stamp on files (e.g., "Andrew000801.err", an error log), which update in real-time based on player activity.

The third example, game environment-as-site, further defines an archaeological site as being within the field of play. In *Diablo*, the player adventures through a series of dungeons in the fictional town of Tristram. The town itself contains houses, a crypt, a smithy, and other buildings. These structures feature portable items that players can discover, loot, or purchase depending on the context in which these artifacts are found. The site of Tristam within which all of the action in *Diablo* transpires, is contained within the bounds of a stone wall on three sides and a river to the southeast. Players engage with the game-as-site, created via the site of the installed files, created from the site of the installation media itself, a site-within-a-site-within-a-site.

In all three definitions the video game is a (digital) built environment made by people for other people to use and inhabit. In the *Diablo* example, all of the artifacts and features are present on the disk I own and on the computer I use. In the present as well as in the future, however, one can and will discover evidence of software—games and otherwise—that can no longer be installed or run. When we deal with the digital, the conceptual approaches and concerns involved are the same as when dealing with real-world sites. Everything tends towards a state of entropy, which is why the archaeological record is both incomplete and difficult to define. While natural/mechanical processes constantly work to erase/change the archaeological past, similar processes occur within digital media, which are by their nature degenerative, forgetful, and erasable (Chun, 2011, p. 192). Digital media are stored (or have storage). Archaeological data are locked in structures and in assemblages both underground and above ground, just as digital data are stored either on-disk or on a drive. In both cases, data are gradually lost, the methods of storage imperfect. But there is also memory (an intangible archaeology), something to be interpreted when the real or virtual site is explored. The concepts of formation processes of the archaeological record and the methodological approaches to them are the same with the synthetic as they are with the natural. Sites, like artifacts, have a history of use that continues from their origin into the present day. Sites are never not used, although they may exist in stasis until (re)discovery through a new installation of old software, or a reactivation of a software program long latent on computer hardware.

Edgeworth (2014) agrees with the idea of digital archaeological sites, using “site” as a term for the locality of human-digital interaction, something beyond what Beollstorff et al. (2012) described when proposing a standardized methodology for ethnography in virtual worlds. To Edgeworth, “the term ‘site of discovery’ might usefully be taken to refer to virtual on-screen realities as well as off-screen ones. Certainly if one were to carry out an ethnographic study of archaeological discovery today, one would surely have to take a multi-sited approach, . . . looking at screen-work as well as spade-work” (2014, p. 4). He continues, stating, “if probed with skill and discernment, the virtual landscape can potentially yield an almost infinite number of new discoveries, each one giving rise to further paths of exploration that can be followed towards further discoveries and insights" (2014, p. 19).

But each of these sites must not be studied by themselves. According to Bayliss and Whittle, "people live in connection with others and move across the landscapes of their own time. Sites are often studied in isolation, but they belong in a wider, spatial context" (2015, p. 230). There is a fractalization in the archaeology of games, spiraling up from individual lines of code, routines, and the artifacts of digital assets into discrete sectors on physical media to regions in synthetic worlds, and up still further to multiple copies of the same game and to how a game fits in with the history of interactive digital entertainment. Context is key to the understanding of games at any level.

This thesis contains three case studies: *Colossal Cave Adventure* (Chapter 3), *Skyrim VR* (Chapter 4), and *No Man's Sky* (Chapter 5), and not all three fit each of the three site definitions as described above. For instance, *Colossal Cave Adventure* was originally installed in 1975 on a mainframe computer via a stack of punch-cards, and the game the cards loaded was text-only. The installation media (stack of cards) could not be considered a site, but the location of the installed files could be. The text adventure creates a cavernous space in the player's mind, full of features and artifacts, and this creates a site of intangible heritage. For *Skyrim VR*, DVD installation media exists (as does a digital download of the same files), creating a discrete site of installation, which when executed produces an immersive open world within which players can interact with features and artifacts. *No Man's Sky* can also be installed from either a DVD or direct download, which also creates a site of installation that, in the case of this game, creates a site-of-sites, a near-infinite environment where every planet in the game becomes a site unto itself. In all three case studies, these sites are temporary for any given locality, installed and playable until the player decides to remove them, or disposes of the hardware on which the site exists. That being said, the ideal version of the game-site, the one that exists for the game's developer prior to release to the playing public, serves as the site-of-record in its unplayed, undisturbed state, something to which clones of the site can be compared to see differences in histories of occupation, use, modification, and abandonment. This activity includes updates, patches, bug-fixes, mods,[13] and expansions to the game installation media and location. At the level of the in-game site, the site changes include the actions of one or more avatars and their effects on the game-space, whether it is moving in-game items from one place to another, or the

13. Nardi (2010, p. 58) makes the case for the importance of player-made mods for real-time data collection: archaeologists should make use of these in the games they study. In *WoW*, for example, the sites of Thottbot (wowhead.com) and Elitist Jerks (elitistjerks.co) provide player and game statistics, which include how often, where, and by whom any example of in-game artifact or portable material culture is "dropped" by non-player characters and collected by human avatars through combat or trade.

destruction or construction of something semi-permanent in the virtual world, not so different from human occupation of sites in the natural world.

2.6. Landscape Archaeology in Synthetic Worlds

To continue making the case in this chapter that archaeology of digital environments is not only possible but necessary, we must also perceive these spaces (which include video games) as landscapes. As done above with sites, "landscape" and "landscape archaeology must first be defined, but a standard definition in the literature remains elusive (Branton, 2009; Casey, 2008; Chapman, 2008; Cummings, 2008; David and Thomas 2008; Darvill, 2008; Dehham, 2017; Eve, 2012; Fennell, 2010; Gillings, 2012; Heilen, Schiffer, and Reid 2008; Ingold, 2000; Johnson, 2012; Johnston, 2012; Thomas, 2012; Tilley and Daum, 2008; Yntema, 2002). The single, common theme shared by archaeologists investigating landscape is the entangled relationship between people and the land.

The nature of that relationship, however, remains a rich source of continued research, but trends towards being centered upon people as agents of change in the landscape. Denham (2017, p. 464) takes a balanced approach, stating that "'landscape' is an integrated term that encapsulates the environmental and human aspects of a bounded area of land. . . . In addition to the physical aspects of past landscapes – in terms of both environmental and human processes – a landscape is explicitly or implicitly associated with layers of human meaning and value." To Denham, "landscape archaeology" then "refers to the understanding of archaeological remains (artifacts, sites, and site complexes) in terms of the wider spatial realms (both physical and meaningful) of past human experience" (2017, p. 464). Grahame Johnston (2012), sees landscapes as a series of "systems and settings, intimately related to human life, and rather than observing the beauty of the countryside, the scene is studied primarily as a foundation to understand living and working. The reality of any landscape is understood in the symbolic, which is another way of saying that landscape archaeologists are examining ancient human culture." Nicole Branton (2009, 51–65), also sees people and landscapes as part of a system, "landscape [archaeology] approaches model places and spaces as dynamic participants in past behavior, not merely setting (affecting human action), or artifact (affected by human action). Christopher Fennell (2010, p. 1), defines "landscape archaeology" as something that "addresses the complex issues of the ways that people have consciously and unconsciously shaped the land around them." Douwe Yntema (2002, p. 13) writes of the landscape "that human actions may occur, and leave an essentially continuous 'blanket' of traces, anywhere in the landscape, that the resulting surface is a palimpsest of such traces through time, and that patterns in this record may be explained in part by the in turn limiting and enabling qualities of the landscape." As early as 1973, the word "palimpsest" was used to describe a landscape archaeologically (Jones, 1973, p. 6), evidence of past activity sharing space with present reworkings of the land by forces understood as primarily human.

Landscapes occur naturally, without human interference, and change through non-human actions of weather, erosion, animal use, and other factors. Human exploration, exploitation, and settlement changes the landscape. But landscapes also change the people within them (Tilley, 2008, p. 274). The elements of the landscape unconsciously direct human behavior, dictating where people can and cannot settle, where they can hunt, where they can defend themselves, where they can extract natural resources. Over time, humans have been able to master the landscapes in which they find themselves, moving from the natural world to a manufactured one (Burtynsky, 2003). A manufactured landscape is one constructed on a colossal scale, creating its own environment. One example used by Burtynsky is a Chinese factory over 1 km long in which over 20,000 people work to create clothes irons.

The idea of humans creating their own massive landscapes atop (or in spite of) natural landscapes supporting them has, in the past forty years, been reproduced on a much smaller scale in the form of software. I published my initial thoughts on video games-as-landscapes in *Archaeogaming* (Reinhard, 2018c, pp. 95–103). To summarize here, landscapes are persistent spaces engaged by both human and non-human agents that both consciously and unconsciously follow rules set by the environment in which they operate. Landscapes are not static, but change at variable velocities based on human and non-human activities. Where humans are concerned, there exist locations and localities, sites and artifacts, evidence of presence, use, settlement, repruposing, and abandonment. This description of what a landscape is must not be limited to the natural world, but may also be applied to the synthetic without changing the definition. The hierarchy of the synthetic landscape, however, runs counter to that of landscapes in the natural world. In the natural world, landscapes host sites, which in turn hold features and artifacts, evidence of past human activity in a localized space. In the synthetic world, with software—games in this thesis—one creates a site of installation through the use of a media artifact (e.g., a CD or DVD), and the execution of the game through the site of installation creates a landscape ready for human occupation and use. Artifacts create sites, which generate manufactured landscapes.

Edler Scrolls V: Skyrim (Bethesda, 2011) should serve to illustrate the idea of game-as-landscape.[14] The game, designed for the solo adventurer (no multiplayer option is available), drops the player into a massive, snow-covered landscape that takes hundreds of hours to explore completely. The game-space is photorealistic, is populated by

14. See Chapter 4 of this thesis for my case study on archaeology in the virtual reality version of this game.

non-player characters (NPCs) both human and humanoid, as well as a vast diversity of flora and fauna, not to mention sites, features, and artifacts with which one may interact as one would in the natural world. The game provides hundreds of manufactured examples of past occupation and use to give the illusion of hundreds of years of biography. The game contains its own natural laws. One's avatar can freeze to death, can be injured in a fall, can be burned. A player's proximity to threats (e.g., wild animals, monsters, brigands, etc.) triggers their aggression. Players learn to adapt to these behaviors set by rules within the game-landscape. The land of Skyrim also contains borders that cannot be crossed, adding boundaries to the landscape, and additional rules for player-travel. To make *Skyrim* an adventure game, its developers filled the world with things to do and places to go, encouraging player-movement from town to town. The landscape therefore becomes what Ingold (1993) calls a "taskscape", where blind exploration is not enough. Players must complete quests in order to open more of the landscape for exploration, and to advance various narratives in the game. *Skyrim* is not unlike other games in its class. Even the very first adventure games (e.g., *Colossal Cave Adventure*, 1975)[15] required players to complete tasks to keep the story going and the landscape unfolding. This landscape-induced behavior is no different from what happens in the natural world, where humans interact with the landscape in order to complete chores, fulfill obligations to employers, friends, and families, advancing the in-real-life plot while growing old in a changing world.

The notion of environmental change resonates in the synthetic as it does in the natural world, too. Game-landscapes remain dynamic during their development and deployment with patches, bug-fixes, and new content (i.e., new quests and areas of the map to explore) changing the rules and appearance of the synthetic world. In some cases (like in *Skyrim* and other games in the *Elder Scrolls* series), the developers grant players the ability to create their own custom clothing, weapons, furniture, and more, even going to far as to allow for the creation of new quests and narratives. The modifications (abbreviated as "mods" by the gaming community), can be shared with others, creating new sites of human occupation and use within an existing, older landscape.

The version of *Skyrim* that I installed in 2011 differs from the version I enjoyed in 2019. The game has undergone a series of "builds" by Bethesda, which were pushed to players and automatically installed, changing the landscape subtly not unlike wind making new dunes. Development also created punctuated changes in the landscape with the addition of expansion packs, which introduced vampires, werewolves, and secret places overnight. Future synthetic landscape archaeologists can document these changes and their effects on players while creating a history of the game and how it was used and modified by communities of players over time.

15. See Chapter 3 of this thesis for the archaeology of this game.

Conducting landscape archaeology (or archaeology of any kind) within a synthetic world might sound tenuous at best, especially when we know that these are all designed environments. Think of these, however, as a proving ground for ideas on method and theory, testing on software we know that is well documented. I predict that by 2025 we will finally see video games set in completely procedurally generated worlds where the cultures that players encounter have never been considered by the game's designer(s), instead created from a complex set of rules that, when mixed together, create emergent cultures distinct from one another. We are already getting glimpses of these "machine-created cultures" (MCCs) in games such as Mark Johnson's *Ultima Ratio Regum*, and more are coming. One day we may have a Turing-style test for cultures to determine what is real. How will we determine that level of reality, and if a new, born-digital culture thrives, what obligations do we have to interacting with it, and ultimately to preserving it and its attending material culture? It is perhaps dangerous to think that archaeology can predict a future, especially for complex societies. What archaeology can do—especially digitally—is to create archives of sites and their data, which can be consulted over time depending on the scenarios for which such consultation is needed.

2.7. Conclusion

An archaeological site communicates many things and can be used in several different ways at once. Holtorf (2005, pp. 92–111) describes the uses and appeals of archaeological sites as having: monumentality (big/visible = important); factual detail (conformity with educational values); commerce (commercial exploitation of sites); social order (reception that mirrors the present); identities (personal relation to the past); aesthetics (romance and scenery of ruins); reflection; aura; nostalgia; ideology; adventures; magical places; and progress. Take a game such as *Assassin's Creed Unity* as a site, and you will find that all of the above uses apply equally to the virtual as they do to the real. In the case of open worlds—games that allow for free movement/play—video games behave even more like their real-world counterparts. In *Eve Online* there are no developer-ordained goals or a traditional endgame. Instead, players band together to create their own goals, annex their own little corner of the universe, form alliances, foster animosities with other groups, and create their own in-game lore (Stanton, 2015, pp. 298–301).

The following three case studies focus on digital games as archaeological entities in order to introduce wider concepts that can be applied to any kind of software from *Microsoft Word* to Google Docs, *Photoshop*, *ArcGIS*, and everything in between. My first case study observes a code-created human culture of storytellers. In the 1970s and 1980s the culture of hobbyist narrative code-writers was new, and their code-artifacts and inscriptions can be studied to better understand this culture of production facilitated by digital machines and communication. My second case study examines how a 100%-human-engineered play-environment created its own material culture, visual language, and lore, which influenced millions of players attracted to this affinity space. My third case study surveys abandoned human settlements left by a new player-culture established within a digital game, players who made the game-landscape their own in order to tell their own stories and create their own history. All three case studies document the emergence and physical remains of human populations self-selected into new and evolving cultures dictated by these digital interactive landscapes. When new digital cultures finally arrive through AI and algorithms, these case studies can serve as a starting point for how to proceed with completely unimagined social groups and networks.

The findings I report below, the approaches to games software, and the tools used to understand them should be scalable and applicable to other, non-entertainment-focused digital built environments. The goals of software differ little between games and non-games: they are coded, are purpose-built for and used by human and non-human agents, and attract a community of practice around both their creation and use. To begin this archaeology of digital things, however, I focus on games (Chapter 3). Games mark an easier entry-point because of their familiarity, community, and entertainment value, plus the fact that they are visual and can contain more traditional examples of artifacts and architecture within them. Boellstorff asks (and answers) (2006, pp. 33–34):

> Why game studies now? Because the information age has, under our noses, become the gaming age. It appears likely that gaming and its associated notion of play may become a master metaphor for a range of human social relations, with the potential for new freedoms and new creativity as well as new oppressions and inequality. Although no methodological or theoretical approach can represent a cure-all for any discipline, anthropological approaches can contribute significantly to a game studies nimble enough to respond to the unanticipated, conjunctural, and above all rapidly changing cyberworlds through which we all in someway are now in the process of redefining the human project.

All software contains artifacts and architecture, but games can provide artifacts that look like artifacts in the natural world. Once the reader has grasped the archaeology of game-space, they will be equipped to make the jump to understanding artifacts as things such as glitches or code-snippets, and architecture such as file structures or the grammar and organization of a coded routine.

3

Case Study One: The Archaeology of *Colossal Cave Adventure*: Epigraphy, Stylometry, Text Analysis, and Human Context

3.1. Introduction

The purpose of this thesis is to demonstrate that archaeology in its many forms can be used to understand and document digital environments. This first case study will prove that archaeological investigation can be undertaken in a digital built environment that contains no graphics whatsoever and can best be defined through understanding its underlying code within a wider human context as a digital text-artifact. This case study focuses on the original interactive digital text adventure game, *Colossal Cave Adventure* (abbreviated as *CCA*).

3.1.1. Research Questions

Two levels of research questions drive this case study: 1) questions about tools and method, and 2) questions about the game itself.

- Can one conduct an archaeological investigation on a digital artifact, specifically one that shares characteristics with clay tablets and papyrus?
- Can existing tools and methods for epigraphy and text analysis be used on a digital text-artifact?
- What can quantitative data tell the researcher about a collection of digital texts that are related to a common source?
- What other archaeological information can one glean from studying a digital text-artifact outside of quantitative analysis?

- Can any of the lessons learned through this case study be applied to archaeology more broadly outside of the digital environment?

3.1.2. Organization

This case study chapter is divided into four parts:

1. Introduction. I begin by outlining my research questions, why I chose *Colossal Cave Adventure* in order to answer these research questions, and an explanation of the game and its history of development.
2. Tools and Methods. This section includes the underlying approach to digital material from a traditional archaeological perspective, ways of looking at digital archaeological artifacts through their context, and an explanation of the Digital Humanities tools I used and why I chose to use them.
3. Quantitative Results. I interpret the findings of various text analysis tools run against my data.
4. Conclusions. I reflect on my approaches to conducting archaeology within CCA and offer future ideas for research.

Seven appendixes follow this case study:

A. Narrative data from the original *CCA*
B. FORTRAN IV source code of the original *CCA*
C. Instructions on installation and use of the software tools employed here
D–G. Tables of results from the quantitative text analysis of *CCA*

These are presented as appendices rather than in the body of the text because they would otherwise interrupt the flow of this chapter with technical documentation, hundreds of lines of code, and hundreds of table entries.

3.1.3. Why *Colossal Cave Adventure?*

Colossal Cave Adventure (often referred to as *Adventure*[1]), written in 1975 by William Crowther and updated in 1977/8 by Don Woods, is the very first example of an interactive role-playing game (RPG) written for the computer that accepts natural language input via keyboard by the player.[2] The game is text-only—no graphics—requiring play-

1. *Adventure* is also the name of Atari's 1980 classic game by Warren Robinett, which is based on Woods' 1977/8 adaptation of Crowther's original story.
2. Readers unfamiliar with how to play *CCA* may do so via this online version created by Rick Adams in 2014: https://www.amc.com/shows/halt-and-catch-fire/exclusives/colossal-cave-adventure (accessed 3 January 2019).

Figure 3.1. *Colossal Cave Adventure* running on a PDP-11/34 as displayed on the minicomputer's VT100 serial console (image source: https://www.ostechnix.com/colossal-cave-adventure-famous-classic-text-based-adventure-game/).

ers to imagine the action and locations in the game while typing commands (Fig. 3.1). The goal of the game is to navigate through the "colossal cave" from the entrance to the exit, solving logic puzzles in order to progress. The game rewards efficiency in moves, the classic version awarding 350 points to the player who completes the adventure in 215 moves/turns. While it is impossible to determine how many people actually played *CCA* or any of its versions, the game was clearly popular with generations of players and programmers, proven by the fact that the game inspired over 100 versions/iterations as listed below. Most of the versions created by other programmers mimic the 350-point game, and other versions exist with scoring as high as 1,000 points.[3] These later versions added additional rooms, puzzles, and treasures.

The game is played in the first-person thereby requiring instructions to be typed in the imperative mood as commands. A programming choice in the use of its original language, FORTRAN IV, which was not designed to handle a lot of text,[4] and the fact that the original game was played directly on the PDP-10 mainframe computers first at Crowther's workplace at Bolt, Beranek & Newman (BBN) and later at Stanford University, commands are truncated to the first six characters per word, and most commands in the game are four characters or less.[5] In the original version, players indicate

3. The number of maximum points to be earned in various versions of *CCA* are listed first in a file's title and secondly within either a version's ReadMe file or found in a commented line of code.

4. Readers unfamiliar with the FORTRAN IV programming language should consult two standard primers: Donald Alcock, 1982, *Illustrating FORTRAN* (Cambridge University Press), and Roger Kaufman, 1978, *A FORTRAN Coloring Book* (MIT Press).

5. See Appendix A for the complete text of Crowther's 1975 narrative data file. See Appendix B for Crowther's complete FORTRAN IV source code.

movement by typing the abbreviation of one of eight directions: n, ne, e, se, s, sw, w, nw. Other commands can include one-word locations (e.g., "Bedquilt"), magic words (e.g., "xyzzy"), and two-word commands using an imperative verb followed by an object (e.g., "get lamp"). In the original version of *CCA*, one of the main challenges to the player was determining the correct verb to use (e.g., "get" instead of "take"). Later 350-point versions (e.g., ticm0350,[6] goet0350, and others) added synonyms to make the game more forgiving, meaning the game would accept either "get" or "take" instead of just "get". Crowther and Woods programmed *CCA* to include a system of hints, and the Woods version docked points from players for using them.

The game's narrative and style follow fantasy tropes loosely informed by the works of J. R. R. Tolkien (e.g., dwarves, edged weapons, a dragon), classic folk tales (e.g., "Jack and the Beanstalk"), and stories about treasure (e.g., *Treasure Island*), yet the game's topography mirrors the actual Kentucky cave system explored by Crowther and his wife, Pat, in the early 1970s. The game is frequently funny, especially when the player asks for a hint or does something wrong (e.g., type "rub lamp" to get the droll response "RUBBING THE ELECTRIC LAMP IS NOT PARTICULARLY REWARDING").

CCA's appeal and popularity informed and inspired generations of players and began the RPG/adventure genre for video games, which continues to be popular and profitable for game publishers over 40 years later.[7] The game's use of a quest, fantastic creatures, an underground location, the looting of treasures, and solving puzzles to progress in the narrative all became universal ingredients for the adventure games that followed, the main differences in the later games being graphics and animation, audio, and complexity in the gameplay with more advanced puzzles as well as the introduction of artificial intelligence. Although *CCA* is not the first computer game (games such as *Hunt the Wumpus* [1972/3] came before it), it is the first known distributed work of text-only interactive fiction entertainment, which would lead directly to the creation of the classic game *Zork* (1977) and the interactive fiction giant that produced it, Infocom, at MIT, followed by thousands of graphical role-playing computer games from hundreds of individuals and companies worldwide.[8]

In 2005, Don Woods recovered Crowther's original source code after requesting a copy of his backed up student account at Stanford University's Artificial Intelligence Lab (SAIL), which contained the five FORTRAN IV files received from Crowther. He used these to create an updated version of the game (Jerz, 2007). Don Woods' 1977/8 version remains the most widely circulated version because Crowther's source code

6. Names such as TICM0350 disambiguate between iterations of *CCA* and refer to the first four letters of a version author's surname and the maximum points allowed by that version.

7. Popular examples of RPG/adventure games include *King's Quest* (Sierra On-Line, 1984), *Grim Fandango* (LucasArts, 1998), *Elder Scrolls Online* (ZeniMax, 2014), and hundreds of others.

8. Wikipedia hosts an ever-increasing list of games in this category: https://en.wikipedia.org/wiki/List_of_role-playing_video_games.

had been lost. In 1977 Woods evolved Crowther's game (with the author's consent), expanding upon the narrative text to give it more of a storylike quality as opposed to the bare-bones adventure created by Crowther, and also added a scoring system. This is an early example of open source coding where the underlying code (as well as, in this case, the narrative) is made freely available to someone else to remix and distribute. Woods followed the unwritten rules of open source etiquette by citing his source, something that would appear in nearly every ReadMe file of later versions of *CCA*. This trail of citations makes it relatively easy to sequence the versions, and registries now exist in several places online in varying states of completeness that list known versions of the game, all of which tie back to the 1975 original (Dalenberg, 2006; Adams, no date; Culver, 2019).[9]

The following table chronologically lists all known versions created by individuals, their names, and the version name as assigned by one of the game's historians, Nathanael CJE Culver (Culver, 2019). The version name concatenates an abbreviation of the author's name with the version's score (games without a scoring system are flagged as "XXX", and games flagged as "0000" are genealogically tied together as direct descendants/copies of Crowther's 1975 original code). These versions were created for a number of reasons: 1) to port the game from old programming languages and platforms to newer ones, 2) to serve as an act of game preservation, and 3) as a programming exercise/challenge. I have flagged with an asterisk individuals who made significant contributions to computer science and video game design either before or after creating a version of *CCA*:

Name	***CCA* Version**	**Year**
Will Crowther*	CROW0000	1975
Don Woods*	WOOD0350	1977
Kent Blackett	BLKT0350	1977
Bob Supnik	SUPN0350	1978
Peter Luckett & Jack Pike	LUPI0440	1978
David Long	LONG0500	1979
George Richmond	RICH0500	1979
Gordon Letwin*	LETW0350	1979
Barry C. Breen	BREE_XXX	1980
Chris Gray	GRAY0375	1980
Michael Goetz	GOET0350	1980
Michael Goetz	GOET0550	1980

9. As of this writing, the most complete register of versions (including download links) is curated by Nathanael CJE Culver, *The Adventure Family Tree*, with ca. 160 separate versions authored by over 120 individuals and companies.

Peter Schmuckal & Leonard Barshack	SCBA0350	1980
John Rausch	RAUS0350	1981
Master Jacobi	JACM0350	1981
Max Manowski	MANO_XXX	1981
Jim Gillogly and Walt Bilofski	GIBI0375	1982
John Jones-Steele	JONE0210	1982
Peter, Nick & Mike Austin	AUST1100	1982
Robert A. Howell	HOWE0301	1982
Michael J. Evis	EVIS0350	1983
David Platt	PLAT0550	1984
Bob Withers	WITH0000	1985
Ken Wellsch	WELL0550	1985
L. C. Calhoun	CALH0000	1985
Paul McGuire	MCGU_XXX	1985
Peter Gerard	GERA_XXX	1985
Ross Harris	HARR0235	1985
Kevin B. Black	BLAC0350	1987
Ravi Bhavnani & Marc Chardon	BHCH0565	1987
Steve Dover	DOVE0550	1987
Tony L. Belding	BELD0350	1987/1992
Peter M. Ibbotson	IBBO0000	1988
Andres Roberto Samudio Monro, Manuel Gonzalez Martinez, Carlos Marques	MOMA_XXX	1989
Alan Miller*	MILL0551	1990
Anton Fleig	FLEI0350	1990
Bob Withers	WITB0000	1990
David Fenyes	FENY0350	1990
David Malmberg	MALM1000	1990
Don Ekman	EKMA0350	1990
Doug McDonald	MCDO0551	1990
Jerry Pohl	POHL0350	1990
Johann Gunnar Oskarsson	OSKA0501	1990
Magnus Olsson	OLSS0551	1990
Anthony C. Ard	ARD_0550	1991
David Gasior	GASI0350	1991
John W. Kennedy	KENN0000	1992
Scott Mayo	MAYO0350	1992
Wolfgang Strobl	STRO0550	1992
David M Baggett*	BAGG0350	1993
David Malmberg	MALM0350	1993

James Lummel	LUMM0350	1993
Jim Gillogly	GILL0350	1993
Michael Goetz	GOET0580	1993
Michael Goetz	GOET058D	1993
Andrew Daviel	DAVI0350	1994
Kent Plotkin	PLOT0350	1994
Robert R. Hall	HALL0501	1994
Jeff Standish	STAN0350	1995
Jim Butterfield	BUTT_XXX	1995
Mike Arnautov	ARNA0660	1995
Don Woods	WOOD0430	1978/1995
Don Woods	WOOD043B	1978/1995
Andrew Plotkin	PLON0350	1996
David Kinder	KINA0660	1996
David Kinder	KIND0430	1996
David Kinder	KINE0350	1996
David Kinder	KINM0551	1996
David Kinder	KINW0550	1996
Jacob Munkhammar	MUNK0430	1996
Paul Muñoz-Colman	MUNO0370	1996
Simon Baldwin	BALD0350	1996
David Kinder	KINT0350	1997
Jay Walton*	WALT0350	1997
Jose Luis Diaz	DIAZ0350	1997
Linards Ticmanis	TICM0350	1998
Toni Arnold	ARNO0350	1998
Ravi Bhavnani	BHAV0565	2000
James M. Hartley Jr.	HART0350	2001
Jason Penney	PENN0350	2001
Jean-Luc Pontico	PONT0350	2001
Mike Arnautov	ARNA0440	2001
Mike Arnautov	ARNA0550	2001
Leo Wong	WONG0350	2002
Nick Nicholas, et al.	NKMP0350	2002
Yuri Robbers	ROBB0350	2002
David Picton	PICT0551	2003
Donald E. Knuth*	KNUT0350	2003
Matt Cox	COX_0350	2003
C. Yong	YONG_XXX	2006
Graham Nelson	NELS0350	2006

Mike Arnautov	ARNA0770	2006
Nick Rogers	ROGE0350	2006
Al Whinery	WHIN0450	2007
Frederik Ramsberg	RAMS0350	2007
Matthew Russotto	RUSS0000	2007
Matthew Smith*	SMIT0350	2007
Ted Beck	BECK0500	2008
Shawn Stanley	STAN1000	2008/2009
Tony Jarrett and Paul Zemlin	JAZE_XXX	2009
Juan del Valle Rodríguez	RODR0350	2010
Richard Rutenberg	RUTE0350	2010
Shawn Stanley	STAN_XXX	2010/2014
Chris Conley	CONL0000	2011
Dom Hamon*	HAMO0350	2011
Neil Van Eck	VANE0560	2011
Robert Dea	DEAR0000	2011
Bennett Standeven	STAD0550	2013
Bennett Standeven	STAD0580	2013
Dave Benham	BEHN0350	2013
David Picton	PICT070+	2013
David Picton	PICT0701	2013
Arthur O'Dwyer	ODWY0350	2014
Arthur O'Dwyer	ODWY0440	2014
Arthur O'Dwyer	ODWY0550	2014
Arthur O'Dwyer	ODWY0551	2014
Rick Adams	ADAM0350	2014
Brian Ball	BALL0770	2015
Jesse McGrew	MCGR0350	2015
Jim Gerrie	GERR0000	2015
Dan Nelson	NELD0350	2016
Daniel Jameson	HAME0551	2016
Eric S. Raymond	RAYM0430	2017
Chuck Crayne	CRAY0350	?
R. Emerson, W. Wirth, et al.	EWHH0366	?
Koch, Fry, et al	KFML0700	?
Troy Fullwood	FULL0000	?
Michael Goetz	GOET0565	?
Al Golden	GOLD1000	?
Wesley Holland	HOLL0350	?
Greg Huntzinger	HUNT0000	?

John Jacobsma	JACO0365	?
Jay R. Jaeger	JAEG0000	?
Stephen O. Lidie	LIDI0366	?
David Long	LONG0751	?
Gary Palter	PALT0350	?
Marvin W. Rasmussen	RASM0350	?
Bob Sloane	SLOA0350	?
Alan Solomon*	SOLO0350	?
Kent Tessman*	TESS0350	?

* = **Notable career:**

- David M. Baggett, co-creator of *Crash Bandicoot*
- Will Crowther, ARPAnet team member (forerunner to the Internet)
- Dom Hamon, lead developer for EA Games/Sports
- Donald E. Knuth, Professor Emeritus of Computer Science, Stanford University
- Gordon Letwin, one of the first 11 Microsoft employees
- Alan Miller, Atari 2600 programmer and co-founder of Activision and Accolade
- Eric S. Raymond, open source advocate and author of *The Cathedral and the Bazaar* and the *New Hackers Dictionary*, among other works
- Matthew Smith, game developer who wrote *Jet Set Willy*
- Alan Solomon, inventor of anti-virus software for PCs
- Kent Tessman, screenwriter and developer of the most widely used screenwriting software program, *Fade In*
- Jay Walton, programmer at Rockstar Games
- Don Woods, programmer and hacker

In this chapter I have included the names of the *CCA* programmers because they have been in the public domain for years and are widely known in the online *CCA* community. All of the versions are open source, and many of them were "signed" by the authors prior to distribution, at times even including postal addresses, email, and telephone contact details (see the ReadMe files for BAGG0350, MUNO0370, BREE_XXX, and many others). What we see in this list of authors and version titles is a kind of prosopography, a subset of epigraphy that deals with lists of people's names, which can then be used to learn more about certain aspects of the ancient world (in traditional epigraphy [Salomies, 2001, p. 75]), or in this case, the late 20th and early 21st centuries. We can check the names assigned to existing versions of *CCA* against other versions as they come to light to either confirm or update attribution of authorship based on file metadata and context.

In *CCA* we also have a kind of digital dendrochronology, later versions of the game created over time, wrapped around the core of code authored by Crowther and Woods. The code is archaeological, as will be described below. This is not the first time that *CCA* has been treated as a cultural artifact in scholarship. In fact, in 1985 Dr. Mary Ann Buckles wrote the very first PhD thesis on what would later become known as "game studies", *Interactive Fiction: The Computer Storygame "Adventure"*, introducing the term "interactive fiction" into the literature as a new genre along with seeing *CCA* for what it was, a digital narrative adventure story, the first of its kind (Buckles, 1985). Buckles approached this new genre from her perspective of literary theory (in fact, her thesis was written for the department of German at the University of California-San Diego). In it, she explores the close relationship between play, games, and literature, looking at traditional literary models and narrative strategies, comparing them with the game, which uses the player/reader as an active story participant for the first time in the hisotry of software.

Buckles correctly forecast what would eventually become digital role-playing games, one of the most popular gaming genres of which *CCA* is the Ur-text:

> With technical development of the computer medium and the growing experience of writing interactive fiction, I think a completely new type of story will someday emerge. . . . One difficulty I do foresee and view as inherent to the interactive computer medium will be creating non-stereotype, subtle characters with whom the reader can interact. One obvious way around this problem will be to have the reader interact with characters who are not human and will not have to respond as such, but I think a more radical solution will come to characterize interaction fiction . . . Unless or until artificial intelligence can imitate human language on any sophisticated level, however, I think that a new focus will be necessary . . . . (Buckles, 1985, pp. 82–83).

My thesis advances that of Buckles', treating *CCA* not only as a cultural and literary artifact from the recent past, but as an illustrative example of living mythology and inscriptional evidence, something that is at once both artifact and literature, thing and text, best understood archaeologically. When she conducted her research, Buckles did not know what would happen to these interactive stories in the hands of future readers/users, and that ultimately *CCA* would have dozens of authors contributing to the story over time, or that digital media would itself undergo multiple changes, which would also affect how the story could be transmitted and interacted with. This case study aims to illuminate archaeologically these areas that she did not predict.

The original 1975 source code of *Colossal Cave Adventure* is a code-artifact written in an old language, an ancient primary source, something that is securely sourced to a person and a location (William Crowther and the PDP-10 mainframe computer at Bolt, Beranek & Newman). The code of *CCA* is not unlike an epic poem, the equivalent of the *Iliad* or the *Odyssey*, but is perhaps most closely aligned with *Gilgamesh*, literally the Ur-epic. In ancient epics as well as within the narrative of *CCA*, we follow the hero's journey, which includes a trip to the Underworld and the collection of artifacts there. As with all ancient epic poems, the core story and characters remain the same, but the story grows and changes over time depending on who is telling it, the context in which the story is told, and the chronological distance between the current telling and the original source. *Gilgamesh* comes down to us from two Mesopotamian sources, both written on clay tablets, one in Akkadian, and another in Old Babylonian. Homeric epics come down to us not only from the oral tradition, but also through clay tablets and papyrus. *CCA* follows suit, with its earliest version written in the "ancient" language of FORTRAN IV, later ported to more current versions of FORTRAN (so it could be played on current hardware), as well as early versions of C. The content of an epic is inscribed on either clay or punchcards, preserved on the early media, but also preserved through the sharing of the stories, which allow for changes to the narratives over time through multiple retellings. Thanks to the open nature of *CCA*, we can see how Crowther's original epic grew and changed over 44 years, a near-eternity in computing.

As with the papyrological record, archaeologists and historians know three things: 1) some papyrus exists, and its texts are complete; 2) some papyrus exists, but its texts are incomplete; 3) some papyrus no longer exists, but once did. This is true with source code versions of *CCA*. We have the original 1975 source code. We have later versions, which may or may not be able to be read by either people or machines in 2019. We also know through research that some versions once existed (e.g., Alan Solomon's Microsoft Fortran version from 1985), but are no longer accessible for whatever reason. Code archaeology could very well be the papyrology of the twenty-first century.

This case study focuses on the evolution of *CCA*'s code. I examined over 70 versions of the game not just by eye, but also with stylometric and text analysis software (*Stylo*, *TextReuse*, and *Textnets* for the statistics program *R*) to see if the current versioning chronology and authorship of the actual programs match up with the historical record. Granted my data set of ca. 70 code versions is relatively small when compared against data sets of code that can contain millions of lines to compare, so while I was not able to determine an author because of a small data sample, I was able to see that code was re-used/shared between authors. As will be shown below, *CCA* allowed me to establish formally an archaeology of code, a control set from which I derived a methodology to use on other sets of code, for example that of Atari 2600 games written in the late '70s and early '80s, training the software on the styles of Howard Warshaw, Carol Shaw, and others, and then running source code of various games through *R* packages to look for evidence of code re-use and other artifacts of code-authorship born in a corporate environment at the birth of the video game industry. We can add quantitative evidence to the oral histories of these companies, not unlike compiling data on Roman sigillata pottery and the international factories that produced it, determining not only makers but also routes of commerce and distribution. With source code, those trade routes take the shape of individual intellectual property circulating under corporate ownership. If archaeology is to undertake the study of 20th- and 21st-century digital culture, economy, and habitation, it must include the analysis of its underlying text.

3.2. Tools and Method

The overall thesis addressed by my three case studies is to evaluate if (and how) traditional archaeological tools, methods, and research questions can be applied to digital built environments (e.g., software, and for this thesis specifically, interactive digital entertainment—video games). For this thesis, I have to start from my own learned experience, modifying it through experimentation within a new, digital-only space. How can an archaeologist (me), who was originally trained in the field in Etruria and Greece, conduct an archaeological investigation of 1,000 lines of FORTRAN (or any programming language)? I propose that archaeological tools and methods and the research questions they address are scalable despite the nature of the landscape, site, or artifact being studied. In the case of a code-artifact, one can apply epigraphy and stylometry, just as one would when considering excavated papyrus or other inscriptional evidence as well as pieces of decorated pottery.

One can begin with authorship: who made the artifact I am looking at? Source code is text, and as such was written by one or more people for a primary audience of either a machine or human to read. By the nature of code being text, it is subject to the study of epigraphy (the study and interpretation of inscriptions, typically ancient) and stylometry (the statistical analysis of variations in literary style between one writer and another).

Some of what epigraphers of ancient writing study offer immediate parallels to investigating computer code: texts carved individually upon stone and metal; texts reproduced in multiple copies by stamps; texts included within pictures on glass or mosaic or painting; painted texts imitating the style and format of monumental texts, but which are public notices of only temporary relevance; a variety of handwritten texts (Cooley, 2012, p. 117) along with defining inscriptions by their method of writing rather than surface on which the writing appears (so stamping, incising, etc.) (Cooley, 2012, p. 119). Instead of ancient text carved on stone and metal or stamped on terracotta, we now have punchcards and typescript files accessible through screens. Instead of stamped multiple copies, we now have copies of digital files. The epigraphy of code maintains a close relationship with classical epigraphy but with an entirely new set of media to explore.

Epigraphy is not just about understanding ancient writing: it includes context, too. In his introduction to *Epigraphic Evidence: Ancient History from Inscriptions,* John Bodel writes, "Most [ancient historians] would concede that the history of classical antiquity could not be written without epigraphy, and many would assert that the proper business of the epigraphist is not only to edit inscribed text but to set inscriptions into their cultural contexts and thus to demonstrate their contribution to history" (Bodel, 2001, p. 1). Where traditional epigraphy not only reviews inscriptions carved in stone, it also considers the monument upon which the inscription was carved. This context of monument and inscription can reveal data about the inscription's production, use, and even reuse (Cooley, 2012, p. 370). An inscription's monumental context and physical location also contain important historical clues (Cooley, 2012, p. 440). The epigraphy of software code can do the same thing for placing modern digital media into their own historical contexts. Bodel also notes two key questions to ask when conducting epigraphical work: 1) How were these inscriptions viewed by the people for whom they were written?, and 2) What motives inspired those who wrote them? (Bodel, 2001, p. 5).

So what does an epigrapher do when encountering a new ancient inscription? The epigrapher often creates a "squeeze" on-site, a non-destructive application of damp paper, which, once dry, contains not only a copy of the inscription impressed upon it, but also other data such as letter depth and height, and the state of preservation of the inscription itself. The squeeze can then be transported to lab or office for future consultation. The epigrapher also notes the location of the inscription (both on the monument and with GIS/GPS), the monument's dimensions, the measurements of the "field" in which the inscription was made, and notes on how the inscription was written. This context can help date the inscription when no date is explicitly given (Cooley, 2012, p. 399). Similar methodology can be applied to code, but with modifications based on medium. For punchcards, photos can be taken, which can then allow others to create facsimile punchcards with their holes punched in the same way as the source. Files can be copied, which includes their underlying metadata (see the section on CHECKSUM below). Metadata can also be recorded about the code itself, where it was discovered, if it is complete/readable, and how it relates to the wider context of its place of discovery.

Stylometry is also key in understanding code. When looking at source code, we are looking at the primary source (or variations of it). Computer programming is an iterative venture, meaning that the code changes over time with modifications to intended functionality, debugging, feature-creep (extra functionality added to a program outside of the scope of the original design specification), etc. These later iterations of code can be authored by others, and are written in a way that can be tracked chronologically via date/time stamps and version numbers. All of these changes can be identified through stylometric analysis, which reviews vocabulary, punctuation, and syntax that can then be used to identify the hand of an author (although not necessarily by name). Everyone writes code differently, which can include how one organizes routines, how one does or does not comment the code, and even how one punctuates or formats the code (e.g., tabs/indents) (Aylin Caliskan-Islam et al., 2015, pp. 255–70).[10] We can attribute code authorship by way of understanding style.

As an art historian of ancient Greek pottery, I can compare this stylometric approach to that of archaeologist John Beazely whose seminal *Attic Black-Figure Vase-Painters* (Beazely, 1956) and *Attic Red-Figure Vase-Painters* (Beazley, 1963) were informed by the non-quantitative "stylometric" theory of art historian Giovanni Morelli (1816–91), who attributed authorship to the style of the painted line. In ancient art history, one continues to rely on conducting a visual comparison of a newfound artifact against an established corpus of *comparanda*: "this thing looks like these other things, which happened to be made by this person/workshop." The art historian can train the eye in pattern recognition to spot an artist's style, or in 2019, can supplement what the human eye sees with a variety of Digital Humanities software tools for visual and non-visual analysis. It is difficult with texts to determine both identity and authenticity of authorship by eye and experience alone. Stylometric software such as *Stylo* (which is open source) can help not just with providing quantitative results for text-authorship, but also with data visualization.

So far this case study has introduced the concept of code archaeology using the game *Colossal Cave Adventure* as its *Gilgamesh*. The code itself underwent both stylometric and text analysis in order to provide a quantified look at how the game grew and changed, and how authors and versions borrowed from one another over the past 44 years, not unlike new settlers in an established community. Before conducting text analysis, however, one must first look at the code sets of *CCA* in a more contextual way, offering additional methods of viewing them, using that data either to confirm or correct past assumptions about a program's history as told by its code (i.e., text-artifact). Think of this as first looking at artifacts at the dig house/magazine prior to sending them to the lab for XRF analysis and other scientific tests.

The next few sections analyze *Colossal Cave Adventure* versions in different ways, each method adding to a more complete understanding of how the game grew and changed, as well as the culture of the people who coded these iterations.

10. This case study is not the first time stylometric and text analysis tools have been used to analyze code-authorship. In Aylin Caliskan-Islam et al. (2015), the authors used code stylometry to determine authorship of computer virus code.

3.2.1. Code Sets

As stated earlier, the first two versions of *Colossal Cave Adventure* were both written in FORTRAN IV for the PDP-10 mainframe computer by William Crowther (1975) and Don Woods (1977/8). The versions that followed through 2017[11] included straight translations/ports and updates in over a dozen computer languages for platforms ranging from mainframes (i.e., DEC) to personal computers to purely Web-based games. The following table lists the languages (where known), version names, and creation years for *CCA* versions created in each language. Years marked with an asterisk (*) indicate that the version year was previously unknown to the *CCA* community but has been supplied by me via EXIF data, which will be described in the next section.

Language	Version Name	Year
A-Code	ARNA0550	2001
	ARNA0770	2006
ANSI C	ANON0340	1994
Atari BASIC	ANAL_XXX	1981
BASIC	CCS__XXX	1981
C	ARD_0550	1991
	KNUT0350	2003
	WOOD0430	1978
DEC FORTRAN IV	LONG0500	1979
	SUPN0350	1978
	WOOD043B	1995
FORTRAN	ANON0501	1979
	ARNA0440 DOS	2001
	ARNA0440 Linux	2001
	ARNA0440 Source	2001
	WOOD0350	1977
FORTRAN 77	JAME0551	2016
	OLSS0551	1990
	OSKA0551	1990
Inform	NELS0350	2006
	NKMP0350	2002
Intel FORTRAN	VANE0560	2011
MS FORTRAN	BLAC0350	1987
	DOVE0550	1987*
MS Micro Color BASIC	GERR0000	2015
OMSI Pascal	BREE_XXX	1980

11. As of January 14, 2019, no *CCA* versions have been published publicly since 2017.

Pascal	BECK0500	2008*
PDS FORTRAN	MUNO0370	1996
PHP	ADAM0350	2014
Quill System	HARR0235	1985
Windows Batch	BENH0350	2013
Z Code	BAGG0350	1993
	BALD0350	1996
Unknown	ARNA0660	1995
	COX_0350	2003
	CROW0000	1976
	DAIM0350	1984*
	EKMA0350	1990
	GOET0350	1980
	KENN0000	1992*
	KINE0350	1996*
	KINT0350	1997*
	KINW0550	1996*
	LUMM0350	1993*
	MALM0350	1993
	MALM1000	1990
	MCDO0551	1990
	MUNK0430	1996*
	PLAT0550	1984
	PLOT0350	1994
	POHL0350	1990
	RUSS0000	2007
	TICM0350	1998
	WELL0550	1985
	WHIN0450	2007
	AUST1100	1982
	BHAV0565	2000
	BUTT_XXX	1995*
	DIAZ0350	1997
	GASI0350	1991
	GILL0350	1993*
	GOET058D	1993
	GOET0580	1993
	HAMO0350	2011
	KINA0660	1996
	KIND0430	1995*

	KING0350	1996*
	KINM0551	1996*
	PICT0551	2003*
	RAYM0430	2017
	WITB0000	1990
	YONG_XXX	2006
	ARNO0350	1998
	CALH0000	1985
	CONL0000	2011
	CRAY0350	?
	EVIZ0350	1983
	EWHH0366	?
	FULL0000	?
	GOLD1000	?
	GRAY0375	1980
	JAME_XXX	2009*
	JONE0210	1982
	LETW0350	1979
	LUPI0440	1978
	MANO_XXX	1981
	MCGU_XXX	1985
	MOMA_XXX	1989
	PENN0350	2001
	PICT0701	2013*
	PLON0350	1996
	PONT0350	2001
	RAMS0350	2007
	RASM0350	?
	RAUS0350	1981
	RICH0500	1979
	ROBB0350	2002
	SCBA0350	1980
	STAD0550	2013*
	STAD0580	2013*
	STAN0350	1995
	VMCM0350	?

3.2.2. EXIF Data and the *CCA* Chronology

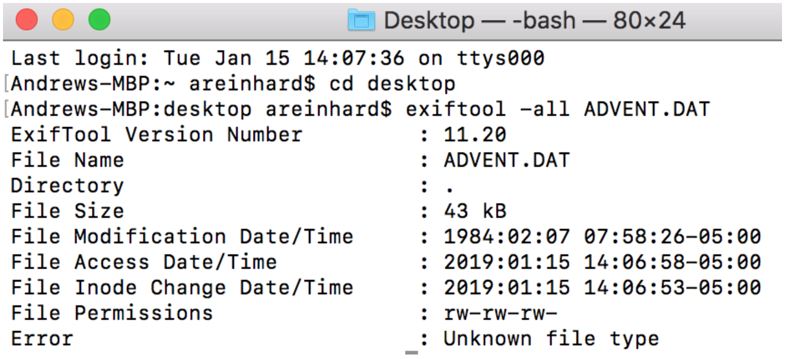
Computer files contain metadata, some of which are easy to obtain, which provides the digital archaeologist with those files' hidden histories. One can either right-click (Windows OS) or press command+i (Mac OS) in order to retrieve information about who created a file and when, and where it is currently located. These data, however, are not always the most accurate, sometimes reflecting the date a file was copied from one computer to another (instead of when the file was originally made). Because of this, one must look into the deep metadata of a file in an attempt to find the actual date a file was created and, if possible, by whom. These more accurate data help to create a more reliable and stable file chronology, something important to determining the order of versions (i.e., strata) of a software application, *Colossal Cave Adventure* in this instance. Compare this to traditional field archaeology where either numismatic, pottery, or inscriptional evidence can prove the date of a stratum. Unlike working with coins, pottery, and text, accessing these deep metadata in text and programming files is not that intuitive and requires borrowing from image file metadata.

Exchangeable Image File format (EXIF) data are embedded into image files via the digital devices used to capture them, and include information ranging from exposure to focal length, as well as the date and time at which an image file was created. The EXIF data of a digital image can be read relatively easily through various digital image software programs such as the Adobe suite of projects (including *Bridge* and *Photoshop*). These image software programs cannot, however, open text files or provide access to their metadata.

I was able to resolve this problem by finding an open access program, *ExifTool*, which can be installed and run from the Terminal (Mac) or Console (Windows).[12] One can use this tool to read all available metadata for any kind of file (not just images) (Fig. 3.2). In this example, note that even though Crowther's original files were downloaded from Woods' website, the actual date according to the *ExifTool* is February 7, 1984. This would indicate that this file is likely Crowther's original work, yet something happened to the file on that 1984 date to change the datestamp on that file. There may be other copies of Crowther's files that will show an earlier date, but the data file from Woods' homepage has had its metadata corrupted, a kind of intrusion into that file's stratigraphy.

Collecting EXIF metadata on *CCA* files allowed me to do three things:

12. *ExifTool* can be found at http://owl.phy.queensu.ca/~phil/exiftool/ (accessed January 6, 2019), and is also available in my Github repository for this case study: https://github.com/adreinhard/cca. See Appendix C for installation and usage instructions.



```
Desktop — -bash — 80×24
Last login: Tue Jan 15 14:07:36 on ttys000
Andrews-MBP:~ areinhard$ cd desktop
Andrews-MBP:desktop areinhard$ exiftool -all ADVENT.DAT
ExifTool Version Number         : 11.20
File Name                       : ADVENT.DAT
Directory                       : .
File Size                       : 43 kB
File Modification Date/Time     : 1984:02:07 07:58:26-05:00
File Access Date/Time           : 2019:01:15 14:06:58-05:00
File Inode Change Date/Time     : 2019:01:15 14:06:53-05:00
File Permissions                : rw-rw-rw-
Error                           : Unknown file type
```

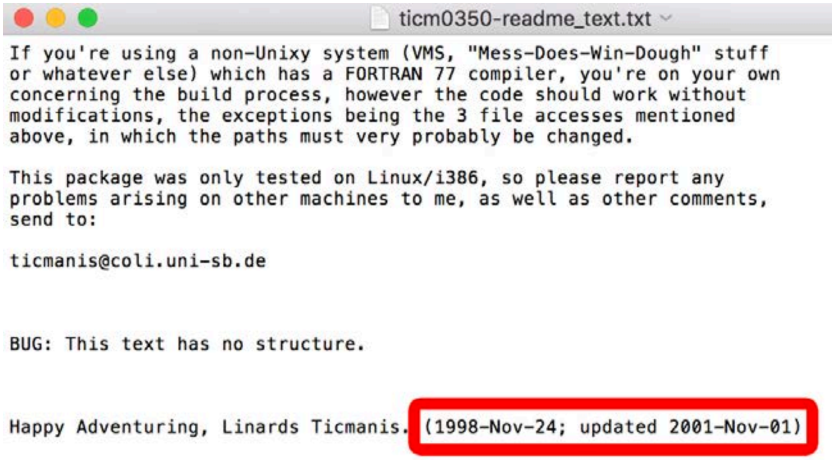
Figure 3.2. ExifTool data retrieved for Don Woods' advent.dat file.

1. Find missing years for some versions of *CCA*;
2. Verify create dates for *CCA* versions taken as fact by the community based on the game's accepted history, which may or may not have been examined critically after the version dates were accepted originally;
3. Correct errant create data for *CCA* versions.

These three tasks help to stabilize/correct *CCA*'s chronology, but are not themselves completely infallible. About one-third of the known versions of *CCA* contain ReadMe files that contain dates as typed by their respective authors (e.g., C. Yong's ReadMe file notes the create date as 2006). When the EXIF metadata matches the date(s) given by the author, one can reasonably assume the verity of the year of creation of that version of the game.

Other ReadMe files contain a few dates to indicate the year of the version being ported/recreated, as well as the year of the port and other years when that recreation was itself updated by the author. For example, Linards Ticmanis, author of TICM0350, notes that his version, created in 1998, is a "standard FORTRAN 77 port" of Crowther and Woods' original game. Ticmanis notes further that this particular iteration is a 2001 update of that 1998 port (Fig. 3.3). When I ran the actual game code (FORTRAN) file through the *ExifTool*, the code reflected the 1998 date. The 1998 code was paired with the 2001 ReadMe, and it is unclear where other changes happened in the various other code or data files for this version. The 1998 date, however, is confirmed by the EXIF data and the ReadMe file and can be assigned at least a *terminus post quem*.

The EXIF metadata alone is not an infallible way of assigning years to versions. As happens on occasion, original file dates can become corrupted through copying or through the incredibly easy way simple text editors allow one to modify original files. What may once have been a file from 1980 can update itself to the present through the accidental press of the spacebar and closure of the file. While EXIF metadata can be quite helpful in confirming the date of a file's creation, one must use it in concert with



ticm0350-readme_text.txt

```
If you're using a non-Unixy system (VMS, "Mess-Does-Win-Dough" stuff
or whatever else) which has a FORTRAN 77 compiler, you're on your own
concerning the build process, however the code should work without
modifications, the exceptions being the 3 file accesses mentioned
above, in which the paths must very probably be changed.

This package was only tested on Linux/i386, so please report any
problems arising on other machines to me, as well as other comments,
send to:

ticmanis@coli.uni-sb.de


BUG: This text has no structure.


Happy Adventuring, Linards Ticmanis. (1998-Nov-24; updated 2001-Nov-01)
```

Figure 3.3. ReadMe file from TICM0350 noting the dates of this particular version (boxed in red).

ReadMe text, checking both against the established chronology. This is not unlike re-checking pottery against stratigraphy and also against the established chronology created over decades of excavation through analysis of shape and contexts.

There is another tool that can be used for additional verification of files as well as demonstrating file-sharing between versions: checksum.

3.2.3. CHECKSUM

When a digital file is created, it is assigned a unique verification number, a "checksum", the purpose of which is to make it easy to compare two files to determine if they are exact clones (Fig. 3.4). If the file's checksum being compared to the original's is off by even a single character, the files are not the same. While this might hint at possible nefarious activity, it often means that one is looking at a modified version of a file instead of a 1:1 clone. This is important for *CCA* because it allows the researcher to see which files (if any) have been shared between versions. This differs from text analysis, which checks for the borrowing of data held within a file as opposed to the borrowing of the file itself.[13]

Checksum is an important (and free) tool in the digital archaeologist's toolbox and should be used to keep files organized especially when creating software chronologies and typologies. I was able to use this utility in order to check those files flagged as identical by my statistical software: were the files actually clones, but renamed, or were the entire contents of the files shared between files of different *CCA* versions?

The next section goes up one level from *CCA* files, specifically in how to use directory structures and programming languages as contextual identifiers for software versions.

13. See Appendix C for instructions on how to run CHECKSUM.

Figure 3.4. CHECKSUM values (boxed in red) in Terminal (Mac OS) for the ReadMe files taken from BLAC0350 and SUPN0350 that prove these are duplicate, identical files.

3.2.4. *CCA* Directory Structures and Languages

All *CCA* versions contain three main types of files: code, narrative data,[14] and ReadMe files. Nearly all versions of *CCA* contain other files as well, sometimes dozens of them, depending on the author and the programming language used. For example, Don Woods' 1977/8 version of William Crowther's original game, written in FORTRAN IV, consists of two files: advent.for (the code) and advent.dat (the narrative data). In 1996, Alan H. Martin presented Woods' original files, adding two more of his own: 1) a .mic executable file (for modern desktop computers instead of the original PDP-10 mainframe), and 2) a ReadMe file that included the checksum numbers of the original Woods files to prove that this 1996 version, WOOD0350, did indeed include the original FOR and DAT files from 18 years prior. FORTRAN grew and changed as a language. Steve Dover's 1987 version (DOVE0550) no longer uses FOR and DAT file extensions, but rather the manufactured filetype ADV, these files called through an EXE Windows executable file. The ADV files include a symbol table, record index, instructions, and narrative text, along with a ReadMe file, all created in Microsoft Fortran, 21 years removed from the FORTRAN IV of Crowther and Woods.

Other languages such as Inform, which was created by Graham Nelson specifically for interactive fiction, self-contains their stories and code in a single .inf file. Compare this against versions of *CCA* written in C (e.g., WOOD0430) that use more than 10 files to recreate a working copy of the game. It is the nature of programming languages to behave according to their own grammar and syntax, which is why it is so important to be able to access the files directly for their metadata as well as for their actual contents. Even though the languages and directory structures change, the *CCA* contents held within them stay relatively stable, old DNA carried in new vessels.

Returning to the original language of *CCA*, FORTRAN, it is perhaps interesting to see when future versions of the game appear in other iterations of the language in

14. Narrative data files are files that contain phrases, sentences, and paragraphs in plain text/language (i.e., not code), which contain elements to the story that are called via code routines.

attempts to remain true to the source: 1975, 1977, 1978, 1979, 1985, 1987, 1990, 1992, 1995, 1996, 2001, 2011, and 2016. These different iterations of FORTRAN could be considered to be dialects, which in traditional epigraphy can help with understanding and placing inscriptions (in this case code) in context (Parca, 2001, pp. 57–72). One could also draw parallels to the appropriation of Greek art and architecture by the Romans who not only used Greek designs and art and architectural vocabulary, but improved upon them for more modern tastes. Many ancient Greek sculptures are known to us thanks to prolific Roman copying of the originals.[15] For the very latest FORTRAN versions, we could be seeing a Classical revival of an Archaic form, like playing 18th-century Classical music on instruments of the period.[16] Music played on instruments of the same period in which the music was composed sounds different than when played on contemporary instruments. The music-as-written is the same, but the performance differs based on the instruments used to play it. So it is with games: playing a game is a performance by the player of the code-as-written. Playing *CCA* in FORTRAN gives the user a less anachronistic gameplay experience than that played in a Web browser. The notes are the same, but there are differences in the performance. Players can enjoy *CCA* regardless of the platform, but unlike more traditional built heritage, players do have the option to play the game in its original form on its original hardware.

One could argue that there is no longer a need to create another version of *CCA* into another flavor of Fortran, especially when several versions already exist in that language, as well as in other formats for ease-of-play (e.g., online) (Fig. 3.5). To the best of my knowledge, none of the FORTRAN versions beyond Crowther and Woods' was ever punched onto cards to be loaded and then compiled, and while versions created after 1980 might have been played on the PDP-10 or -11 mainframe computer in an office or university, it would arguably be easier to run on a microcomputer either at home or at school. All of these versions, even though they differ in languages, platforms, size, scale, and scoring, are *CCA*, drawn from the same set of tablets telling the Ur-story of a mammoth cave system in Kentucky and the dwarvish goings-on inside.

3.2.5. Translations

Stepping away from programming languages used to create versions of *CCA*, the game's narrative text has been translated from English into seven "natural" languages, all of which are incorporated into Z-code as part of Graham Nelson's *Inform* interactive fiction authoring platform. The translations can be classed as separate versions of *CCA*, but do not deviate from the underlying *Inform* programming. All translated versions

15. See the Apollo Barberini, the Dying Gaul, and the Laocoön for a few of the most famous examples.
16. Listen to the music of contemporary ensemble Europa Galante to hear how period music played on period instruments sounds when compared to listening to the same piece performed by a modern orchestra.

Figure 3.5. The most recent online iteration of *CCA* was created by one of the game's leading historians, Rick Adams, for the AMC television show, *Halt and Catch Fire* (https://www.amc.com/shows/halt-and-catch-fire/exclusives/colossal-cave-adventure).

reflect the 350-point version from Don Woods as first ported into *Inform* by Graham Nelson in 1996:[17]

Spanish: José Luis Diaz (1997)
German: Toni Arnold (1998)
French: Jean-Luc Pontico (2001)
Dutch: Yuri Robbers (2002)
Lojban (invented language): Nick Nicholas, et al. (2002)
Russian: Denis Gaev (2004)
Swedish: Fredrik Ramsberg (2007)

3.2.6. A Geography of *CCA* Versions

With the variations in the game written by so many people, and with translations into a handful of languages, the archaeologist correctly assumes that the game-as-artifact has crossed cultural and geographic boundaries to be a shared by an ever-increasingly connected user group. Adding to the contextual value of everything presented so far, code also includes geographical data, this locative value important to all archaeological artifacts. This is yet another specialized area of epigraphy known as onomastics. Onomastics is the study of names and their geological and chronological distribution.

17. http://www.ifwiki.org/index.php/Adventure#Z-code_ports_.28350_points.29 (accessed January 6, 2019).

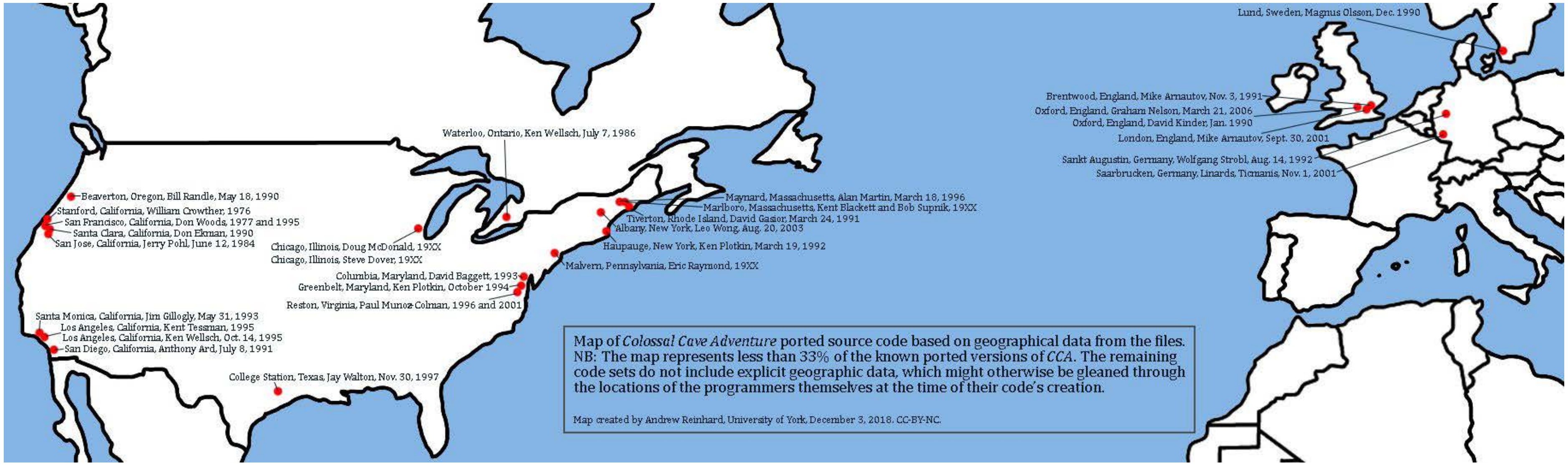
Common names used in common areas and a common time are then distributed and begin to appear in other places and other times (commonly seen as the Roman Empire expanded [Salomies, 2001, p. 76]). This also happens with code, especially in the cases of viral file-sharing, of which *CCA* is an early example.

William Crowther coded *CCA* in 1975, but in order to play it he had to compile the code on a mainframe computer at his office where it was later discovered and updated by Don Woods in 1977/8 in the San Francisco Bay Area. Software is made in a place by one or more people writing it in the natural world. Roughly 25% of the known versions of *CCA* created between 1975 and 2019 include a city, state, and/or country in which the version was produced; this data, when available, may be found in the versions' ReadMe files. I was curious to see how *CCA* spread, especially before the widespread availability of a global internet ca. 1996 and later. I therefore created a map of versions with known source file locations (Map 3.1).

Based on the ReadMe file data, *CCA* versions come from at least five countries: the United States, Canada, United Kingdom, Germany, and Sweden. The versions did not migrate neatly from west to east, but rather hopscotched around thanks to early versions of email and networking. This is how *CCA* could be developed in California in 1975, move to Massachusetts in 1979, Canada in 1986, appear in both Sweden and England in 1990, Germany in 1992, while continuing to blossom in the San Francisco Bay Area, greater Los Angeles, Chicago, College Station, Texas, and the Eastern seaboard in the '70s, '80s, '90s, and early '00s. Software-sharing does not follow the same patterns of the topography-dictated spread of Indo-European languages from population to population (Renfrew, 1987), but might be more closely aligned with the spread of pottery (both the objects and methods of pot-making) by hunter-gatherers (Cohen, 2013). With digital sharing, humans become "post-geographic" in many cases where content is discoverable through online networks—in the case of *CCA* wide area networks (WANs), bulletin board systems (BBSs), and CompuServe—and word-of-mouth.[18] This discovery of *CCA* by others would have also been facilitated by the circulation of printed newsletters and computer magazines (e.g., *Compute!* For the Commodore 64, which was famous for its lines of code that subscribers could type into their own computers, or the games-only *Computer Gaming World*), which often contained sample, non-proprietary code for readers to input at home.[19]

18. This follows other early open software trends from the 1970s and 1980s such as the evolution of the Unix operating system, first created in 1969/70 and then updated by various user groups through online networks ultimately resulting in Linux in 1990. For a brief history of the open source software movement and how geographically diverse groups of coders worked together to evolve software, see Andres Guadamuz, 2008, "Free and Open Source Software" in *Law and the Internet*, 3rd ed., L. Edwards, C. Waelde, eds., Oxford: Hart, 2009, pp. 362–64.

19. One early example is from the April 1982 issue of *Your Computer* magazine, "Adventure on ZX-81," by Graham Thomson, pp. 24–27, which included source code for a version of *CCA* written in ZX-81 Basic. The ZX-81 was produced by Sinclair in the UK and was a ubiquitous feature in British



Map 3.1. Geographical distribution of *CCA* source files based on placenames found in ReadMe files.

I have been unable to determine exactly how various authors found their way to *CCA* or why the game reached individual programmers when it did, but the data indicate scattershot adoption of the code. The obvious absence of *CCA* versions from South and Central America, Africa, and Asia beg their own questions, and one wonders if it is a language barrier, a difference in cultural interests, availability of networking, privilege of computer access/ownership, or other issues that have kept other parts of the world from interpreting the game. But this is not the only hole in the story.

3.2.7. Gender and *CCA* Versions

This section on tools and methods began with analyzing metadata from individual game files, explored how these files were organized, and used data to determine how the game spread from person-to-person. This final section looks more closely at the people who wrote various versions of *CCA*, specifically at their gender, which produced one of the biggest surprises of this case study.

The fact that 99% of the authors of *CCA* versions have been men was unknown to me when I started this case study. The absence of women's voices did not show up in my quantified work using the text analysis tools (see below). Instead, it required me looking at the individual files, finding signatures, and researching the game's history in order to determine that only one woman created a translation of *CCA*. The same could be said of other filters applied to the data corpus: race, politics, age, etc. Instead of (or along with) gender, I could just have easily examined the growth of *CCA* in one of these other ways, ways unable to be derived through quantitative analysis. I chose gender because of its striking disparity in code authorship as a possible additional research question above and beyond stylometry and text analysis of the code in this case study.

Of the 120 individuals responsible for creating versions of *Colossal Cave Adventure* from 1975 until the present, 119 are male. The one woman in this list, Toni Arnold, created the German translation of *CCA* based on Graham Nelson's 2006 version authored on the *Inform* interactive fiction-programming platform. To see if this gender disparity was mirrored in the interactive fiction (IF) community, I visited the main clearing-house for all IF (of which *CCA* is the first example), the *Interactive Fiction Database*.[20] As of this writing, *IFDB* hosts 11,146 registered members. Because many members registered with screen names instead of their given names, and chose not to identify as a particular gender, it is difficult to determine what the actual gender-split is. A previous study has shown that the gender split is weighted 3:1 in favor of women authors for fan fiction (Sendlor, 2010), a contemporary analogue to interactive fiction

households in the 1980s. The combination of published source code in popular magazines with readily available hardware led to an early Renaissance of games programming. Several versions of *CCA* were created on various iterations of ZX personal computers: AUST1100 (1982), EVIS0350 (1983), HARR0235 (1985), JONE0210 (1982), and ADSO_XXX (1987).

20. https://ifdb.tads.org/ (accessed 6 January 2019).

where amateur writers create new stories based on existing characters from various popular historic and contemporary media, publishing these stories online for others to read and comment upon. The oldest and most popular fan fiction site is fanfiction.net with over two million registered users—most of them women—who have written over eight million pages in over 30 languages since 1998. Based on the demographics of creators of original interactive and fan fiction content, one would think that this would spill over into the creation of *Colossal Cave Adventure* versions by women, either as a classic reworking / reprogramming of the tale, or perhaps a reimagining of it through a woman's perspective. This is clearly not (yet) the case. Perhaps there is something else at work here.

Of the 120 authors of *CCA* versions, the data confirm that 77 (64%) of them had (or currently have) professional careers in IT (software, programming, development, management, technical writing, game design).[21] 31 (26%) of the authors have an unknown career, but judging from the online presence of 20 of them, their career likely intersected with IT in some way. While careers in computer science have been (and continue to be) ca. 75% male,[22] women have been present from the very beginning in all aspects of professional computing (yet largely unrecognized), including programming (Ada Lovelace), wireless communication (Hedy Lamarr), and game design (Carol Shaw, Atari), so it remains unclear why there are not more women *CCA* authors over the past 40+ years, especially when the code is open source and easy to find. In 2018, 45% of the active gaming population in the United States identified as girls/women,[23] and nearly 40% these players opted to play various types of role-playing games (RPGs) either online or as solo campaigners (i.e., single-player games) (Yee, 2017).[24] *CCA* is classed as an RPG, one played in the first-person, and although written by a man in 1975 as a way to heal from his divorce and to keep a relationship with his two young daughters,[25] the language of the game's narrative is gender-neutral, is largely non-violent and never explicit, and instead focuses on explo-ration and puzzle-solving. *CCA*'s story, tropes, and mechanics parallel those of games that remain popular with all players, women and men.[26]

In looking at the ReadMe files for the versions of *CCA* that have them, many of the authors explicitly state that their versions port the "original" (or a close variant) to an-

21. I determined ties to IT careers from Internet searches as well as data retrieved from *CCA* ReadMe files created by authors of some of the later versions.

22. See the January 2018 report from Graf et al., Pew Research Center, on STEM careers: http://www.pewresearch.org/fact-tank/2018/01/09/7-facts-about-the-stem-workforce/ (accessed January 6, 2019).

23. https://www.statista.com/statistics/232383/gender-split-of-us-computer-and-video-gamers/ (accessed January 1, 2019). Records before 2016 are not available online.

24. https://quanticfoundry.com/2017/01/19/female-gamers-by-genre/ (accessed January 1, 2019).

25. http://rickadams.org/adventure/a_history.html (accessed January 1, 2019).

26. https://www.technavio.com/blog/top-10-most-popular-game-genres (accessed January 24, 2019). Technavio is a global market research firm. Games in 2018 similar to *CCA* fall into the categories of action-adventure (ranked 4th in the world for popularity among all players), role-playing (5th), and adventure (6th).

other language, or fix bugs in earlier versions, or treat this as a programming challenge (like a rite of passage, just like playing *CCA* itself), or serve as an act of preservation, keeping the game alive in contemporary programming languages and platforms. This kind of nostalgia and preservation started slowly in the 1970s and 1980s likely because games were still new and were easily discovered. By the 1990s with *CCA*, enough time had passed for a sense of nostalgia to set in for early interactive fiction games. 86 versions (72%) were created in 1990 and after, so one should think that more woman-authored versions of *CCA* would have become available as more women learned to code either for fun or through classroom instruction, although historically women have always been talented programmers in the early days of computing on machines such as ENIAC, through to the present day. It is possible that versions of *CCA* were written by women but never published for several reasons, the main ones being male gatekeeping in the coding community, and male-dominated threads in *CCA* forums such as the *Colossal Cave Adventure* Forum on Delphi Forums, whose visitors and content-posters since 2016 have been primarily (if not exclusively) male.[27] The original versions were written in FORTRAN and were often ported to C, but it remains unclear why women programmers in these languages did not latch onto *CCA* for similar reasons as their male counterparts. While the possible reasons for this are outside the scope of this thesis, the reasons behind the number of male authors of *CCA* versions are statistically significant and deserve to be studied.

One can again revisit the Classical tradition in the creative arts to see (unfortunately) that the more things change, the more they seem to have stayed the same. Most of the potters, painters, sculptors, and architects known to history from ancient Greece and Rome were male,[28] which may indicate two things, which are not mutually exclusive: 1) that the artisans in the ancient Mediterranean world were predominantly men, and 2) there is a historical bias in scholarship and in records of the period that amplify male voices.[29] When looking at the more modern tradition of software engineering, we see the same issues at work: 1) a predominantly male workforce, and 2) an amplification of male voices. *Colossal Cave Adventure* was the first adventure-style interactive digital role-playing game; it happened to be authored by a man who worked in a mostly male office focused on computer science, that was later discovered by another male computer scientist, updated, and circulated by other male programmers, hackers, and IT professionals. Stepping away from *CCA* itself, we see that contemporary game development studios and gamer culture remains a male-dominated area, and the re-

27. https://forums.delphiforums.com/xyzzy/start (accessed January 6, 2019).

28. See Eleni Hasaki, 2012, "Craft Apprenticeship in Ancient Greece: Reaching beyond the Masters," in *Archaeology and Apprenticeship*, Willeke Windrich, ed., pp. 171–202. While the archaeological record in ancient Greece shows that apprentices to artisans could be both boys and girls, the masters themselves were likely exclusively male.

29. For the most recent scholarship on male bias, Classics, and Classical archaeology, see Donna Zuckerberg, 2018, *Not All Dead White Men: Classics and Misogyny in the Digital Age* (Harvard University Press).

ception of games created by women and of women who play games competitively are frequently targeted for harassment by men.[30] This toxic culture might explain why we have not seen more than one *CCA* version written by a woman and publicly shared, especially in recent years..

It became increasingly clear during this case study that while quantified data are certainly valuable (see below), they can also leave out a big chunk of context, which is important to the understanding of anything archaeological, digital, or otherwise. Any future digital archaeology project should take gender (among other socio-politico-economic parameters) into account when investigating software creation and usage as a core issue for late twentieth- and early twenty-first-century material culture lest site reports feature only some of the demographic impacted by various digital sites and artifacts of which *CCA* is but an early example. The consideration of gender can be codified into project design and workflow, but this will need to be done in three ways over the next few years until it is normalized: 1) individual/independent projects can include this as part of their workflow, analysis, and publication so that it becomes part of the literature that can be read/cited by others; 2) authors/editors of widely read books on excavation planning and methods as well as general books on archaeological theory and history (e.g., Martin Carver, Steve Roskams, Colin Renfrew, Paul Bahn, Bruce Trigger) can begin to include this in future editions of their work; and 3) granting agencies can make this a requirement of the projects they fund.

3.2.8. Method for Stylometric Analysis of Software

Several dozen versions of *Colossal Cave Adventure* exist, created over the past 44 years by enthusiasts for the game. It served to reason that these sets of code were not all independently created, but rather relied on the source code of the second version of the game. The first version of *CCA*, authored by Will Crowther in 1975 (CROW0000), was discovered by Don Woods in 1977 who subsequently revised it with Crowther's permission (WOOD0350). He then posted his version as open source at which point people in North America and Europe began to create their own versions of the game as early as 1978 (SUPN0350 and LUPI0440).

Curious to see if I could prove evidence of code-reuse across the entire lifespan of *CCA*, I decided to borrow digital tools used by historians and scholars of literature for their work in text analysis, which includes stylometry, a statistical comparison of a

30. There are plenty of ethnographies about the harassment of women in games and online: Anita Sarkesian often critiques how women are portrayed in video games, for which she herself was harassed. Sarkesian, A. *Feminist Frequency* [Online]. Available at: https://feministfrequency.com (Accessed: 24 January 2019). See also Jane, Emma A. (2016) *Misogyny Online: A Short (and Brutish) History*. London: Sage Swifts; and Quinn, Zoë (2017) *Crash Override: How Gamergate (Nearly) Destroyed My Life and How We Can Win the Fight against Online Hate*. New York: PublicAffairs. Jennifer Brandes Hepler (2017) presents current research on women game developers in *Women in Game Development: Breaking the Glass Level-Cap*. Boca Raton: CRC Press.

corpus of writing to determine authorship by way of writing style. For example, a classic exercise used to train scholars in the use of digital text analysis tools is the set of *Federalist Papers*, forerunners to the creation of the United States Constitution, which were published anonymously although later revealed to be by Alexander Hamilton, John Jay, and James Madison. The issues resolved by stylometric analysis included attributing sole authorship to 12 disputed essays claimed by both Hamilton and Madison, and to reassign an essay to Madison originally thought to be written by Jay.[31] The *Federalist Papers* example is a good one when considering the corpus of *CCA* versions because there is a finite number of authors (three), and a small corpus of data (85 separate papers). By running the text of the corpus through text analysis software one can determine authorship by virtue of the writing style, which is further supported by comparing a questionable text against the corpus of an author's other works.

The code of *Colossal Cave Adventure* is not unlike the *Federalist Papers*: there is a finite set of authors (120, although it is likely that other people wrote their own versions but never published them online) and a small corpus of known texts (162). In order to achieve usable results with the software, the corpus of texts needed to be prepared. This was achieved by first identifying three classes of files within each version: code, narrative, and ReadMe. Figure 3.6 shows how this case study organized the filetypes and then analyzed them.

Code Files

Versions of *CCA* have been written in 12 programming languages, beginning with FORTRAN IV and continuing on to contemporary languages such as Python. *CCA* has even been ported to the Nintendo 3DS handheld gaming device. Despite this variety of programming languages, most code sets could be broken into three distinct parts, which could then be stylometrically analyzed. The first part is the code itself. It made little sense to compare sets written in FORTRAN IV to sets written in C (it would be like comparing an Akkadian text to something written in English). It was, however, possible to collect over a dozen examples written in various versions of FORTRAN, and to compare those code sets against each other to see how much (or how little) of the FORTRAN code had been re-used by other authors over time. *CCA* was ported to other languages by people who wanted to play the game on other computers and operating systems, and while some of the original text was preserved (mostly in the game's narrative data as will be shown below), the entire system of delivering the playable narrative had to be rebuilt from the ground up. At least with FORTRAN one can equate

31. See *Applied Bayesian and Classical Inference: The Case of the Federalist Papers*, 2nd ed. (2011), by Frederick Mosteller and David L. Wallace (Springer-Verlag), and for a summary, see Patrick Juola, 2008, *Authorship Attribution* (Boston: Now), pp. 9–11.

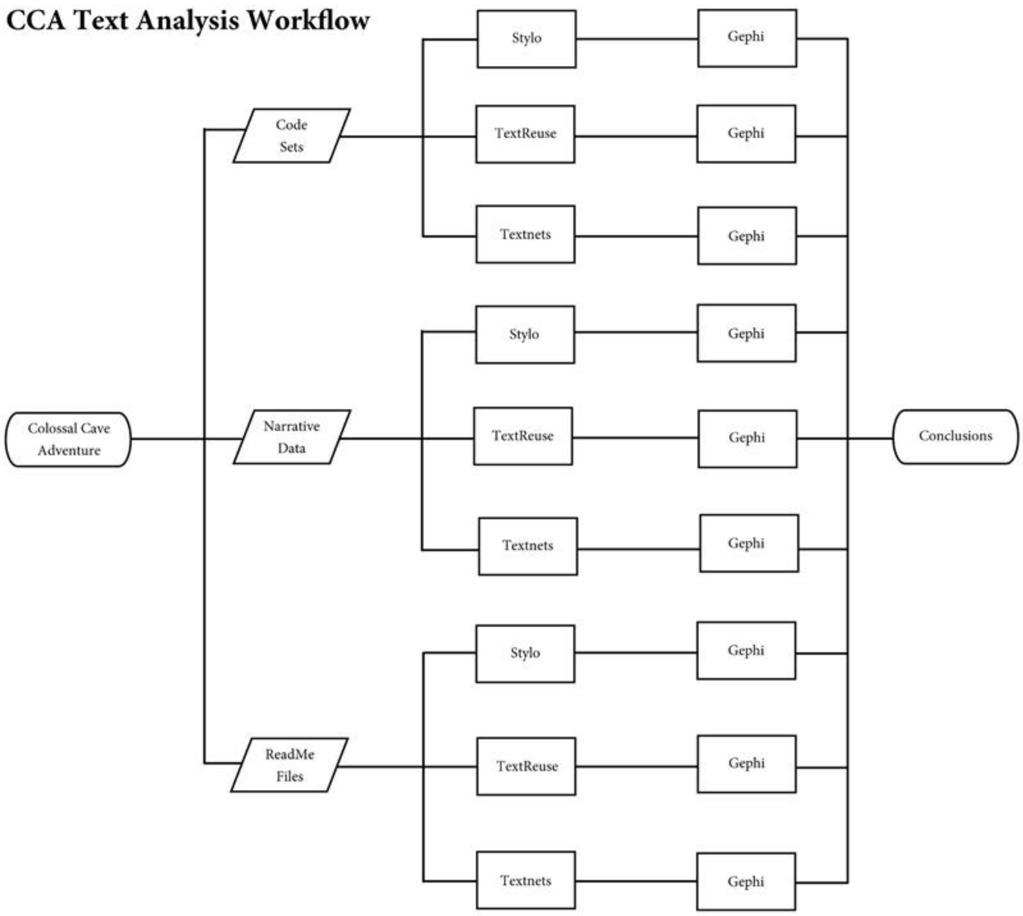


Figure 3.6. Flowchart showing the organization of files and analytical tools used in this case study.

different versions of the language as being akin to seeing changes in how an engine is designed and built in a particular model of car over a period of years.

As an example, Figure 3.7 shows the first lines of code from WOOD0350 (1977), and Figure 3.8 shows the first lines of code from VANE0560 (2011). Both files are quite similar in content and organization—at least in the beginning. The files begin with comments from the programmers, which are indicated with "C" and "!" respectively, that tell a reader (usually another programmer) what certain lines of code do. These opening remarks are then followed by parameters and definitions that frame the game code underneath. The code files for *CCA* tell the hardware running the game how to operate, how to interpret user input, and how to score the game. The code file works in concert with the narrative file, calling out to it as the player interacts with the game to advance the story.

Narrative Files

The second set of files shared across the spectrum of *CCA* contains the "data" files. *CCA* is a narrative game and as such contains "human-readable" text in the form of statements presented on the screen to the player depending on what the player types. These statements include descriptions of areas within the cave, of creatures encountered during the adventure, bad puns, and notoriously humorous ways to die. The game's narrative was often packed into its own distinct file, which was separate from the file containing the code that ran the game. The narrative text in the data file was given line numbers, which were called by the main program during the game's operation. The game's narrative evolved over time, with later authors adding other rooms to the cave, other adventures, and more. Stylometric analysis can identify what (and how much) of that narrative was preserved and shared across versions.

Figures 3.9 and 3.10 show examples of the narrative data files from both WOOD0350 and VANE0560. Note that the line-numbering and organization of the early narrative action are identical, which points to the larger trend in *CCA* versions of preserving as much of the spirit and actual language of the original game. Van Eck's version (VANE0560) does go on to make additions in both puzzles and player vocabulary, but the early parts of the story remain the same.

ReadMe Files

The third class of files to undergo text analysis included the "ReadMe" files. Many programs—especially those created in the 1980s and 1990s—contained a ReadMe file, a simple text file containing brief instructions for the player as well as copyright information and, on occasion, a history of that program's creation. Roughly half of the *CCA* code sets contained a ReadMe file, and I was curious to see if these, too, had been shared over time. All but one of the ReadMe files I found were written in English. Jose Luis Diaz wrote a Spanish translation of *CCA* in 1997 (DIAZ0350), which included a Spanish ReadMe file.

As with the code and narrative files above, Figures 3.11 and 3.12 show the contents of the ReadMe files for WOOD0350 and VANE0560. Note that the WOOD0350 ReadMe file is actually from 1996, written by another *CCA* version author, Alan H. Martin, and included with Woods' original code and narrative files, which he proves by providing the CHECKSUM numbers. In the ReadMe file, Martin notes that, "this is the source code for the original Crowther and Woods Colossal Cave Adventure, 350 point verion [sic], in PDP-10 FORTRAN. There have been many ports of this, in both FORTRAN and C, but all of them can be traced back to this version."

As has been demonstrated by Culver (Culver, 2019) and in this case study, other versions exist in other languages, but these were unknown to Martin in 1996. This demonstrates the importance of checking secondary source material against a corpus of primary sources before drawing conclusions.

```
C  ADVENTURES

C  CURRENT LIMITS:
C       9650 WORDS OF MESSAGE TEXT (LINES, LINSIZ).
C        750 TRAVEL OPTIONS (TRAVEL, TRVSIZ).
C        300 VOCABULARY WORDS (KTAB, ATAB, TABSIZ).
C        150 LOCATIONS (LTEXT, STEXT, KEY, COND, ABB, ATLOC, LOCSIZ).
C        100 OBJECTS (PLAC, PLACE, FIXD, FIXED, LINK (TWICE), PTEXT, PROP).
C         35 "ACTION" VERBS (ACTSPK, VRBSIZ).
C        205 RANDOM MESSAGES (RTEXT, RTXSIZ).
C         12 DIFFERENT PLAYER CLASSIFICATIONS (CTEXT, CVAL, CLSMAX).
C         20 HINTS, LESS 3 (HINTLC, HINTED, HINTS, HNTSIZ).
C         35 MAGIC MESSAGES (MTEXT, MAGSIZ).
C  THERE ARE ALSO LIMITS WHICH CANNOT BE EXCEEDED DUE TO THE STRUCTURE OF
C  THE DATABASE.  (E.G., THE VOCABULARY USES N/1000 TO DETERMINE WORD TYPE,
C  SO THERE CAN'T BE MORE THAN 1000 WORDS.)  THESE UPPER LIMITS ARE:
C       1000 NON-SYNONYMOUS VOCABULARY WORDS
C        300 LOCATIONS
C        100 OBJECTS

        IMPLICIT INTEGER(A-Z)
        LOGICAL DSEEN,BLKLIN,HINTED,YES,START

        COMMON /TXTCOM/ RTEXT,LINES
        COMMON /BLKCOM/ BLKLIN
        COMMON /VOCCOM/ KTAB,ATAB,TABSIZ
        COMMON /PLACOM/ ATLOC,LINK,PLACE,FIXED,HOLDNG
        COMMON /MTXCOM/ MTEXT
        COMMON /PTXCOM/ PTEXT
        COMMON /ABBCOM/ ABB
        COMMON /WIZCOM/ WKDAY,WKEND,HOLID,HBEGIN,HEND,HNAME,
        1       SHORT,MAGIC,MAGNM,LATNCY,SAVED,SAVET,SETUP

        DIMENSION LINES(9650)
        DIMENSION TRAVEL(750)
        DIMENSION KTAB(300),ATAB(300)
        DIMENSION LTEXT(150),STEXT(150),KEY(150),COND(150),ABB(150),
        1       ATLOC(150)
        DIMENSION PLAC(100),PLACE(100),FIXD(100),FIXED(100),LINK(200),
        1       PTEXT(100),PROP(100)
        DIMENSION ACTSPK(35)
        DIMENSION RTEXT(205)
        DIMENSION CTEXT(12),CVAL(12)
        DIMENSION HINTLC(20),HINTED(20),HINTS(20,4)
        DIMENSION MTEXT(35)
        DIMENSION TK(20),DSEEN(6),DLOC(6),ODLOC(6),HNAME(4)
```

Figure 3.7. The first lines of FORTRAN code from WOOD0350 (1977/8).

```
!  ADVENTURE 7 MAXIMUM 560 POINTS. RE-WRITTEN IN STANDARD FORTRAN 2008 FROM ADVENTURE 6 WITH
CORRECTIONS AND ADDITIONS

!  OF SOUNDS, COLOR, BASILISK, MERMAID AND RUBY YACHT BY NEAL VAN ECK, 2011.


!  Adventure 6 was based on Adventure 5 with additions by David Long, and an anonymous coder
around 1984.

!  Doug McDonald changed it so that it would compile with f77 in 1990.


!  Adventure 5 was extended from the 350 point original to 501 points by David Long at the
University of Chicago around 1978.


!  NOTE: PROGRAM AGENDAT CREATES THE INTERNAL DATABASE USED BY ADVENTURE


!  CURRENT LIMITS:

!     22000 WORDS OF MESSAGE TEXT (LINES, LINSIZ).

!      1400 TRAVEL OPTIONS (TRAVEL, TRVSIZ).

!       600 VOCABULARY WORDS (KTAB, ATAB, TABSIZ).

!       250 LOCATIONS (LTEXT, STEXT, KEY, LOCCON, ABB, ATLOC, LOCSIZ, MAXLOC).

!       150 OBJECTS (PLAC, PLACE, FIXD, FIXED, LINK (TWICE), PTEXT, POINTS, HOLDER, HLINK,
OBJCON, PROP, WEIGHT, MAXOBJ).

!        60 "ACTION" VERBS (ACTSPK, VRBSIZ, VKEY).

!       300 VERB/PREP/OBJ COMBINATIONS (PTAB, PTBSIZ).

!        50 ADJECTIVES (ADJKEY, ADJSIZ)

!       150 MODIFIED NOUNS (ADJTAB, MAXOBJ)

!       450 RANDOM MESSAGES (RTEXT, RTXSIZ).

!        12 DIFFERENT ADVENTURER CLASSIFICATIONS (CTEXT, CVAL, CLSMAX).

!        20 HINTS, LESS 3 (HINTLC, HINTED, HINTS, HNTSIZ, HNTMIN).
```

Figure 3.8. The first lines of FORTRAN code from VANE0560 (2011).

```
1
1       YOU ARE STANDING AT THE END OF A ROAD BEFORE A SMALL BRICK BUILDING.
1       AROUND YOU IS A FOREST.  A SMALL STREAM FLOWS OUT OF THE BUILDING AND
1       DOWN A GULLY.
2       YOU HAVE WALKED UP A HILL, STILL IN THE FOREST.  THE ROAD SLOPES BACK
2       DOWN THE OTHER SIDE OF THE HILL.  THERE IS A BUILDING IN THE DISTANCE.
3       YOU ARE INSIDE A BUILDING, A WELL HOUSE FOR A LARGE SPRING.
4       YOU ARE IN A VALLEY IN THE FOREST BESIDE A STREAM TUMBLING ALONG A
4       ROCKY BED.
5       YOU ARE IN OPEN FOREST, WITH A DEEP VALLEY TO ONE SIDE.
6       YOU ARE IN OPEN FOREST NEAR BOTH A VALLEY AND A ROAD.
7       AT YOUR FEET ALL THE WATER OF THE STREAM SPLASHES INTO A 2-INCH SLIT
7       IN THE ROCK.  DOWNSTREAM THE STREAMBED IS BARE ROCK.
8       YOU ARE IN A 20-FOOT DEPRESSION FLOORED WITH BARE DIRT.  SET INTO THE
8       DIRT IS A STRONG STEEL GRATE MOUNTED IN CONCRETE.  A DRY STREAMBED
8       LEADS INTO THE DEPRESSION.
9       YOU ARE IN A SMALL CHAMBER BENEATH A 3X3 STEEL GRATE TO THE SURFACE.
9       A LOW CRAWL OVER COBBLES LEADS INWARD TO THE WEST.
10      YOU ARE CRAWLING OVER COBBLES IN A LOW PASSAGE.  THERE IS A DIM LIGHT
10      AT THE EAST END OF THE PASSAGE.
11      YOU ARE IN A DEBRIS ROOM FILLED WITH STUFF WASHED IN FROM THE SURFACE.
11      A LOW WIDE PASSAGE WITH COBBLES BECOMES PLUGGED WITH MUD AND DEBRIS
11      HERE, BUT AN AWKWARD CANYON LEADS UPWARD AND WEST.  A NOTE ON THE WALL
11      SAYS "MAGIC WORD XYZZY".
12      YOU ARE IN AN AWKWARD SLOPING EAST/WEST CANYON.
13      YOU ARE IN A SPLENDID CHAMBER THIRTY FEET HIGH.  THE WALLS ARE FROZEN
13      RIVERS OF ORANGE STONE.  AN AWKWARD CANYON AND A GOOD PASSAGE EXIT
13      FROM EAST AND WEST SIDES OF THE CHAMBER.
14      AT YOUR FEET IS A SMALL PIT BREATHING TRACES OF WHITE MIST.  AN EAST
14      PASSAGE ENDS HERE EXCEPT FOR A SMALL CRACK LEADING ON.
```

Figure 3.9. The first lines of narrative data from WOOD0350 (1977/8).

```
1

1       You are standing at the end of a road before a small brick building.

1       Around you is a forest. A small stream flows out of the building and

1       down a gully.

2       You have walked up a hill, still in the forest. The road slopes back

2       down the other side of the hill. There is a building in the distance.

3       You are inside a building, a well house for a large spring.

3       Off to one side is a small pantry.

4       You are in a valley in the forest beside a stream tumbling along a

4       rocky bed.

5       You are in open forest, with a deep valley to one side. Not far away

5       is a large billboard.

6       You are in open forest near both a valley and a road.

7       At your feet all the water of the stream splashes into a 2-inch slit

7       in the rock. Downstream the streambed is bare rock.

8       You are in a 20-foot depression floored with bare dirt. Set into the

8       dirt is a strong steel grate mounted in concrete. A dry streambed

8       leads into the depression.

9       You are in a small chamber beneath a 3x3 steel grate to the surface.

9       A low crawl over cobbles leads inward to the west.

10      You are crawling over cobbles in a low passage. There is a dim light

10      at the east end of the passage.

11      You are in a debris room filled with stuff washed in from the surface.

11      A low wide passage with cobbles becomes plugged with mud and debris

11      here, but an awkward canyon leads upward and west. A note on the wall

11      says "Magic Word XYZZY".
```

Figure 3.10. The first lines of narrative data from VANE0560 (2011).

Martin's ReadMe file also remarks of Woods' version that it includes "cave hours". He continues: "Since the PDP-10 was a timesharing system, it was often considered desirable to prevent people from playing games during business hours. The game has a 'wizard mode' which allows the system administrator to set the hours and optionally allow short demo games during the off hours."

Martin's note about this added functionality echoes in other ReadMe files attached to other versions of the game, which is one of the primary purposes of this kind of file. In VANE0560, Van Eck not only gives the paradata about his version, but also lists a brief genealogy of how he arrived at his version, and what he himself added to the narrative:

> Adventure 7 maximum 560 points. re-written in standard Fortran 2008 from Adventure 6 with corrections and additions of sounds, color, basilisk, mermaid and ruby yacht by Neal Van Eck, 2011. Adventure 6 was based on Adventure 5 with additions by David Long, and an anonymous coder around 1984. Doug McDonald changed it so that it would compile with f77 in 1990. Adventure 5 was extended from the 350 point original to 501 points by David Long at the University of Chicago around 1978. The program was compiled as an Intel Fortran Composer Quickwin project using a few Quickwin routines for color and standard APIs for sound.

The end result of running these three distinct sets of files through the text analysis software would show a history of text reuse, a borrowing of code, and a genealogy of *CCA* versions, all of which contribute to understanding the history of the game, but also point to future use on other sets of code for any kind of software as archaeology continues its turn from more traditional investigations to those of digital landscapes, sites, and artifacts. In the cases where the archaeologist cannot speak directly with a creator, this paradata is the next best thing to provide a wrapper of context around quantified, stylometric results, as will be shown below.

The next section discusses the tools and processes used to affect the text analysis of a corpus of code. This is followed by an interpretation of the results, and a conclusion about the utility of this kind of approach to increasing one's understanding of the digital archaeological record.

3.2.9. Tools for Stylometric Analysis of Software

In order to conduct any kind of modern text analysis, one needs to employ software, which is programmed to recognize complex patterns (vocabulary, syntax, punctuation) within collected bodies of work. Classics was one of the first disciplines in the Hu-

```
advent.readme
3/18/96

This is the source code for the original Crowther and Woods Colossal Cave
Adventure, 350 point verion, in PDP-10 FORTRAN.  There have been many ports
of this, in both FORTRAN and C, but all of them can be traced back to this
version.

A notable feature of this version which made it into few of the ports is the
concept of "cave hours".  Since the PDP-10 was a timesharing system, it was
often considered desirable to prevent people from playing games during
business hours.  The game has a "wizard mode" which allows the system
administrator to set the hours and optionally allow short demo games during
the off hours.

There is probably no point in trying to compile this code on anything other
than a PDP-10, because it depends on string packing of five characters per
word of memory.

For more information see "http://www.winternet.com/~radams/adventure/".

Provided courtesy of Alan H. Martin <AMartin@TLE.ENet.DEC.Com>, from a rescued
copy of the LINK-10 regression test system.

Contents of advent.tar.gz:

 filename     length    sum     md5sum
----------    ------   -----    --------------------------------
advent.dat     55455   29252    9f12da0c3e129b7fe5a1d91bbfebe02f
advent.for     81857   50809    ce54256f8e732b4a5e570bc64dd8536f
advent.mic        78   22009    01e6efc8fe0644531c908c25c0aa225e
advent.readme
```

Figure 3.11. The first lines of the ReadMe file from WOOD0350 (2011).

```
Adventure 7 maximum 560 points. re-written in standard Fortran 2008 from Adventure 6 with
corrections and additions

of sounds, color, basilisk, mermaid and ruby yacht by Neal Van Eck, 2011.


Adventure 6 was based on Adventure 5 with additions by David Long, and an anonymous coder
around 1984.

Doug McDonald changed it so that it would compile with f77 in 1990.


Adventure 5 was extended from the 350 point original to 501 points by David Long at the
University of Chicago around 1978.


The program was compiled as an Intel Fortran Composer Quickwin project using a few
Quickwin routines for color and standard APIs for sound.
```

Figure 3.12. The first lines of the ReadMe file from VANE0560 (2011).

manities to adopt computational methods for understanding primary texts, with David Packard (son of the co-founder of Hewlett-Packard) leading the way. His seminal 1974 book *Minoan Linear A* (Packard, 1974) outlined his successful deployment of computational text analysis to help decipher Linear A based on statistics and the placement of logograms and phonetic symbols. Gregory Crane (University of Leipzig) continues to serve as the editor-in-chief of the Perseus Project[32] that facilitates Digital Humanities research on Classical texts, including text analysis. Online resources such as the Classical Language Toolkit[33] currently offer easy ways (and tutorials) on how to conduct text analysis of ancient language corpora. The software quickly executes this function by comparing text in every document in a corpus of documents against every other document in that corpus. The resulting data show a number from 0 to 1, with numbers in the .8 and .9 range (i.e., 80%–90%) showing very close matches/relationships between documents, and numbers closer to 0 indicating originality/non-relationships with other documents in the corpus.

After consulting with colleagues in the Digital Humanities, I decided to use three packages developed for the *R* language and environment, and *Gephi* for data visualization. *R* is a widely used, free, cross-platform statistics program that encourages the creation of open source packages that perform a variety of statistics analysis tasks.[34] I selected the *Stylo* package, which is widely used for stylometric analysis of texts written in any language, including those with non-Latin alphabets. I also selected the *TextReuse* package, originally developed for the field of law, which specifically checks for the presence of text copied between one or more documents. Lastly, to step outside of individual files in order to look for patterns in them as a group, I selected the *Textnets* package, which identifies sets of documents that share common features thereby creating a network of related texts. With *Stylo* I hoped to see the presence of "hands" across the many versions of *CCA*. With *TextReuse* I wanted to be able to determine which versions of the game were borrowing from other versions, and how much text was shared between them. With *Textnets* I hoped to see a network of usage of borrowed code/data between various versions of *CCA*. All three of these packages share the same limitation, however: while they show that certain files are similar (or different) from other files in a corpus, they do not go so far as to highlight any of the text that is actually shared between files. Functionality such as this does exist in anti-plagiarism software such as *Grammarly*, but has not yet been implemented into the various packages for *R*. That kind of close-up work regarding shared data must be done "by hand", incorporating human intelligence to interpret the output generated from machine learning.

32. perseus.tufts.edu.
33. cltk.org.
34. *R* is short for *The R Project for Statistical Computing*, www.r-project.org.

Complete results are below, but to summarize the findings:

1. Code itself was not widely shared within the *CCA* community. This was largely because of the changes to programming languages over time; FORTRAN IV is completely different from C, which is completely different from BASIC, and so on. Even within the same language, versions of FORTRAN became as distinct as reading Middle v. modern English. Code largely had to be rewritten completely by authors of new versions of *CCA*.
2. The game's narrative text was often copied directly between versions, with additions in later versions accounting for the creation of new rooms and puzzles.
3. The game's ReadMe files were a mix of original and copied content between versions, regularly citing previous versions and authors while clearly indicating bug-fixes, new features, and instructions for installation and play.
4. There are two possibly divergent goals in the creation of new versions of *CCA*: a) preservation of the original game across platforms and languages over time (e.g., SUPN0350, GASI0350, etc.), and b) adding to old gameplay so that the new version serves as an homage to the original while adding something new and fresh (e.g., STAN1000, BALL0770, etc.).

Going beyond the data produced through these statistics packages, these data can also be visualized, which allows the researcher to take a different approach to interpreting results derived from experimentation. I needed a way to see if/how *CCA*'s code was being shared, and how various versions connected with others (if at all). *Gephi* is a free and open, cross-platform digital visualization tool, and one that is commonly used by Digital Humanities scholars.[35] Again, I wanted to use robust digital tools that are either free or outright open source to demonstrate that one can achieve results when on a budget that is either tight or non-existent, something familiar to most archaeologists. With *Gephi*, I could upload my CSV spreadsheets created through the *Stylo* and *TextReuse* packages for *R*, and convert them into color-coded graphs displaying links as well as weights showing the popularity of some versions over others in regards to how code was borrowed between versions.

In Appendix C, I define the digital tools used for stylometric analysis and data visualization, how to install/use them, who made them, and a brief history of their creation in an attempt to identify bias while also placing these tools into context with my research: R, *Stylo* for R, *TextReuse*, *Textnets*, *Gephi*, and *ExifTool*.

35. Download *Gephi* at gephi.org.

3.3. Stylometric Analysis of Code: Quantified Results

At the start of this case study, it was unclear whether or not I would be able to perform text analysis on the sets of files from the numerous versions of *Colossal Cave Adventure* because these were coded programs instead of traditional texts. Working with the packages in *R* and visualizing the output in *Gephi* proved that not only was it possible, but that there are now conclusions to be drawn about the 44-year history of *CCA*'s development.

As mentioned in Part 1, Tools and Methods, I decided to divide the files up into three groups: code, narrative, and ReadMe files. The code files also needed to be separated by language, with the largest grouping reserved for 12 sets of FORTRAN code. It was unclear if any meaningful results could be gotten from looking at possible code-sharing with this small data set written in various versions of the same language, but I felt it worth the effort to try. In considering FORTRAN generally, updates in the language reflected changes in modern hardware and provided additional vocabulary, grammar, and syntax to keep pace with contemporary programming demands. When used for coding *CCA*, however, the FORTRAN was modified for the sake of enhancing the gameplay experience, everything from keeping score (e.g., WOOD0350) to adding a save-game feature (e.g., OLSS0551).

To report the results, I have broken them down into three sections of three parts each, the top-level sections pertaining to the three classes of files followed by the three text analysis tools used on each of the three classes of files (Fig. 3.6). *CCA* version names have already been established in the literature. Those version names, dates, and creator names, are maintained by Nathanael CJE Culver as part of his *Adventure Family Tree* and are generally accepted as being accurate (Culver, 2019).[36] The names and dates I use below are derived from Culver's project.

3.3.1. FORTRAN Code Sets

Out of the dozen programming languages from which to choose to run stylometric analysis against the underlying code of *CCA*, I chose FORTRAN because I wanted to work with the source material as part of my data set, comparing it with later versions also written in that language. Which source code files influenced others? Was any source code reused/shared between versions over time? Which code sets were the most influential?

36. I have downloaded and archived the versions in the Github repository created for this case study: https://github.com/adreinhard/cca.

Stylo

The *Stylo* package for R looks for shared traits of authorship over a corpus of files. The goal of running code, narrative, and ReadMe files through *Stylo* was to see what (if any) text was borrowed by the authors of *CCA* versions over a span of 40+ years.

Stylo read the contents of each of the 12 FORTRAN source code files and then compared each set of code against every other set in the small corpus. Once the comparisons were completed, *Stylo* assigned a weight to each pairing of files, a higher number meaning a close match and a high probability that one set of code borrowed heavily from another (Fig. 3.13).

In the case of the FORTRAN code sets, weights between 1 and 6 were assigned to the analyzed file-pairings, a weight of 6 meaning that the files were identical. *Stylo* compares each pair of files backwards and forwards, meaning that each pairing is analyzed twice where each file in the pair takes a turn being the Source and then the Target during the comparison.

Barring a score of 6 given when a file is compared against itself for calibration, *Stylo* discovered two sets of identical FORTRAN code: 1) long0500 and oska0551, and 2) wood0350 and wood043b. For the first set of identical files (Fig. 3.14), oska0551 is a direct, 1:1 port done in 1990 by Johann Gunnar Oskarsson to FORTRAN-77 from long0500, which was written by David Long in 1979 in FORTRAN IV for the DEC mainframe. For the second set of identical files, it is clear that Don Woods copied his own code from 1977's direct port of Will Crowther's original source code (1975) for FORTRAN IV for the PDP-10 mainframe to his 1977/8 version, which became the source for all future versions of the first iteration of *CCA*.

Two sets of code received a weight of 5: 1) black350 and dove0550, and 2) vane0560 and wood0350. Kevin J. Black's version of *CCA* was written in Microsoft Fortran in 1987, and because it used a popular Microsoft product, it became a more accessible ported version of the game for others to borrow from, nearly as popular as Don Wood's 1977 source code, wood0350, from which Neal Van Eck borrowed heavily in his 2011 version, vane0560.

Three sets of code received a weight of 4: 1) arna0440 and wood0350, 2) blac0350 and jame0551 and 3) vane0560 and wood043b. Mike Arnautov's code (2001) first appears here derived from Woods' original. Arnautov would also create versions in the A-Code language. Daniel Jameson (jame0551) ported Kevin Black's Microsoft Fortran (blac0350) to FORTRAN-77 in 2016 for the BBC Micro.

By the time we reach code-comparisons with a weight of 3 or less, we have begun to see popular authors repeated: Don Woods and Kevin Black. Their code, written in 1977 and 1987 respectively, appears to be the wells most frequently visited by other authors

	A	B	C
1	**Source**	**Target**	**Weight**
2	blac0350-code_text	blac0350-code_text	6
3	long0500-code_text	oska0551-code_text	6
4	oska0551-code_text	long0500-code_text	6
5	wood0350-code_text	wood043b-code_text	6
6	wood043b-code_text	wood0350-code_text	6
7	blac0350-code_text	dove0550-code_text	5
8	dove0550-code_text	blac0350-code_text	5
9	vane0560-code_text	wood0350-code_text	5
10	wood0350-code_text	vane0560-code_text	5
11	arna0440-source_text	wood0350-code_text	4
12	blac0350-code_text	jame0551-code_text	4
13	dove0550-code_text	dove0550-code_text	4
14	jame0551-code_text	blac0350-code_text	4
15	vane0560-code_text	wood043b-code_text	4
16	wood0350-code_text	arna0440-source_text	4

Figure 3.13. Stylo results for FORTRAN code sets.

writing in FORTRAN, which is borne out in the data visualization as well as in hand-checking the various file-pairings.

Six sets of code received a weight of 3: 1) arna0440-dos and blac0350, 2) arna0440-source and vane0560, 3) blac0350 and muno0370, 4) black0350 and olss0551, 5) black0350 and supn0350, and 6) dove0550 and jame0551.

Seven sets of code received a weight of 2: 1) arna0440-dos and dove0550, 2) arna-0440-dos and long0500, 3) arna0440-dos and oska0551, 4) dove0550 and supn0350, 5) dove0550 and muno0370, 6) dove0550 and olss0551, and 7) wood043b and arna0440-dos.

Six sets of code received a weight of 1: 1) arna0440-dos and jame0551, 2) blac0350 and long0500, 3) blac0350 and oska0551, 4) jame0551 and muno0370, 5) jame0551 and olss0551, and 6) jame0551 and supn0350.

These last sets of code seem to indicate that the more versions of FORTRAN became available for various operating systems, the more that new CCA code was authored individually, copying less from established source material.

Visualizing the Stylo FORTRAN Data

Translating data into a visual representation assists the archaeologist in interpreting information. Drawing a section or reviewing a Harris matrix representation of stratigraphy helps one make connections and draw conclusions that otherwise might have been missed in the field. I used the open source *Gephi* program to visualize networks of data shared between the files in my corpus.

Running the data through *Gephi* provided the graph in Figure 3.15. I tweaked *Gephi* to ignore code sets with weights lower than 4, displaying sets with weights 4, 5, long0500-code_text.txt

```
20      START=.FALSE.
        IF(SOON)GOTO 30
        IF(PTIME)GOTO 25
C22    IF(EQV('CHEM  ',VEC(13))) GOTO 23
C22    IF(EQV('CHEM  ',VEC(13))) CALL EXIT  /* DISALLOW CHEM TO ACCESS
22    CONTINUE
        SAVED=-1
23    CALL BREAK$(.TRUE.)
      CALL LOGIN
        RETURN
C  COME HERE IF NOT RESTARTING TOO SOON (MAYBE NOT RESTARTING AT ALL), BUT IT'S
C  PRIME TIME.  GIVE OUR HOURS AND SEE IF HE'S A WIZARD.  IF NOT, THEN CAN'T
C  RESTART, BUT IF JUST BEGINNING THEN WE CAN OFFER A SHORT GAME.
25      CALL MSPEAK(3)
        CALL HOURS
        CALL MSPEAK(4)
        IF(WIZARD(.FALSE.))GOTO 22
        IF(SETUP.LT.0)GOTO 33
        START=YESM(5,7,7)
        IF(START)GOTO 22
        CALL EXIT
C  COME HERE IF RESTARTING TOO SOON.  IF HE'S A WIZARD, LET HIM GO (AND NOTE
C  THAT IT THEN DOESN'T MATTER WHETHER IT'S PRIME TIME).  ELSE, TOUGH BEANS.
30      CALL MSPEAK(8)
        IF(WIZARD(.FALSE.))GOTO 22
33      CALL MSPEAK(9)
        CALL EXIT
        END
```

oska0551-code_text.txt

```
20      START=.FALSE.
        IF(SOON)GOTO 30
        IF(PTIME)GOTO 25
C22    IF(EQV('CHEM  ',VEC(13))) GOTO 23
C22    IF(EQV('CHEM  ',VEC(13))) CALL EXIT  /* DISALLOW CHEM TO ACCESS
22    CONTINUE
        SAVED=-1
C23    CALL BREAK$(.TRUE.)
C NO IDEA WHAT ABOVE LINE IS FOR, REMOVING IT SEEMS TO WORK M.V.
      CALL LOGIN
        RETURN
C  COME HERE IF NOT RESTARTING TOO SOON (MAYBE NOT RESTARTING AT ALL), BUT IT'S
C  PRIME TIME.  GIVE OUR HOURS AND SEE IF HE'S A WIZARD.  IF NOT, THEN CAN'T
C  RESTART, BUT IF JUST BEGINNING THEN WE CAN OFFER A SHORT GAME.
25      CALL MSPEAK(3)
        CALL HOURS
        CALL MSPEAK(4)
        IF(WIZARD(.FALSE.))GOTO 22
        IF(SETUP.LT.0)GOTO 33
        START=YESM(5,7,7)
        IF(START)GOTO 22
        CALL EXIT
C  COME HERE IF RESTARTING TOO SOON.  IF HE'S A WIZARD, LET HIM GO (AND NOTE
C  THAT IT THEN DOESN'T MATTER WHETHER IT'S PRIME TIME).  ELSE, TOUGH BEANS.
30      CALL MSPEAK(8)
        IF(WIZARD(.FALSE.))GOTO 22
33      CALL MSPEAK(9)
        CALL EXIT
        END
```

Figure 3.14. Stylometrically identical FORTRAN code files.

and 6. As expected, long0500 and oska0551 are connected by two thick "edges" (lines) indicating equivalence, as are wood0350 and wood043b. Frequently borrowed code of black0350, dove0550, and jame0551 and to a lesser extent arna0440-dos appears in large font and node (ball) to indicate popularity of use, linking stylistically to several other code sets. The code sets are also grouped in green, purple, and orange to show where the greatest stylistic comparisons lie, showing how the style of various code sets appears across the range. Based on the chart, there are three main divisions to the style of the code, very much like shared DNA, which after reviewing the code indicate different versions of FORTRAN used by different groups of programmers. I expected for wood0350 to be more prominent in the chart, but then again the information most copied from Wood's version was not the FORTRAN code, but instead the narrative data as will be demonstrated below. Stylistic similarities in the code do appear, and the chart links families of programmers together that shared the same root code for the versions of FORTRAN in which they worked. This could parallel what archaeologists see in sigillata factories across the Roman Empire, similar forms and molds but different clays (Lewit, 2015, and Brughmans, 2010).

TextReuse and FORTRAN Code

TextReuse compares every document against every other document in a corpus in order to see what percentage of text was borrowed/shared between files. Different than stylometrics, which are a bit more forgiving and take into account vocabulary, syntax, and punctuation, *TextReuse* takes a brute-force approach to determine if blocks of text were copied 1:1 between files. The results are weighted from 0 to 1, 1 being 100% copied/match, and zero meaning no copying at all.

Unlike the results explained above for *Stylo*, only three pairs of FORTRAN files showed significant outright copying/formatting. Scoring a weight of 1, black0350 is an exact match with supn0350. Curiously, these two files received a weight of 3 from *Stylo*. When I opened the files to compare them visually, it was clear that both files were identical to each other, even though they were not written in English, and appeared instead as hundreds of pages of non-English gibberish, which lined up exactly (Fig. 3.16).[37] The discrepancy may be that with *Stylo*, one can set an "n-value" meaning that one can check every seventh letter (n=7), or can set that number higher or lower. In dealing with older FORTRAN files, we might be seeing odd results with n set so high,

37. Some programming languages and their coded files cannot be read in a simple text editor as natural language, but must instead be viewed in a specific programming environment. The limitation of using the statistical packages for *R* is that corpus files are to be saved as TXT filetypes prior to analysis, sometimes ill-suited to software code. Even so, these symbol-filled TXT files could still be analyzed for overlap in *R* based on the underlying ASCII values assigned to each character in each file in the corpus being analyzed.

In conversation with Prof. Jeremy Huggett on 20 January 2020, I learned that these two files are actually machine code (executable files) rather than source code. I will formally address this issue and its implications in the forthcoming publication of this case study.

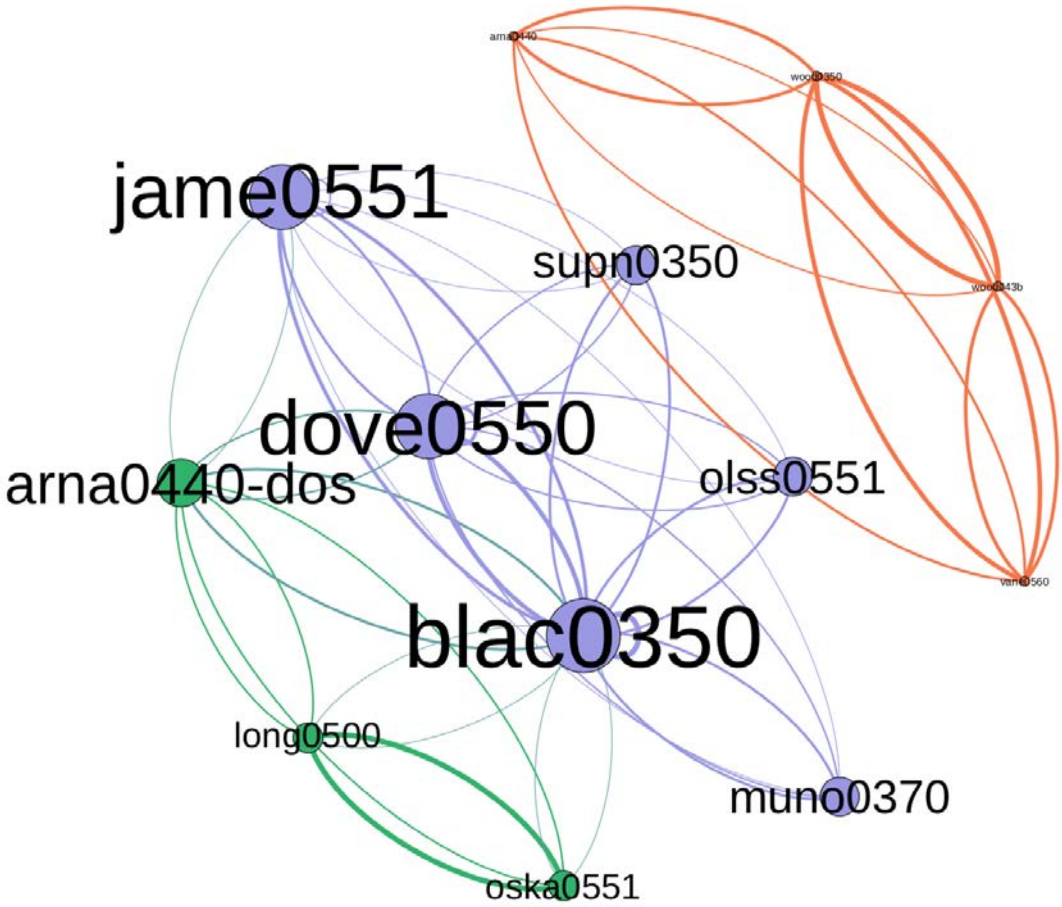


Figure 3.15. Visualization of the stylometric analysis of FORTRAN code. The colors show clusters (i.e., families) of similar data, in this case files that share very similar characteristics.

and future analysis can test with a finer grain to see if this impacts the weight not unlike increasing the magnification of a microscope when viewing a sample.

The second set of files sharing 70% of copied text contains long0500 and oska0551, which makes a bit more sense seeing as oska0551 is a direct port of long0500 and was assigned a weight of 6, meaning identical style. Noting the difference, I visually inspected both files, at first believing them to be identical, which meant that they should have a *TextReuse* weight of 1 (or 100%). To test, I re-ran the *TextReuse* package against just these two files keeping "n = 7" to check against every seventh word in the file. The package still returned a score of 70%. Tightening the n value to "1", the match improved to 85%. Still bothered by the anomaly, I re-opened each of the FORTRAN files and noted subtle differences in punctuation (e.g., the inclusion of "!" in one line and the addition of three extra lines of commented code marked with "C") (Fig. 3.17).[38] The computa-

38. In programming, every character counts and has meaning. For operational behavior, any character out of place results in a syntax error. As versions of FORTRAN evolved, so too did the need to make later versions of *CCA* conform to the updated rules of grammar in order to keep the game "grammatically correct" and functional, not unlike updating one's writing based on the current version of the *Chicago Manual of Style*.

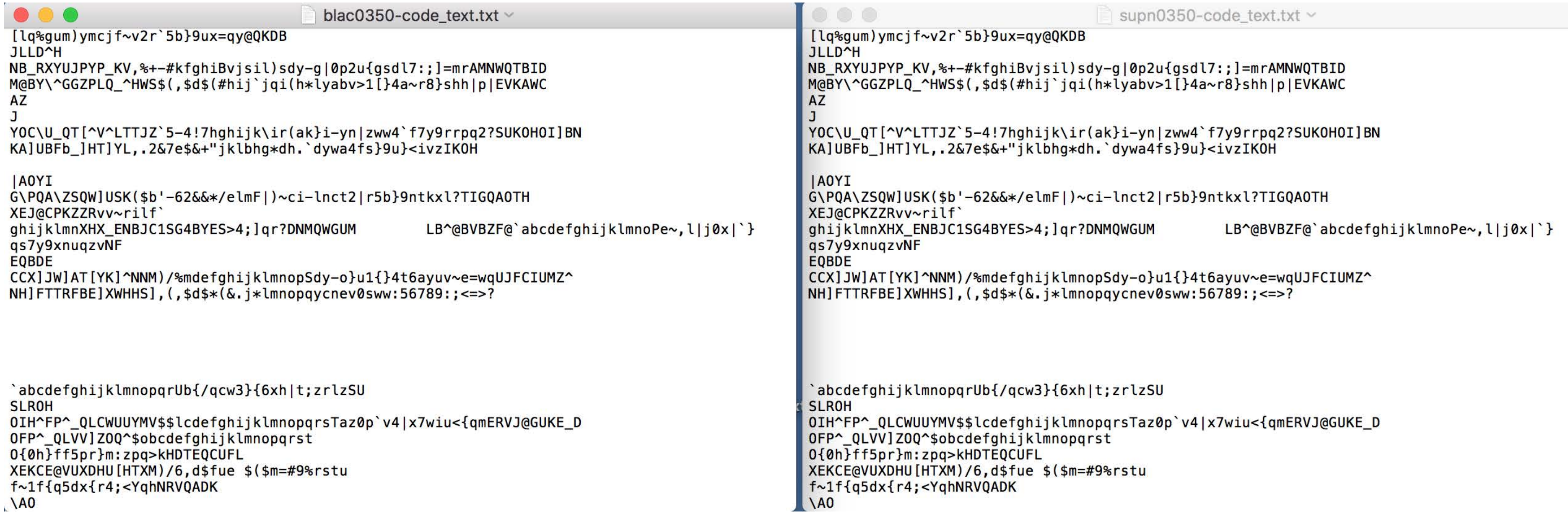


Figure 3.16. Identical set of FORTRAN machine-readable files.

tional results were indeed correct, showing me that my initial, visual review of the files was wrong. While the *style* was a perfect match, not all of the text was re-used between this pair of files, showing the difference in what the *Stylo* and *TextReuse* packages actually do. Resetting the n-value also tightened up the results.

The third set of files has a weight of 17% text shared between wood0350 and arna0440, yet has a stylometric weight of 4. One could interpret this as arna0440 being written in the manner of wood0350 without explicit copying of blocks of code.

Visualizing the TextReuse FORTRAN Data

Running the FORTRAN *TextReuse* data through *Gephi* shows five families of text (in dark green, light green, light blue, pink, and orange) (Fig. 3.18). Dove0550 shows as an outlier unrelated to any other code sets, meaning this FORTRAN is completely original. The other families of code sets are loosely connected through thin edges indicating slight relationships, something borne out by the data. Code sets most widely borrowed appear in a larger font, even if that borrowing is minimal. The 1977 code of wood0350 is one of two most-widely used sets, which is understandable because of its age and proximity to Crowther's Ur-code. The code of Black and Supnik and of Long and Oskarsson are twinned in the graph and reflect the quantified data explained above, copying each other, but not being copied by other FORTRAN iterations. In these instances, it is clear that the later code author chose earlier code from exactly one version of the game from which to borrow. Even though there are a handful of FORTRAN code sets available for study, there is already a diversity of versions splintering off from the original source code largely showing a mixture of adoption of code while adding original content when updating the game.

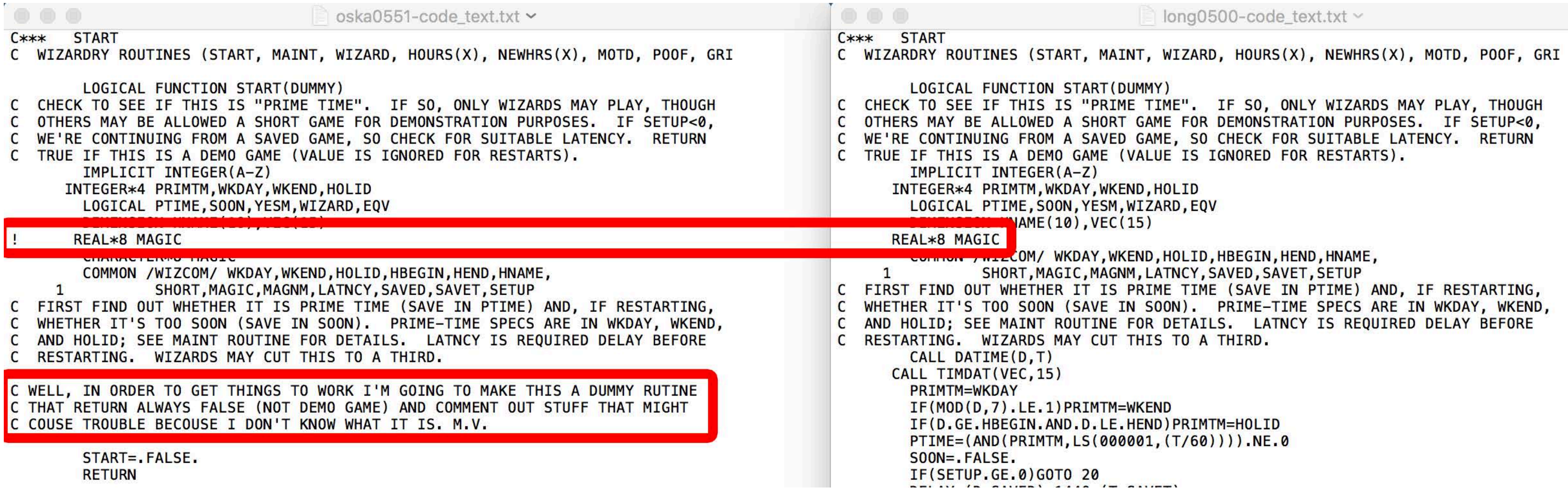
Textnets and FORTRAN Code

The *Textnets* package for *R* creates visualizations of networks shared between a corpus of texts, and also shows how various networks of texts relate to each other. Unfortunately the FORTRAN code sets caused the text analysis tool to fail, erroring out because of non-English and special characters.[39] *Textnets* did, however, work for the sets of narrative data and ReadMe files, but in a curious way as will be shown below.

Analysis of FORTRAN Code

I compared the two data visualizations for Stylo and TextReuse on the FORTRAN code sets in order to see 1) if there was an intersection between "families" of code as identified by the statistics packages, and 2) if the quantified data matched up with the oral histories of the code sets, which included data from the ReadMe files.

39. This issue likely will be resolved when removing the two machine code files from the data set. This will be done for the forthcoming publication of this case study.



oska0551-code_text.txt

```
C***   START
C  WIZARDRY ROUTINES (START, MAINT, WIZARD, HOURS(X), NEWHRS(X), MOTD, POOF, GRI

        LOGICAL FUNCTION START(DUMMY)
C  CHECK TO SEE IF THIS IS "PRIME TIME".  IF SO, ONLY WIZARDS MAY PLAY, THOUGH
C  OTHERS MAY BE ALLOWED A SHORT GAME FOR DEMONSTRATION PURPOSES.  IF SETUP<0,
C  WE'RE CONTINUING FROM A SAVED GAME, SO CHECK FOR SUITABLE LATENCY.  RETURN
C  TRUE IF THIS IS A DEMO GAME (VALUE IS IGNORED FOR RESTARTS).
        IMPLICIT INTEGER(A-Z)
      INTEGER*4 PRIMTM,WKDAY,WKEND,HOLID
        LOGICAL PTIME,SOON,YESM,WIZARD,EQV
!      REAL*8 MAGIC
        COMMON /WIZCOM/ WKDAY,WKEND,HOLID,HBEGIN,HEND,HNAME,
     1          SHORT,MAGIC,MAGNM,LATNCY,SAVED,SAVET,SETUP
C  FIRST FIND OUT WHETHER IT IS PRIME TIME (SAVE IN PTIME) AND, IF RESTARTING,
C  WHETHER IT'S TOO SOON (SAVE IN SOON).  PRIME-TIME SPECS ARE IN WKDAY, WKEND,
C  AND HOLID; SEE MAINT ROUTINE FOR DETAILS.  LATNCY IS REQUIRED DELAY BEFORE
C  RESTARTING.  WIZARDS MAY CUT THIS TO A THIRD.

C WELL, IN ORDER TO GET THINGS TO WORK I'M GOING TO MAKE THIS A DUMMY RUTINE
C THAT RETURN ALWAYS FALSE (NOT DEMO GAME) AND COMMENT OUT STUFF THAT MIGHT
C COUSE TROUBLE BECOUSE I DON'T KNOW WHAT IT IS. M.V.

        START=.FALSE.
        RETURN
```

long0500-code_text.txt

```
C***   START
C  WIZARDRY ROUTINES (START, MAINT, WIZARD, HOURS(X), NEWHRS(X), MOTD, POOF, GRI

        LOGICAL FUNCTION START(DUMMY)
C  CHECK TO SEE IF THIS IS "PRIME TIME".  IF SO, ONLY WIZARDS MAY PLAY, THOUGH
C  OTHERS MAY BE ALLOWED A SHORT GAME FOR DEMONSTRATION PURPOSES.  IF SETUP<0,
C  WE'RE CONTINUING FROM A SAVED GAME, SO CHECK FOR SUITABLE LATENCY.  RETURN
C  TRUE IF THIS IS A DEMO GAME (VALUE IS IGNORED FOR RESTARTS).
        IMPLICIT INTEGER(A-Z)
      INTEGER*4 PRIMTM,WKDAY,WKEND,HOLID
        LOGICAL PTIME,SOON,YESM,WIZARD,EQV
      REAL*8 MAGIC
     1          SHORT,MAGIC,MAGNM,LATNCY,SAVED,SAVET,SETUP
C  FIRST FIND OUT WHETHER IT IS PRIME TIME (SAVE IN PTIME) AND, IF RESTARTING,
C  WHETHER IT'S TOO SOON (SAVE IN SOON).  PRIME-TIME SPECS ARE IN WKDAY, WKEND,
C  AND HOLID; SEE MAINT ROUTINE FOR DETAILS.  LATNCY IS REQUIRED DELAY BEFORE
C  RESTARTING.  WIZARDS MAY CUT THIS TO A THIRD.
        CALL DATIME(D,T)
      CALL TIMDAT(VEC,15)
        PRIMTM=WKDAY
        IF(MOD(D,7).LE.1)PRIMTM=WKEND
        IF(D.GE.HBEGIN.AND.D.LE.HEND)PRIMTM=HOLID
        PTIME=(AND(PRIMTM,LS(000001,(T/60)))).NE.0
        SOON=.FALSE.
        IF(SETUP.GE.0)GOTO 20
```

Figure 3.17. Small differences in otherwise identical FORTRAN code sets.

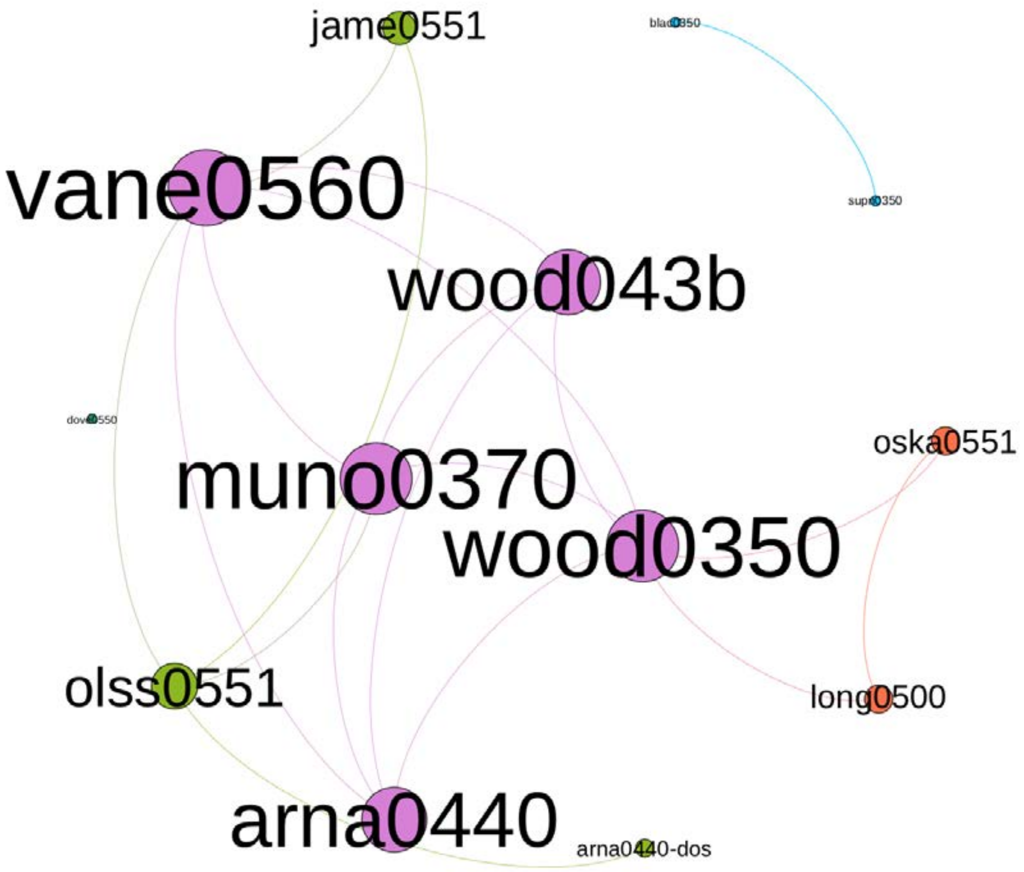


Figure 3.18. Data visualization showing reuse of text between versions of code.

The Stylo package returned three distinct families of code sets. The major grouping for these sets included jame0551, dove0550, blac0350, supn0350, olss0551, and muno0370. The minor family included arna-0440-dos, long0500, and oska0551. The outlying family grouped arna0440-source, wood0350, wood043b, and vane0560, which while strongly showing kinship with each other barely touched the major family and did not touch at all the minor family.

The TextReuse package returned five families, one of which—dove0550—was a solo outlier (a black sheep). The major family included vane0560, wood043b, wood0350, arno0440-source, and muno0370. The first minor family included olss0551, jame0551, and arna0440-dos. Two pairs of outliers included 1) oska0551 and long0500, and 2) blac0350 and supn0350, each pair of files connected only to themselves and not to other outliers or families.

The Stylo major family only overlapped with muno370 in the TextReuse major family. Curiously, the TextReuse major family overlapped (4 out of 5 code sets) with the family of outliers returned by Stylo.

From the visualizations of *CCA* FORTRAN, kinship groupings are evident based on the style of the code authors or by the evidence of reused text, but the kinship does not cross over from style and text analysis (or vice versa). When comparing the Stylo visualization against the oral histories of the files themselves:

> Dove0550: Microsoft FORTRAN (a port from an unknown PDP-11 version, n.d.)
> Supn0350: FORTRAN IV (a port of blkt0350, 1978)
> Blac0350: Microsoft FORTRAN (a port of supn0350, 1987)
> Olss0551: FORTRAN 77 (a port of mcdo0550, 1990)
> Muno0370: PDS FORTRAN (a port of wood0350, 1996)
> Jame0551: FORTRAN 77 (a recompile of mcdo0550, 2016)

Here are the members of the major family returned by TextReuse, supplemented by oral history data:

Wood0350: FORTRAN 10 (a port and expansion of crow0000, 1977)
Wood043b: FORTRAN IV (an expansion of wood0350, 1995)
Muno0370: PDS FORTRAN (a port of wood0350, 1996)
Arna0440: FORTRAN 77 (a port of lupi0440, 2001)
Vane0560: Intel FORTRAN 2008 (derived from mcdo0550, 2011)

It appears that in the case of the FORTRAN code sets, not a lot of data can be gathered and compared in a statistically significant way. There is little crossover between style and text-reuse, which is likely a byproduct of the several versions of FORTRAN uses.

There are two major takeaways in interpreting the FORTRAN data:

1. One can quantifiably show kinship between files/versions of software. What this means for *CCA* and other software applications is that we can conceivably go one step beyond a simple tree diagram (Culver, 2019), creating kinship diagrams as used in anthropology. While traditional kin diagrams show relationships between parents, children, brothers, sisters, etc., software "kin" diagrams might often show either a single parent or a community of parents with future software versions indicated by "brother" and "sister" pairings or "marriages" between sets of code from different versions that were merged to create a new, distinct version. This kind of visualization would make it easier for digital archaeologists to comprehend changes to digital built environments instead of relying on a simple tree diagram with annotations.

2. Software is not as ephemeral as I had originally believed. This observation comes from looking at the creation dates of the FORTRAN code sets, which show an unexpected range from 1978–2016 (Stylo) and 1977–2011 (TextReuse). I would have thought that FORTRAN programmers would have all been working in that language clustered in the 1970s or 1980s, but that is clearly not the case. These versions were created over time, later versions basing themselves off of earlier ones, authored in a now-archaic language, not unlike reanimating an extinct mammoth from the DNA found in the blood of a prehistoric insect trapped in amber. The digital past remains available to us.

3.3.2. Narrative Data Files

The second group of *Colossal Cave Adventure* files contains narrative data referenced by the game's code. In Crowther's 1975 original game and in Woods' port of the game in 1977/78, there is a narrative data file, advent.dat. This .dat file can be opened in a simple text editor (e.g., *Text* for Mac OS and *Notepad* in Microsoft Windows). It contains a few hundred lines of human-readable text (i.e., not in FORTRAN or another programming language), each line sequentially numbered and containing a description of where a player is (e.g., a room of the cave) or of player-related actions (e.g., death).[40] Of the 100+ versions of *CCA* known to exist, 37 have the data file split off from the main program. I was able to prepare these 37 files for text analysis, and then ran this corpus through the packages for *R*.

As with the source code files analyzed in section 3.1, I was curious to see if (and how) narrative data was shared between versions and carried forward through time. This story data is what gives *CCA* its flavor and makes it instantly recognizable to players. I wanted to see which versions maintained the original narrative text, and which authors chose to augment the storytelling in the game.

Stylo and Narrative Data Sets

As with the FORTRAN files, I used *Stylo* to check for stylometric similarities between texts in a corpus. These texts were weighted from 1 to 6, 6 being a perfect match, which would likely mean that the data from each set in the pair being compared were identical. Because the game changed over the course of 44 years, I expected to see some exact matches for cavern rooms and events, as well as some close matches.[41] See Appendix D for tables of the results.

40. See Appendix A for the original narrative data file.
41. Players can visit 66 distinct rooms within the cave in Crowther's original *CCA*. Woods more than doubled the number of locations in his 1977/8 revision, and most of the "preservation" versions of the game mimic these, occasionally adding rooms, treasures, and things to do.

Weight of 6 (4 sets)
It is important to note the numbers in the filenames. These numbers correspond to the maximum score players can achieve in *CCA*. The original high score was 350 points, and versions named "0350" are typically closest to the original version of the game. This also means that the name and number of the rooms in the cavern as well as the things that happen to the player are roughly the same. Filenames with higher scores typically indicate later versions, and one can see parallels between these files as well. Here bhch0565 (1987) and well0550 (1985) share the same data file for their higher-scoring version. Also David Malmberg copied his own data file between malm0350 (1993) and malm1000 (2000).

Weight of 5 (8 sets)
Again we see parallels between scores and files, with 350-files and 440-files borrowing from each other, not to mention Woods borrowing from himself. Oska0551 (1990) borrows from anon0501 (1979), both versions of which follow the code created by long0500, both files listed below with a weight of 4.

Weight of 4 (4 sets)
Similarly scored files continue to pair with each other.

Weight of 3 (17 sets)
The remaining weights (3, 2, and 1) show an increased diffusion of human-readable text spread across various, later versions of the game as authors continued to change the points system, while adding rooms and events not native to Crowther and Woods' original *CCA* (Fig. 3.19).

Visualizing the Stylo Narrative Data Sets
As above with the FORTRAN code sets, I ran the narrative data sets through *Gephi* to visualize the stylometric relationships between data sets. I established a cut-off of relationships weighted below 4. The resulting graph is below and shows six distinct stylometric families (light green, dark green, red, purple, orange, light blue) (Fig. 3.20). The most conspicuous data source turns out to be long0500 (1979). This file might have been more popular than Woods' because of its discoverability on early computer networks: people looking for *CCA* might have discovered it more easily than Woods' version (or found Long's version instead of Woods' when searching) thereby copying its contents. Again the graph shows shared DNA that demonstrates whose code was derived from others and showing the primary source of data within each of the six families. Note that these six families are clustered roughly by score, meaning that games in

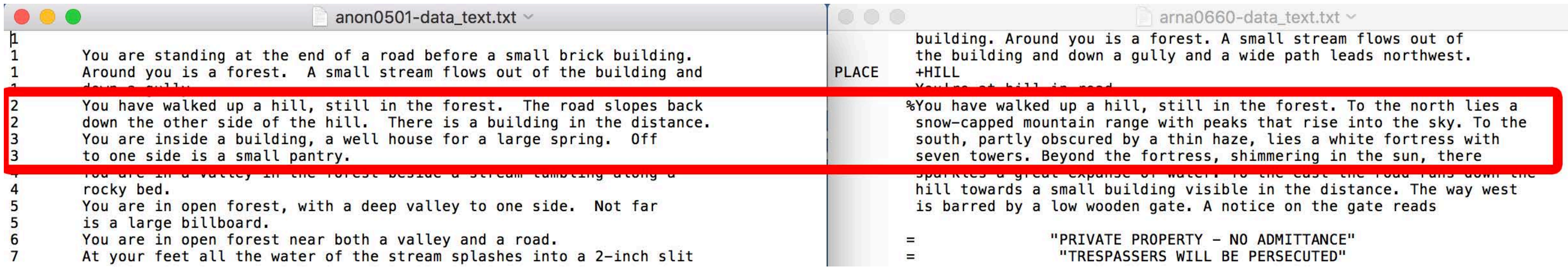


Figure 3.19. Comparison of ANON0551 and ARNA0660 showing differences in the narrative data.

the 350-range are lumped together, as are the games in the 400– to 500-range, and the games with maximum scores of 600 or more. This shows that as *CCA* evolved and became more complex, people (mostly) copied later versions, keeping like with like, these later versions already incorporating narrative data from the original 350-point game. This would appear to mimic current, iterative software development where one does not build a new version on top of the base programming, but instead overlays new code atop the most recent version, another layer of strata.

TextReuse and Narrative Data Sets

The *TextReuse* package was able to show the percentage of text borrowed between versions of *CCA,* 1 being 100% down to 0. Unlike with *TextReuse* and *CCA* FORTRAN code shown above, due to the nature of the game's narrative data, many versions (despite the programming language) use the same (or very similar) descriptions for cavern locations and player-events. 33% of the data sets are weighted above 50%. Later versions remained true to the open source spirit of this game and its programming, copying the narrative as both an act of preservation and as an homage to the original. See Appendix E for the tables of results.

Weight = 100% (10 sets)

Perfect matches of the English narrative data include Jacob Munkhammer porting Woods' original game from FORTRAN IV to DOS. John W. Kennedy updated Jerry Pohl's Macintosh OS/2 version to a more modern Mac operating system. While the code changed, the narrative data did not. In 2007, Matthew Russotto updated the FORTRAN-77 code of Crowther's original, and like Kennedy's port of Pohl, he left the narrative data set alone. Mike Arnautov recycled his data set as well between his three versions of *CCA* made for different platforms, but all with a 440-point maximum score. Wood recycled his data, too, for the 430-point version of the game.

Weight = 90–99% (10 sets)

Ten more sets of data fall between 95% and 99%, meaning a near-exact copy of the narrative data shared between two versions of *CCA*. The very minor differences relate to small variations in formatting and punctuation. For all intents and purposes, these 10 sets can be included with the 10 perfect matches above.

Weight = 80–89% (5 sets)

When we get to data in the 80% range, differences in the text become easier to spot. For example lumm0350 is single-spaced and whin0450 is double-spaced. This is enough to register a statistically significant change to how *TextReuse* compares the data. One

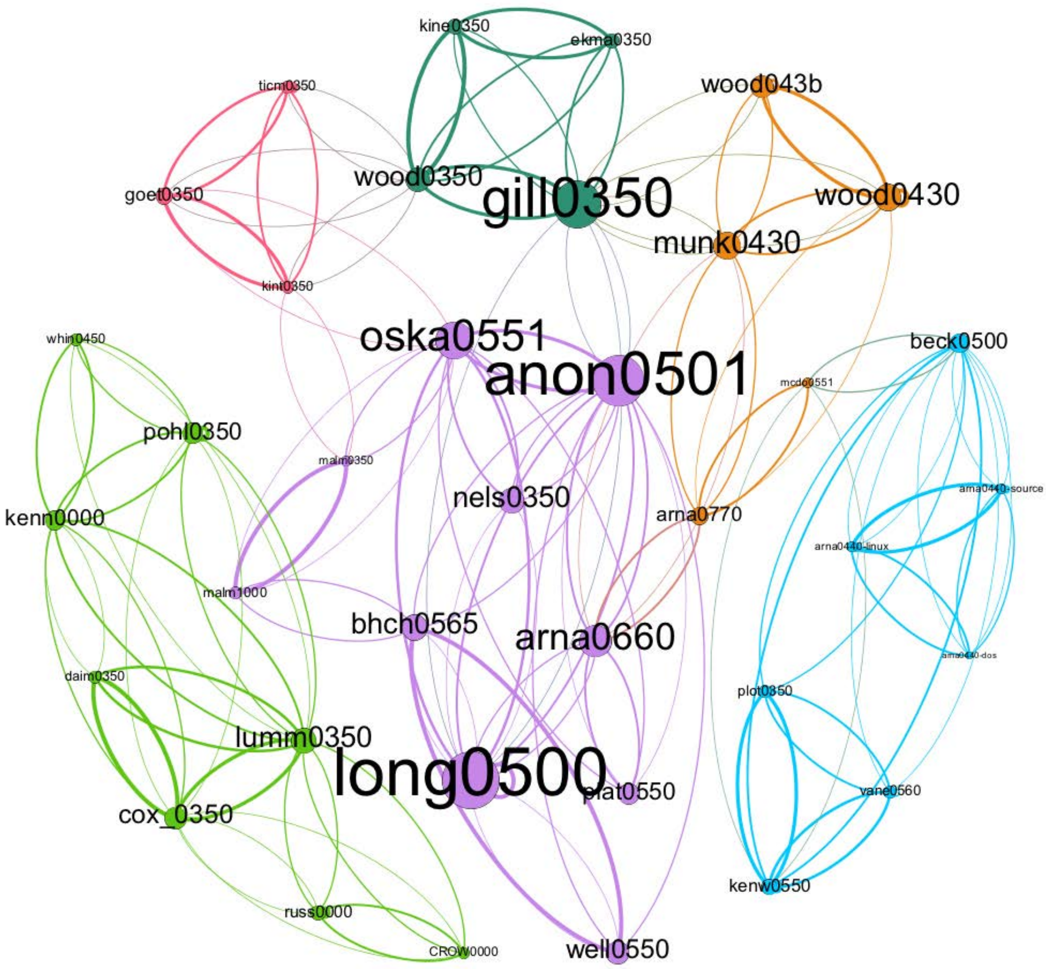


Figure 3.20. Data visualization of stylometric analysis of narrative data sets.

could change the spacing of whin0450, but that would manipulate the data.[42] All data in this case study remain as they were discovered in the wild. The differences discovered with *TextReuse* on the narrative data files are largely cosmetic; the actual story content remains relatively unchanged.

Weight = 70–79% (11 sets)

Data in the 70% range show more significant deviations, in part with style and formatting, but also now with actual data. For example ticm0350 has for line 201, "Colossal Cave is ALWAYS open, provided this is your computer," and ekma0350 states "THERE'S NO POINT IN SUSPENDING A DEMONSTRATION GAME" (Fig. 3.21). This line recalls the Woods' version of the game that included "Wizard Hours" where

42. After discussing with Prof. Jeremy Huggett on 20 January 2020 my reluctance to remove the blank lines of whin0450, I will attempt this for the forthcoming publication of this case study.

a system administrator could revoke access to *CCA* to players on a mainframe or company network, but in these two versions the authors have changed the line for a more contemporary audience.

Weight = 60–69% (4 sets)
The drop from the 70s to the 60s is 8%, and looking at the data files shows not only changes in data, but also in how the data are organized. The reasoning behind this is because these four sets of files are all from different programming languages, which call the data in different ways.

Weight = 50–59% (8 sets)
The trend in the 60s continues in the 50s for the same reasons, but like the other examples, affects only a small number of sets. This brings us to sets under 57%, which make up the majority of the *TextReuse* results: 107 data sets (compared to 48 total data sets weighted above 50%):

Weight = 40–49% (35 sets)
Weight = 30–39% (32 sets)
Weight = 20–29% (40 sets)
Weight = 10–19% (0 sets)
Weight = 0–9% (0 sets)

The one thing to notice about the data sets in the lower 50% of the weighted corpus is that there are no sets below 20%. In reviewing the CSV file, the lowest percentage is 25%, which has a logic to it: *CCA* is a classic game with plenty of puzzles adored by countless players since 1975. Failure to copy-paste any of the narrative text would result in a game distinctly separate from *CCA*. The fact that *TextReuse* bottoms out at 25% proves that.

Visualizing the TextReuse Data Sets

To get meaningful results from visualizing the data in *Gephi*, I limited the weights of the sets of data files to over 50%. The resulting graph shows two core versions of the English narrative text (green and pink) (Fig. 3.22). The large fonts and nodes show the popularity of the data that was borrowed from one version to the next. Interestingly, three small groups of outliers also appear: CROW0000 and russ0000, which are a 100% match, the three Arnautov files, also 100% matches, as well as the kenn0350 and pohl0350. These perfect scores create outliers in the chart surrounding the remaining files in various states of linking and usage. Perhaps the most interesting thing to note in

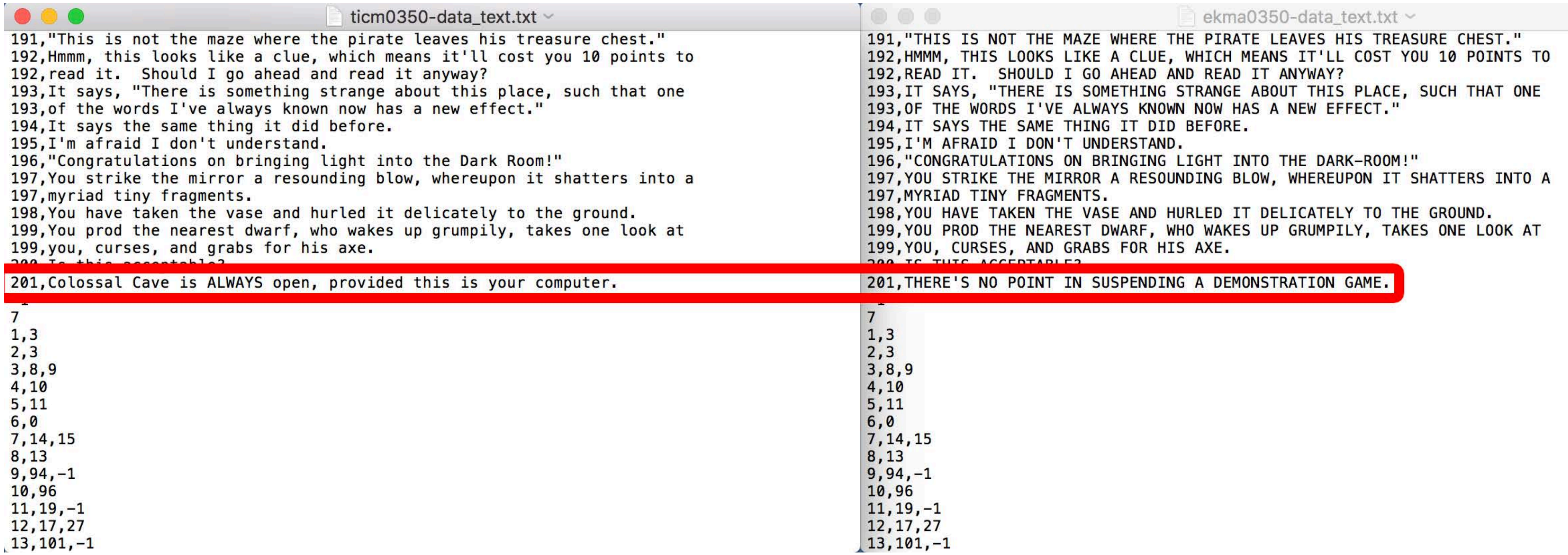


Figure 3.21. Comparison of TICM0350 and EKMA0350 showing both copied narrative text and a subtle difference/update (boxed in red).

the graph, however, is the near-uniformity and mass of connections from every node to nearly every other, linked by edges of almost uniform thickness. This visualizes how the narrative data from Woods' 1977/8 game has been reused again and again by every version of *CCA*, each iteration largely remaining true to the source, a phenomenon addressed in this chapter's conclusions. We might see something similar in copies of manuscripts or edicts circulated throughout a region, the core information reproduced by copyists with only slight variations. The difference with the digital, however, is the time taken between the creation of other versions of the game. Circulated, copied text is typically done within a very small window of time, but with the digital, time appears to be unimportant when compared to the content of the message itself. If *CCA* is treated like an archaeological artifact, it remains *in situ* until activated by the archaeologist upon discovery, or in the case of version-creation, by a new programmer. The original contents (code) remain as they were, but once removed from their context (files) become something contemporary.

Textnets and Narrative Data Sets

The *Textnets* package for *R* displays networks of related text files and how (or if) they connect. The package does not output a CSV file for visualization, but instead has the researcher dump the contents of each file in the corpus into its own row in a two-column spreadsheet. The package then reviews the contents and draws a graph showing how the sets of files relate. I ran *Textnets* against the 35 sets of narrative data to produce the graph in section 3.2.6 in order to see if there were smaller networks of authors linked together by how they chose to modify *CCA*'s narrative data.

Visualizing the Textnets Narrative Data Sets

I remain unsure how to interpret the graphical results (Fig. 3.23). This could be because 1) the results provide me with nothing new, or 2) the results seem to provide new information but in a format that I as a researcher have so far been unable to understand. In this instance of using *Textnets* with the narrative data sets, two groups of text appear as red and black connected by a line running directly from whin0450 (black) to bchc0565 (red, in between the two groups), and newdoc (red), which connects other files exhibiting somewhat tenuous relationships. The two main colors may be attempting to show data similar to that retrieved from *TextReuse*, showing the two major groups of text being shared across versions. All of the nodes in the black network are interrelated, whereas the red nodes appear to be much less entangled. The visualization could indicate that whin0450 is on its own in how it presents the narrative of *CCA*, although connected in spirit to the other versions. In reading the actual data file for whin0450, it does present the narrative text differently than its contemporaries, double-spacing the

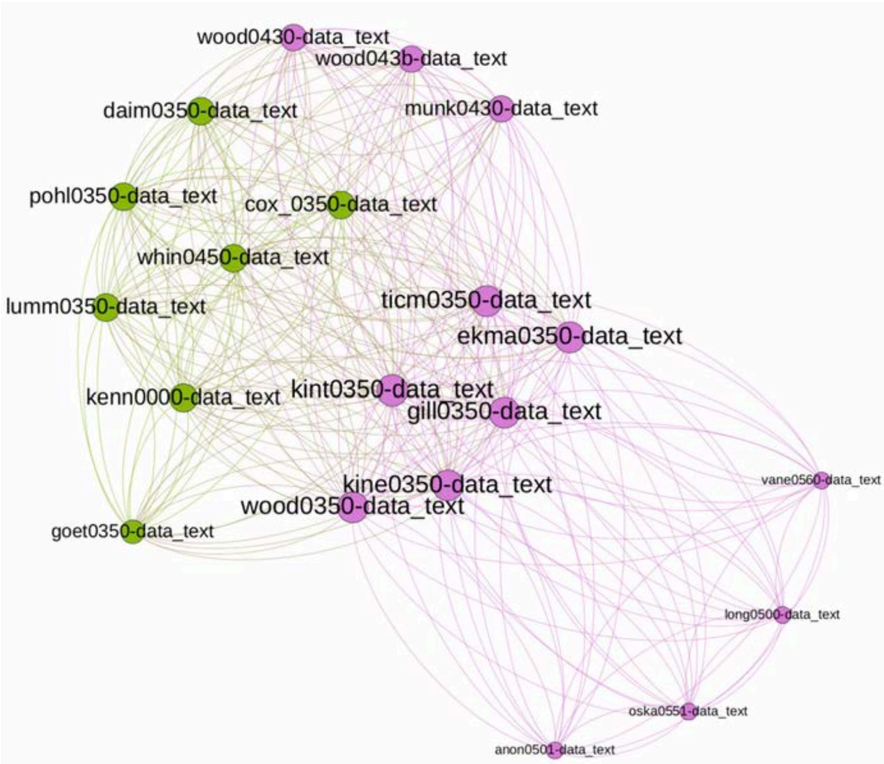


Figure 3.22. Data visualization of reused text in narrative data sets.

text, using hashtagged numbers to designate places and events in the game. The content and its organization are similar, but the presentation within the TXT file is different enough to make this version an outlier.

Analysis of Narrative Files

As above, this section analyzes the family groupings of narrative data sets returned by Stylo and TextReuse to look at the relationships between and within these groupings. Beginning with the sets visualized from their Stylo-generated data, there are six groupings and no outliers or single files. Five groups surround the central major family whose members include long0500, anon0501, oska0551, well0550, nels0350, bhch0565, arna0650, plat0550, malm1000, and malm0350. This family does not bond neatly with the surrounding groups, although some slight relationships exist (e.g., arna0660 with arna0770, both authored by the same person at different times). Each of the other families appear to be self-contained, sharing a style common between them indicating similar source material. For example, in the minor grouping containing ticm0350, goet0350, and kint0350, kint0350 is an Amiga port of ticm0350, one version cribbing from the other. This relationship is verified through the evidence of text reuse, the visualization of which weights all three versions in this small family equally regarding how much of the narrative text was copied from one version to the other. Similar results appear with the small family of gill0350, wood0350, kine0350, and ekma0350. Gill0350

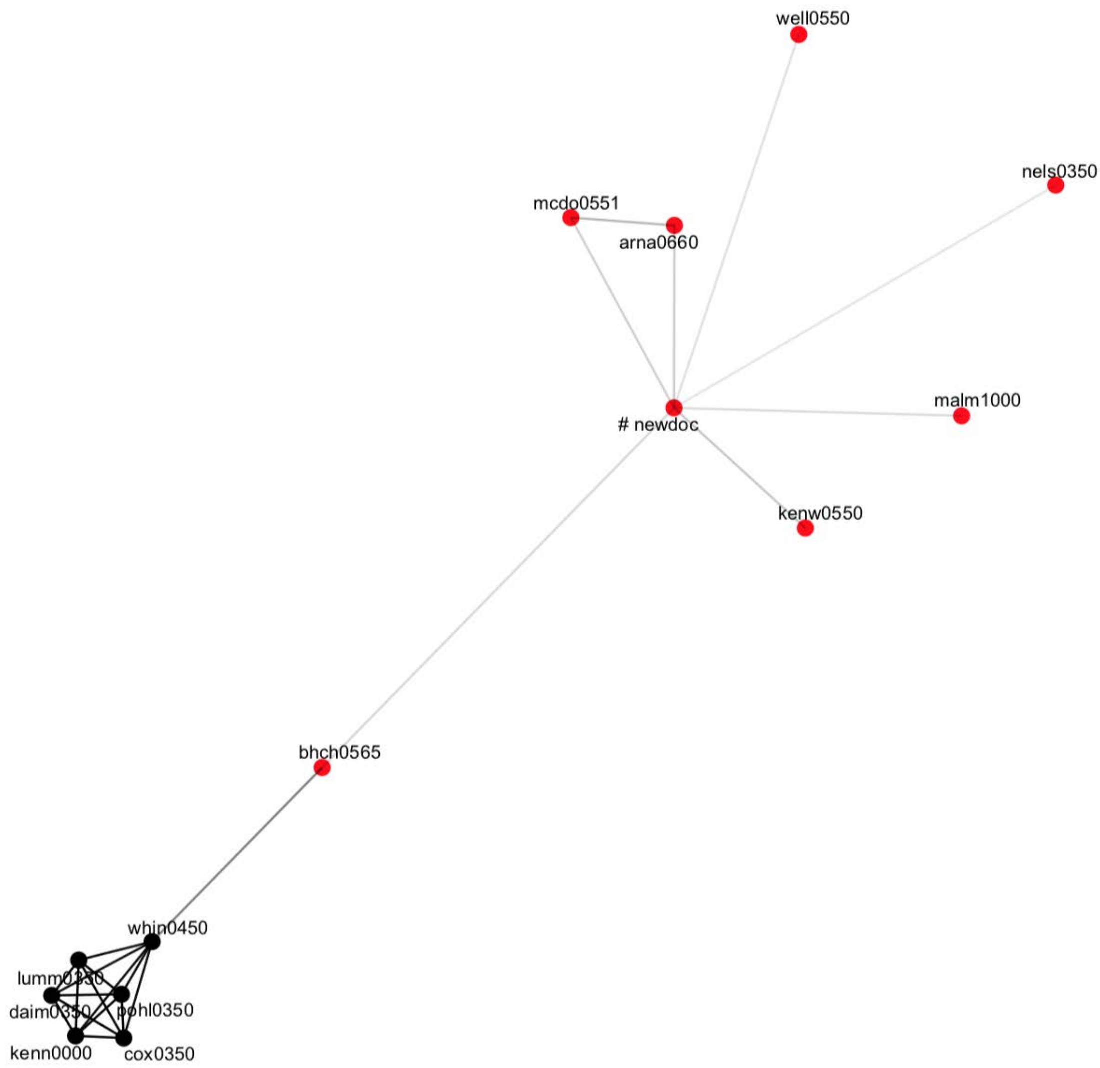


Figure 3.23. Data visualization of narrative data sets showing text networks.

is a 1:1 Unix/C port of Wood0350, as is Ekma0350, and Kine0350, albeit to different platforms (Unix/C, Amiga, and DOS respectively). The narrative text also remained the same, with nothing added. Based on the ReadMe file paradata for two of three versions porting Don Woods' original (gill0350 has no ReadMe file), the only things that were changed rested wholly on the programming side as quoted directly here:

> KINE0350: Adventure was the very first text adventure, written by Will Crowther and Don Woods, circa 1977. The original (which had a maximum score of 350 points) has been modified and extended by many people. Presented here is a version extremely close to the original, which was written for the DEC PDP-10 and contained many dependancies on the nature of that machine. The source used here was modified at DEC to run on the PDP-11, and later ported to MS-DOS by Don Ekman. This very early version of Adventure

still has the all-capitals text of the PDP-10 version. While this is authentic, it can be somewhat annoying after a while, so the program has the ability to convert the text to a more normal output. To do this either run the game from the Shell with Adventure –c or, for Workbench, add the tooltype "CASE" to the icon. This port has an Amiga specific front-end, with proper command line editing and a command line history (use the cursor up/down keys to step through previously entered commands). It requires at least Kickstart 2.04. The porting was performed by David Kinder kinder@teaching.physics.ox.ac.uk

EKMA0350: This is a resurrection of the old Adventure, written for the DEC-10 and ported to the PDP-11/70, ported this time to the MS-DOS environment. No new features have been added. The only changes made were those required to get the program to compile using the Microsoft FORTRAN V5.0 compiler.

Moving on to quantifiable evidence of reused narrative text between versions, there are five groupings including two major families and three outlying groups. The first major family has 13 members that are tied directly to wood0350 and largely weighted similarly: wood0350, wood0430, wood043b, munk0430, ticm0350, goet0350, ekma0350, gill0350, vane0560, long0500, oska0551, anon0501, kine0350. The higher the score is in the filenames the more difference there is in the amount of copied narrative text, indicating which files added additional narrative features while remaining "true" to Wood's version of the game. Wood himself copied his own text between three of his versions.

The other major family has seven members all equally weighted: whin0450, cox_0350, daim0350, pohl0350, kenn0000, lumm0350, and goet0350. All of these files' narrative text data come directly from pohl0350, which is descended from calh0000, itself directly descended from jaeg0000 (Culver, 2019). While the first family shares core DNA with wood0350, this major grouping descends from a different major thread of narrative text that ultimately ties back to wood0350 and crow0000 with a few extra bumps between generations.

The three sets of outliers deserve special mention. One grouping contains three distinct versions of the 440-point game by Mike Arnautov in 2001. They are grouped together because the narrative text files, when opened in a simple text editor, are in quasi-English and are not organized like the other family groups of narrative files. The three-member family of plat0550, kenw0550, and well0550 share the same narrative text file, which like Arnautov's, are wholly separate from the other families. Well0550 is a direct port of plat0550, as is kenw0550. The organization and appearance of the narrative text in these three versions, while in English, is completely separate from the other families. Perhaps the most interesting outlying group contains russ0000 and the original crow0000. Recall that Crowther's orginal source code had been lost until the mid-2000s (Jerz, 2007), so it makes sense that nearly every other *CCA* version relied on the more easily discoverable code from Don Woods. In 2007, Matthew Russotto created a FORTRAN 77 version of it, the only port of the original game. Comparing the narrative text between russ0000 and crow0000 shows them to be identical and without the embellishments added by Woods in 1977. Unfortunately Russotto did not include a ReadMe file with paradata about his project completed 32 years after Crowther wrote *CCA*. An online search revealed that he is an independent software engineer who began his career at IBM in 1992, but it does not appear that he wrote publicly about the port.

The network analysis visualization provided by running the TextNets package shows the divergence of the two major *CCA* narrative families emphasizing the tight cluster of the smaller major family of ports of pohl0350. Version bhch0565 is shown as a connector between the two groups, although the other visualizations do not show that connection. There is no ReadMe file for bhch0565, and the narrative text file itself shows additional writing in the style of long0500, but without reusing a significant amount of text from files within that family, a genetic anomaly.

The main lesson to be learned from analyzing the quantified narrative data results is not that there was major evidence of sharing of the story, but that two major variants of the narrative text separated early and continued to be copied independently of each other depending on what files each version's programmer worked from. Unfortunately the statistics and visualization packages cannot highlight similarities in the text used between/across versions, which must instead be done by eye. At least the quantified data provides a starting point.

Using *Gephi* as a data visualization tool helps make sense of the clustering of similar versions, the color-coded families making it easier to divide the corpus, and the heavier-weighted labels showing stronger links between files within the corpus being studied. The results remain largely superficial, however. While one can see that there are similarities and differences with the files in a corpus, one cannot tell where the differences are within each file, and cannot therefore extrapolate human meaning from the results and visualization. Running a corpus through *R* shows that something is going on with the data, but human intelligence is required to tease out the meaning behind those results.

Conducting text analysis and then visualizing the results of the narrative sets of files in *CCA* does not actually address what these files are, and how they contribute to the game. In reading these individual files to check them against the results presented through *R* and *Gephi*, the patterns are indeed there in the text and do show very conservative behavior by the authors of versions that post-date Don Woods' 1977/78 original (WOOD0350). The authors do not offer reasons why they stuck so closely to Woods' narrative, but based on the ReadMe files (see the next section), it would appear that the goal of creating these versions was to recreate, in the words of version-creator Mike Arnautov (ANON0440), a "faithful" play-through experience for people using new operating systems, hardware, and interfaces. Those who chose to update or changed the story significantly to offer a new gameplay experience informed by Crowther and Woods' earliest efforts did so not in creating another text adventure game version, but rather created new games outside of the corpus of derivative files (e.g., Warren Robinette's 1980 *Adventure* game for Atari).

3.3.3. ReadMe Files

The final set of *CCA* files that I analyzed was the ReadMe files. ReadMe files are often created by programmers to explain who created a program and when, what the program does, and how to install and run it. While code sets and narrative data files reflect copy-pasting of text, or changes to the presentation of the game via interface and story, ReadMe files offer a place for an individual programmer's expression. In these files, however, the coder makes that individual claim to something that is not really original, but is often rather a copy, or at best a modified copy. The coders take pride in their work in creating the copy, and the ReadMe files behave like marginalia to a copied medieval manuscript, a personal touch to an ultimately derivative thing.

47 versions of *CCA* included ReadMe files, which can all be read in a simple text program. I was curious to see if text from the ReadMe files had been borrowed between versions over time. All three *R* text analysis packages proved this to be the case, again to varying degrees as shown with the code and narrative data sets.

Stylo and ReadMe Files

As with the other two groups of files, ReadMe files were compared against each other and then given a weight from 1 to 6, 6 being a perfect stylometric match or possible clone of the ReadMe file of one version by another. See Appendix F for the tables of results.

Weight = 6 (5 sets)

For the five sets of perfectly matched ReadMe files, Mike Arnautov shared his between his different versions. The ReadMe file shared between Jim Gerrie (2015) and Barry Breen (1980), however, is odd: neither version is a port of the other, and they were written in different languages (BASIC and Pascal respectively). Reviewing the files by hand, these should not be matched at all, and it is unclear why the two ReadMe files were matched (Fig. 3.24). This odd mismatching continued with other ReadMe files of different weights, and required another round of using *Stylo* for *R* to see how and

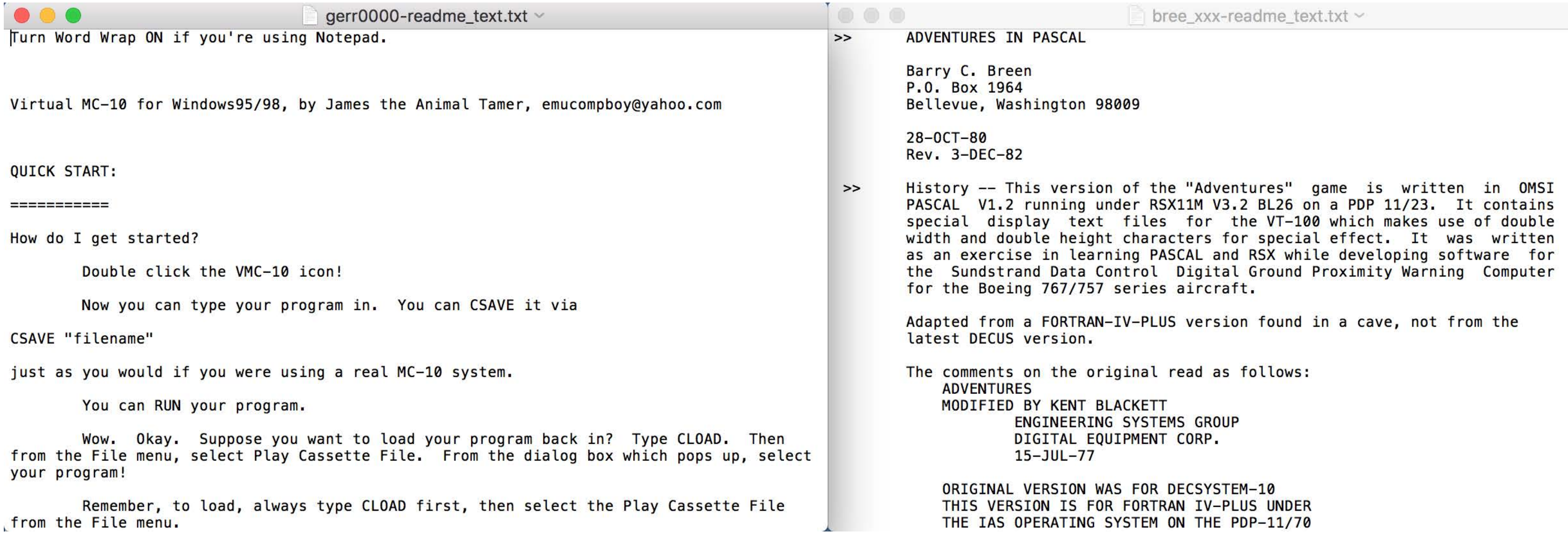


Figure 3.24. GERR0000 and BREE_XXX mismatched ReadMe files.

where errors might have crept in. Re-running *Stylo* against the ReadMe corpus returned identical results, and I am left wondering if I am personally unable to interpret these correctly.

Weight = 5 (3 sets)
Weight = 4 (8 sets)
Weight = 3 (27 sets)
Weight = 2 (32 sets)
Weight = 1 (39 sets)

Visualizing the Stylo ReadMe Files

Gephi graphed the ReadMe *Stylo* data to create another collection of families sharing similar traits between files (dark green, light green, blue, orange, pink) (Fig. 3.25). The pink grouping is almost wholly set apart from the rest, instead sharing style between a dozen classic game versions with the nodes of diaz0350, gasi0350 and muno0370 standing out. Kenw0550 dominates the orange group, while kinm0551 and kint0350 have the biggest pull for the blue nodes. Bree_xxx and gerr0000 top the green nodes, and I continue to wonder why. As with earlier graphs, Mike Arnatauv's versions continue to stand by themselves as outliers, linked to themselves. The ReadMe files he produced are his own, written in his own style, and are copied between his various versions forming a kind of closed loop. The takeaway here is that ReadMe files do follow similar organization and style across all versions of *CCA* and that all versions within a discrete family (as well as the families themselves) are interconnected. This organization reminds me of human family organization (or even cliques) within a larger society, and demonstrates that human-created code can follow similar patterns.

TextReuse and ReadMe Files

Having received confusing results in *Stylo*, I was curious to see if *TextReuse* would return more logical results when checking to see what versions of the game's ReadMe files borrowed text from other versions. See Appendix G for tables of the results.

100% (3 sets)

I visually checked each of these ReadMe files and can confirm that each set does indeed duplicate these files between versions. As seen above, Kevin Black's 1987 port of Mike Supnik's 1978 version remains faithful across all files. The same is true of John Kennedy's Mac OS update of Jerry Pohl's (1990) original Mac version. Jacob Munkhammer also updated David Kinder's version for the Amiga and kept the ReadMe file the same (Fig. 3.26). I wanted to see if these 1:1 matchups were mere copy-pastes of text from

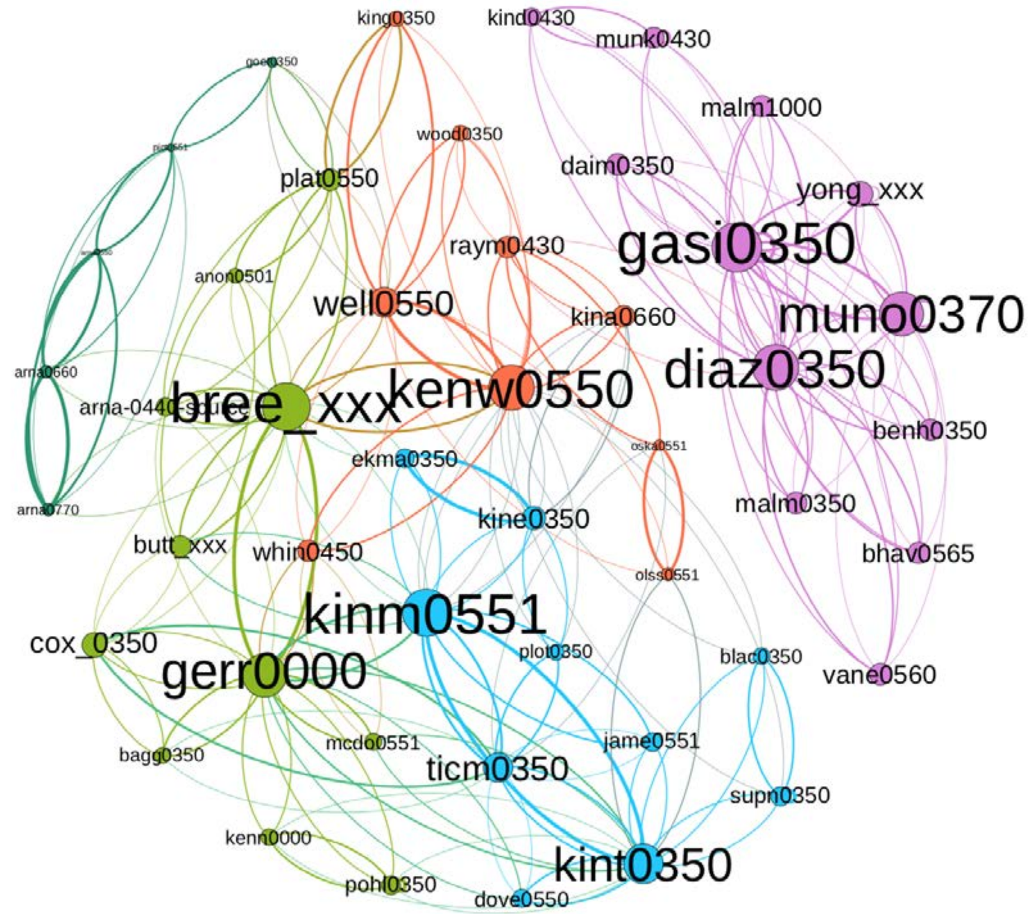


Figure 3.25. Data visualization of stylometric analysis of ReadMe files.

one file to another, or if it was the ReadMe files themselves that were duplicated and used in new versions. As it happens, all three pairs of files are duplicated files. I figured this out by running CHECKSUM against the versions by Munkhammer and Kinder, which proved that the ReadMe file is exactly the same: (c95db7d5b7a3cc6bd1b78de5da 40af9ae5ff0267).[43] I repeated the process for the other two pairs of files, which returned the same results: these pairs of files were clones of each other. How this could happen? For Munkhammer and Kinder, the actual content of both ReadMe files mentions that the versions are derived from Woods' 1977/8 version. The ReadMe files for Kennedy and Pohl, while identical, are actually two copies of the ReadMe file for Kennedy's 1992 update of Pohl's 1990 version. Why would Pohl's 1990 version of *CCA* be bundled with a copy of Kennedy's ReadMe file, which was created two years later? While the code and narrative data are not clones of each other, the ReadMe files are and hint at some kind of file mix-up when Culver or another *CCA* collector / historian was assembling downloadable files for preservation. The same issue is true of the third pair of files in this list by Black and Supnik (Black's ReadMe file is included in both versions even though they are separated by nine years).

43. See Appendix C on how to use CHECKSUM for identifying duplicated files.

munk0430-readme_text.txt

```
Don Wood's Adventure 2.5: (c) Copyright 1995 by Donald R. Woods.

This software may be freely redistributed if this notice is retained.
(The author apologises for the style of the code; it is a result of
running the original Fortran IV source through a home-brew Fortran-to-C
converter.)
```

kind0430-readme_text.txt


```
Don Wood's Adventure 2.5: (c) Copyright 1995 by Donald R. Woods.

This software may be freely redistributed if this notice is retained.
(The author apologises for the style of the code; it is a result of
running the original Fortran IV source through a home-brew Fortran-to-C
converter.)
```


Figure 3.26. Identical ReadMe files (MUNK0430 and KIND0430).

90% (3 sets)
70% (2 sets)

Below 70% (29 sets)
The remaining ReadMe files showed either no overlap, or overlap of less than 1%, meaning that 70% (29) of the 42 ReadMe files were uniquely written by the authors of these versions. This is important because while the code and narrative data often copy earlier versions of *CCA*, the ReadMe files offer a chance at individual expression, which could include personal reasons why a new version was created, or an individual interpretation of the long history of *CCA* itself. These individual stories are arguably more important than the cloned files because taken together, the ReadMe files create a kind of unintentional oral history of the game's evolution. For example, Alan H. Martin created a ReadMe file on 18 March 1996 for Don Woods' original source code (WOOD0350) from 1977/78. In it, he gives a little history about the initial version:

> This is the source code for the original Crowther and Woods Colossal Cave Adventure, 350 point verion, in PDP-10 FORTRAN. There have been many ports of this, in both FORTRAN and C, but all of them can be traced back to this version.
>
> A notable feature of this version which made it into few of the ports is the concept of "cave hours". Since the PDP-10 was a timesharing system, it was often considered desirable to prevent people from playing games during business hours. The game has a "wizard mode" which allows the system administrator to set the hours and optionally allow short demo games during the off hours.

The ReadMe file created by Ken Wellsch (WELL0550) on 7 July 1986 describes how he created his version, who he borrowed from, followed by a brief history of how the code was updated:

> This version of Adventure is taken from a Zerox Sigma-9 (rest her soul!), originally written by Dave Platt of Honeywell under CP-V (in Fort-77). I rewrote it into Ratfor many years ago and a couple years ago rewrote it again in C. This is the 550 point version of Adventure (for those who only know the 350 point original).
>
> 1979 winter: Running on XEROX SIGMA-9 under CP-V. Written in Fortran-77 by David Platt.

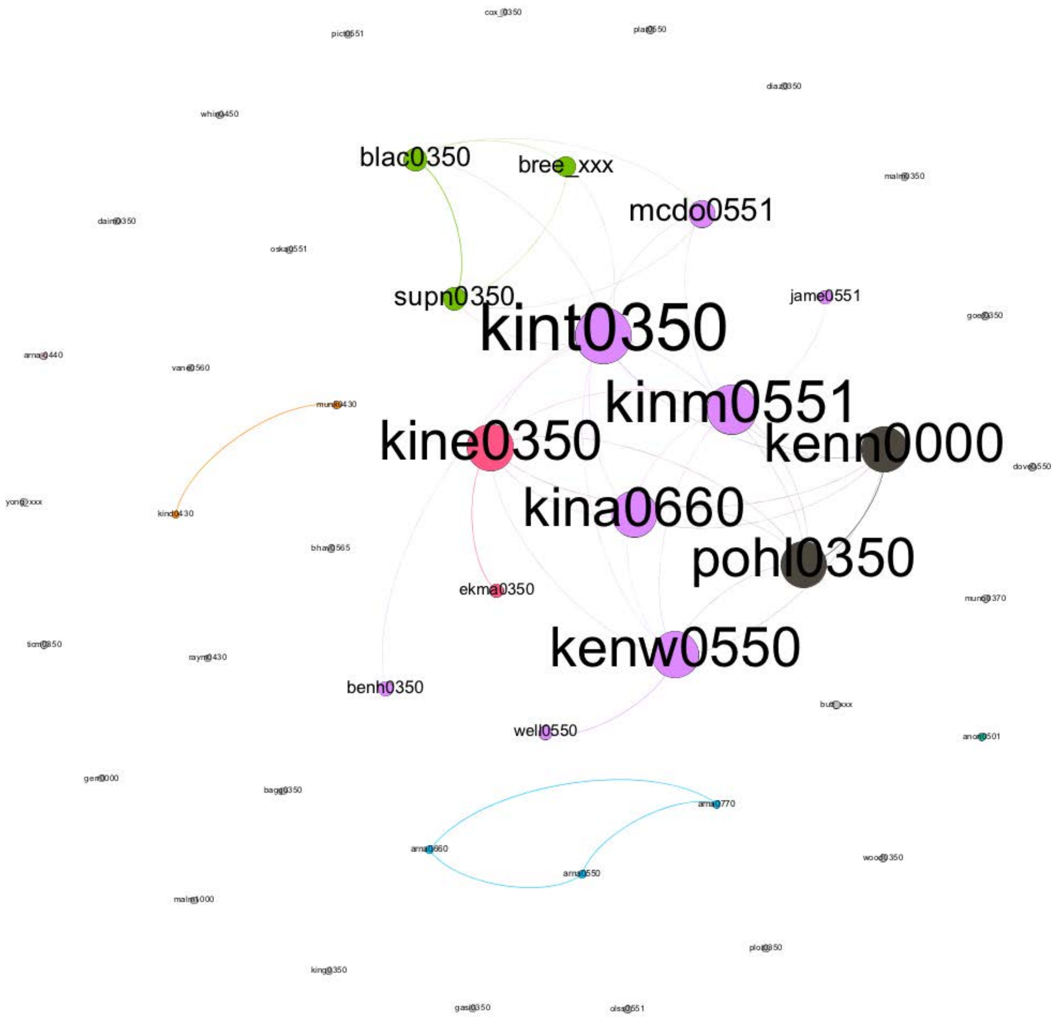


Figure 3.27. Data visualization of text reused by ReadMe files.

> 1982 winter: Completely rewritten for PDP 11/44 under UNIX Version 7. Written in Rational FORTRAN (ratfor) by Ken Wellsch.
> 1984 fall: Once again rewritten, this time for a VAX 11/780, under UNIX BSD 4.2. Written in C by Ken Wellsch.

In 2011, Neal Van Eck compiled his own version of *CCA* (VANE0560), and included a ReadMe file containing a history of versions that inspired his.

> Adventure 7 maximum 560 points. re-written in standard Fortran 2008 from Adventure 6 with corrections and additions of sounds, color, basilisk, mermaid and ruby yacht by Neal Van Eck, 2011. Adventure 6 was based on Adventure 5 with additions by David Long, and an anonymous coder around 1984. Doug McDonald changed it so that it would compile with f77 in 1990. Adventure 5 was extended from the 350 point original to 501 points by David Long at the

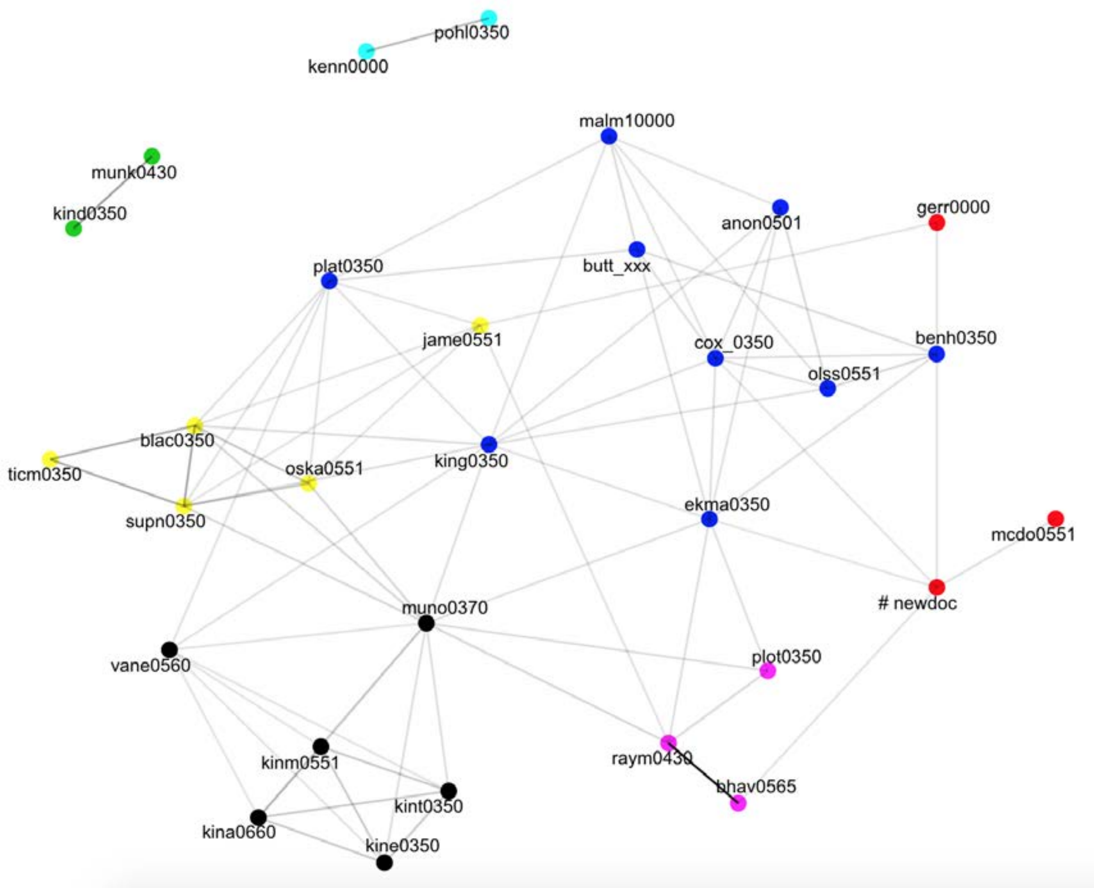


Figure 3.28. Data visualization of ReadMe files showing text networks.

> University of Chicago around 1978. The program was compiled as an Intel Fortran Composer Quickwin project using a few Quickwin routines for color and standard APIs for sound.

These are only three examples of ReadMe files that create an oral history of the game. The quantified methods and tools of R and Gephi can show that these files are unique, but they do not address the valuable contents held within. The archaeologist must open and read the files, rewarded with content and context not able to be provided by automated functions.

On the occasional instance of cloned ReadMe files, these point either towards expedience (or laziness) by a programmer of a new version, or could be interpreted as the programmer attempting to be faithful to the source material without injecting any new language into a version being ported from one language or operating system to another, more modern one.

As will be shown in the next section, the *TextReuse* data seems to be a much more accurate representation of the circulation and sharing of the *CCA* ReadMe files than that returned by *Stylo*.

Visualizing the TextReuse ReadMe Files

The visualization of the *TextReuse* data by *Gephi* also returns more logical data, correctly reflecting the sharing of ReadMe text amidst three-dozen outliers, the size of the nodes again showing the degree of matching nodes where the text was shared (Fig. 3.27). Most of the authors of most of the ReadMe files wrote theirs independently opting not to copy/clone other ReadMe files. This differs from the narrative data sets, which were frequently borrowed from because of the shared source of that data, namely Woods' early version of *CCA*. With the ReadMe files, we see a diversity of authors writing their own introductions to a familiar game and as has been shown in the examples above, the styles might be similar between the files, the content is as independent and varied as the authors themselves.

Textnets and ReadMe Files

Just as I did with the *CCA* sets of narrative text data, I used the *Textnets* package for R to see if any networks of usage appeared across the 42 ReadMe files.

Visualizing the Textnets ReadMe Files

Five loose networks (black, red, yellow, blue, pink) and two outliers (green, light blue), show how the versions interrelate based on the ReadMe files (Fig. 3.28). The data, however, might not be accurate because based on the *TextReuse* data, most of the ReadMe file overlaps were less than 1% and often 0. This might explain why most of the "edges" (lines) in the graph are gray instead of a solid black. The loose groupings do point to similarities in structure, yet there is nothing strong enough here to point to actual, intended networks. ReadMe files are individual efforts created for a duplicated game, and follow a similar structure, which is what the *Textnets* tool is designed to interpret/display.

Analysis of the ReadMe Files

The ReadMe files were the final set of files analyzed with the statistics packages and visualization software. As described above, these were the files most likely to contain individual self-expression as version authors added paradata to their *CCA* code sets. When looking at style, five families of files emerge, four major and one outlier. In opening the ReadMe files in each of the families, however, little similarities are apparent in both content and organization, with the exception of the outlier, which contains three files by Mike Arnautov that mostly copy each other.

Compare those results with the visualization of reused text between ReadMe files, and one can immediately see which files exercised self-expression. Of the 47 ReadMe files analyzed, 27 are original and unconnected to any other file. Six families emerge, one major, three minor, and two outlier. The family of kenn0000 and pohl0350 are copies of each other. The family of kine0350 and ekma0350 were both written by David Kinder, but he modified his ReadMe text between the two files, making kine0350 longer and more elaborate while including copied text from ekma0350. The larger dots in the visualization show evidence of greater copying/kinship as demonstrated by kina0660 and kenw0550, which are very nearly identical.

When reviewing the ReadMe files' text network, six node-groupings center around a seventh. As with the results from Stylo on the ReadMe files, the data returned and organized by the digital package looks interesting, but the reasons for that organization are not easily teased out when returning to the actual files to see how they connect to each other in a grouping, or connect to other groups in the text network.

The main takeaways from this analysis include the fact that for some file sets, it is not necessary to run them through various statistics packages. In the case of ReadMe files, we know who the authors are and can use TextReuse to see who copied (and how much was copied) between ReadMe files for different versions. This analysis also showed that, unlike code and narrative files, the Readme files demonstrate the most individual expressions with more than half of the examples containing completely unique text. Tied to the game's narrative, independent authors mostly used the ReadMe files for branching away from preservation of historic code. This then begs the question of why the authors limited themselves to expression in ReadMe and not in the narrative files. When given the chance at creation enabled by digital tools/platforms, why are people conservative in their use?

In the ReadMe file created by Mike Arnautov (ANON0440) on 30 September 2001, he writes: "I won't bore you with details, but after some fairly intense software archeology work (and, of course, a lot of typing!), we now have an F77 source and the database to go with it. To the best of our knowledge it comes as close as possible to being a faithful reproduction of the 'AdventureII experience.'" Nearly every other ReadMe file contains similar language on how that version attempts to be a "faithful" recreation of Don Woods' version of the game, while occasionally fixing a bug specific to an operating system: ARNA0550, ARNA0660, ARNA0770, BREE_XXX, BUTT_XXX, COX_0350, DAIM0350, DIAZ0350, DOVE0550, EKMA0350, GASI0350, GERR0000, GOET0350, JAME0551, KENN0000, KENW0550, KINA0660, KIND0430, KINE0350, KING0350, KINM0551, KINT0350, MALM0350, MALM1000, MCDO0551, MUNK0430, MUNK0370, OSKA0551, PICT0551, PLAT0550, PLOT0350, POHL0350, RAYM0430, SUPN0350, TICM0350, WELL0550, WOOD0350, and YONG_XXX.

Three ReadMe files either hint at or explain outright any new features introduced to the classic version of the game. In September 1990, Magnus Olsson (OLSS0551) notes that there are "several new rooms and puzzles added," but does not say what they are. Neal Van Eck (VANE0560) in 2011 states that his version includes "additions of sounds, color, basilisk, mermaid and ruby yacht." Al Whinery (WHIN0450) states rather cryptically that "I added many new features."

None of the ReadMe files note that the classic story from Don Woods had been altered in any way, even though some new rooms or features had been added on occasion in later versions. As has been shown above, the quantified results returned by R and *Gephi* indicate some discrepancies in the narrative files, but it takes human eyes to read each of these files to determine where and what the differences are. These automated tools cannot yet produce any kind of interpretation or analysis of the contents of files, but merely signpost that similarities and differences exist, and to what extent. Grouping the files together in clusters/families provides some value, helping the archaeologist select which files to read and compare. But the automation cannot stand alone as a diagnostic tool for code archaeology.

3.4. Conclusions

I have divided my conclusions to this case study into three parts: 1) answers to my research questions; 2) data, analysis, and digital community and storytelling; 3) a reflection on digital tools.

3.4.1. Research Questions Revisited

Can one conduct an archaeological investigation on a digital artifact, specifically one that shares characteristics with clay tablets and papyrus?

I wanted to test my overarching thesis, that digital artifacts and environments can (and should) be studied archaeologically. Digital archaeology seems to focus currently on digital tools in methods instead of on digital things themselves, things created by people for other people to use.

As demonstrated, an archaeologist may study programming code as one would study inscriptions on monuments or as a corpus of papyrus fragments, using epigraphic recording methods supplemented with digital tools. The files themselves contain additional metadata and paradata providing additional information and context supplementing quantified data. Through a blend of human and artificial intelligence, I was able to document a history of a significant digital text-artifact. Jeremy Huggett calls this approach "empathetic," meaning an "approach to archaeological digital data [that] sees the data for what they are: not simply as raw materials to drive inadvertent algorithms but as contemporary observations about attributes we consider to have some value in understanding past human activities" (Huggett, 2014b).

The humanity of code, however, did not appear through the use of digital tools such as *R* and *Gephi*, which were good for establishing a chronology of versions and linked relationships between them. To consider deeper meanings, which include answers to why programmers chose to re-code *CCA* or how they handled programming and debugging problems, I had to open individual files to examine their contents for clues. Most of the narrative and code files were uncommented and provided little useful data, but the ReadMe files—where available—illuminated programming decisions, sometimes in fine detail (e.g., GERR0000, BREE_XXX). The code-artifacts themselves are examples of the output of past human activities, but looking within the files gives glimpses into the *input* of past human activities, too, influencing the course of future events.

Can existing tools and methods for epigraphy and text analysis be used on a digital text-artifact?

Another aspect of my overarching thesis is to see if existing tools and methods can either be used or repurposed for examing digital things and environments. Do digital artifacts behave like those composed of more traditional materials? Are new tools needed for studying digital artifacts?

As demonstrated above I was able to record data about inscriptions, in this case programming code either punched into physical cards or written onto computer hard drives or disks, using context (e.g., findspots, maker names, oral histories), supplementing that data via digital tools created to determine author attribution, text reuse, and text networks. As will be described below, these digital tools were not created specifically for analyzing code, which required additional attention to be paid to the output, checking that against the *CCA* files themselves. Future code epigraphy will require a dedicated set of tools purpose-built for digital archaeology.

What can quantitative data tell the researcher about a collection of digital texts that are related to a common source?

Digital archaeology sometimes works with Big Data, and I was curious to see what, if anything, could be learned from using *R*, which is part of the Digital Humanities toolkit. It is relatively easy to retrieve bad data, or to make incorrect inferences based on lax settings in the quantitative software environment. Repetition and reproducability of results is important to check one's work, and to guard against any bias in the data, the output, and the tools used to generate that output.

I learned that each type of *CCA* file (code, narrative, ReadMe) had its own groupings of authors based around commonalities in style and text. In some instances, I determined the "alpha" code set referenced by others in a family grouping, and ultimately traced data back to the source. The quantified data also clearly showed that borrowing occurred between versions, that there is a genealogy of versions, but that in the family tree of *CCA* branches can form anywhere at any time based on when a programmer decides to create a derivative version. The quantified data demonstrated that most programmers took a conservative approach in retelling *CCA*'s game narrative, and chose to exercise their voices primarily in their ReadMe files. I suspect that similar results may be found in the analysis of other software programs.

What other archaeological information can one glean from studying a digital text-artifact outside of quantitative analysis?

Positivism gives way to post-processualism in the instance of reading and interpreting code-artifacts versus putting them through an algorithm that generates numeric output. Both are necessary, however, as they can be used to create a richer context for the digital artifact, and can be used to check results and interpretations.

A file itself contains information regarding its author, date of creation, and purpose. Its findspot places it in a location in relation to other, related files, and these files can be a part of a program, or part of a wider context of similar files kept in separate locations. One can view these files stratigraphically, versions building on other versions, as well as an assemblage where files found together relate to serve one or more functions. These files communicate a history of use, have biographies, and contribute to the material culture of human creators and users. As shown above in Map 3.1 and through the use of file metadata through the use of tools such as EXIF and CHECKSUM, files can show patterns of discovery or migration as the archaeologist uncovers reasons behind how, why, where, when, and by whom these text-artifacts flourished. Again, ReadMe files and commented lines of code also contribute to the wider context of a software artifact, occasionally providing places of creation and use, and even the names of the coders themselves.

Can any of the lessons learned through this case study be applied to archaeology more broadly outside of the digital environment?

One of the goals of this thesis is to learn whether anything applied within these case studies can translate to other non-digital things and places. It is clear in this case study that one can apply tools and methods from traditional archaeological subjects to those that are digital, but does it work the other way around?

The archaeology of digital things is not altogether different from the archaeology of traditional artifacts, sites, and landscapes. With the digital, the archaeologist could take as a starting point 1946, the year that ENIAC, the first digital computer, was completed. Over the next 70+ years, humanity has gone from the Digital Revolution into the Information Age, creating its own material culture of mass-produced consumer electronics, which include digital games and the hardware on which they are both created and played. As seen above with *CCA*, these games create their own communities and influence others through communication and sharing via various media, both print and digital, as well as word-of-mouth. Much of archaeology attempts to create a narrative about humanity, its individuals and groups, through material evidence, and digital archaeology continues in that tradition, albeit operating closer to the spark of creation. Connections made by digital archaeologists can add to that human narrative already well underway by archaeologists of more traditional materials. The human narrative tied to the evolution of *CCA* is discussed in the next section.

3.4.2. Data, Analysis, and Digital Community and Storytelling

The archaeological evidence throughout this case study suggests that *Colossal Cave Adventure* is "Patient Zero" for open source coding and viral gaming. We know where and when the game originated and who the creator is. There is a robust oral history surrounding the origin of the game and its initial growth as the trunk of a tree in the late 1970s that later grew a number of branches in the 1980s up to the present day. Each of these branches corresponds to central figures in the coding history of versions of *CCA* and those who followed, using these later iterations to inform their own work as they made the game their own. By using text analysis and stylometric tools, I was able to better understand the "genetics" of various versions in order to determine who the main influencers were in the game's history (Don Woods, Jerry Pohl, Bob Supnik, Mike Arnautov), and to see what code survived between versions over time that called back to the original (mostly the story as told by the game, which in every version opens with Will Crowther's words, "You are standing at the end of a road before a small brick building").

The game is fun and challenging to both play and program, which explains its appeal to generations of players and coders since the late 1970s. The fact that *CCA* was the first of its kind as an interactive digital adventure game that used natural language input and output to advance an exploratory narrative also garners significant attention from players, programmers, and now archaeologists. As happens in studying the archaeology of the recent past, several creators of digital artifacts are still alive, as is the case with *CCA* and its two most famous programmers, Will Crowther and Don Woods. Although neither responded to me for this case study, a number of my sources had contact with Crowther and Woods as they wrote their histories of the game.[44] To address the question of "why don't you ask the maker?", such histories (especially oral histories

44. Specifically Rick Adams (http://rickadams.org/adventure/a_history.html) and Dennis Jerz (https://jerz.setonhill.edu/intfic/colossal-cave-adventure/) (accessed January 17, 2019).

taken from the creators themselves) rely on the memories and ephemera of individuals. Through archaeology, one can supplement the history through artifactual evidence—in this case computer files—that can further add to the history of one of the most famous and influential games ever made. As explained above, some of the results of this case study will update current scholarship about the game, adjusting the chronology, and proving the influence of some versions over others as the game's history grew.

Through the study of *CCA*, one can begin to understand the early days of software networking and the open source community (before such a thing was called "open source").[45] It is not enough to demonstrate that the artifacts changed over time (and how they changed). Because people both designed and played these versions of the game, we see the growth of informal file-sharing networks where programmers could stash their code for others to discover, reverse-engineer, and use. While now commonplace and industry-recognized with open source platforms such as Github (independently launched 2008 and acquired by Microsoft in 2018) and international groups such as the Open Source Initiative (OSI), open source began with geographically dispersed communities of coders united in creating non-proprietary operating systems such as Unix/Linux, and the creation of groups of corporate employees interested in working outside the bounds of their companies (e.g., DECUS for DEC programmers, and SHARE for IBM and General Motors). The movement stemmed from the early efforts of Richard M. Stallman of MIT who worked on PDP-10 mainframe computers (recall that PDP-10s ran the first versions of *CCA* and MIT was the home of interactive fiction developer Infocom). Stallman wrote the GNU Manifesto and launched the Free Software Foundation, ultimately writing the GNU General Public License in 1989, which would ultimately guide the creation of the modern Creative Commons licensing scheme. Stallman himself was a hacker in the 1970s (as was Don Woods), and the culture for improving the quality of life of programmers, of sharing work to make things easier for colleagues, evolved in parallel with *CCA*. The game would appear to be a product of its culture, one populated by engineers and hackers interested in freedom and sharing of information. *CCA* is the first work of interactive fiction to be shared in a way similar to that of the Unix/Linux operating systems and the Netscape internet browser, and as such occupies a place in the open source pantheon. While many games remain proprietary intellectual property of their respective developers, there are a number of game-creation engines that are free to use: Unity, Unreal Engine, and CryEngine being the most popular.

CCA earned its reputation through this kind of discovery and play (Jerz, 2007), "play" meaning both gameplay as well as the activity of coding largely by hobbyists who

45. For a concise history of the open source movement, see David Bretthauer, 2007, "Open Source Software: A History" (2001). *Published Works* 7 (University of Connecticut).

would go on to share their work. Based on the number of creators who ended up as IT professionals, some of whom went on to do great things (or who did great things and then decided to write an iteration of *CCA*), the game clearly attracted a certain social group of technically minded men both young and old who took it upon themselves to preserve and care for the game's legacy while also adding their own signatures to it, a "family tree" of "modders" and their modified games. *CCA* was likely the earliest game to combine the open source community with avid game and programming hobbyists who chose to modify the existing game with new (or corrected) content to share with other players on what would become the Internet.[46]

Colossal Cave Adventure's gameplay, narrative, sense of humor, and also its sense of adventure proved so popular among its early players that it inspired them with the possibility of what one could do for entertainment on computers. After the initial iterations in either FORTRAN or C in the 1970s, the early 1980s witnessed the availability and relative affordability of personal computers, specifically the TRS-80, the Spectrum, the Sinclair ZX series, the Amiga, "IBM-compatible" desktop machines running MS-DOS, the Apple II, and the first Macintosh model. One no longer needed to run FORTRAN through a compiler on a mainframe at a university. One could design and play games at home that did not necessarily need graphics. The growth of *CCA*'s family tree can be attributed in part to affordable personal computing,[47] emerging bulletin board (BBS) services and modem technology, and the ease at which files could be discovered and shared. Digital rights management (DRM) and copy protection was in its infancy and for young people at the time (like me), we wanted to find as many games and other programs as we could for free in order to play, and also to take apart so we could learn how to make our own in the programming languages we were teaching ourselves. These early skills would translate into careers for some (as listed at the beginning of this chapter).

With *Colossal Cave Adventure*, however, this is an original game built before game engines existed. The versions *CCA* spawned all hearken back to the original even if they add new elements along the way. For example, Gibi0375 added a stock certificate puzzle to Don Woods' version of the game in 1982. Walt0350 added magic spells to it in 1997. These additions had little/no effect on future versions of the game, but instead were one-offs standing on the shoulders of Woods' widely adapted game. Playing a version of the game in 2019, one knows based on the text-interaction and narrative struc-

46. For insight in game modders and modding culture, see Olli Sotamaa, 2010, "When the Game is not Enough: Motivations and Practices among Computer Game Modding Culture," *Games and Culture* 5.3: 239–55. For a look at the largest host of game-modding communities online as of 2019, visit nexusmods.com. As of June 14, 2019, the website hosts "222,387 files for 730 games from 92,584 authors serving 17,524,442 members with 3,168,490,872 downloads to date." Interestingly, no modified versions of *CCA* have been posted here.

47. Many of the ReadMe files contained information about the platform for which the *CCA* version was written, which included diverse brands of personal computers.

ture that the version recalls *CCA* from the 1970s. *CCA*'s versioning (especially different iterations written in the same programming language) exhibits characteristics of autographs and other manuscripts, those that are written in antiquity and then copied and changed over time because of mistakes compounded across versions.[48] For example, in Beck0500, a version largely based on Wood0350, the programmer notes "some bugs fixed by George Schreyer," but does not indicate which ones. The creator of Hunt0000, which is likely based on Jaeg0000 (itself a first-generation BDS C port of Wood0350), states that some spelling errors were corrected. As with Beck0500, the specifics are not mentioned.

The iterative nature of the code-artifact of *CCA* can either encourage reverse-engineering by those programmers who come to the game desiring to rewrite it for a different platform or operating system, or allows for recompiling of the FORTRAN code on alternate platforms. One cannot tweak the game in FORTRAN in order to have it run as a Web-based, Java-scripted game online. In some cases, the game must be stripped down to the studs and built anew, using the game narrative and structure as a guide while the underlying engine is rebuilt to a modern standard. This kind of re-engineering is perhaps different than that of other ancient cultures who would attempt to copy the technology of other groups albeit with varied results.[49] In *CCA*, the quantified data detailed above shows that different families of versions clustered around each other, growing from a new version created in a new programming language (or a new dialect of an existing language such as FORTRAN). Many early ports of *CCA* were done in C (Culver, 2019), a task facilitated by Bell Laboratories f2c compiler, which took FORTRAN 77 code and compiled it in the C language, which could be understood by Unix (and later DOS) computers. But later ports like the online version created by Rick Adams for *Halt and Catch Fire* are standalone versions preserving the story but reinventing how to tell it through a Web browser.

There are two purposes in reverse engineering games, and one can lead directly to the other: 1) to understand how a game works by way of examining its coding and construction, and 2) rebuilding the game based on discoveries made in deconstructing the original. With *CCA* specifically, it remains unclear exactly which of the various versions were actually reverse engineered vs. those iterations built through gameplay-observation and access to files containing the game's narrative data. Each new version became its own game while at the same time sharing the characteristics and much of

48. See Otto Skutsch, "Textual Studies in the Bucolics of Martius Valerius," in *Classical, Medieval and Renaissance Studies in Honor of Berthold Louis Ullman*, II (Rome 1964), pp. 21–36, specifically p. 33 ff. on how both ancient copyists and modern scholars introduce error into primary texts.

49. See Robert L. Bettinger and Jelmer Eerkens 1999 article in *American Antiquity* 64:2, "Point Typologies, Cultural Transmission, and the Spread of Bow-and-Arrow Technology in the Prehistoric Great Basin," pp. 231–42. The article discusses a confusion about corner-notched projectile points in an overlapping region of the American West and mistakes made by both cultures in trying to copy one another, which led to mistakes in typologies created by archaeologists.

the story created by Crowther and Woods. Although the game evolved, it is still recognizable and arguably backwards-compatible to *CCA* from the 1970s. Only one of the versions has gone beyond the point-of-no-return: Warren Robinett's *Adventure* (1980) for the Atari 2600. In this case, *CCA* inspired the game,[50] but *Adventure* has little to do with the original's puzzles and wordplay, instead focusing on a video-adventure of navigating a maze to find treasure. There is no backwards-compatibility here. To discuss the differences between his graphical version of the game and the text-only original, Robinett wrote (Robinett, 1983):

> This video game, Atari 2600 *Adventure*, was inspired directly by Crowther and Woods' text *Adventure*. I tried at first to create video game counterparts of features in the text game. The magic rod can create a crystal bridge to span an impassable fissure in the text version; I tried a rod-shape which, when it touched a maze wall, caused a bridge-shape to appear. The "maze of twisty little passages, all alike" became a very confusing 8-room video maze. These direct transliterations from text to video format didn't work out very well. While the general idea of a video game with rooms and objects seemed to be a good one, the graphic language of the video game had different strengths than the verbal language of the text dialogue. Just as the art form of film slowly diverged from its parent, drama, the animated adventure game diverged from the text adventure game because of the difference between the medium of text and the medium of animated graphics.

Perhaps the biggest surprise of the entire case study was in learning how little the narrative of *CCA* changed over time after Don Woods shared his update of Crowther's original. One does not really get a sense of how the story remains static until after running the TextReuse package in *R* and then visualizing the results through *Gephi*. When reviewing the narrative data files one-by-one, the similarities are undeniable. For those versions that did add extra rooms, puzzles, and treasures (e.g., Anon0340, Gibi0375, Walt0350), these failed to influence other programmers keen on recreating the "original" game on other platforms.

Why then, in 2019, with so many open source game-creating tools available to professional and hobbyist programmers (e.g., *Twine, Unity, ink*), have they not expanded upon the story of what happens within the Colossal Cave or even gone so far as to laser-scan the interior of the Kentucky cavern system upon which *CCA* is based to create a 3D version of the classic adventure? Even versions created after 2010 are largely either

50. Robinett writes about this inspiration himself in his unpublished manuscript about the development of *Adventure*, which he posted on his website: http://www.warrenrobinett.com/inventing_adventure/ (Accessed 22 March 2019).

modern C ports of the game for Windows or Macintosh operating systems (mostly by Arthur O'Dwyer), or recreate the text-only play albeit on an iPhone screen (Juan del Valle Rodriguez). Perhaps there is a reverence for the source material, which the community feels is good enough. Each version of *CCA* ends with the player lost in an area of the cave called "Wit's End" and concludes with a detonation to blast a hole in the wall to grant the player escape. At first glance, this adherence to tradition goes against the nature of open source software, which encourages remixing and making new content derived from existing programs. But in reviewing the entire history of *CCA* through its versions and files, the personal creativity manifested in ways outside of the narrative, which is treated like a constant, and instead focused on creative ways of bringing the game forward in time to share with new audiences. The majority of programmers of *CCA* versions are coders and hackers who express their creativity though programming, using their creativity to solve difficult problems in porting the game into new languages and operating systems.

3.4.3. A Reflection on Digital Tools

When I first ran the *CCA* files through Stylo, TextReuse, Textnets, and Gephi, I was delighted by two things: 1) I, as a researcher without any experience in data visualization and in the *R* statistical platform, could actually install and use it, and 2) the results appeared to make sense, and the data looked usable.

Data Skepticism

Disillusionment occurred once I started comparing the results to the file contents, learning in some cases that I needed to tune the software to improve the quality of results (e.g., using Stylo on the FORTRAN code sets), and in other cases that I was using an unnecessary tool on a set of files that could be better analyzed with a different tool (e.g., Stylo and TextReuse with the narrative text sets). With *Gephi* I had to learn how to read the graphs it produced, checking these against the data to better know how to analyze the results. On my first pass over the data, I was too willing to abdicate my human intelligence to what machine learning was producing, but in future passes I injected myself into the process not just in tuning the tools but in scrutinizing the results.

I realize that the stylometric, text analysis, and data visualization software applications I used (not to mention all of the *CCA* files) live online in a state of flux. To mitigate this for the purpose of this case study, I archived all of the tools and files in a Github repository so that people who want to revisit my research can do so with the files and tools that I used, a date- and time-stamped snapshot into my year's work, which can assist others in testing the repeatability of my results. If my evidence has shown me anything, I believe that new versions of *CCA* will continue to be created, and that missing or anonymous versions already noted in the corpus will be found and identified. These new files and discoveries can then be added to my existing data set, and the entire corpus can be run through text analysis tools once more. It is likely that these existing tools will be updated and new tools will be created, some of which will be purpose-built for analyzing code. These revised/new tools might improve upon my original results, albeit with continued, careful human oversight during implementation and use.

Digital tools and the data they produce are not an archaeological panacea. Studies into human abdication of agency in favor of deferring to digital surrogates and their output (i.e., digital tools and their resulting data) have already been undertaken (Walker, 2014a; Smith, 2018). The main issue here is that contemporary users are often not critical with their use of technology or the data that technology produces, that we take results at face value without considering the algorithms behind their production. One necessity to combat this is "greater research-based education of multiple publics . . . to unsettle and decouple their doxic relationship with data, and to illustrate how their lives are structured and inscribed in multiplex ways as a result of the data they purposefully and inadvertently presume" (Smith, 2018, p. 12). How and where this public education is to be done is outside the scope of this thesis, yet archaeologists can promote this kind of digital literacy and data skepticism in the classroom and in the field as part of any preliminary training. Jeremy Huggett calls this approach "introspective digital archaeology," stating that "it seeks to examine the ways in which digital technologies within archaeology may have changed what we do, how we do it, how we represent what we do, how we communicate what we do, how we understand what we do, and how others understand what we do" (Huggett, 2015b, p. 88).

By documenting my process, archiving my tools and data sets, and sharing my results, this might lead to the development by others of more specific tools created for code epigraphy, something for the Digital Humanities and digital archaeologist's toolkit.

My stylometric and text analysis approaches in *CCA* demonstrated that this kind of work can be done just so long as the archaeologist is mindful of the digital tools used to extrapolate themes from the data, and places the data and their results within the greater context of the code and other digital and printed assets of the software being studied. While authorship of *CCA* versions was a matter of public record, the results of studying author attribution of proprietary intellectual property through stylometrics could lead to potentially damaging results to companies and individuals with regard to privacy and anonymity, and must be handled ethically and with care (Caliskan et al., 2015; Brennan et al., 2012).

Studies have already been done on gendered language in computer-mediated communication (Palomares and Lee, 2009; Murphy et al., 2006), and those methods could be applied to future research on the gender of software code. In my *CCA* case study, the context and public record showed that nearly all *CCA* versions were created by men, especially those with past and current IT backgrounds and careers. Future work can create stylometric tools that focus on gendered language to attempt to discern gender of coders, something I was unable to see from the tools that I used—they were not purpose-built for this. How does the spectrum of gender-identity match up against the spectrum of software developers and development, and how can code archaeology contribute to that understanding? How does the baked-in bias of digital tools and artificial intelligence (Osoba and Welser, 2017; Crawford, 2016) affect our reception and interpretation of the data they return, and how can we better address that bias?

In my *CCA* case study, it was clear from both reading and performing text analysis on files that the coding of most versions of the game was written from the ground up while reproducing the historic, narrative data almost as-is. The attitude towards open source and code-sharing remains strong in the *CCA* community, but how does that compare with other games as well as with other classes of software? How do corporations react and how do human creators feel when their work is either adapted or outright copied, how is that copying done, and is the copied content (like *CCA*'s narrative) largely unchanged from the source file? How do these copies spread? I was able to determine to some extent how *CCA* traveled to different players through the use of file meta- and paradata. It is possible that similar methods can recover similar information on other digital applications to understand human patterns of trade and their underlying digital networks, which is not unlike discovering and documenting ancient trade routes and land use (Pálsson, 2018; Brughmans, 2010).

With *CCA* I was able to learn programmer identities and contact details. Thanks to the commented code, in some cases I was able to interpret the reasons behind why a coder made the decisions he did when writing routines. In the ReadMe files I was able to learn an oral history about the game, and could trace the DNA between versions, which were then verified via text analysis. A similar tack can be taken with other software applications to get human information not readily available in analyzing code directly. Code marginalia (comments) adds humanity to digital things, but it also adds a layer of ethical considerations into privacy, anonymity, and how/if those personal details should be shared, and in what context.

4

Case Study Two: The Archaeology of *Elder Scrolls V: Skyrim VR*: Phenomenology, Landscape Archaeology, Photogrammetry, GIS, and Sharing Digital Heritage Experiences

4.1. Introduction

The first case study demonstrated that one can conduct an archaeological investigation of a digital heritage artifact, focusing on both text and context. This case study will show that other archaeological approaches and tools can be used to understand an interactive digital environment that attempts to appear and behave like the natural world as realized through virtual reality technology. The game featured in this case study is *Elder Scrolls V: Skyrim VR*. Other researchers have used *Skyrim* to study the game and its players from several perspectives: anthropology (Rubtcova, et al., 2017; Simpson, 2015), linguistics (Purnomo, et al., 2017), medieval studies (Cooper, 2016), and religious studies (Knopf, 2013) among other disciplines. The game has also been studied archaeologically with a focus on lore and artifacts (Maldonado, 2012) and human player ethnography (Johnson, 2013).

The goals of this case study are to apply archaeological thinking to something (e.g., a video game) that has not traditionally been considered archaeology (either as a landscape, site, or artifact). Starting with a very large game, its sheer scale lends itself to a landscape, one populated with entire towns, waterways, mountain ranges, forests, and ruins, imbued with manufactured history that players tease out over the duration of their habitation. What can we practice in a VR gaming space that can be transferred to those seeking to integrate 3D and VR into their project plans for digital reconstructions and ultimately public engagement and outreach? These are some "Big Questions" of contemporary archaeology, with its current focus on digital reconstruction/reenactment, and games can be a powerful tool in helping to provide some answers.[1]

4.1.1. Research Questions

Virtual reality shows a lot of potential for archaeological applications, not just in offering environments for showcasing reconstructions or fostering heritage tourism for those who cannot visit sites in person in the natural world, but in also providing tools for the archaeologist to conduct investigations while "inside" a digital environment (Forte, 2014; Lercari, et al., 2013; and Oikarinen, 2015, have done similar archaeological work, but for digitizing sites in the natural world). For all intents and purposes, *Skyrim VR* is a heritage game, or at least a heritage-based game, and the lessons learned through archaeological engagement are easily transferrable to other VR environments both fantastic and based completely on reality (either *in situ* or reconstructed).

My research questions are addressed thematically in two groups: technology and interpretation. I introduce the questions below, and discuss the results in the following sections of this chapter following a word on tools and methods.

Technology

- Does the embodiment facilitated by virtual reality help or hinder the archaeologist studying the digital environment? What are the benefits and drawbacks of the embodied digital experience within a synthetic world? For the purpose of this case study, I understand "embodiment" to mean the technology-mediated interface between a person and the digital space being visited by that person so that the individual feels like they are there "in person."
- Can VR hardware be used for archaeological investigation of digital built environments? What is the level of detail that can be observed by a player wearing a modern VR headset when exploring a world created largely from pho-

1. The question of archaeology's "Grand Challenges" was raised in two places in 2014 (Kintigh and Huggett), and again in 2016 by over 60 archaeologists participating in Doug Rock McQueen's blogging carnival (https://dougsarchaeology.wordpress.com/2016/02/01/what-do-we-archaeologists-see-as-our-grand-challenges/, accessed 3 August 2019). Of these entries, only one addressed the use and distribution of 3D digital models as part of archaeological reportage (Bernard Means, https://vcuarchaeology3d.wordpress.com/2016/01/31/what-do-i-think-open-access-archaeology-should-look-like/, accessed 3 August 2019). Only one of the 15 authors in Kintigh et al.'s article mentioned digital tools in passing, in this case for creating digital spatial data, but the challenges presented throughout that article centered around the use of Big Data in answering questions about human interaction with natural sites. The table on p. 82 contains identifiers for how to identify a Grand Challenge, but the article does not place the archaeology of digital spaces within that context, or the use of VR or 3D tools. Instead Huggett uses the article as a call to arms for digital archaeologists to step forward with their own grand challenges. I propose that archaeologies of digital built environments be one of them, using VR and 3D imaging and immersion as tools with which to explore and document those spaces.

togrammetry? How can archaeologists share their own VR experiences from their projects with colleagues who could conceivably work on sites remotely via VR hardware?

- Is it possible to conduct in-game photogrammetry of digital things/artifacts in the VR space, and then produce actual 3D-printed reproductions of them? What are the benfits, drawbacks, and ethical considerations of 3D-printing intellectual property?
- Is it possible to create GIS maps of digital evironments, and what might the archaeological benefits be from making these maps?

Interpretation

- How do VR worlds handle the idea of phenomenology, either subverting it or redefining it within the context of born-digital spaces, and how does that compare with phenomenology of the natural world? What can archaeologists learn from the phenomenology of digital environments?
- How can the lessons learned through playing a photorealistic, history-based game such as *Skyrim* in VR be applied to archaeological projects that want to use VR for site visualization and tourism?

4.1.2. Organization

This case study chapter is divided into six parts:

1. Introduction. I begin by outlining my research questions, why I chose *Skyrim VR* in order to answer these research questions, and an explanation of the game and its history of development.
2. Virtual reality technology. I explore the pros and cons of using VR technology for conducting archaeological research in synthetic environments.
3. Practical archaeology in digital environments. I evaluate the possibilities of photogrammetry, 3D printing, GIS, and shared VR experiences within the context of *Skyrim VR*.
4. Landscape archaeology in synthetic worlds. I apply and reflect on contemporary theory of landscape archaeology to designed digital landscapes.
5. Phenomenology. I consider how phenomenology works in digital environments and how that affects archaeology conducted within those spaces.
6. Conclusions. I reflect on my approaches to conducting archaeology within *Skyrim VR* and offer future ideas for research.

Figure 4.1. Nordic buildings outside the town of Whiterun, Skyrim.

Figure 4.2. Sony PlayStation Virtual Reality (PSVR) hardware.

So as not to break up the flow of the chapter, Appendix H follows this case study, and includes step-by-step instructions for how to use various software applications for photogrammetry, GIS mapping, and recording and sharing VR experiences.

4.1.3. Why *Skyrim VR*?

This case study focuses on the game *Skyrim VR*, which is set in a designed, open world with over 230,000 concurrent players at its peak on the Steam gaming platform in 2012 (for the original game), and 11,000 peak concurrent players of the VR edition in 2019.[2] I wanted this second video game case study to tick a number of boxes in order to answer my research questions: it must be popular; it must contain a vast area for exploration and play; it must have recognizable bits of heritage in it; it must be enabled for Virtual Reality (VR) to allow for a player's full immersion into that environment. Many modern games trend towards open world experience where players can spend literal days walking to the ends of that space, investigating all it has to offer. These spaces often contain architecture and ruins, and have baked-in lore and heritage for either real or imagined cultures. The addition of VR—now largely attainable through headsets such as Sony VR, HTC Vive, and Oculus Rift, plus the budget-friendly Google Cardboard—adds an extra dimension of immersion into a digital world. Players no longer interface with a two-dimensional flat screen, but are instead surrounded by the sights and sounds of an imagined landscape. *Skyrim VR* contains square miles of landscape, and all of a sudden, through the donning of a headset, the archaeologist of the natural world becomes an archaeologist both in and of the synthetic. One cannot help but address this VR digital world as one would in visiting actual Norway, albeit a Norway from a recreated 1,000 years past.

To provide some back-story about the game, on 11 November 2011, Bethesda Game Studios released the fifth title in its wildly successful *Elder Scrolls* series of open world fantasy role-playing games: *Skyrim*. Set in the snowbound northern reaches of the fictitious continent of Tamriel, *Skyrim* features art, architecture, crafts, books, and even recipes modeled after the Vikings (Fig. 4.1). The game includes archaeological ruins as well as its own archaeologists with whom players can interact. On 17 November 2017, *Skyrim* was released as a 100% virtual reality game, making use of the Sony VR headset and controllers (Fig. 4.2), rebuilding the Viking-like world from the ground up, turning the adventure from 2D into fully immersive 3D. This marks the first time a popular 2D game has been redone completely for the 3D VR experience, fully immersing players

2. Numbers reflect concurrent players on Steam only (https://steamcharts.com/app/72850#All). Playstation and Nintendo Switch do not offer public player metrics. According to Todd Howard, *Skyrim*'s creator, the basic game has sold over 30 million total copies in seven years (https://www.pcgamer.com/skyrim-reaches-nearly-250000-concurrent-steam-users-on-day-one-topples-mw3/, accessed 3 August 2019). Approximately one million copies of *Skyrim VR* were sold for all platforms during its first year of release (https://nwn.blogs.com/nwn/2018/07/skyrim-vr-beat-saber-psvr-steam.html, accessed 3 August 2019).

in a Norse-like landscape where they can explore the interiors of stavkirches, houses, markets, and other buildings, created via either laser-scanning or photogrammetry. I played the original game for over 200 hours, and started over with the VR edition to see how the landscape and archaeology of the world changed, and had been reimagined. York funded my purchase of the Sony VR headset, and I was eager to use it within this archaeological context.

Following my first case study (Chapter 3), I wanted the game for my second case study to be a 100% designed world (without procedural generation, as will be discussed for the final case study with *No Man's Sky*) that is made for single players only. There is no multi-player or community option, which ensured that I played alone and experienced the world as the designers intended it. *Skyrim VR* is, in effect, a "control" in my digital archaeology experimentation. Nothing in the game changes unless I want it to based on my own actions within that space.

4.2. Tools and Methods

To understand my approach to studying *Skyrim VR*, one must first understand the hardware at my disposal. Sony's PlayStation VR (PSVR) contains four pieces of hardware, which allow the user to engage with any VR content including over 500 PlayStation 4 games[3] as well as other VR video that can be viewed on channels such as YouTube VR.[4] There is a main headset (helmet) with adjustable head-strap and faceplate, the latter of which contains two lenses through which one can see immersive environments. A cord issues from the left side of the helmet and runs to a box that is in turn connected to the back of the PlayStation console. Connecting to that wire is a set of in-ear headphones to communicate stereo surround-sound. Perched atop the console or television display (used for accessing 2D content) is a stereo camera, which is also plugged in to the back of the PlayStation console. This camera observes the user's movements, translating those to actions within VR software. PSVR also includes two handheld motion controllers studded with buttons to allow for action and access to data. The total cost for the VR hardware alone is ca. US$500, and the PS4 itself costs ca. US$300. These costs alone provide a serious barrier to entry for archaeologists without funding, but is close to the cost of many international return airfare tickets and other transportation costs to archaeological sites in the natural world, Uncrewed Aerial Vehicales (UAVs, i.e., drones), Gound-Penetrating Radar (GPR systems), and lower-end LIDAR systems. One criticism of conducting any kind of VR archaeological research is that there is not yet any set of standards, and that hardware such as PSVR can be proprietary, and is not platform agnostic.

3. https://www.playstation.com/en-us/explore/playstation-vr/ (accessed 3 November 2019).
4. https://www.youtube.com/channel/UCzuqhhs6NWbgTzMuMo9WKDQ (accessed 7 February 2018).

In *Skyrim VR*, one can either use the standard PlayStation controller or two motion-control sticks (called "Playstation Move"). The standard controller is held by both hands at once, with two thumb-sticks and roughly a dozen buttons for executing various in-game actions. The motion-control sticks, however, are held in each hand and become extensions of one's limbs within the game, allowing for object-manipulation, combat, and data-manipulation. For the purpose of this case study, I opted for the motion-controllers for a more "natural" phenomenological experience. An attempt to switch back to the standard controller proved clumsy and inefficient; it was easier to use my two "hands" within the game. The motion-controllers contain modest means for communicating haptic responses to the environment via vibrations. If my left hand is near something I can use, the left controller vibrates. The same effect happens with my right hand for things on my right (e.g., door handles, artifacts, quest items). Although elementary, the fact that one can have data communicated to them through one's hands is remarkable, and I (and others) expect future haptic experiences to include textures (smooth v. rough) as well as temperature.[5] When I explore the wilderness in the natural world, I rely primarily on sight, sound, and touch, and *Skyrim VR* faithfully represents that kind of data accumulation within its digital, open environment. PSVR tools enabled me to create data in a more physical way, which relates to knowledge-making during traditional fieldwork. In my first and third case studies (Chapters 3 and 5), I was restricted to two-dimensional screen observations and data collection. PSVR added that extra dimension, which was appropriate for the work I conducted in *Skyrim*. I did not require anything 3D or VR for my work in the text-only *Colossal Cave Adventure*, but it would have helped in surveying and excavating sites in the open universe of *No Man's Sky*.

One half of archaeology lies in data collection, while the other half resides in sharing that data with others. One can share one's VR experience with colleagues via screen and video captures. In *Skyrim VR* (as with other PlayStation games), one can use the native screen- and video-capture tools to take screenshots and to record up to 15 minutes of video (with audio) at a time. These files (JPG and MP4 files respectively) can then either be shared directly via social media, or can be downloaded to a USB drive. All of the images and video for this case study were captured by this method. VR offers some special cases for sharing visualizations with a public who do not (yet) have access to virtual reality-enabled hardware or software. It was important for me to figure out

5. For speculation on the future of haptic VR technology, see Matthew Huttson, "Here's What the Future of Haptic Technology Looks (or Rather, Feels) Like," *Smithsonian.com* (https://www.smithsonianmag.com/innovation/heres-what-future-haptic-technology-looks-or-rather-feels-180971097/), accessed 3 August 2019. For reporting on the actual science behind making touch- and temperature-sensitive haptic wearables, see M. Hosseini et al. 2018. "A Novel Haptic Glove (ExoTen-Glove) Based on Twisted String Actuation (TSA) System for Virtual Reality," in D. Prattichizzo et al. (eds.), *Haptics: Science, Technology, and Applications. EuroHaptics 2018*. See also Teng, Han et al., 2018. "HydroRing: Supporting Mixed Reality Haptics Using Liquid Flow," *UIST '18 Proceedings of the 31st Annual ACM Symposium on User Interface Software and Technology*, pp. 913–25.

Figure 4.3a. Screen capture taken through the PSVR headset.

Figure 4.3b. Photo of the same scene as displayed on-screen.

how to communicate the experience of exploring a VR environment with this audience, and my *Skyrim VR* case study allowed by to explore ways of doing so. Later in this chapter, I will describe how I was able to turn a filmed instance into a shared VR experience with Google Cardboard (or similar inexpensive/free viewing hardware). I will also show how to create 360-degree panoramic images and 3D-printable models of the objects found within games, bringing digital-only artifacts into the natural world. As for interacting with the game as an archaeologist, I was able to conduct myself as I would in the natural world through walking through the landscape, documenting with image and video, making observations based on my research questions.

This digital work has been done before, but for landscapes and sites in the natural world. VR heritage experiences are now commonplace (e.g., John, et al., 2018; Katifori, et al., 2018; Kersten, et al. 2018b; Martinez, et al., 2019), yet for the most part remain inaccessible to the public outside of these sites and museums. 3D panoramic, spherical, and 360-degree images of cultural heritage sites are also common (e.g., Gottardi and Guerra, 2018; Jakobsen, et al., 2017; Wahyudi, et al., 2019), but have not yet manifested within digital environments. 3D-printing artifacts and even entire archaeological sites is also not a new concept in the archaeology of traditional materials and landscapes (e.g., Al-Baghdadi, 2018; Hermon, et al., 2018; Vranich, 2018), yet the same technical operations have yet to be completed in digital spaces. This case study marks the first time archaeological work of this nature has been translated to and conducted within a digital environment, specifically and open world video game. The lessons learned here can be applied to future work within digital built environments—games or otherwise.

4.3. Applied Archaeology in a Digital Built Environment

This section describes what I did and what I found in order to answer my technology-oriented research questions. I begin with the technical aspects of VR archaeology in a game, and conclude with the more interpretive side of *Skyrim VR*.

4.3.1. VR Technology and Video Game Archaeology in *Skyrim VR*

When testing *Skyrim VR*, I used a first-generation PSVR headset while also broadcasting my explorations on a flat-panel display. While the images on the display were sharp and in high definition (my PlayStation 4 connects to my television with an HDMI cable), the images as seen through the headset were fuzzy and were of considerably lower resolution (Figs. 4.3a and 4.3b). Environments and buildings seen at a distance were relatively clear, and seeing those in VR mimicked what one sees when looking at things from far away. The closer I got to a structure, however, the fuzzier it became, almost as if the resolution was working backwards from how things appear in the natural

Figure 4.4a. Rusticated masonry as seen from a distance.

Figure 4.4b. Flat texture of rusticated masonry as seen up close.

world. Compare this to how things work in the natural world where the closer one gets to actual materials, the more detailed those materials become.

However, the more time I spent in VR, the more accepting I became of how the world appeared, and I was able to operate without being distracted by the difference between the clarity of what I saw through the headset versus what I could see on screen whenever I removed the headset. I also used the PSVR headset to access purpose-built VR games, those that were expressly designed for the PSVR hardware, and found the graphics to be quite clear and crisp. I believe that what one sees in *Skyrim VR* is an artifact of porting a seven-year-old game into 2017 technology, which has a much higher resolution. If constructing a heritage experience, it may be prudent to develop for current VR technology instead of developing for 2D and then porting to immersive 3D, which can result in a lack of image quality, and therefore a less satisfying VR experience. I would be interested in testing a second-generation PSVR headset (now commercially available) to see if this is true. Was fine-grained detail needed in the digital archaeology I was attempting to conduct? In most cases, no, but in the case of 3D printing, a more realistic level of detail would have helped to produce a sharper model (see below).

When using the VR headset, the level of detail was enough to communicate meaning through objects with which I interacted. It remained easy to differentiate between different items based on their design and architecture. For example, the thatched, half-timbered houses and farms of the Nords of Windhelm remained distinct from the abandoned stone-and-brass dwarven dwellings of the Dwemer.

When viewing anything in *Skyrim* VR, one sees models rendered in 3D, which are mapped with a 2D "skin." I can manipulate an apple I find on a table in a Nord's kitchen, turning it, viewing it from every angle, but when I hold it up close to my face (through the VR headset), there is a limit to the texture that belies its manufacture. The apple's skin becomes blurry and looks flat. The same is true of walls. When viewed from a few feet away, the texture of a stone wall tricks the eye into believing that the masonry is rusticated sporting actual rippling topography across the faces of the stones (Fig. 4.4a). However, standing face-to-wall, that illusion vanishes, and one is left with a flat, 2D representation of the wall's texture (Fig. 4.4b). It's a trompe-l'oeil effect not uncommon in 2D art imagining a 3D space, inviting the viewer to reach out and attempt to take what's depicted. In VR, in the case of objects, one actually can, as that 2D skin is wrapped around a wire frame like sculptor's clay on a wire armature. This textured skin communicates the idea of "appleness" or "wallness", and also gives the digital archaeologist a way to gauge how technology either changes over time or between versions of the same software title. One can record in-game representations of things while also documenting software and hardware evolves.

For the intention of archaeology in VR, that kind of close-up scrutiny might only yield valuable information if the resolution is sufficiently high, but it might actually not be necessary. For example, colleagues at Princeton University, Rebecca Napolitano and Anna Blyth, use a drone to fly close to heritage structures, filming their surfaces during flight, creating a real-time VR representation of what is being filmed.[6] The purpose is to use the drone to reach places people cannot, to film what cannot be seen easily, and then to consult the 3D image after the fact to look for possible damage on these structures to make decisions on what needs to be conserved or repaired. The resolution provided by the camera and resulting image is sufficient enough to show the presence of cracks, but need not show anything of greater detail. Cracks are present, and the locations of the cracks are noted for future work by the managers of that heritage structure. Their project's purpose is not to create a reconstruction for audience engagement, but rather it serves as a tool for the conservation of built heritage. That being said, their scans could be repurposed by their clients in order to provide 3D models for the public to engage with online as something value-added to their on-site experience either before they arrive or after they return home. The photogrammetry files can serve a dual purpose: a diagnostic tool to aid in the conservation of a structure, and as an online model for educational purposes that happens to be at a very high resolution. Project-planning should aim for the highest-possible quality, assuming that at some point the results of scanning could be used for other, related projects with outputs for different audiences. Working in the opposite direction (repurposing low-quality scans for other audiences and outputs) rarely produces usable results (see Dolcetti, 2019).

Skyrim VR derives much of its popularity and value from being a game steeped in designed heritage and lore (Gallagher, 2017). This lore is built on 820 unique documents found in-game, which includes 307 readable books with no function other than to add to the lore of the continent of Tamriel in which *Skyrim* is set. A high level of visual detail is not needed by the player in order to enjoy the space. There is no real need for the archaeologist to use VR to search for anything inherently wrong in the structures within the VR environment of a designed game. Instead, VR becomes an experiential device that places the wearer directly into a fully realized, 3D environment with interactive objects as well as surround-sound containing directional ambient noise. In other, future games containing procedurally created buildings and towns, one could conceivably use VR to closely examine these structures for wear-and-tear, for evidence of a history of use. But in current VR games, such as *Skyrim*, everything is designed, and nothing ages or changes. The VR hardware becomes merely a method of extra-sensory locomotion that communicates the data of places discovered. For the

6. Pers. conversation, 17 Nov. 2017. Article currently under peer review for *Computers and Structures* by Rebecca Napolitano and B. Glisic, "Methodology for Diagnosing Crack Patterns in Masonry Structures Using Photogrammetry and Distinct Element Modeling."

player, this discovery serves largely as entertainment and a way to advance through the game. For the archaeologist interested in communicating digital heritage through VR environments, this hardware enables one to think deeply about the environment as programmed and experienced in order to better understand how people would have used these spaces in the natural world.

Paul Backhouse, Head of Imaging for Historic England, was part of a team that recently concluded a VR project in imaging Stonehenge. During his 23 January 2018 lecture at the University of York (Backhouse, 2018), he showed the finished VR reconstruction and explained the tools and methods used to faithfully image the henge as it is in order to bring it to a wider audience. For those not able to interact with the site directly through prior arrangement with English Heritage and are unable to pay the attendant fee, providing an immersive VR experience allows them to engage with Stonehenge digitally. While the visuals are excellent and allow the viewer to interact with Stonehenge (one can clamber over the triliths), the experience is isolated, removing the viewer from interaction with others who might be sharing a similar experience while wearing a VR headset. It also removes the viewer from the surrounding landscape, perhaps hiding the sense of scale and the relation of Stonehenge to the wider region. VR continues to struggle with providing haptic feedback: one cannot touch the face of the stones, smell the rain, or feel the wind, all of which provide additional sensory data when experiencing features in a landscape.

This work at Stonehenge and the VR-realized open world of a designed heritage space are similar in that they allow users to do what they want within a digital space populated with heritage features. This has both pros and cons, the pros being that users can treat spaces how they would like to when exercising personal freedom, which allows them to answer independently their own questions about these heritage features. This open approach also allows for asynchronous experiences of heritage spaces as opposed to following an enforced, linear tour. The cons include the absence of any formalized questions or guidance to help the VR visitors who need/want instruction and structure when visiting sites. For modeling a "real" site like Stonehenge, this is a critical error, but within the context of a video game, the lack of a formal framework adds to the mystery of the space and encourages exploration and discovery. Also, heritage spaces within *Skyrim* are always tied to the surrounding landscape, which provides added context. With the Stonehenge VR model as demonstrated in 2018, the monument was separated from the surrounding landscape from which it might have benefitted in either setting Stonehenge within its modern setting, or in the past, or perhaps even both.

Archaeologist Stuart Eve continues to explore the possibilities of adding sensory data to AR and VR heritage reconstructions as seen in his early work, *Dead Men's Eyes* and his follow-up project *Dead Men's Nose*, which attempt to find ways to integrate the other senses into a more fully immersive landscape experience within augmented/mixed and virtual reality.[7] The purpose of the Stonehenge VR project is to allow visitors to interact with the monument for a few moments, but it does not go far enough for any kind of meaningful archaeology, which could include it in a wider map of the region, or could allow one to view Stonehenge at any date/time in relation to astronomical data. Including metadata about Stonehenge within the VR's Head-Up Display (HUD) could also be helpful, as it is in other VR games (as seen in both *Skyrim VR* and *No Man's Sky: NEXT*), a kind of augmented virtual reality (AVR), but one couched within a landscape to provide additional contextual information instead of being depicted as a monument in isolation.

Skyrim VR does two things particularly well: 1) it emulates how things appear in the natural world during the course of discovery, and 2) it provides a constant flow of data without interfering with the user's experience of place. Regarding discovery, the game maps the environment onto a curved surface, which yields a believable horizon. As one walks, landscape elements come into view, and then into greater focus. Ambient noise from animals, leaves, wind, as well as towns increase in volume as one approaches, and the sound is mixed in 360º surround-sound so that what the player hears is tied to a distinct point of origin. One can tell if a sound comes from the left or right, in front or behind, and after some experience can even estimate distance to the sound's origin. As for navigation, mountains require passes in order to climb over them, although bouldering can be done on shallower slopes. Not unlike the natural world, travel can be done either on foot or by horse via roads and paths, or cross-country for point-to-point travel. The game contains desire lines in the form of worn tracks that can be followed to points of interest, and encourages open exploration of the wilderness, which includes rivers to ford, glacial tarns, copses of trees, fields of ash, and navigational hazards that behave as they do in the natural world.

Regarding other means of communicating data, *Skyrim VR*'s design packs a lot of information into unobtrusive, logical spaces. During exploration, one can consult a compass at the base of one's eyeline (Fig. 4.5). The compass is not viewed top-down, but is instead a thick, black line in which the cardinal directions move to the left or right depending on one's direction of travel. As one moves, elements in the landscape appear on the compass, becoming larger the closer one gets to them. For example, in my walk to a town, I note the sickle-and-wheat icon for a farm, a cave icon, and a trident icon for nearby ruins. As I continue walking, I change my direction of travel towards one of these points of interest. The icon remains gray as I approach, and turns white upon my

7. Stuart Eve, *Dead Men's Eyes: Embodied GIS, Mixed Reality and Landscape Archaeology* (Archaeopress, 2014). See also his project write-up for *Dead Man's Nose*: http://www.heritagejam.org/2015exhibitionentries/2015/9/25/dead-mans-nose-stuart-eve (accessed 7 February 2018) and 2018's "Losing Our Senses: An Exploration of 3D Object Scanning," in *Open Archaeology* 4:1 (accessed 3 August 2019).

Figure 4.5. *Skyrim VR* compass.

Figure 4.6. *Skyrim VR* world map.

arrival. This kind of map interface with its dynamic icons could conceivably be adopted by survey teams enabled with augmented reality technology to assist in identifying landscape features and marking them as places to revisit.

My arrival at a point of interest also triggers two additional events. First, my world map (Fig. 4.6) updates with this new location, turning it white on that map as well. Other unexplored locations that I have passed by but not stopped to explore appear as black icons on this map. This is helpful to me as an explorer because I can always open the world map, see where I have not yet been, and then travel to these spots. The map's interface and functionality could be deployed in purely archaeological visualizations of areas to survey within a landscape, updating day-to-day based on the progress of teams of fieldwalkers perhaps via live GPS/GIS updates to a central, shared map, with recorded features, artifacts, and ecofacts appearing on the map in real-time. This would aid the principal investigator to make more efficient/logical choices in deciding where to survey next, as well as how to interpret survey data as the walks happen.

When it comes to data visualization and mapping for use in the field, archaeologists can learn a lot from game design. I return to Eve's work on "embodied GIS", which allows a fieldwalker to receive data about their surroundings based on their location in the landscape (Eve 2012a; 2012b). Any contemporary open world video game contains an interactive map. Some of these maps show an entire region with features clearly marked, while other maps only display places discovered by the player, with the rest of the region generally defined, but devoid of features. An archaeologist in the field should be able to access real-time data through a smartphone or tablet based on their GPS location, which might help in suggesting routes for travel, or can provide data about nearby features in the landscape that could contribute to a better understanding of the area currently being explored on foot. Using Eve's mixed reality approach, one experiences the landscape in person while being fed locative data dynamically through a handheld device. These data can be downloaded on-the-fly should there be an Internet connection (WiFi, 3G, 4G, LTE, etc.), or ideally could be downloaded in advance of fieldwalking should no internet connection be available on-site.

Despite the potential for conducting archaeological research in VR-enabled space, there is one element currently missing from the many VR and 3D reconstructions of sites and monuments ranging from Stonehenge to Çatalhöyük to Pompeii to the Rome Reborn Project: the social. The issue is not the size, quality, or even the possibility of engaging with a digitally reconstructed space. Archaeology can be a social pursuit where archaeologists work in a team environment, be it a 3-person CRM crew or a cast of hundreds on a major site. Archaeologists talk to each other (most of the time) in order to communicate data especially when on-site during a field season. At the conclusion of the field season, the conversations can continue based on the data recovered.

Çatalhöyük attempted to work around this by creating a reconstruction in *Second Life*, an online sandbox that facilitates visitation by several people at once, and includes both voice and chat features (Morgan, 2009). In theory, this was a good approach to public outreach, but it is as yet unclear of its short- and long-term value to the archaeological team once the reconstruction was completed. It did, however, add another form of practice for understanding the site, at least for the person undertaking the reconstruction, providing a platform for reflecting on archaeological evidence while creating a digital model based upon that evidence. Ten years later, this reconstruction is now its own archaeological artifact to be visited, a digital simulacrum of a structure in the natural world, a monument to an earnest, early effort to leverage digital tools for archaeological interpretation, which has become part of the regular methodology of those rebuilding past natural environments in digital spaces using game engine technology (e.g., Smith, et al., 2019; Vletter, 2019; Witek, 2017).

Returning to *Skyrim VR,* another event triggered by my arrival at a new location on the map is that I receive text data on-screen, that gradually fades away over time. I can read about the place, and know that in a few seconds the window will dismiss itself, but can be called back for future reference at any time after its initial triggering. Data windows in the game do not occupy the entire field of vision, but rather appear in discrete, translucent boxes with options either to dismiss them, or to drill down for further information. Other data can be accessed by pointing a motion controller at either a person or an object and then activating a window for more information. Data for people are often communicated verbally by the person themselves (with an option for subtitles). Data for objects includes a 3D, rotating image, title, definition, use, value in gold, and weight (Fig. 4.7).

Data and the environment merge in the VR world map, which allows one to fly over the entire world of Tamriel shown in high relief. This visualization of topography is a marked difference between the 2D and 3D VR version of the game. One can now see (Fig. 4.8) how some cultures have settled on plateaus, while others prefer the protection of the forest, and others care to live close to the sea. The topographic visualization also assists in route-planning and wayfinding, allowing players to be smarter about how they move between destinations. One can also zoom the map in for additional detail, and can toggle between the world map and a local map once inside the walls of a town (Fig. 4.9). Granted, the world of *Skyrim VR* is a 100% designed experience where little is left to chance. The benefit of being the single human player in such a large world is that one can be an active participant in a massive agent-based modeling experiment to see how populations react to various actions, and how the landscape dictates their movement through it. The indirect observation then of fully designed landscapes is more about how the designers perceive the world they create and how they generate a

Figure 4.7. Artifact data for a typical object in *Skyrim VR*.

Figure 4.8. *Skyrim VR* world map showing placement of features based on topography.

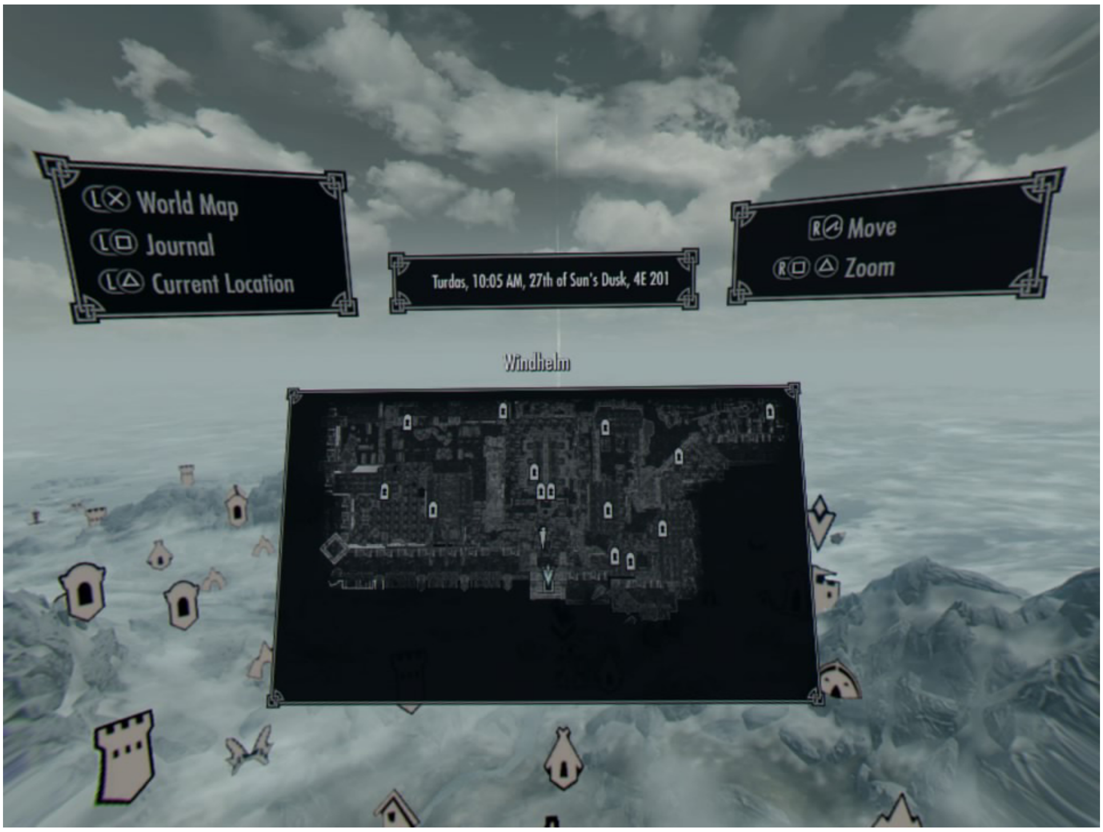


Figure 4.9. Local Map of Windhelm in *Skyrim VR*.

landscape to support narratives while also providing spaces for in-game conflict. With games such as *Skyrim VR*, we are able to interpret landscapes from the inside-out and from the outside-in. The difference between a natural landscape and a designed one, however, is that the latter places the player and player-experience first as opposed to the natural landscape, which at first developed without human intervention, and later blended with human intent and need. *Skyrim*'s environment artist, Noah Berry, said as much: "At the outset [of designing the world], I sought to keep the player's experience – from their actual view and perspective, as well as with the unfolding of any and all progressive gameplay events – fully in mind."[8]

The main takeaway from using VR technology in a heritage-rich environment such as that found in *Skyrim VR* is that it offers complete, immersive engagement within the landscape, and invites users into the wilderness as well as into towns and villages and individual houses, farms, and shops wherein one can engage in potentially lengthy dialogue with non-player character (NPC) residents,[9] can trade with them, and can learn about the place where they are standing. Exploring a landscape alone is one thing, but is without any kind of social, cultural, or historical context. Interacting with others

8. https://80.lv/articles/skyrim-designer-on-building-virtual-worlds/ (accessed 4 August 2019).
9. NPCs are a mainstay for role-playing games, providing automated nodes of communication with which human players can interact.

Figure 4.10a. Bookshelf in *Skyrim VR*.

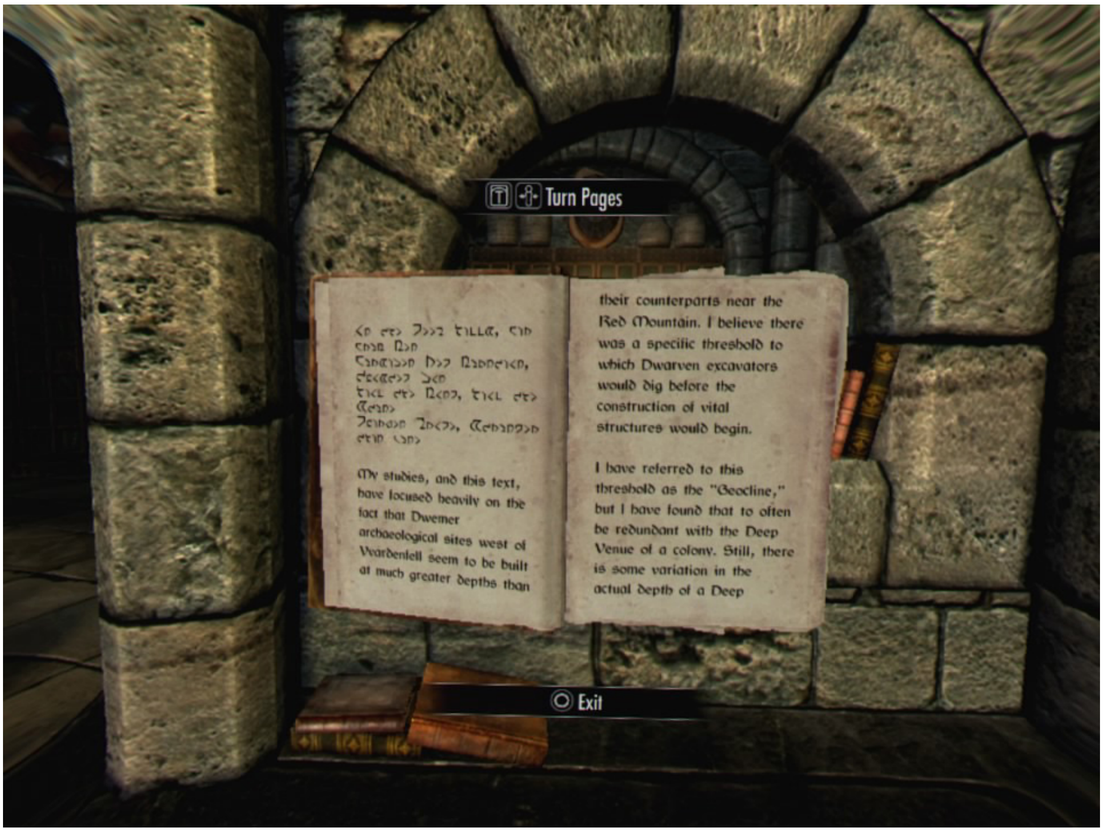


Figure 4.10b. Book in *Skyrim VR*. Note the bilingual text.

who "live" in a digital space adds those extra layers of meaning. Going one step further, *Skyrim* offers players thousands of short books to read (Figs. 4.10a and 4.10b), which are scattered throughout the world of the game, each containing history and lore, offering incentives for building a virtual library, and encouragement for reading by way of "buffs" (special increases in player strength and skill). One can see the possibility in taking what *Skyrim VR* does best and then adapting those features and functionality into digital reconstructions of sites in the natural world, encouraging engagement, virtual tourism, and advanced study (e.g., Bendicho, et al., 2017; Borba, et al., 2017; Kontogianni and Georgopoulos, 2015).

Archaeologists can take a more professional look at sites created for VR using the topography and structures to better understand the nature and history of a site, to consider it from a variety of angles and distances, to see how a site relates to the landscape and to other nearby sites and natural features. Archaeologists can walk within VR reconstructions to get a sense of space and scale, drawing conclusions about the site and its features, using the reconstruction as a model to answer a variety of research questions, visiting this space virtually when away from the actual site in reality. *Skyrim VR* is proof that this can be done, albeit in a fictitious and designed space. As expressed above, with modern advances in photogrammetry, laser-scanning, GIS, and open source software for constructing 3D environments, one can approach the kind of data-rich engagement offered by contemporary games. One could conceivably query data while standing within a structure in VR, adding to the database about this UK-based feature in real-time while sitting in an office in the US. These are practical applications derived from those modeled and executed within a modern game-space. Lessons learned can then be applied to other synthetic spaces and digital built environments both real and imagined.

Through my time in *Skyrim VR*, I was able to make three core observations on how archaeologists can work in (and benefit from) VR-realized digital environments, be they new constructions or produced from 3D laser-scanned places:

1. VR allows the archaeologist to see as one does naturally (as opposed to viewing something in a room on a flat screen in 2D). When I played the original version of *Skyrim* in 2012, the views were beautiful, but I was still separated from them. It felt like I was engaging with a film with a keyboard and mouse as prosthetics used for environmental engagement. Seeing the same world realized in 3D VR, I became an active participant in the landscape and urban areas, immediately felt a sense of scale, and could behave as I would in the natural world with my explorations. The distance between me and artifacts and building interiors vanished for me in 3D VR, which to me is essential in conducting archaeological fieldwork in open worlds and producing digital heritage experiences.

2. VR allows the archaeologist to consider things from a variety of angles, of points-of-view, from different distances. Interacting with a two-dimensional environment introduced a distance between myself and whatever I was observing/holding. It presented a reduced form of engagement relying on visual perception but without additional context. It was like looking at a photo of an artifact instead of beholding the artifact itself. When I picked up a bowl from a table in *Skyrim VR*, I got a sense of size, a better sense of shape, of volume, and I could manipulate it as I would had I found this pottery during excavation. When considering landscapes, I can look at a picture of a field with mountains in the distance, but when the same scene is experienced in 3D VR, the enormity of that distance feels more real as I walk towards those mountains. This personal perception gets at what other people might feel when they experience(d) the same landscape. While this might not be as archaeologically important in a designed landscape such as *Skyrim*, it can be useful in interpreting human interactions with natural landscapes when those are ported to 3D VR settings. Janeh, et al. (2017), Linkenauger, et al. (2015), and Steed, et al. (2017), among others, have all conducted research into distance perception within 3D VR environments, the technology behind how the illusion of distance is rendered, and how distance is experienced through avatars. The technology continues to improve, but there are still issues to address including translating actual human height into a digital environment, which is important when considering issues of scale.

3. VR allows for repeat visits to a site as it was at the point the site was scanned and digitally reconstructed. These repeat visits can lead to answers to questions that might have been missed if the archaeologist had only one chance to see a space or feature before it was lost to continued excavation or other formation processes. If one scans and digitally reconstructs a site in VR several times over the course of several seasons, one can also explore how things change within the site's history, and can also use these VR representations as a reflexive tool for reviewing how and why a site was excavated the way it was. In *Skyrim VR*, the landscape never changes, which can be beneficial to archaeologists who need to return to various places in that digital environment to continue/complete observations at the very moment of digital-capture, something one cannot do in the natural world. For sites in the natural world that have been scanned and imported into 3D VR, this opportunity affords the archaeologist 24/7/365 access to this snapshot of the landscape from anywhere in order to continue asking and answering research questions of it when separated from it, and in the instances when a digital landscape changes drastically with a software update or by human impact, one can compare the current landscape against how it appeared during earlier documented visits (see Chapter 5).

VR technology also assists with constructing narratives, something very important to the mission of any archaeological project. Archaeologists use data and evidence collected from the field in order to build various stories about their sites, and this is as true in the natural world as it is in the synthetic. In *Skyrim VR*, the landscape not only assisted me in my travels, but the game's many narratives also gave me both direction and purpose. As Tilley (1994, p. 32) writes, "Narrative is a means of understanding and describing the world in relation to agency. It is a means of linking locales, landscapes, actions, events, and experiences together providing a synthesis of heterogeneous phenomena." Tilley's observation is seconded by Paul Moody (2017) in his consideration of VR and 360-film technology as they relate to heritage and storytelling, something that goes beyond two-dimensional print publication.

There are two threads to Moody's argument. The first is that the most successful storytelling in a VR/360 medium will be done over commercial infrastructure, and he specifically cites the release of the PSVR hardware as driving content creation specific to that platform (Moody, 2017, p. 42). VR is now mainstream and approachable in price on hardware specifically designed to run massive amounts of data at speeds that make a VR game viable. Although Bethesda Game Studios have not confirmed this, one could interpret their first entry into VR gaming, *Skyrim VR*, as an experiment to test game mechanics as well as the public's appetite for an engaging, open world, VR experience.

But not all VR heritage experiences need to be the size and scope of *Skyrim VR*, nor can they be based on the typical time and materials needed to create even a small synthetic environment. Moody (2017, p. 47) notes the 2016 PSVR game *Virginia* and how it isolates and then connects various events while keeping the world small. "This enables the viewer to remain immersed in the story world of the game, but provides ways for the game designers to shift location and move back and forth in time" (Moody, 2017, p. 47). Keeping things small could make it easier for smaller heritage sites and organizations to create engaging virtual reality content, focusing on key stories that they feel are of interest to their audiences. This can be done through immersive VR, but Moody also makes mention of revisiting the idea of the 360-degree film, something that is even easier to produce, perhaps in advance of creating something in virtual reality. It depends on who the audience is and what the heritage site sees as the need when it comes to digital reconstructions in support of narratives. Making these narratives available on commercial platforms is key, however. Picking a universal platform such as Steam (which supports both Vive and Oculus Rift) might be the obvious entrypoint for delivering that content. Making content for Sony PlayStation or Microsoft (Xbox) is considerably more difficult mostly because of licensing, although heritage organizations have had some success in creating heritage-based games for these platforms (although not yet in VR).[10] The takeaway here is for heritage organizations to bring their interactive content to standardized platforms used by millions of people, which can facilitate discovery, promotion, and use.

From an outreach and public archaeology perspective, adding narrative layers to 3D/VR reconstructions gives more depth and added value to those digital spaces created for other archaeological, technical work. With a game such as *Skyrim* (and its VR edition), because of the brand recognition and loyal fan base there is little problem for its major studio, Bethesda, to find a home for it on major delivery platforms. Bethesda can also afford to advertise its games everywhere from online and television media to posters on city buses internationally. Such reach is practically impossible (as of this writing) for VR heritage projects. From my 100+ hours spent in-world, *Skyrim VR* works as a heritage-communication vehicle because of its immersive nature, wealth of content, and the fact that it is not overtly didactic. One learns about the world and its culture through interacting with the landscapes, artifacts, and its "people" as much or as little as one wants. This approach might be something for heritage-directed VR experiences to consider: freedom for the audience to choose how far to become immersed in a site and its history. But VR is not the perfect panacea.

When using VR technology, there are, as Eve calls them, "breaks in presence" (BiPs). A BiP is something that interferes with someone's experience of a synthetic space, and is itself an artifact (see below). A number of these intruded on my own walks within Skyrim, created by a blip in the connection between hardware and software, or an overburdened processor overwhelmed for an instant by multiple data sources all vying for attention at once:

- Glitches: I saw a mammoth fall from the sky. I also experienced a 3-sphere phenomenon[11] when the game froze, leaving me to view an infinite array of windows into the environment from which I was just removed, placing me into the fourth dimension (Fig. 4.11).
- Flashes: On occasion the game-screen would flash white for an instant for no apparent reason.
- Skips: Sometimes the game would freeze for a moment, and I would then "skip" ahead along the path I trod.
- World assembly: As I walked through Skyrim, I could watch as mountains and buildings constructed themselves as I approached them. I have seen this before in other games, VR and otherwise.

10. See the 2014 game, *Never Alone*, created on the *Unity* platform as a collaborative project between E-Line Media, Upper One Games, and the Cook Inlet Tribal Council for play on Xbox, PlayStation, and desktop computers.

11. A 3-sphere is a four-dimensional spherical counterpart to the four-dimensional hypercube. For the mathematics behind how these are formed, see https://en.wikipedia.org/wiki/3-sphere.

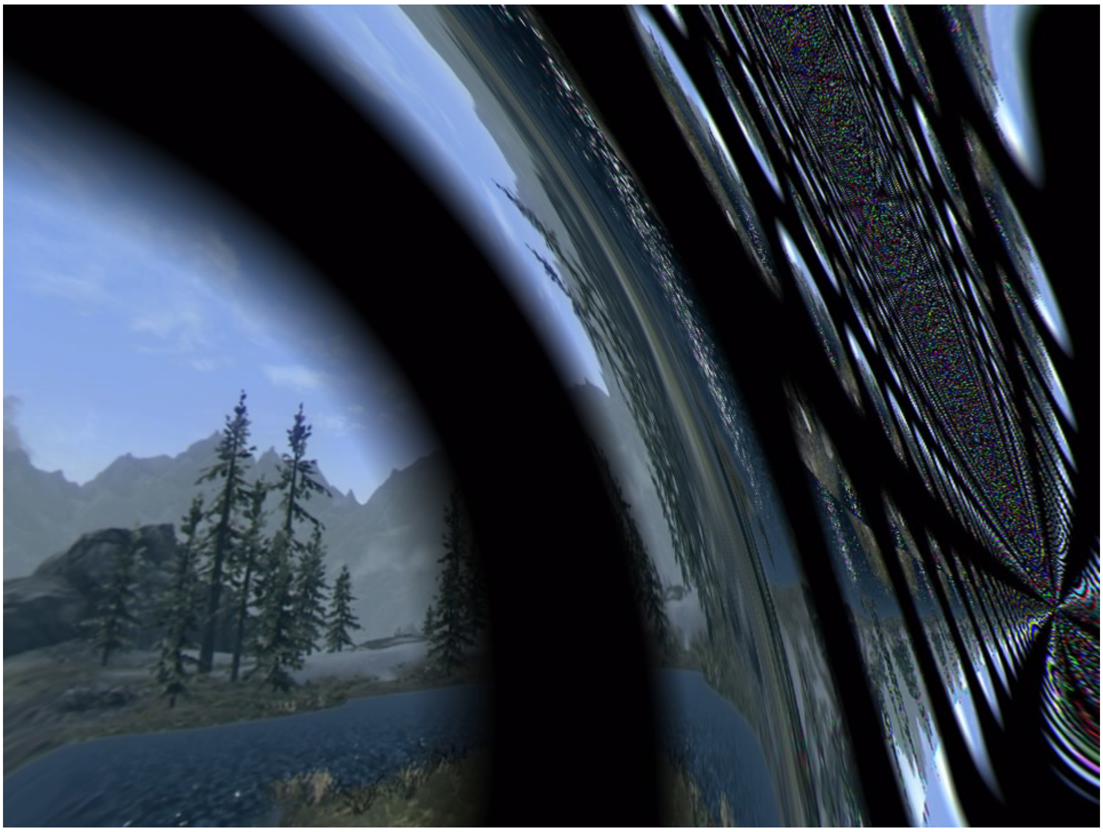


Figure 4.11. Four-dimensional glitch.

Figure 4.12. A disembodied motion controller in *Skyrim VR*.

- Missing controllers: On occasion, one of my controllers would either disappear, or would appear several "feet" away from me in my field of view (Fig. 4.12). This is an artifact of direct sunlight interfering between the motion-controls and the camera mounted atop my television. The light gets scrambled, and the signal is either lost or misread. Playing in a darkened room cancels this glitch.

These breaks-in-presence are themselves artifacts from the game. While one can interpret the things one is intended to find within the game as artifacts, these glitches also communicate information about the digital built environment, and can often be reproduced. For example, on 1 January 2018, I discovered a glitch in *Skyrim VR* that locked the motion in the game and changed the VR visualization so that I could see infinite iterations of the space where I currently stood.[12] The technical word for what I experienced is "glome", a four-dimensional spherical equivalent to a hypercube/tesseract. Other players logged this glitch on reddit, and it was enlightening for me to read their hypotheses on what might have cause the glitch. Siny_Ninetales_Loki posited that "both times I ran into this, it was relatively close to the edge of the map, but not quite ON the edge. Like, maybe 20-50 steps away from it. So [the glitch] could be related."[13] *Archaeogaming* reader "Terry" replied to my post on 5 January 2018 stating, "I just stumbled onto this as well it's super trippy. I thought something from *Stranger Things* was going to get me." My experience was in the middle of the map. Between the three of us, the glitch occurred in a different place in the synthetic world, but at the same place with regard to a human interfacing with the game through the PSVR headset. The response from each of us was a typically human, "well *that* was weird," paired with a little confusion and some amusement, yet each of us continued to play the game after the fact. It is not unlike a person in antiquity seeing a comet for the first time, explaining it to others, and learning that other people have seen similar phenomena yet have no logical explanation for it. Life continues, enriched by these random encounters, yet they are written into the lore of a culture of shared experience, which in the 21st century is reddit, or in antiquity in the form of carvings, tapestries, and illustrated manuscripts and books.[14] Interestingly, this glitch never appeared on Bethesda's official support page and instead is part of the gameplay "folklore" as reported by players elsewhere.[15]

12. I blogged about the glitch (with images and video) here: https://archaeogaming.com/2018/01/01/interstellar-glitch-in-skyrim-vr-a-3-sphere-phenomenon/ (accessed 4 August 2019).

13. https://www.reddit.com/r/PSVR/comments/7e14j9/list_of_skyrim_vr_glitches_and_bugs/ (accessed 4 August 2019).

14. For example, the Bayeux Tapestry (c. 1066) depicts Halley's Comet, and the *Augsburg Book of Miracles* (15th century) illustrates various astronomical phenomena from history within a single volume. The "Vulture Stone" at Göbekli Tepe (c. 10950 BCE) documents the Younger-Dryer comet storm (Sweatman and Tsikritsis, 2017).

15. https://bethesda.net/community (accessed 4 August 2019), with 22 pages of hundreds of *Skyrim VR* glitches.

The fact that some of these glitches are caused by hardware means that these synthetic worlds are not as virtual as one would believe, but instead communicate a blended reality reliant on actual machines to keep these worlds afloat and interactive. Breaks-in-presence allow the player to look beyond the veil and see evidence of the natural world that underlies the synthetic. These glitches must be recorded as soon as they happen, documented through screen- and video-capture, along with the date, time, and location as well as a note about how the glitch might have been triggered. In some cases, glitches are one-offs, but the archaeologist can benefit from tools such as the PlayStations video-capture feature which is always running and buffers the past 15 minutes of activity, which can then be saved as soon as one triggers a glitch. This data and media can then be uploaded to the project's website, a shared project drive, or even YouTube and reddit for community feedback on the discovery.

For the professional archaeological audience, they realize that what they are seeing is a model or synthetic reconstruction of an actual place, and should be able to tolerate any BiPs they experience while using that synthetic space for their work. The downside of using any 3D/VR reconstruction is that it is hardware dependent, often requiring newer computers with faster processors, more memory, and gaming-level graphics cards to produce the interactive reconstruction in a usable way, available to some archaeologists but not to others because of cost and other barriers to access. As I will describe below, however, there are alternatives to these massive, resource-heavy reconstructions that can be shared with people—professionals as well as members of the curious public—who do not have access to top-of-the-line hardware.

4.3.2. Photogrammetry, 3D Printing, Videography, and GIS in Synthetic Worlds

My final work with exploring the technological possibilities of game-based VR with possible crossover application to archaeology in the natural world included a series of experiments involving photogrammetry, exporting VR content for others to use, GIS of digital spaces, and conducting actual landscape archaeology in one small region of the game. While photogrammetry, GIS, and landscape archaeology are commonplace in traditional archaeology, I wanted to see if I could use these within a video game because I see games as digital environments populated by human players interacting within these synthetic spaces as they do in the natural world. One of the first steps in building an archaeology of digital environments is to see what is scalable from the natural to the synthetic: can we treat these spaces as landscapes? Can we map them? Can we scan them? Can they be interpreted as another kind of human-occupied space despite being made of digital media where visits are mediated by screens?

Skyrim VR afforded me a landscape, sites, and artifacts with which to make an attempt. I will describe what I learned below, including the step-by-step procedures for those who want to reproduce what I did in *Skyrim VR*, but applying those methods in other games and synthetic worlds.

Photogrammetry and In-Game Artifacts

VR spaces are often created by scanning real-world objects or structures, importing those scans into software (e.g., Sketchfab) that then renders them into 3D models, finally allowing the archaeologist to import those models into a game engine such as Unity. It is possible to reverse-engineer the process, but the precise steps vary depending on the VR environment being observed. For example, in the version of *Skyrim* for PC, the 3D models already exist as program files that can be discovered, downloaded, and 3D-printed by players. These same models, however, are inaccessible to players on the PS4 version of the game (VR or otherwise), an issue not faced by players of the game on PC where digital assets are accessible for printing. For PlayStation users, the player must record video of an item on a turntable, export the video to a software application such as *Blendr*, which will then cut the video into hundreds of images that are then rejoined in a 3D rendering program such as Sketchfab that can then export 3D-printing instructions for an item (Figs. 4.13–14). Similar tactics can be used for other games on other platforms.

As will be shown below, the benefit of exporting items/structures from VR spaces into the natural world is to preserve and record those things that only exist within digital built environments that might otherwise never be encountered. With 100% designed digital environments such as *Skyrim*, the developer (Bethesda Softworks) and the hobby community can archive the game and its assets. Methods described here and in Appendix H can be applied to procedurally generated spaces and artifacts that are not part of the core game files, unique constructions created at the intersection of code and player agency. In future games, I expect that more and more items found within games will be created by algorithms, which assemble various artistic bits to create unique weapons, armor, and more. If we can establish VR-to-reality item-export protocols now, we can apply them to future games set in synthetic worlds.

One of the more useful ideas for archaeologists in digital built environments is to conduct photogrammetry of the artifacts they find and then export them for 3D printing. For my test case, I used a static artifact from *Skyrim VR*, something completely created by one of the game's artists that looks the same for anyone else playing the game anywhere else in the world. Success here means that one can use similar methods and software tools to extract procedurally generated artifacts from future synthetic worlds, these artifacts created through algorithms instead of explicit design. For games such as *No Man's Sky*, a player could scan and print a plant, animal, or building, which had not been created by a person. In a designed game like *Skyrim VR*, a player using a PC could

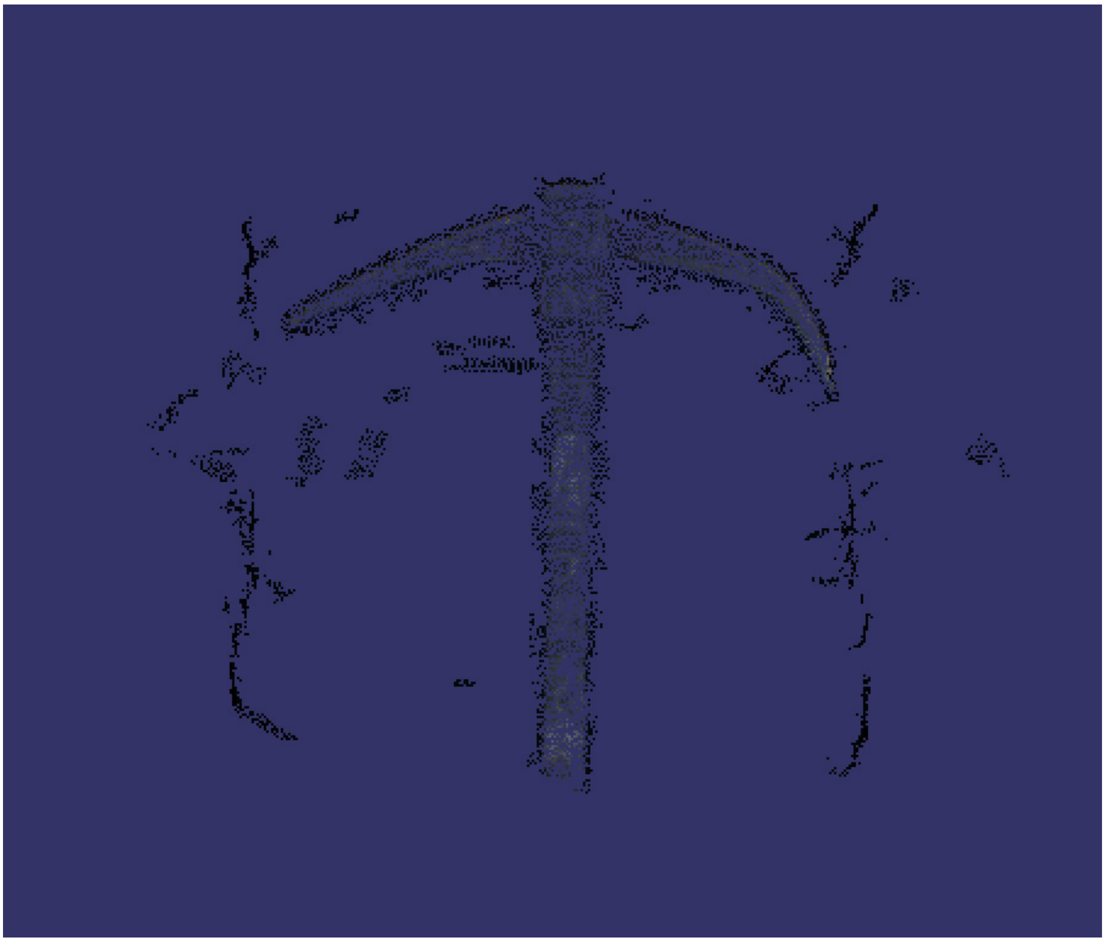


Figure 4.13. Dense point-cloud prior to creating the solid mesh for the pickaxe.

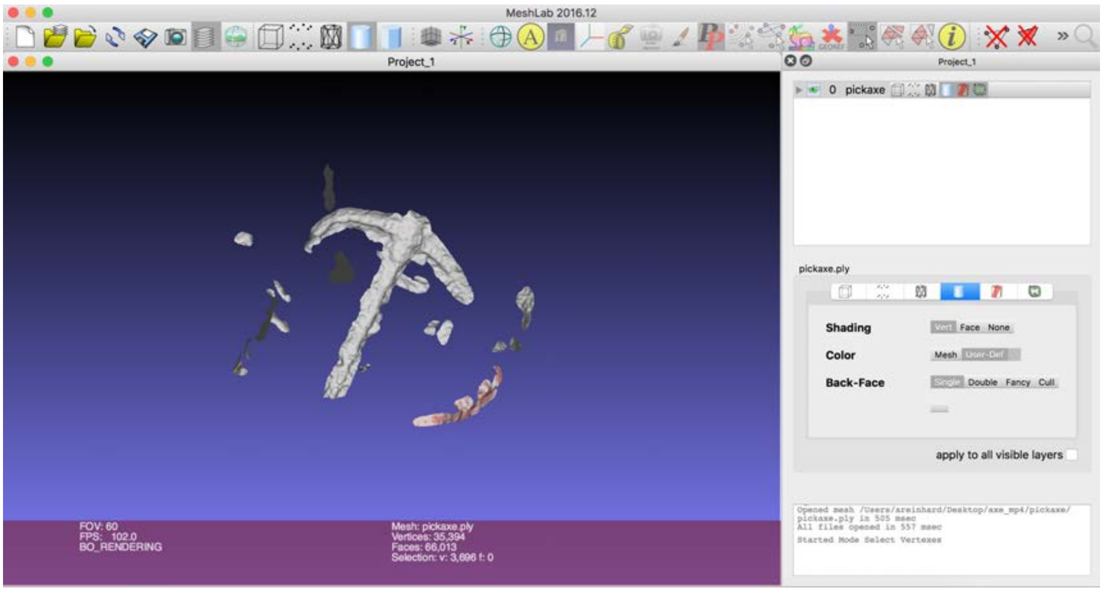


Figure 4.14. 3D mesh of the pickaxe prior to cleaning.

Figure 4.15. Ancient Nord Pickaxe to use in the photogrammetry experiment.

easily locate the image file for the artifact or, as in the case of this test, scan the artifact through the gaming console in order to achieve usable output. In both cases, we are extracting something in 2D (with the appearance of being 3D), and then creating an actual 3D replica of it that we can hold in our hands, a phenomenon that Dawson and Reilly call "phygital" (Dawson and Reilly, 2019). For my test case, I was able to successfully conduct photogrammetry of an "ancient Nord pickaxe" in my player inventory in *Skyrim VR* (Fig. 4.15), its handle incised with vine-like decoration.

The purpose of this experiment with *Skyrim VR* was to see if one could conduct in-game photogrammetry and then 3D print the results (Figs. 4.16–17). Such photogrammetric work has the potential to add another level of interpretation, supplementing synthetic text, 2D images, and 3D models with something someone can hold in the hand that is reproduced exactly from the source material. Artifacts—especially digital ones—can be both fragile and fleeting, and scanning and printing them can help preserve them for future research. This is something that we need to take seriously as archaeological practitioners.

Figure 4.16. Photogrammetry (l.) and 3D-printed (r.) Nord pickaxe.

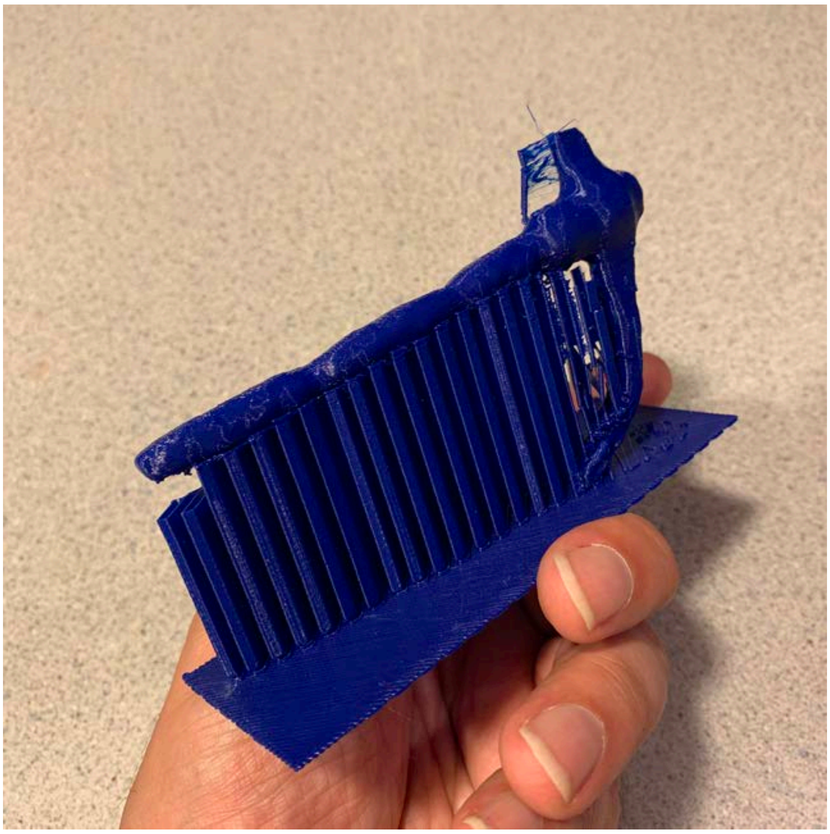


Figure 4.17. Second attempt at printing the Nord pickaxe.

There is one major issue facing the archaeologist of digital environments especially when it comes to sharing scans, printed objects, images, and video. All digital environments are the intellectual property of either an individual, group, or commercial enterprise, and those rights (including moral rights) must be acknowledged. Typically questions about usage rights for IP are spelled out in the Terms of Use created by a game's creator, but many of those documents have yet to include clauses on 3D scanning and printing of a game's digital assets, although language is common that players can create and share images and video with others so long as the source is cited and the resulting media is provided as non-commercial. This is not unlike publishing photos of sites in Greece where the country has copyrighted its patrimony and requires acknowledgement when being printed in scholarly journals or monographs. For IP belonging to individuals, every effort should be made by the archaeologist to contact the rights-holder for permission either to publish or reproduce assets and media from those independent games and game-based creations.

Videography and Sharing 3D VR Experiences with the Public

For my second experiment with VR via *Skyrim VR*, I wanted to see if I could address the important issue of sharing complex data with the general public and to archaeologists reading a site report of a digital built environment. One of the issues with the archaeology of synthetic worlds (and especially VR) is communicating the results to the reader. Most readers will not have access to VR hardware, not to mention a gaming console or the game being investigated. In many instances, what the archaeologist finds is unique to that gaming session, so the results should be recorded and shared with others who cannot depend on access to a particular event. The goal of using VR tours, 3D models, and recreations of the spaces being studied is to make these comprehensible and available to all; it also allows the landscape to be brought to the viewer instead of the other way around. Lowering that barrier to entry includes exporting data and visualizations to Google Cardboard (or similar VR headsets into which smartphones may be placed, priced under US$10). Publishing the results through WebVR in Wordpress or sharing via YouTube VR are both free and easy for the public to use and the archaeologist to manage.

Note, however, that both Wordpress and YouTube are—while public—proprietary platforms, and although are widely used and accessed by millions of people will likely either change or disappear (e.g., MySpace in 2008 and GeoCities in 2009). While these popular platforms should certainly be used for disseminating digital archaeology to the public now, the archaeologist must plan in advance for obsolescence, placing copies of data and digital media on other perpetual platforms such as OpenContext.org or the Archaeology Data Service or the Internet Archive, which permanently archive those

Figure 4.18. Still image of the final 3D/VR output of the walking tour video.

assets while assigning them stable URIs to ensure perpetual online access for as long as there is reliable Internet.

For this proof-of-concept of creating and sharing VR experiences, I wanted to allow a guest with a smartphone to watch a VR video filmed via my PSVR headset (including sound) as I walked from the foothills into the village of Rorikstead. The viewer would feel immersed in the world and could experience what it was like to approach the town. In the future, technology will likely become available that will export 360 VR in full motion as opposed to the simulation of VR in a static video. The value of the static video, however, is that the viewer sees what the archaeologist wants the viewer to see. One can add a soundtrack to the video, inviting the viewer to listen to an archaeological interpretation, much like what one finds in audio museum tours. If used in a public setting, archaeologists can interact with the viewers as they experience the landscape in 3D and can ask questions in real-time, which could potentially guide future research. Hardware and software tools will define the quality of the VR videos, the quality varying between paid and free VR video-conversion utilities when combined with output produced via recording within Steam-based games, or through consoles that differ in screen resolution. In some cases such as *Skyrim VR* as captured through PSVR hardware and then converted using a free online utility, average-quality output is about the best one can expect, which still might be good enough to communicate a sense of place (Fig. 4.18).[16] If one has the option of turning off the archaeological soundtrack, the 360 VR video will allow the viewer to then experience a space largely independent of the archaeologist's biases, which might contribute to additional information about the space being studied.

16. Before and after videos can be accessed through https://archaeogaming.com/2018/01/20/skyrim-vr-sharing-a-walk-to-rorikstead/ (accessed 7 February 2018).

See Appendix H for technical instructions on how to do this.

Heritage specialists in the natural world and those working in the synthetic suffer similar issues in creating quality output for digital interactive experiences. Crispness of picture (resolution), the speed of the hardware used to compile 3D VR heritage experiences, the quality (and availability) of high-speed internet for streaming the digital content, and the lack of standards across tools and methods are all shared issues (Champion, 2019). Those involved with creating augmented and virtual reality (AR and VR) experiences will certainly benefit from all of the attempts made previously by museums and culture heritage sites (e.g., Styliani, et al., 2009; Chelaramani, et al., 2017) as they find their way forward, balancing quality of presentation with technical availability, audience (and their technology learning curve), messaging for that audience, whether or not that messaging is presented in a linear or non-linear fashion, or adapts to a user's interests over time, and ways to recongnize and counter bias in that messaging (Kalay, et al., 2007). This thesis may introduce new ways of exporting media from digital environments to be used for archaeological interpretation and possibly heritage tourism, yet the same issues exist regarding quality and purpose with which natural-world sites grapple as they attempt to add digital components to their programs of public outreach.

360° Panoramic and Spherical Photos and Sharing These with the Public

Another option for visualizing an environment for others is to create 360° panoramic and spherical photos, which situate the viewer at the center and allow them to view the panorama or complete environment through Google Cardboard or similar inexpensive viewer paired with a smartphone. Both the panoramic and spherical VR images can be created through the same process, with the spherical image requiring two extra, simple steps as explained in Appendix H.[17]

As with the VR videos, panoramic and spherical photos allow for access to site data to those people who do not have access to the digital environment or to high-end VR hardware. The downside is that lower-quality hardware often yields lower-quality images, which can still communicate the idea of a place although without the photo-realistic version. Again, this might be good enough for most people who want to see what the archaeologist saw without the need of fine-grained detail. In the instances of panoramic and spherical photographs, the observer is at the center of the world and can observe it from the vantagepoint of the archaeologist who snapped the image. This is helpful for landscape photogrammetry as well as for understanding where things are within a digital environment in relation to where one is standing. This is little differ

17. Examples of my *Skyrim VR* panoramas can be found at: https://archaeogaming.com/2018/01/20/creating-3600-panoramic-and-spherical-photos-from-within-skyrim-vr/ (accessed 7 February 2018).

Figure 4.19. 2D “filmstrip” version of the 360-degree panoramic image of the Rorikstead valley.

ent from snapping photos of features and architecture within the wider context of the natural landscape in which they were found.

Spherical photography and other panoramic media (including VR) in archaeological space is not new, and they go beyond serving as immersive representations of space. For example, at the site of Petra (Haggrén, et al., 2004), the project used panoramic stereo photography for photogrammetric purposes, using the resulting 3D photographs to measure structural remains of barrage systems and terrace walls. The Australian rock art site of Mulka's Cave (Goldsmith, 2011) used spherical imaging to place the rock art within the context of the cave in which they are sited. Cultural heritage sites in Bulgarian towns were photographed and turned into spherical and cylindrical panoramas to visualize the interiors of the structures (Koeva, et al, 2017). In these three examples, the resulting images provided immersive, to-scale representations of enclosed heritage spaces. The Bulgarian project used proprietary software to stitch 2D images together to create a 3D space. Going beyond photography, sites such as Angkor (Vietnam), Caracol (Belize), Stonehenge (UK), and many, many others have been scanned via LiDAR with the resulting scans translated into 3D visuals.

Within digital environments, however, the digital archaeologist is restricted by the tools available within those spaces. For example, in *Skyrim VR* on the PlayStation 4, I was limited to taking single photos or recording video that could then be cut up into dozens of still images, which could then be stitched together to create panoramic views (Fig. 4.19). The videos could also be converted into stereoscopic 3D experiences as described above, which, unlike LiDAR, can include an audio component to add to the user's experience. It is unclear/unlikely that photogrammetry in digital environments can be used for anything purely quantitative (e.g., calculating absolute distances), but rather will serve the purpose of communicating what the digital landscape looks like to those without access to the actual space. It may be possible that modders could create LiDAR tools for use within digital environments, but as of this writing, this has not yet come to pass for in major modding communities such as Nexus Mods or Steam Workshop for any video game.

GIS Mapping of Synthetic Worlds

The final, practical activity that I wanted to try in *Skyrim VR* was to see if I could create a GIS map of a synthetic world.[18] The goal was to see if I could generate enough usable data for a GIS software application to return answers to queries run against the map, or to create heat maps and other data visualizations. I succeeded in importing quality data points, creating a GIS-informed topographic map of a place that does not exist in

18. For this case study, I piggybacked on a public domain topographic map created by T. Cook. For the forthcoming publication on mapping synthetic worlds, I will generate the underlying topographic map myself from a procedurally generated landscape as well as from a standard, designed landscape like that of *Skyrim*.

the natural world. The steps below can be followed by others mapping similar spaces in other digital built environments whether those are games or something else. By following my procedure, one can create GIS maps from any static image. While I did this for my case study using a fantasy world, one could conceivably do the same for older maps of cities, counties, or countries, and then overlaying those older, now-annotated maps over the top of contemporary maps that already exist as public domain for GIS users.

One of the main uses of GIS by archaeologists is to see how geography and culture change over time. For the GIS map I created of Skyrim, the map is static, and does not yet account for topographical changes introduced by Bethesda Softworks (e.g., the official expansions of Dawnguard, Hearthfire, and Dragonborn, which include new locations for players to explore), or for new areas introduced by the robust modding community. Future GIS research could integrate map layers indicating both developer- and player-created locations for researchers to see how viewsheds changed, changing catchment areas or regions of resource collection, including hunting and fishing, as well as showing similarities and differences between how the game's developer chose to change the landscape, versus how players modified the landscape themselves. In both cases, the engineered digital landscape is no longer static, but becomes flexible and evolving just as landscapes in the natural world, flexibility GIS can display (Gillings and Goodrick, 1996). GIS-analysis could help map these changes and offer ways for archaeologists to interpret them.

Using GIS software (e.g., *QGIS*, *ArcGIS*, and others), however, is not without risk. As with other software tools used in this thesis (see Appendix C), GIS software is also not without bias (Burg, 2017). This software's relative out-of-the-box ease-of-use invites users to create maps and data without critically thinking about the process underlying that data's creation. Fortunately, both *QGIS* and *ArcGIS* have robust user communities, some of whom create PlugIns as either correctives or to provide additional functionality for various niche uses, and with personal vetting by individual researchers, the pitfalls of biased maps and data can be avoided.

For 100%-designed digital environments as well as for procedurally generated landscapes, it is as yet unclear what biases might exist within GIS software applications applied to creating maps of these spaces. Open world video games such as *Skyrim* feature completely imaginary landscapes designed to facilitate exploration and to advance various game narratives, while others such as *Watch Dogs* 2 and *Assassin's Creed: Unity* are set in contemporary San Francisco and late 18th-century Paris respectively. These latter games set in "real world" locations do carry their own biases on how they are presented to players, and geographic elements they choose to keep and omit. These design biases can carry over into GIS maps generated from the games, which can potentially offer insight into how some people choose to visualize and remember both

Figure 4.20. Topographic 2D map of Skyrim made by T Cook (CC0).

the present and the past. In the case of *Skyrim VR*, the baseline map I created in *QGIS* can conceivably be used to compare how the land of Skyrim itself has changed between the 2011/2017 incarnation and the early 2020s release of the next iteration of the *Elder Scrolls* series. For procedurally generated landscapes (e.g., *No Man's Sky*, Chapter 5), GIS maps might be used by archaeologists in order to predict future placement of resources, settlements, and other archaeological features, as they have been in the natural world (Kempf, 2019; Nicu, et al., 2019).

For this case study, I used the following software programs for Mac OSX as I created a usable GIS map based on the topographic map created by T. Cook: Adobe *Illustrator* CS5 (Figs. 4.20[19] and 4.21), *Inkscape* v0.92 (Fig. 4.22), and *QGIS* v2.18 (Fig. 4.23).

19. Original, flat topographic map created by T. Cook (public domain) from: https://www.nexusmods.com/skyrim/mods/36159/ (accessed 7 February 2018).

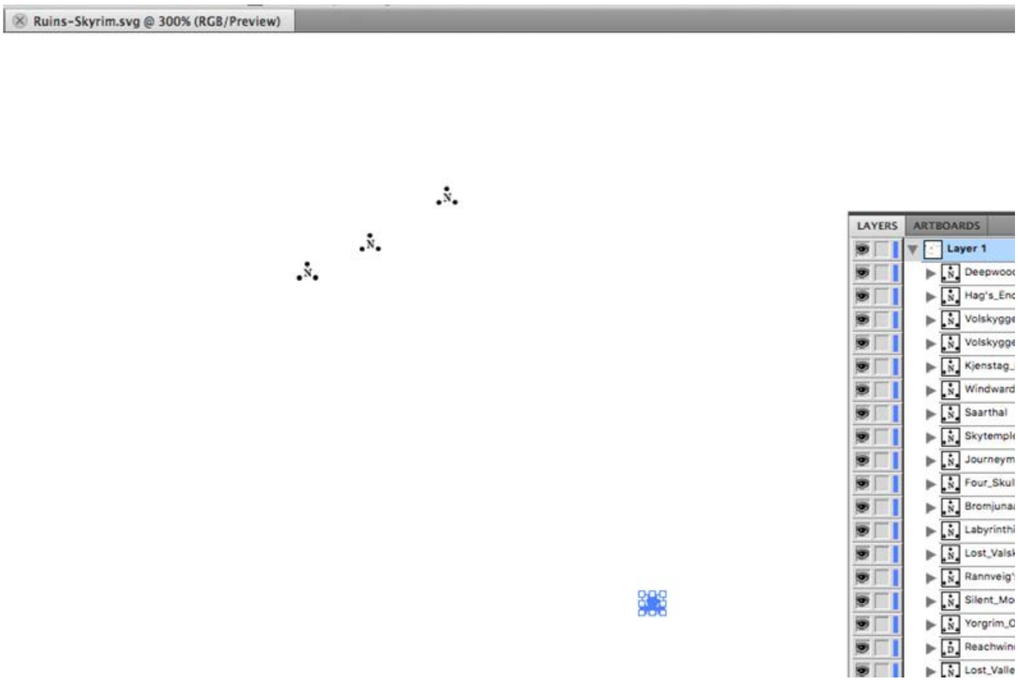


Figure 4.21. Ruins SVG layer as seen in Illustrator.

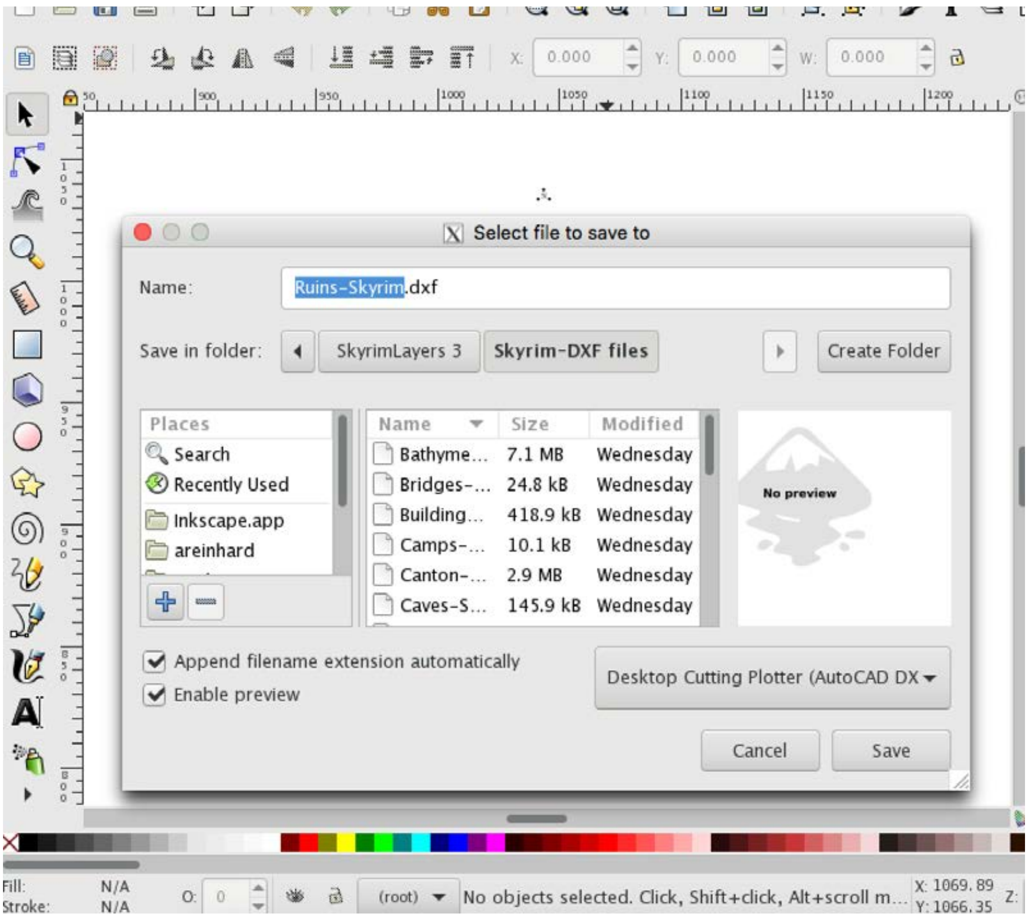


Figure 4.22. Converting the SVG file to a DXF file in Inkscape.

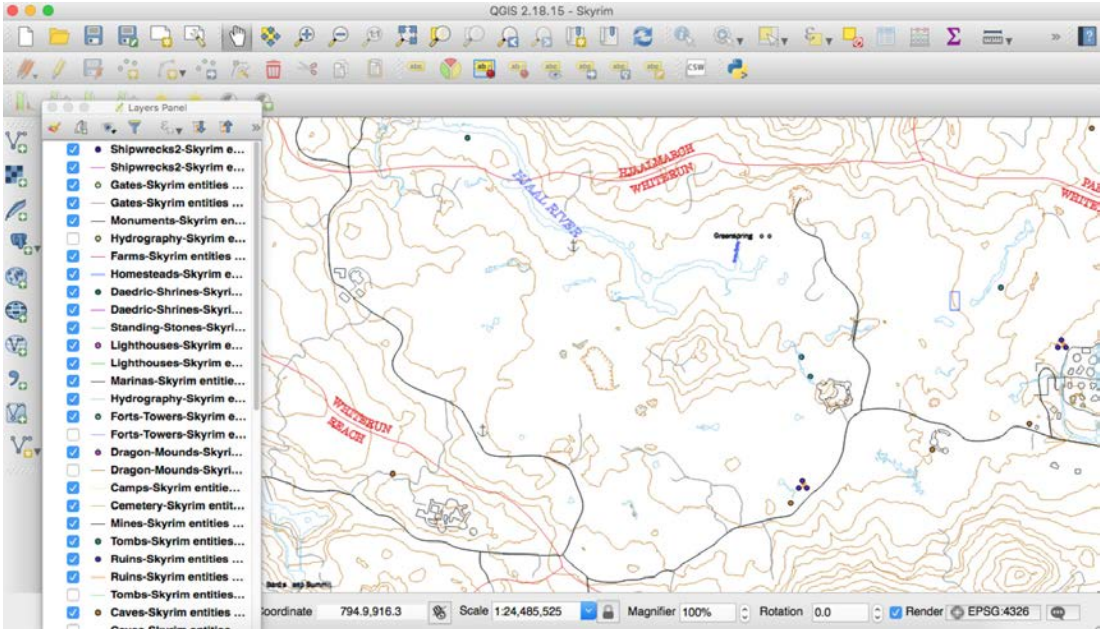


Figure 4.23. Completed QGIS map of Skyrim with layers.

See Appendix H for technical instructions on how to do this.

4.4. Landscape Archaeology in Synthetic Worlds

In completing my archaeological investigation of a landscape in *Skyrim VR*, I followed the definition of "landscape" as defined by Tilley and Cameron-Daum in *Anthropology of Landscape* (2017): [20]

> Landscapes gather. They gather topographies, geologies, plants and animals, persons and their biographies, social and political relationships, material things and monuments, dreams and emotions, discourses and representations and academic disciplines through which they are studied. So landscapes are mutable, holistic in character, ever-changing, always in the process of being and becoming.

The landscapes described in the above quote can be either natural or synthetic (although I assume that the authors only had natural landscapes in mind).[21] As an archaeologist, I was curious to see if I could conduct landscape archaeology in *Skyrim VR*, but do it in the immersive world of the virtual reality (VR) edition of the game. Granted

20. This book and its definition of "landscape" has been well reviewed and generally accepted. For reviews, see e.g., Stobiecka (2019) in the *Polish Journal of Landscape Studies*, and Houlbrook (2018) in *Time and Mind: The Journal of Archaeology, Consciousness and Culture*.

21. I emailed Prof. Tilley about this on 7 May 2019 but received no reply.

the game is a 100% designed environment that has been documented by the user and game journalism community for the past six years, and at first look it would seem to be a pointless exercise to archaeologically investigate something where there are theoretically no mysteries. I suggest, though, that software design is a formation process that sculpts the landscape inhabited by users, and that the landscape created by that process is not devoid of secrets that archaeologists are good at uncovering in order to bring additional understanding to how people and landscape affect each other.

Eve's PhD thesis and his 2012 article on augmented reality, phenomenology, and landscape archaeology provided the necessary framework for me to undertake my Skyrim explorations. I wanted to follow Eve's methodology of using one's senses and the landscape to navigate towards a small village in the game. I was curious to see if I could hear things going on in a village before I could see the village, and if my proximity to the village would trigger events that I could observe and perhaps reproduce. This marked the beginning of an intensely rich investigation of the landscape (the valley of Rorikstead) as told through a narrative of a walk thought the environment in VR (Reinhard, 2018b).

What worked here—conducting and recording short walks through the landscape to a central feature from different directions, cataloguing flora and fauna in the surrounding area and comparing it to the goods found in the village's buildings, comparing ruins found in the valley to contemporary practice of worship in the village—can also work in future, procedurally generated environments that contain a cultural component, something I test in my third case study (Chapter 5) in *No Man's Sky*. I was able to successfully use Tilley and Cameron-Daum's methods in a synthetic world to document their eight characteristics of a landscape, in this case the Rorikstead Valley:

Nature	Valley wilderness meets village domestication and cultivation
Habitat	Mild weather and peaceful neighbors lead to a peaceful village
Artefact	Likely the result of a receding glacier
System	People and land co-exist for non-exploitive subsistence
Problem	Remoteness leads to personal and provincial isolation
Source of Wealth	There is enough to survive on, but nothing to advance wealth
Ideology	Local shrine to Akatosh and valley shrines to Talos and Zenithar
History	Recent, Fourth Era village atop possible prehistoric settlement

The VR technology enabled this exploration and provided the bridge between technical experimentation with actual interpretation of archaeological evidence in a synthetic world. This naturally led me to consider more theoretical questions about working in a digital space, and how VR spaces compare and contrast with the presentation of heritage in the natural world.

4.4.1. Phenomenology and Interpreting Heritage in *Skyrim VR*

VR technology encourages embodied exploration of a place, and allows the user to better understand how a human can experience a space or place, and get a better, human feel for time and distances between things, even when one is not at the actual site itself. *Skyrim VR* facilitated this embodied exploration well, communicating time, distance, and scale at a generic, human size, supplementing the experience with audio design and haptic feedback through the controllers (e.g., vibration triggered by nearby falling debris). The player is in-the-world as opposed to being a passive passenger in a flyover of a reconstruction or landscape. It takes real time and effort to explore and experience Skyrim.

The scholarship on phenomenology is already rich. One need only reference the works of Merleau-Ponty (2004), Heidegger (1996), Husserl (2012), Tilley (1994), and Ingold (2000) to see that landscape is to be observed and perceived, that it affects action in both human and non-human agents, and that these agents in turn impact the landscape to affect both conscious and unconscious change. Their thinking is advanced by Barad (2003) and Haraway (2016) who no longer place people at the center of the landscape and its formation processes, but move them off-center as one of many agents of activity that intersect with space, focusing instead on materials and the interactions between materials, human-human, human-nonhuman, and nonhuman-nonhuman relations and reactions. The focus on the interaction of materials and agents, where landscape itself is an agent allows us to consider alternative landscapes, what they are, how they work, and how they can be observed as phenomena. Archaeologists can engage with the phenomenon of a landscape through direct, bodily observation, throwing themselves into the environment in an attempt to experience the world from a potentially ancient, experiential, sensual point-of-view. *Skyrim VR* sits somewhere in the middle of phenomenology and the calls for decentralization of humans in the landscape. Digital environments persist without direct human involvement—the world of Skyrim persists without human players—yet, the digital environment changes with the presence of a human agent. Human presence in Skyrim changes the landscape and its digital inhabitants from passive to active.

Tilley and Cameron-Daum (2017, p. 298) feel that a landscape's significance derives from it being a dynamic, holistic, material presence through which we can creatively think people's social worlds, using the medium of the material world that they inhabit. All archaeologists engage in the creative act when bringing their experience and interpretations to bear on whatever it is they observe, be it a thing or a landscape.

The material merges with the human need to create, to bring order. Latour (1993, p. 7) dubbed this junction "nature-culture," a way to understand the inherently interconnected nature of Cartesian opposites. The dualism of nature versus culture is false, something observable in *Skyrim VR*. The game's design explicitly ties the landscape to the fictitious race of the Nords within it. Throughout the realm of Skyrim, the clothing, architecture, history, and even wild and domesticated animals, fruits, and vegetables reflect the harshness of what lies beyond a firelit tavern. The wintry landscape shaped the Nords while they, in turn, made their home within it.

Tilley (1994, p. 12) states that phenomenology involves the understanding and description of things as they are experienced by a subject. "It is about the relationship between Being and Being-in-the-world. Being-in-the-world resides in a process of objectification in which people objectify the world by setting themselves apart from it." This definition is echoed by thing-theorist Bjørnar Olsen (2010, p. 63), who says that, "phenomenology is concerned with the world as it manifests itself to those who take part in it." To both Tilley and Olsen, people are at the center of phenomenology, even if they are not the things being observed. Olsen (2010, p. 63) defends this anthropocentric approach to phenomenology: "1) our relatedness to the world. We are entangled beings fundamentally involved in networks of non-human beings. 2) We relate to the world not (only) as thinking subjects but also as bodily objects—our 'being-in' this world is a concrete existence of involvement that unites us with the world." This approach is clear in digital environments as well: we log in to the synthetic world for the specific goal of being involved with it and within it.

It would seem to both Tilley and Olsen that humans are creators of phenomena by being present to observe them. This is perhaps more true when investigating synthetic spaces, which would seem to require the presence of a human agent in order to spawn a landscape or trigger an event or series of events. In digital built environments, reactions between phenomena wait for that human nudge, unlike natural phenomena, which do not require human intervention at all in order to interact with other phenomena. This may very well be the case in *Skyrim VR*, but it is impossible to observe whether the non-human agents cease their movements when a player logs out, or if they continue walking along their programmed routes, even after the player turns out the lights.

Synthetic spaces and the synthetic things within them are phenomena. We perceive them as such, humans observing the non-human. Through our observations we apply our humanity to that which we observe. "The profoundly nonhuman experiences of material objects and agents are consequently modified or obscured through this process of human perceptual legibility" (Pasek, 2015). The observation of the nonhuman gets even more complex in synthetic spaces where things appear to be what they are not. Their matter is arranged to create the appearance of something composed of other matter that is assumed by the viewer. Pixels mimic wood and stone (for example) giving implied materials and materiality. Smith calls this a *veil of appearance* that stands between one's visual experience and the external object (Smith, 2012, p. 18). The archaeologist must continually remember that they are perceiving two phenomena at once: an organization of pixels and the things those pixels are organized to represent. One could consider this representation to be a kind of sign or symbol. Eduardo Harris (2013, p. 66) writes that, "the real is more than that which exists . . . . The lives of signs, and of the selves that come to interpret them, are not just located in the present, or in the past. They partake in a mode of being that extends into the future possible as well." Phenomenology is timeless, governed by symbols and representations of things, especially in digital spaces. People conflate "real" with "tangible", but working in a digital space negates that false assumption. In the digital space, seeing is believing as we observe the representation of something and unconsciously make the connection that what we are seeing is not a representation, but the thing itself. So what exactly is being perceived in a digital environment? Is it a phenomenon, or is it something else, perhaps something more?

Karen Barad (2003, p. 814) departs from the human-centered approach to phenomenology, making the case that phenomena are defined by their interactions with both humans and non-human agents (whether or not they are observed), and are themselves products of their materials. We have become post-human in this approach that "allows matter its due as an active participant in the world's becoming, in its ongoing 'intra-activity'. It is vitally important that we understand how matter matters." Barad continues:

> Phenomena are produced through agential intra-actions of multiple apparatuses of bodily production. Agential intra-actions are specific causal material enactments that may or may not involve "humans." Indeed, it is through such practices that the differential boundaries between "humans" and "nonhumans," "culture" and "nature," the "social" and the "scientific" are constituted. Phenomena are constitutive of reality. Reality is not composed of things-in-themselves or thingsbehindphenomena but "things"-in-phenomena (2003, p. 817).

Barad therefore bridges the gap between understanding phenomena of the natural and synthetic worlds. In the instance of objects in digital spaces, we see things-made-of-things bounded by coded natural and social laws. They are created by interactions and relationships; the interactions define the things as phenomena. But while phenomena are identified by their interactions, they are defined by their underlying materials.

Ingold (2007, p. 3) questions if we "might not learn more about the material composition of the inhabited world by engaging quite directly with the stuff we want to understand: by sawing logs, building a wall, knapping a stone or rowing a boat? Could not such engagement – working practically *with* materials – offer a more powerful procedure of discovery than an approach bent on the abstract analysis *of* things already made?" This observation might not be applicable to synthetic worlds where everything is composed of the same material. But even if all that we see in these worlds is made of pixels, those pixels are coded to behave in different ways. This digital raw material is encoded with data, transmuted into lead as well as gold. We can then abstract meaning from what these pixels come to represent. These pixels then are not the "bland homogeneity of different shades of matter but a flux in which materials of the most diverse kinds – through processes of admixture and distillation, of coagulation and dispersal, and of evaporation and precipitation – undergo continual generation and transformation" (Ingold, 2007, p. 7). Into what are these pixels (and in procedurally generated spaces, voxels—3D pixels) transforming?

We might consider these pixel-based creations to be "digital-beings," as described by Joohan Kim. To Kim, digital-beings "lack the essential properties of "thingly beings"—duration in the world-time and location in the world space (2001, p. 87). Digital-beings are not beings in any sense of being self-aware, but are instead things made of digital material that exist in synthetic space. "Digital-beings such as virtual billiard balls have neither 'temporal extensions' nor 'duration' within 'objective time.' It would be meaningless to ask 'how old' the virtual billiard balls are, since they do not fit within an objective time" (2001, p. 97). With digital phenomenology, especially in digital built environments such as video games that are reproduced in the millions, we have the same things copied over and over again so that these same representations of virtual billiard balls exist in millions of places all at the same time, spawned from a few lines of code, some digital texturing, that was created once and then replicated, appearing because of some interaction in a particular part of the game. In the physical, natural world (quantum physics excluded), things can only exist in one place and one point in time. Games such as *Skyrim VR*, then, address the complex issue of profusion of examples of material culture especially from the recent past. Even though there are millions of copies of a single game (or of an artifact in that game), the digital archaeologist only needs one copy to serve as the "control" example of this digital environment. Any glitched examples or other breaks-in-presence can be collected as separate "variables" illustratrating what can emerge from interactions between human players and complex systems.

When dealing with digital material culture—especially that in VR—phenomenology gets more complex as we consider both perceived form and assumed function. There are several kinds of cups to be found in Skyrim. When I find a cup, I can pick it up, and I can rotate it to examine it up close and from all angles (Fig. 4.24). I cannot, however fill it with liquid, arguably the primary function for a cup.

Figure 4.24. Typical tavern tankard in Skyrim VR.

In *Skyrim VR*, a cup is made of the same raw, electrical material as a horse, but the cup is encoded differently, receives a different shape, a different texture, and is then placed in a spot where a cup should be normally. As a player in a VR world, it is easy to forget that the cup set before the adventurer is not a cup, not really, but it communicates its cupness through context and design. The player suspends the fantasy and interacts with the cup as if it were real. The game even assigns it a weight. It takes up space in the player's inventory even though that inventory is also just made of pixels and code, and arbitrary space created to challenge the player with either keeping the cup or tossing it aside as something that cannot fit into an overstuffed travel bag. Some players might be disappointed in not being able to take the cup with them. So what is its real use? It is a prop in the game to make a house look homely as part of an assemblage of other household items all imbued with similar purpose. It can be sold for a bit of coin (also just pixels and code). When we "hold" that cup in VR, we hold both a cup and not-a-cup, understanding both underlying meanings simultaneously, that it is both cup and code, a thing, and a representation of a thing. The cup is no longer phenomenon but phenomena, features in the digital landscape both seen (cup) and unseen (code).

Access to these digital phenomena (and to observing their interactions) are mediated through hardware. In the case of accessing *Skyrim VR*, that world may only be entered by people equipped with the technology the game requires to transmute the being into digital-being. Once we enter those synthetic worlds, however, we are struck immediately by a sense of wonder, a very real emotion prompted by an immersive digital space. As Bogost (2012, p. 124) concludes, "the act of wonder invites a detachment from ordinary logics . . . To wonder is to suspend all trust in one's own logics . . . and to become subsumed entirely in the uniqueness of an object's native logics." This is exactly what happened during my data collection within *Skyrim VR*. It was too easy to forget about the work I was supposed to be doing, or that I was sitting on a couch in New Jersey, overcome with wonder. This is, perhaps, an occupational hazard with attempting to conduct archaeological investigation within interactive digital entertainment: no danger, but rather the possibility of missing something because of some wondrous distraction. At times like these, VR-embodiment can be a hindrance to the work.

The feeling of that embodied digital experience feels remarkably like that when one experiences a natural wonder. We are beings-in-the-world, our disbelief suspended because of what our senses perceive through this new technology. For Mark Gillings (2012, p. 608), "instead of using spatial technologies to model or somehow represent aspects of human perception and experience (or claim that such technologies are capable of doing so), we should use them to explore the experiential affordances of the landscapes, events, and features we are studying."

As an open world video game, *Skyrim* (2011) was purpose-built for exploration and wonder, which was further enhanced by the addition of VR technology (2017). As an archaeologist interested in communicating in-world experiences to others, I was able to leverage technology by way of imaging in the round, and of recording my walking survey and then exporting the video for stereoscopic replay. 3D printing also enabled the creation of physical objects from synthetic space that anyone can hold and manipulate without the need for digital mediation. The game itself provided me with access to the entire landscape-site of Skyrim, and I (and others with access to the game) could repeatedly experience events and interact with features. This ability is important to the archaeologist who might need to return to trigger actions in the landscape in real-time, not just to observe, but rather to experience something. The archaeologist always becomes part of the narrative of whatever they investigate, and operating as a human agent in interactive digital space takes this to its logical conclusion.

With VR, we have finally arrived at a technology that integrates emotion and narrative with place. We can perceive phenomena and their relationships in-world as we would in nature, or we can step back to consider the underlying rules governing the appearance and behavior of the phenomena observed. With digital built environments there are always these two levels of observation. We can passively interact with the space as we perceive it normally, or we can actively engage with that environment as a purpose-built space that has other reasons-for-being that go beyond communicating data about heritage that the digital space represents.

I have described above how enjoyable it is to play a VR game that is heritage-rich, even if that heritage is a fabrication. The thing about *Skyrim* in any of its multiple editions and expansions over the past six years is that players continue to engage with the game, creating new characters to explore and inhabit a space that has become as familiar as home. In fact, players can purchase houses in several towns within the game and then decorate them. They can marry. They can adopt up to two children from the orphanage in Riften. With all there is to do in the game there are tasks for every taste and level of patience, and the list is nearly inexhaustible. The game appears to be purpose-built to keep players in that world, and to keep them coming back. Heritage organizations might take a lesson from *Skyrim*'s development team at Bethesda Game Studios and the vibrant modding community to find ways of encouraging digital engagement. These digital projects need not (and likely cannot afford to) have the scale and scope of *Skyrim*, but they can still be both fun and enlightening.

4.5. Conclusions

Everything described in this case study transpired within a 100% designed open world video game experienced through a VR headset and two handheld motion controllers observed by a PlayStation stereo camera, which translated the signals of my body into real-time motion and direction within that synthetic space. My in-game archaeological and emotional experiences were mediated by this hardware that granted me both access and agency within that space. Donning the VR rig is little different that putting on my hardhat, Class II high-visibility vest, Carharts, eye protection, and steel-toed boots in order to conduct archaeological fieldwork safely in the natural world. This gear enables my archaeological performance.

I also realize that the region of Skyrim is a designed play-space with the express intent of encouraging open, wilderness travel, while providing traditional infrastructure (roads). The map feels naturally organic and behaves like the natural world in everything from terrain to flora and fauna to how the landscape and these "human" and "non-human" agents co-exist in that space. Non-natural features in the landscape draw players ever onward and in to the world on purpose, the underlying logic in giving players places to visit and objectives to achieve. Performing as an actual archaeologist in this kind of space still yielded results and information about the designed space, a critique of its construction, but also created an understanding of the machinery of the world. The tools and methods I learned how to use within *Skyrim VR* can be applied to other synthetic spaces, but can also be used for sites and landscapes in the natural world.

Going one step further with virtual reality, mapping, and movement, one could conceivably pilot a GPS-equipped drone or robot via VR headset in order to explore remote or hostile environments, or places too small or inaccessible for people to fit bodily. When playing a VR game, one is essentially piloting a drone (albeit often in the shape of a human/humanoid avatar) whose location is constantly updated on the map in relation to surrounding features. We are already seeing this kind of mixed reality, locative mapping in relation to geographical features in games such as *Ingress* and *Pokémon Go*. It should not be difficult to transfer that technology into an interactive site gazeteer with either AR- or VR-assisted archaeology where one could conceivably survey a site remotely or, should a site or region be mapped and scanned (such as in Google Earth VR), one can bring a recorded 3D, immersive image into one's office for additional work. Time, money, politics, and other issues can prevent extended stays within an environment/landscape, so being able to take the landscape with you for remote access later should be an obvious VR benefit to archaeology. We already do this every day with games, and can use that approach and technology for conducting archaeological investigation of the natural world in a scanned, digitally produced space.

Through my interaction with the VR version of *Skyrim*, I was able to experience synthetic landscapes in an embodied way. I could handle artifacts, explore built heritage sites, and even get lost in surrounding landscapes. All of these experiences contributed to a sense of "enchantment" (Perry, 2019), where my engagement mediated through VR technology encouraged me to spend more time exploring and learning, a goal that heritage sites may wish to achieve. The other aspect of using VR inside digital built environments was that I could conduct an embodied archaeology of the spaces-as-built in order to understand design choices while also experiencing the effects of those choices as I worked. I was able to "hijack" certain game mechanics (e.g., digging or using an artifact turntable in my inventory) to conduct archaeological investigation, which was not on the developer's list of priorities.

Further options in using VR within digital heritage spaces include the minimum time of engagement with a VR site (i.e., what is the shortest amount of time in which a guest can learn and retain something before feeling the negative physiological effects of VR, such as dizziness and nausea)? How much information is too much information in a VR reconstruction of a heritage site? When people wear VR gear to engage with heritage, what do they want to do, what is instinctual for them, and how can developers guide interaction without making it feel forced/required? Cost and hardware durability remain two significant barriers to entry for public VR experiences on-site, so it may be that heritage organizations create online VR experiences for people to explore at home instead. These questions need to be considered and answered by developers of VR heritage experiences prior to writing a line of code.

In *Skyrim VR*, I was able to take a topographic map of an imagined/designed digital landscape and turn it into something potentially more useful via GIS software. Although I cannot anticipate future research questions on GIS maps of virtual worlds, at least there is now a procedure in place to instruct archaeologists in their creation, once a topographic map is in-hand. While potentially useful for understanding 100%-designed games and how design decisions of placement of landscape features can affect player movement, this same technique could be used ultimately for mapping and studying future, procedurally generated landscapes.

Having done this, one can now do similar things with procedurally generated landscapes (such as in *No Man's Sky*), or even landscapes filmed by drones and then translated to 2- and 3-D maps for detailed work. One can also create maps of graphical user interfaces in order to indicate various features and functionality, then mapping those across other examples of similar software to check for similarities and differences in both design and usage.

The *Skyrim* and, as will be seen in Chapter 5, *No Man's Sky* case studies both proved that people can scan in-game digital artifacts for exporting and printing in the natural world, creating physical examples of born-digital material culture. With *Skyrim*, the experiment succeeded in printing a designed digital artifact (a pickaxe), not from a game file, but instead through in-game photogrammetry. In *No Man's Sky*, the experiment succeeded in printing a settlement built and then abandoned by a human player. The settlement no longer exists, and the physical, printed base provides a "concrete" representation that supplements the images, video, and text description of the habitation.

Following this case study, archaeologists can now begin to consider answers to those questions concerning the crossover of material culture from the digital to natural worlds, about public use and possession of private and semi-public intellectual property, about whether shared 3D models and printing files impacts communities of use as well as developer communities who might see such capabilities as additional ways to monetize digital games and souvenirs. To date, I have not been able to find any proscriptions by games developers to 3D-printing artifacts and digital assets found in digital games. It could be that the law has not yet caught up with the speed of progress and innovation made by hobbyist-gamers who have begun to print things they enjoy from games for non-commercial distribution. I have also not been able to locate in the literature examples or analyses of 3D-printed video game assets and their potential environmental or copyright impact.

Imagine visiting a VR heritage site online, finding an artifact you like, and then paying a few dollars for the privilege of printing it for personal use. Currently players can purchase manufactured toys and trinkets for games such as *Fortnite*, but games developers could potentially save on production costs by selling printer files to customers who would then print these toys themselves. People can legally print intellectual property owned by others, and those rights-holders have the potential to monetize that demand. This introduces an entirely new class of artifact into the physical archaeological record of the twenty-first century, for better of for worse. Through the photogrammetry exercise undertaken for this case study, we now see a new class of trash, one that exissted only in the digital world, yet is now able to manifest in the natural for temporary enjoyment followed by discard.

One of the main takeaways from the *Skyrim VR* case study was the ability to enable access to 3D VR for people off-site (or those who cannot get to a site for mobility, economic, political, or logistical reasons). Although I received no explicit feedback from end-users, the fact remains that I was able to export VR video and still images to low-end platforms and hardware lowers the barriers to entry significantly to those who wish to share in a VR heritage experience while lacking the privilege of game-ownership or access to higher-end VR hardware.

With exported VR experiences, anyone can visit and explore a site to learn more about it and to play within it. The first time I experienced heritage VR was with the 360° VR video on YouTube's VR channel of the 2015 Liverpool Street Broadgate ticket terminal excavation of a suspected plague pit burial. I was awestruck by the actual scale of things, how my human body fit inside these spaces as well as in the site itself. That sense of wonder translates to additional time spent in a VR environment, and to increased curiosity and engagement, to see how the space is now, and perhaps what it might have looked like in the past (Watterson and Poller, 2017). Designing experiences like these, even at scales much smaller than contemporary open world games, can assist with fundraising and grant applications: digital heritage can make these places accessible to nearly everyone. Accessibility in this case means facilitating inexpensive means for anyone to access VR heritage content. The current literature on VR experiences (e.g., Bekele et al., 2018; Campi et al., 2019; Drossis et al., 2018; Ferarri and Medici, 2017; Han et al., 2019; Secci et al., 2019) focuses on the fact that heritage sites themselves are largely inaccessible to the public, who would therefore benefit from VR technology in order to access the sites, albeit from a distance. A few researchers, however, (e.g., Ch'ng et al., 2018; Haindl and Sedláček, 2016; Pybus et al., 2019) acknowledge the fact that the hardware and software themselves need to reach a level of accessbility for people to appreciate the VR heritage created by scholars and heritage sites. At this time, such widespread accessibility does not exist and must be provided by the creators of these VR experiences. In order for these to be made truly useful for everyone, barriers in cost and availability of things such as VR headsets must be reduced significantly or eliminated outright, along with considering sustainability for sometime in the future when that goal of accessibility can be met.

5

Case Study Three: The Archaeology of Abandoned Human Settlements in the Digital Environment of *No Man's Sky*

> Virtual worlds are places of imagination that encompass practices of play, performance, creativity, and ritual. The social lifeworlds that emerge within them are very real. They represent a complex transaction between their designers, who have certain goals and desires about what people will do, and the denizens of virtual worlds themselves, who exercise individual and collective agency. They draw upon physical world cultures in multiple ways yet at the same time create possibilities for the emergence of new cultures and practices.
> —Tom Boellstorff et al. (2012, p. 1)

5.1. Introduction: Can Real Archaeology be Done in Digital Environments?

This thesis contains three disparate case studies that demonstrate how archaeological work can be done in digital built environments. The current chapter uses the game *No Man's Sky* (Hello Games, 2016) to illustrate how traditional archaeology (survey, excavation, and interpretation) can be ethically conducted within a synthetic space and to note similarities and differences in tools, methods, and research questions between an archaeology of the natural world and an archaeology of the digital. Unlike *Skyrim VR*, a game designed for single players, *No Man's Sky* both enables and encourages collaborative play and community-building within the game's environment, which would prove to be archaeologically impactful as will be shown below.[1]

Created by a small team of developers based in Guildford, England, *No Man's Sky* is classed as an "open world sandbox" game, largely nonviolent (excepting predatory fauna and the occasional space pirate), one that has a loose narrative plot, but encourages players to explore and build in order to make the game their own by creating personal narratives. Players can roam the entirety of space, visit planets and moons, and can ultimately choose to build one or more settlements. Upon release, it was a very lonely game even though millions of players purchased it.[2] The space is so vast that in the earliest version of *NMS* it was nearly impossible to find and meet another human player. The first time such a meeting happened, it was a major news event for games media.[3] Now that two players had met in the infinity of space, could an in-game civilization of players follow, and what might that civilization look like?

Because the game follows actual (astro)physics and planetary science, it contains various star- and planet-types, each with its own subset of topographies, climates, biomes, resources, and hazards, with an incredible amount of diversity and nuance. In order to survive many of the worlds encountered, players must continually upgrade their kit of spacecraft, "exosuits", and handheld multitools, adding features and functionality through the discovery of blueprints. The better-equipped one is, the more rewarding the game. Players who invest time early on in technology can spend the rest of the game exploring the universe in relative comfort, some opting to "win" the game by reaching the center of the galaxy.

I initially chose *No Man's Sky* over other games for this thesis because of the *NMS's* scale and because of its use of algorithms to generate procedural environments.[4] The game earned international recognition for its audacity to create a game about space exploration and discovery within a universe the size of our own, with extreme distances, planets that take actual days or even weeks to circumnavigate on foot, and the promise of digitally created cultures including artifacts, architecture, and even language. Everything in the game is procedurally generated, meaning that computer code populates "seeds" of planets that bloom upon a player's arrival, using the 3D voxel data structure to determine climate, topography, and settlement down to a very fine grain.[5] *NMS*

1. For ethical guidelines in designing ethnographic research projects in synthetic worlds, see Boellstorff et al. 2012, ch. 8. In a preliminary archaeological research project I conducted in *No Man's Sky* in 2016, team members L. Meghan Dennis, Catherine Flick, and I wrote and published a Code of Ethics for interacting within this particular digital environment (Flick et al., 2017).

2. See https://steamspy.com/app/275850 for the Steam numbers, ca. 2M; plus average concurrent players = 11,000 v. 212k at launch. The website is updated in real-time.

3. "Two *No Man's Sky* Players Manage to Meet, but Apparently Can't See Each Other," Tom Marks, *PC Gamer*, August 9, 2016. https://www.pcgamer.com/no-mans-sky-multiplayer/ (Accessed 6 July 2019).

4. Procedural generation uses computer code routines as a kind of programming shorthand to create and populate environments.

5. A voxel is the 3D version of the pixel. Voxels are used in 3D software applications and contain im-

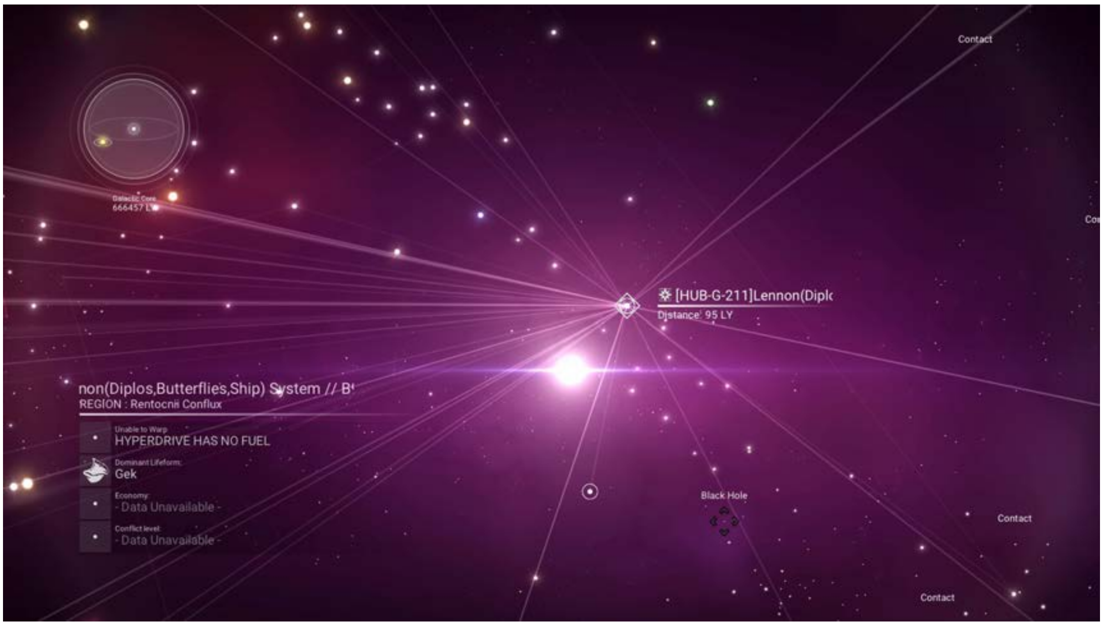


Figure 5.1. Star map of the Galactic Hub region, 22 June 2018, showing the capital planet, Lennon, and related worlds.

differs from other games in the space- and science-fiction genres because of its sheer scale and the presentation of environments as actual size. For example, one might see a building on the horizon that is 5,000 m away, and it takes an actual, real hour to walk there (or a few actual, real minutes to drive).

While archaeologically interesting in and of itself, *No Man's Sky* became more relevant to traditional archaeological approaches when studying the settlements of a community of hundreds of human players in a region of the universe now known as the Galactic Hub (Fig. 5.1).[6] This Utopian enclave adopted the game as a secondary habitation supplementing their residences in the natural world, spending hundreds or thousands of person-hours exploring, building bases and farms, and creating a robust community of players who shared wealth, resources, and knowledge. Established for over a year, the community was upended by the catastrophic event of a software update, version 1.3 (also known as Atlas Rises). The update literally changed the names, climates, and topographies of every planet in the universe without warning. The "paradise"-class planets—temperate, resource-rich worlds—occupied by Hub citizens were now extremely hot, cold, and/or toxic. Within a week, the community took the decision to uproot themselves and conduct a climate-induced mass migration to a more welcoming part of the universe.[7] It was the first time that a large group of human players was displaced by a digital climate change event, creating an exodus.

mense amounts of data. In the case of *NMS*, a voxel contains data on how to display a landscape, including elevation, features, and climate.

6. https://www.reddit.com/r/NMSGalacticHub/ (accessed 19 July 2018).

7. https://www.reddit.com/r/NMSGalacticHub/comments/6t2y4r/on_atlas_rises_content_changes/ (accessed 19 July 2018).

Figure 5.2. View of Lennon's portal surrounded by communication stations left by other players. The black-and-white icons are visible in space and invite people to find them. The green icon shows another human player, something once nearly impossible to encounter. During my work on Lennon I would frequently see other players visiting as heritage tourists.

After 11 August 2017—the date of Atlas Rises—players began abandoning their settlements. Many left messages behind for others to find. On the Hub's capital planet of Lennon (renamed by the update to Drogradur NO 425),[8] the community held a farewell party leaving behind dozens of messages prior to heading for the stars (Fig. 5.2).[9] This was the digital equivalent of the Dust Bowl in the United States in the 1930s, farmers leaving Oklahoma to find their fortunes elsewhere now that the land was killed by drought and heat.[10]

With the v1.3 update, I could now investigate patterns of original human settlement in a digital space, as well as patterns of abandonment, creating a gazetteer of these sites. I could record the contents of the messages left behind, and document the state of the abandoned, ruined, and buried bases, reconstructing life in the Hub before the change. During my work, I could also communicate with the Hub's current community, sharing my work on their abandoned homes, providing a kind of closure for those who were curious about how their homesteads look now. There was some urgency in

8. The choice of the Hub's original capital planet was voted upon by the Hub's player community in early 2017, with 60% of the votes cast for Lennon (https://www.reddit.com/r/NMSGalacticHub/comments/5ksmix/hub_capitol_announcement_hubg211_lennon/. Accessed 14 July 2019).

9. https://www.reddit.com/r/nomanshigh/comments/6tyvxn/the_portal_party_last_day_in_the_old_galactic_hub/ (accessed 19 July 2018).

10. As of this writing, scholarship about human occupation in *No Man's Sky* specifically has only been published by one author, Kevin Schut, "Hello Games' *No Man's Sky*", in *The Routledge Companion to Imaginary Worlds* (Mark P. Wolf, ed.), pp. 425–32 (2018). No other archaeological or anthropological article or monograph about *NMS* exists yet in scholarly literature. While Schut does not address directly the archaeology of *NMS*, he does hint (p. 425) at the potential of archaeological work within a procedually generated game-space: "[*No Man's Sky* is] undoubtedly an excellent case study for considering the possible strengths and weaknesses of imaginary worlds constructed by algorithms, rather than direct human intention."

this case study as well, as the next major update, version 1.4 (aka NEXT), was scheduled to deploy on 24 July 2018, which would likely reset the universe again, potentially destroying all previous habitations from 2016 and early 2017. My project became a salvage operation.

Below I outline my research questions established prior to beginning this case study in April 2018. In the next section I detail the methods used in the case study, and present my method and analysis of 30 site reports, a note on mapping, georeferencing, and videography in a digital universe, the results of my work and interpretation of the data, how I interacted with the displaced Hub community, and a reflection on my approach to the project and its success in responding to my research questions.

5.1.1. Research Questions

In their book on ethnographic methodology when studying virtual worlds, Boellstorff, et al. (2012, p. 6) state that, "we want to make clear that we advocate that the study of virtual worlds be driven by research questions, not a priori methodological dogmas or preferences" (Boellstorff et al., 2012, p. 6). One does not conduct ethnography for the sake of doing so. Section 5.1 outlines three types of research questions to be asked when investigating synthetic worlds: emergence, relevance, and personal interest (2012, p. 52). Based on what I had already observed from playing over 100 hours of *No Man's Sky* prior to beginning this case study, I had two overarching goals with these questions: 1) did the behavior of a human population forced to migrate because of a catastrophe within the game mirror that of the natural world?, and 2) did my approach to the archaeology of human occupation in a synthetic space differ from archaeological approaches used in the natural world? Additional research questions followed, which I have broken down into Boellstorff et al.'s three divisions, all of which are answered in the balance of this chapter.

Emergence (new ideas from new spaces):

- How did players live on the world designated by the Galactic Hub's citizens as its capital?
- Has anyone else visited the capital world post-update? How can I tell?
- Is it possible to recreate (or reimagine) the original landscape based on what was left behind?

Relevance (observations related to archaeology):

- Can I intuit the abandonment processes in the Legacy Hub?

- What did players leave behind when they evacuated their homes?
- Are there patterns to settlement and abandonment?
- How might this migration reflect (or predict) how disaster-driven movements of populations behave in the natural world?

Personal Interest (questions driven by my own curiosity):

- Are there any update-induced, non-human-made aberrations (i.e., glitches) on Drogradur?
- What message(s) did players choose to leave for others to find?
- How does my interpretation of site formation and abandonment evidence and processes match or differ from those recorded by the original settlers?

5.2. Methods: How I Designed and Executed my Research

The Legacy Hub (née Galactic Hub) is a landscape of systems and planets in a portion of the Euclid Galaxy of *No Man's Sky*, which was settled by hundreds of people beginning in October 2016, two months after the game launched.[11] The Legacy Hub is composed of 18 regions consisting of dozens of star systems each containing between one and seven planets, some of them with moons. Each system and body within that system contains a unique identifying address composed of a 12-character numeric code, which is then translated into glyphs for use in fast-travel portals. Residents of the Legacy Hub kept detailed records about their homeworlds, and nearly always published a public address along with photos of the landscape as well as the homes and farms that they built for themselves.[12] This Utopia encouraged players to visit their neighbors, and the goods grown on farms were shared with all travelers whether they were official members of the Hub, or "Interlopers," a term of endearment for those just passing through. Although the game offers player-rewards in the form of technology upgrades and/or "units" of currency, it is up to the players to plant, grow, and farm their own resources in order to build new technologies. Hub players understand that it is easier for everyone in the community if these farms and resources are shared instead of leaving everyone to farm on their own, remaining both cash- and technology-poor.

My case study was originally meant to document the abandoned capital planet of Lennon, but with the deadline of 24 July 2018 looming, it became imperative to complete my archaeological investigations of as many of these Legacy Hub heritage sites as

11. Many of the Hub players contribute scientifically to the community largely following a nineteenth-century model of exploration, documentation, and reportage, pushing the boundaries of the local map and increasing the resulting knowledge of the regional ecosystem with every new plant, animal, and element discovered. Everything is catalogued by this group of players.

12. Typical player-base homepage: https://nomanssky.gamepedia.com/Peaceful_Pepperbase (accessed 19 July 2018).

Figure 5.3. nmsportals.github.io tool displaying portal coordinates and glyphs, which can then be used for fast-travel.

possible. My data and documentation serve two purposes: 1) to support answers to my research questions about human settlement and abandonment in a synthetic universe, and 2) to serve as a salvage excavation to preserve as much information as I could gather on behalf of the Galactic Hub player community. I realize that this second point goes against the grain of archaeology in 2019 concerning massive data collection and total excavation (see, e.g., Novaković and Horňák, 2016; Holtorf and Kristensen, 2014) but in the instance of this case study, the disappearance of these sites was guaranteed and could not be prevented, which would leave zero evidence of human settlement and abandonment post-update. Future studies of human settlement in digital environments will likely have more time to conduct fieldwork in a way that is not of a crisis mentality, but one must be prepared for the eventuality that future access to these digital sites is limited and might ultimately disappear.

This section details the methods I used on how to locate an abandoned heritage site within the Legacy Hub, and what I did once I got there in order to understand and create a preliminary publication of its archaeology.

5.2.1. Location

Because the universe of the game is the actual size of our own natural universe (albeit contained within a server farm), it is easy to get lost, and is nearly impossible to stumble upon ruins of an abandoned human settlement. While the capital planet of Lennon was easy to find and record, other systems, planets, and bases needed external signposting. The Galactic Hub had created a page on their wiki, which listed planets with abandoned bases, each with their own links and pages.[13] Many of these contained dedicated addresses that could be converted into glyphs via the open source tool, nms-

13. Galactic Heritage Archive homepage: https://nomanssky.gamepedia.com/Galactic_Heritage_Archive (accessed 19 July 2018). Consulting the wiki as well as other Hub-authored documentation online reflects the methodology of Boellstorff et al. in their 2012 handbook on ethnography and virtual worlds (p. 6). External resources help inform work within digital spaces.

portals.github.io (Fig. 5.3). Systems and planets without explicitly published addresses could have their approximate locations inferred via naming conventions, through oral histories—which included galactic landmarks/waypoints/features—or galactic georeferencing where I was able to match nebula clouds and constellations followed by dead-reckoning to certain locations. To maximize my time, I opted for the low-hanging fruit of known addresses whenever possible, broadening my search later in the project.

Ordinarily with a site-rich landscape, one creates a sampling strategy of sites to visit. For this study, the more sites I documented, the more useful the data would become to establishing connections tying each of the sites together, a method described by Boellstorff et al. (2012, p. 59).

With the Hub, I was given a list of sites known and thought important by the community's leadership. Because the Atlas Rises update release date loomed with the threat of changing landscapes and destroying/burying sites, I organized the site-list in the order of ease-of-access. The first sites to find were those often visited and recorded by players on reddit, and ones with easy-to-discover locations within relatively short distances of the capital planet, Lennon. Fortunately I was able to visit and document each site on the list. Had I tackled this same project in the summer of 2019 with the major update of *No Man's Sky: Beyond* on the horizon, I would have had to create a sampling strategy and a separate strategy for survey and excavation. By July 2019, *NMS* allowed for multiple player-bases on individual planets (instead of one-per-system as in 2016/7). Also the Hub census had grown from an original roster of 175 players in *No Man's Sky: Pathfinder* (2017)[14] to 509 in *No Man's Sky: Atlas Rises* (2018)[15] to 754 in *No Man's Sky: NEXT* (2019),[16] many of whom chose to build. Note that players must opt in to the Hub's census, and it is likely that many other players occupy this region of the game without explicitly completing the census form. Also, because the Hub has had to move twice after its original creation, the census for each game update must be compiled freshly, as not all Hub players chose to abandon their settlements in earlier Hub regions.

Player demographics and other statistics for any video game are difficult to find, but games hosted on the Steam platform benefit from the service's player statistics. On 14 July 2019, I checked the all-time player history for *NMS* on Steam, which showed that the greatest number of concurrent players on PC was 212,321.[17] Average daily players hover anywhere between 3,000 and 5,000, with peaks and valleys. During major game updates, the number of players spikes. In June 2018, the month before the deployment of *No Man's Sky*: NEXT, the average number of concurrent players on PC was 1,035.

14. https://nomanssky.gamepedia.com/Census_-_Galactic_Hub_(Pathfinder) (Accessed 14 July 2019).
15. https://nomanssky.gamepedia.com/Census_-_Galactic_Hub_(Atlas) (Accessed 14 July 2019).
16. The current census is posted on the Hub's wiki, updated regularly: https://nomanssky.gamepedia.com/Census_-_Galactic_Hub (Accessed 14 July 2019).
17. All statistics gathered via: https://steamcharts.com/app/275850#All (Accessed 14 July 2019).

When the update launched in July 2018, that number ballooned to an average of 14,554 players, and then 28,083 in August before falling back to 5,911 in September once most players had finished exploring the game's new content. Note that these statistics only reflect players on PC via Steam. To date there is no way to see similar statistics for players on PlayStation4, although the GameStat utility shows an average monthly player-count of 64,000, making the PS4 platform the preferred one for players of this game.[18] The age and gender of players is unavailable for all platforms, and even though the Galactic Hub has a formal census,[19] it does not collect any personal data, instead opting for gamertag, reddit username, game platform, home system/planet, date of arrival in the Hub, and game mode (normal, creative, survival, permadeath).[20]

Once I had an address of a settled planet in the Legacy Hub, I activated the portal on Lennon to enter the coordinates. Arriving on the new world, I set a galactic waypoint through the game's Discovery interface, and then returned back through the portal in order to board my starship. Establishing an orbit over Lennon, I activated my star map and then navigated to the waypoint I marked earlier. Planets in the Hub are rarely farther than 1,000 light years away from any other Hub world, which means typically only one jump through hyperspace is needed to get to an abandoned heritage site. Understanding and then utilizing game mechanics (i.e., how things work in a game) became crucial to making efficient use of my time in this space as an archaeologist, and should serve as something future digital archaeologists must be aware of prior to beginning a project in synthetic space. If I had not understood how the game worked—especially with regard to travel—I would have documented many fewer sites than I did.

Upon arrival in an abandoned system, I scanned it through my head-up display (HUD) to identify the location of the old player base. When conducting this research in 2018, the game permitted only one base per system, so if the base survived, it would appear on its original planet as either a flag icon or a colored beacon icon (Fig. 5.4). Once identified, it was only a few minutes' sub-light-speed travel to the old homeworld of a player.

Upon arrival above the planet, icons for communication stations would appear, indicating messages left behind by other players (Fig. 5.5). Clusters of these icons indicated an area of archaeological importance, typically either a base or a portal. On some occasions when bases could not be scanned from space, arriving at these clusters would reveal the presence of a human-built structure.

18. http://gamstat.com/games/No_Mans_Sky/ (Accessed 14 July 2019).

19. The Galactic Hub census form can be completed here: https://docs.google.com/forms/d/e/1FAIpQLSc7v3iy-Wm-hwKK_nnWBkZoa_95A-qM7ZCxjIoMRdLpqp8ChQ/viewform?c=0&w=1 (Accessed 14 July 2019).

20. Players can choose between three modes of play. "Normal" mode offers a standard gameplay experience where people must make an effort to gather resources an explore the universe, occasionally dying only to be resurrected to continue the adventure. "Permadeath" mode means that once a player's avatar has died, the game is over. "Creative" mode allows players a mortality-free experience with infinite resources for constructing settlements.

Figure 5.4. Special icon and notification of the location of a player's base.

Figure 5.5. Player-base identification and communication station indicators on an abandoned world in the Legacy Hub.

After landing near a base, I would record the coordinates given by the local signal booster (if present), or I would construct my own in order to confirm the precise location of the base not only on the planet, but also in the universe. This is not unlike assigning a set of GPS coordinates to an earthbound feature. Translating these into glyphs, I would enter both the numeric and glyph versions of the site's address into my log for that particular planet, treating it as a discrete site within the landscape of the Legacy Hub. These addresses enable future visits by heritage tourists—a phenomenon that already exists in *No Man's Sky*—and allowed me to return to each of these sites after v1.4 deployed in July in order to see what damage, if any, occurred based on the software update. As of this writing, all of the original Hub settlements have either been destroyed or buried beyond the maximum depth allowed by the game's design, out of reach, because of subsequent major game updates.

5.2.2. Reconnaissance and Mapping

Reconnaissance

I conducted three levels of reconnaissance prior to doing any physical work at a given site: orbital, suborbital, and terrestrial.

A. Orbital Reconnaissance: A *No Man's Sky* starship is a versatile piece of mobile hardware. Upon arrival at planet, I treated it like a satellite, taking images from space of what was often a planet-wide dispersal of archaeologically significant sites. I could easily identify clusters of features from space, marking those as primary points of interest to be explored first. I also took the opportunity to calculate the circumference of the planet, which would allow me to calculate volume. I learned that planets can be classed into two sizes, and moons have their own diminutive size.
B. Suborbital Reconnaissance: Having identified points of interest from space, I then entered the atmosphere and flew to the main clusters of communication stations as well as to the abandoned base itself, noting their locations in my paper notebook. Prior to touching down, I flew to other icons indicating places of interest, deciding which to review first, and which to visit later.
C. Terrestrial Reconnaissance: Returning to bases or comm-clusters, I landed in a location within walking distance (1–2 minutes) of the feature/structure so as not to interfere with its composition as well as with site photography. On occasion, my presence within a site would alter its location and/or contents (as described below), so it was important to keep my distance and approach on foot

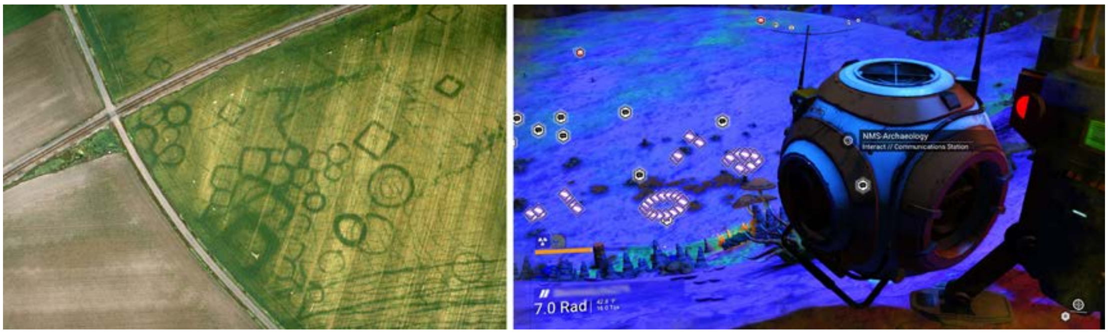


Figure 5.6. Remote sensing revealing cropmarks at the protohistoric site of Grézac, France (l.), and cropmarks at the site of Syn1334's base (r.). Images by Jacques Dassié, CC-BY2.5 (l.) and Andrew Reinhard, CC0 (r.).

with discretion. I also had the opportunity to engage in remote sensing. Game mechanics allowed for disturbance-free sub-surface scans, which could return evidence of buried, human-created structures (Fig. 5.6).

Mapping

Depending on the site, I created between one and three maps of it.

A. Pen-and-ink: It was easiest first to hand-draw a map in my paper notebook of sites that had multiple items of archaeological interest in various spots around the globe. I drew the base (or other fixed point) on the center of the page with north at the top. Standing at that fixed point, I then rotated 360° clockwise from north, stopping to mark icons as they appeared. These icons indicated a walking-time to them. I indicated the compass position and time on the map as well as any other landscape features (e.g., mountains, ridges, floating islands, water, etc.).
B. Time-maps: After completing my investigation of a site, I created a digital time-map in Adobe Photoshop CS5 based on my paper map. The time-maps had the key feature (typically a player base) in the center, with comm stations, portals, and other areas of interest marked within a compass rose. Because planets in *No Man's Sky* v1.3 only have cardinal directions and no reliable Cartesian grid, archaeological and landscape features are relative to the fixed point. I know that the site of a base is fixed, and can create a reliable map indicating time, distance, and direction of travel to other features, which may or may not remain in the future. To the best of my knowledge, this is a new kind of map, differing from those ancient maps listing how far one can travel in the course of one or more days. The fixed point of the base is treated as the planet's pole, and all directions stem from that immovable location (Fig. 5.7).

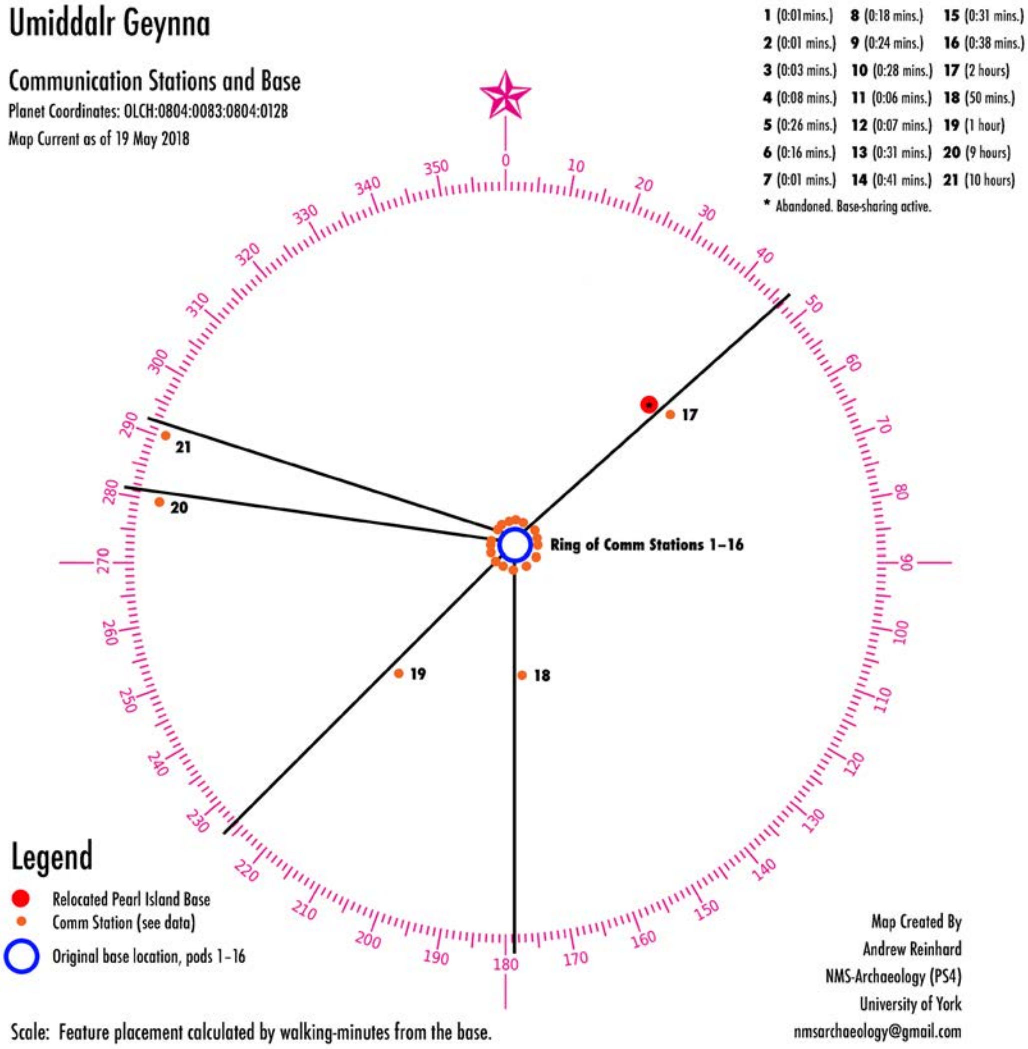


Figure 5.7. Sample time-map showing the location of a base, portal, and communication stations.

C. State plans: On rare occasions I found base locations with dozens of communication stations and other features (e.g., beacons, save-points, and signal boosters).[21] For these, I took overhead photos via drone (either my starship or through the game's Photo Mode, which allows players to position a camera in the sky ca. 50 m above the surface). Exporting to Photoshop, I oriented the image and identified each of the features by consecutive number on a plan (Fig. 5.8). These numbers tied into numbered rows in a spreadsheet that contained information about what was pictured, who placed it, and any other data of note.

21. Players can create their own tools in *NMS*. Beacons are permanent markers similar to US Geological Survey markers and are used for similar purposes. Save-points are portable devices that allow players to save their progress in the game from the surface of a planet. Signal boosters allow players to search remotely for structures on a planet's surface.

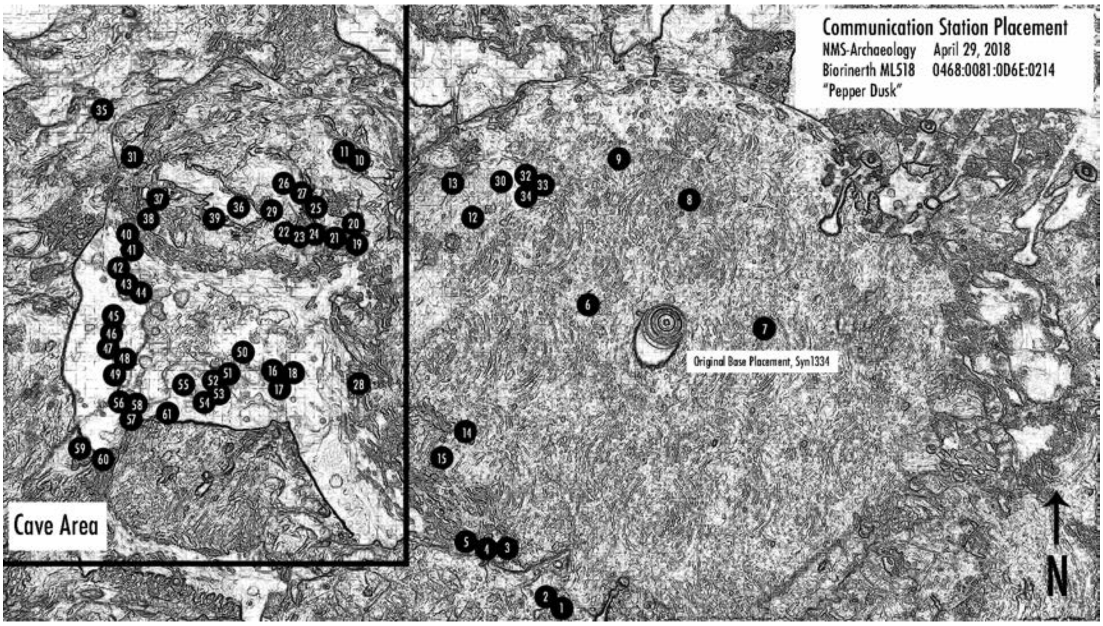


Figure 5.8. Sample state plan indicating numbered communication stations.

Figure 5.9. Sample site photo including the data from the head-up display (HUD).

5.2.3. Photography and Videography

I used the photo and video capabilities of Sony's Playstation 4 console to document each site, activating *NMS*'s Photo Mode when necessary (see below). All photos/videos were saved initially with a date- and time-stamp. I then renamed each file to indicate the order in which the file was created, the name of the planet/base, and a brief description of what was depicted. These were then uploaded to my Wordpress site as well as backed up to a 1 TB removable hard drive as well as my Google Drive at the University of York in anticipation of transferring all files and data to York's Archaeological Data Service.

Photography

I photographed each site first with *No Man's Sky*'s head-up display (HUD) active. The HUD displayed the name of the planet along with other environmental data, very much like including a scale when photographing artifacts, or a chalk/whiteboard when photographing site features/trenches (Fig. 5.9). I photographed each base within its landscape from a distance and also from overhead to get a feature's footprint. I then photographed an abandoned base clockwise: N, NE, E, SE, S, SW, W, NW. Following that, I photographed interiors including various views of rooms and their contents, as well as any other unique identifiers (e.g., base IDs and Trade Terminal IDs) in order to gather as much data as possible within each frame. After completing the initial photography, I repeated the process in Photo Mode, which removes the HUD from the frame, providing clean images. Also in Photo Mode, one can adjust the time of day, which allowed me to photograph sites in daylight and in starlight, as well as with raking light should a feature require it.

In the frequent presence of communication stations, I photographed (with the HUD on) the unit *in situ* in relation to its surroundings, and then a detail photo of it once I activated it to read the message.

Different kinds of photography served complementary functions for site documentation. The diagnostic photography taken from each compass point and from inside a player-built environment attempted to provide complete photographic coverage on the likelihood that the base would be either destroyed or buried out of reach by a future software update. These photos also allow readers to compare the images against the text of each site report. Taking the clean images provided a more "artistic" or human look at the site and the landscape in which it was situated, as opposed to an image cluttered with metadata. As seen in some of the site reports, members of the player community recorded the reasons why they chose the building sites they did, many of whom placed a high value on aesthetics rather than proximity to natural resources. The human and emotional decision-making of siting a structure cannot be overlooked; photography and videography helps with the interpretation.

Videography

After completing photography, I took two site videos: 1) walkthrough,[22] and 2) flyover.[23] The walkthrough was done with the HUD activated so that locality information was displayed throughout the video, touring the outside of a structure followed by a walk around its interior. The flyover was done in Photo Mode in order to get a full representation of the structure in the landscape. On occasion, bases and other features were buried, so it was important to show the relationship between the built structure and the planet's topography. A buried base (or buried comm stations) indicated a change in the landscape that can only occur through major software updates from Hello Games. As explained above, each major software update "resets" the universe, which includes changing planet topography and biomes. Finding a buried human settlement indicates that it was built pre-update. Finding buried comm stations shows that the settlement was also visited pre-update.[24] In the instances where I needed to excavate, I filmed the excavation with the HUD turned on.[25] On certain occasions where the base or its landscape was glitched, I would record what happened during a flyover in order to demonstrate the nature of the glitch.[26]

Three-Dimensional Video and Printing

As I did with the second case study, I wanted to attempt to create three-dimensional video and 3D printing specs for the built heritage and surrounding landscape. Three-dimensional video is important because not everyone has access to a game being studied, yet it is important to communicate discoveries in a visual way. I wanted to attempt to

22. Sample walkthrough of the Sanctuary Base, 31 May 2018: https://www.youtube.com/watch?v=BiKUbiXl-3k

23. Sample flyover of the Sanctuary Base, 31 May 2018: https://www.youtube.com/watch?v=DNhs0NBJNCU&t=14s

24. The first documented instance of excavating a buried communication station was posted to YouTube by the Hub's founder on 6 December 2016, one week after the launch of the *No Man's Sky: Foundation* update (https://www.youtube.com/watch?v=XLLlnqyTcXE&feature=youtu.be. Accessed 14 July 2019). Unlike later game updates that buried existing structures by changing the landscape, this comm station was buried intentionally, exploiting a game glitch that filled in holes made by players when other players visited the same spot. The message left by player Subtle_Augur states: "Buried comm station. –pwittygud". Because it is impossible to add a message to another player's comm station, this inscription indicates that the player buried the message on purpose for someone else to find, a hint at things to come in later updates of *NMS*.

25. Example video of in-game excavation, 14 June 2018: https://www.youtube.com/watch?v=XQbufeY3jzo

26. Sample video of a recorded framerate glitch (at 1:35), 6 May 2018: https://www.youtube.com/watch?v=bBZ25AYTE0o

Figure 5.10. In-game photo (l.) and 3D-printed model (r.) of the *NMS* player base, "Mr. McDillard's Pad."

demonstate the feasibility and relative ease and cost-effectiveness of using open source tools to communicate visually these reproductions of digital environments. I also wanted to make sure that these digital representations would be available in several formats once the source material disappeared. Although shaped by my research questions, this media can conceivably also be used by researchers—archaeological or otherwise—both now and in the future to answer additional research questions that I was unable to articulate. *NMS* is a 3D environment the features of which are best understood through immersion. For 3D printing, it is important to capture a site or artifact that can then be reproduced in the natural world in a variety of scales for preservation and future study, but the potential problem with this is the profusion of digital and printed materials. I attempt to address this issue in my conclusions (Chapter 6). For *NMS*, I used the same tools and followed the same procedures that I did in the case study with *Skyrim VR* with success, sharing the results with the Hub's player community (who responded positively on Twitter).[27]

Because this case study was conducted on a PlayStation 4, I was unable to access digital asset files, which would have made it much easier to 3D print things from *No Man's Sky*. Players on PC have easy access to files and can create high-quality, 3D-printed models relatively easily. With player-created bases, however, one must video the outside of the structure after first using the *NMS* photo settings to control the angle of sunlight and amount of shadow and contrast so as to not obscure any structural details. The video coverage cannot film underneath a structure, so one must create a solid base using software such as Agisoft or Meshlab. Any holes in the photogrammetric model must be filled by this software prior to printing in order to make it "watertight."

As of this writing, my 3D-printed model of "McDillard's Pad" is the first and only 3D print of a player base in *NMS* (Fig. 5.10).[28] It is the first time something player-

27. Sample 3D VR *No Man's Sky* video (viewable with Google Cardboard or similar app and headset): https://archaeogaming.files.wordpress.com/2018/07/abundance-flythru-3d.mp4

28. Sample 3D printable model of a *No Man's Sky* player-base: https://twitter.com/i/status/1018113866599976962

made in the game has been exported into the natural world. The model is to scale and preserves the footprint of the structure, yet instead of crisp lines the model is "fluffy" because of the low-resolution of the video used in the 3D mesh's creation. Future hardware and software should be able to create a more faithful reproduction of a structure from this game (and others), but what we have now is almost impressionistic. Its information supplements the 2D photos and video and synthetic text to provide another tool for understanding built heritage. Built heritage is not two-dimensional and can be comprehended in the round in the field. With digital built environments (or spaces appearing within digital games and other synthetic worlds), the three-dimensional aspect is mediated through a two-dimesnional screen, even in virtual reality. 3D-printing gives the researcher a way to extrapolate a 3D structure or artifact literally from 2D space, which can be scaled up or down depending on the researcher's needs. The other benefit is that the 3D-printed object is not dependent on digital infrastructure post-printing, and can exist theoretically perpetually long after the digital original is gone.

Now that I have proven that one can 3D-print artifacts and built heritage from video games, this raises at least two ethical questions: 1) what might the impact be for commercial owners of digital intellectual property? and 2) what does this mean for individual creators within commercial and non-commercial digital gaming spaces? As of this writing, the End User License Agreement (EULA) for Hello Games and *No Man's Sky*, last updated on 25 July 2018, makes no explicit mention of printing, 3D or otherwise, but does make provisions of what can or cannot be shared from the game.[29] Section 3.2 states that players are allowed to "share non-commercial screenshots and videos of your Game gameplay on your personal social media." One can interpret this as permitting 3D printing as the models are derived from player video further deconstructed into images. Because players understand that their personal buildings can be visited by others and can elect to make their constructions publicly visible, they waive their rights to having their work shared, at least in a non-commercial way. No provision is made, however, to protect moral rights of players, and it becomes murky when considering player intellectual property created within the IP of a for-profit corporation, that could then be copied and shared by third parties. This includes archaeologists-as-third-parties when investigating player-constructions. Future fieldwork within synthetic worlds that include any kind of 2- and 3D imaging should make good faith measures to connect with IP owners—which include players—prior to creating and publicly sharing those reproductions.

29. https://store.steampowered.com/eula/275850_eula_0 (Accessed 7 July 2019).

Figure 5.11. Sample of on-site georeferencing on "Dancing Bear."

Georeferencing

New to this case study, I was able to implement a program of georeferencing on a handful of occasions. Some archival records of player-bases in the Legacy Hub contained photos of the bases in their original landscapes pre-v1.3. I then recreated those photos during my site visits, ultimately lining them up as Photoshop layers to create composite images of past and present. In some cases, the results led to additional excavation of hidden features (Fig. 5.11).

5.2.4. Excavation

I often needed to conduct excavation of features and/or bases in the Legacy Hub. This was achieved in two ways: 1) using the Terrain Manipulator tool, and 2) performing a game-save.

Hand-Excavation

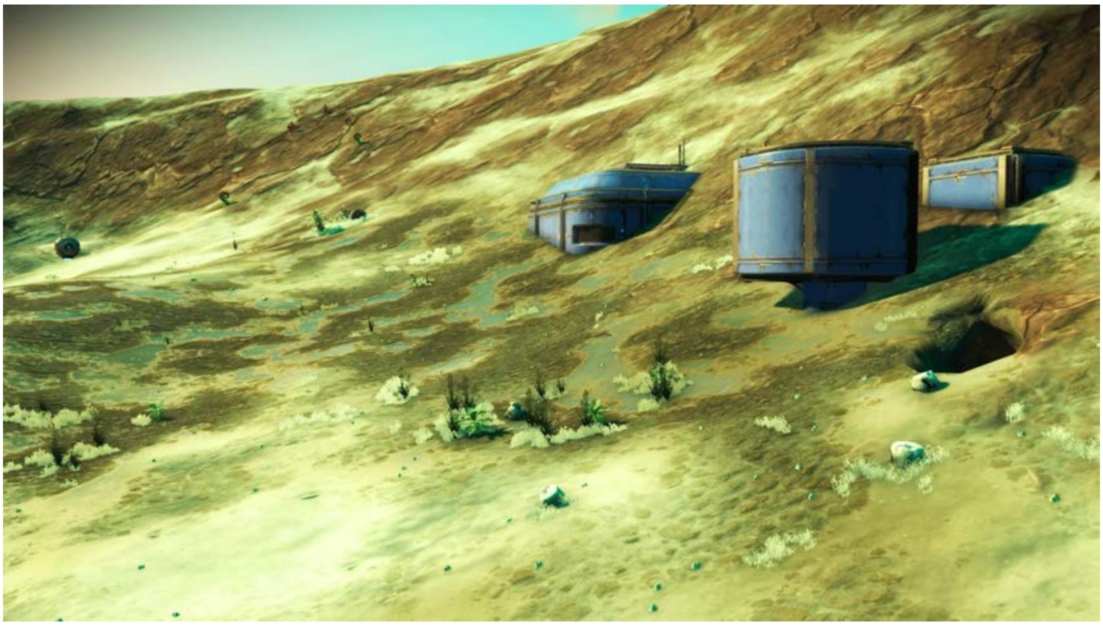


Figure 5.12. Semi-buried player base, “Langley.”

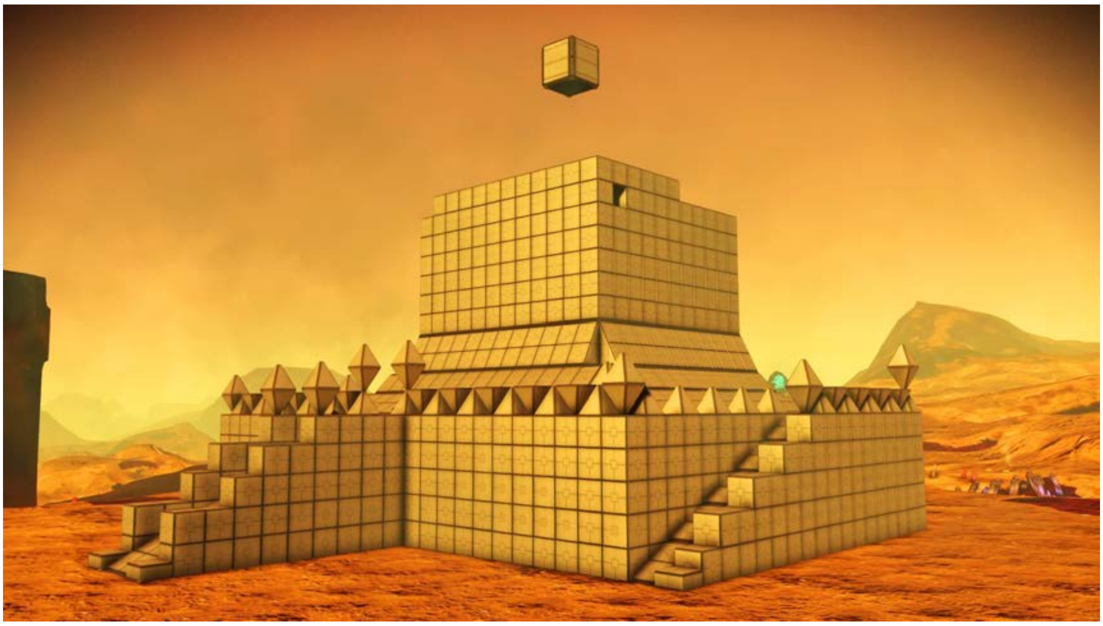
Because Atlas Rises altered the topography of every planet in the universe, the new mountains/hills/rocks would often cover up significant archaeological features, most notably bases and communication stations (Fig. 5.12). To excavate, I activated the game’s Terrain Manipulator feature of the mining tool, increasing the diameter of the hole to be dug, and then fired the tool in the direction of the buried comm station or base. The overburden would disintegrate, leaving a tiny hole a few meters deep. Continued excavation would remove additional rock until the station or base was found and recorded. On rare instances the buried feature would lie beneath bedrock, which could not be excavated. In those cases I would mark the location of the feature on my map and then move on.

There are only two levels of strata on *NMS* planets: “topsoil” and “bedrock.” Topsoil can be removed, but bedrock cannot. There are no layers to read, and the game is not yet sophisticated enough to obey the Law of Superposition. Note also that the Terrain Manipulator does not damage artificial structures, so there is no risk of accidentally “biffing” or breaking an artifact or structure during excavation.

Game-Saves

Something I discovered by accident is that committing an explicit game-save while at the site of a buried (or suspended) base will often relocate the entire base to a flat building site elsewhere on the planet, restoring the structure to its complete and original form (Fig. 5.13a–b). The issue here is of course that moving the base removes it from its context, although the communication stations remain behind to mark the original

Figure 5.13a–b. Player base, "Horner," in original context (top), and relocated/"excavated" (bottom).



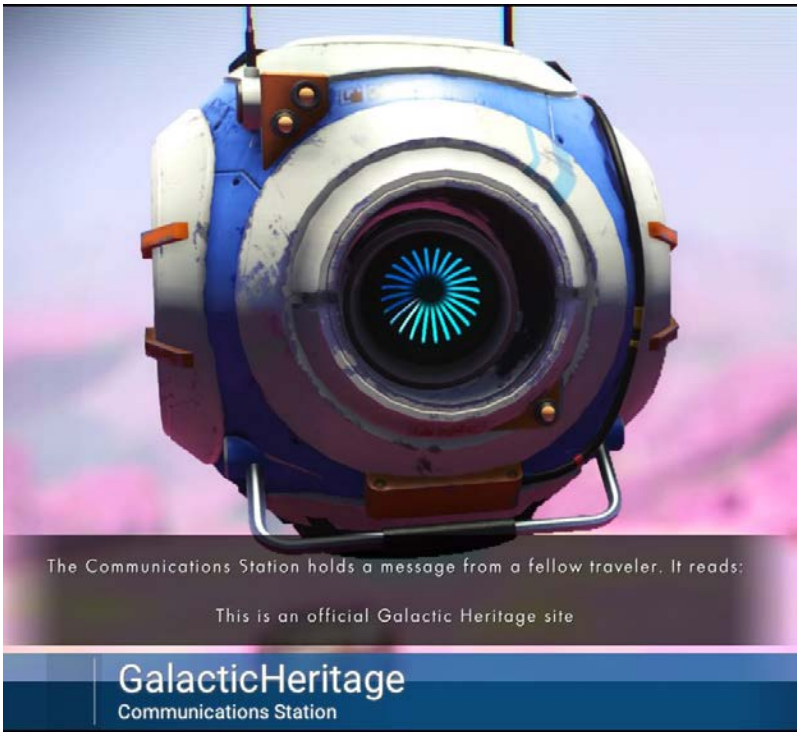


Figure 5.14. Heritage marker placed by Hub heritage coordinator Zaz Ariins at the abandoned site of "Peaceful PepperBase."

site of the base. The restoration and relocation enables the base to be visited by heritage tourists or through chance arrival, and also takes the guesswork out of what the base used to look like. On the other hand the contemporary ruins are destroyed, even though they are reassembled someplace else. In communicating this to the Galactic Hub community and the people responsible for documenting Hub heritage, the Hub's chief excutive and founder, Syn1334, and his officer in charge of Hub heritage, Zaz Ariins, both communicated on behalf of the Hub community that they were fine with relocating the bases.[30] For the leaders of the Galactic Hub, it is important to them that their community and heritage tourists see these structures as they were originally built, even if they now appear in a new location, albeit on their original planet.

5.2.5. Digital Heritage Designation in a Synthetic World

In 2018 after the release of the catastrophic Atlas Rises update, player zazariins on 2 March 2018 proposed to Galactic Hub leadership the concept of Heritage Sites, and following approval on 25 April 2018 began the Galactic Heritage Archive on the *No Man's Sky* wiki under the auspices of the United Federation of Travellers, an umbrella community group of which the Galactic Hub is a part.[31] The stated goal of the Ga-

30. Pers. comm. 25 April 2018 from Zaz Ariins, the officer in charge of Hub heritage..

31. https://nomanssky.gamepedia.com/Galactic_Heritage_Archive (Accessed 14 July 2019). I began my archaeological investigation into Lennon on 2 April 2018, and my work was discovered by Ariins later that month after he began his community-based project, establishing a professional relationship of

lactic Heritage Archive was to "document player bases, which had undergone structural transformation by the Atlas Rises biome reset (and any subsequent resets) and recognizes certain builds [bases] with Galactic Heritage Site classification" (Fig. 5.14). Heritage officer Zaz Ariins defined four major classifications of significant "builds": 1) a Legacy civilisation "capital" build (e.g., Peaceful Pepperbase),[32] 2) a landmark build made significant through player lore (e.g., the Bez-Harr Embassy),[33] 3) a grandiose, sophisticated build (e.g., the Unknown Interloper Tomb),[34] 4) a build with high "drawcard" appeal (aka tourist destinations, e.g., Ty Beecham's Pearl Farm).[35]

Ariins designated the earliest settled part of the Galactic Hub as the "Galactic Hub Project Legacy Region," which consisted of 11 settled areas by Galactic Hub-affiliated players prior to Atlas Rises. This area marks the oldest community-settled region in the game, and as such has pride-of-place among all of the player groups within the United Federation of Travellers.[36] The Legacy Heritage Archive details known sites left as ruins post-Atlas Rises.[37]

As a matter of site preservation because of the sensitivity of these locations where player agency could directly or indirectly move (or even remove) heritage sites, Ariins posted: "specific glyphs or coordinates are not being made public." Ariins would, upon request, give coordinates to sites by way of nearby systems from which players could fly in order to conduct a site visit. Ariins further warns that: "as Heritage Sites have generally been abandoned by their original architect, they are impossible to recover if someone else should settle in the same solar system. Due to this, Legacy Heritage Sites are restricted based on their assigned Significance Level. Additionally, Portals may be 'locked down' by Galactic Hub staff if they are not useful to access the system's Heritage Site, in order to discourage Portal-travelers from claiming bases and overwriting the Heritage Site." This is not unlike fenced (e.g., the Palace of Nestor at Pylos) or otherwise obfuscated site locations (e.g., such as those in the tDAR repository, the Digtal Archaeological Record) in the natural world where public access is blocked as a protective measure to guard against destruction and looting. With the software updates to *NMS*, however, the need for hiding heritage site locations was only temporary because they were ultimately destroyed by Hello Games.

The Galactic Hub was quite receptive to Ariins' idea, and offered support as he conducted his work, often helping to identify abandoned settlements in the Legacy Hub

data-sharing. I received permission to visit all of the Heritage Sites so long as I provided access to my data and media as I progressed.

32. https://doi.org/10.5284/1056110.

33. https://doi.org/10.5284/1056623.

34. https://doi.org/10.5284/1056630.

35. https://doi.org/10.5284/1056625.

36. https://nomanssky.gamepedia.com/Galactic_Hub_Project_Legacy_Region (Accessed 14 July 2019).

37. https://nomanssky.gamepedia.com/Legacy_Heritage_Archive (Accessed 14 July 2019).

region.[38] Working with Hub leadership, specifically the Hub's founder Syn1334 in April and May 2018, community guidelines were quickly established around identifying and preserving these sites in anticipation of Heritage tourists and future software updates that would likely damage these sites further.[39]

Hub Ambassador GenBra Space Corps provided additional thoughts in community archaeology methodology:[40]

> I think the best way to start would be to make a list of all the coords and portal addresses of the places you have in mind. Note all the working portals and which planet index they are. I think a list is a powerful tool. You could easily bury it on the wiki until it's ready for presentation or not. Maybe become the secret society of 'Heritage', But to have the list is the thing. You can copy any of the table formats I have on the wiki, or just send me the coords and I can make the list for you, or at least help. In the end the story might be all that's left. Pictures help, while you are there take a good dozen images of every site. I love galleries, they help tell the story.

Hub Ambassador andykrycek stated the following in his support of Ariins' heritage project:[41]

> Something that should be focused on is the history of our civilisations for sure. I speak for myself but we are hear [sic] for the long run and this is a great way to preserve such sights and memories from past occupied areas.

The Hub leadership, none of whom are trained archaeologists or heritage professionals, found their way to a very traditional approach to recording and preserving their legacy sites: lists of names and locations and media showing what the old settlements looked like prior to the next game update. They did not operate from within a formal archaeological framework, but instead took what they felt to be a common-sense approach to archiving the history of the Hub, an indigenous community taking charge of their own heritage. They recognized the fact that these sites were fragile and also that future game updates would likely destroy the record of past settlements and so took the conservative approach of hiding their coordinates as an emergency measure to prevent heritage tourists and community members from accidentally impacting ruins.

38. https://www.reddit.com/r/NMS_Federation/comments/8eymei/galactic_heritage_archives/ (Accessed 14 July 2019).
39. https://www.reddit.com/r/NMS_Federation/comments/81bn38/federation_heritage_sites/ (Accessed 14 July 2019).
40.https://www.reddit.com/r/NMS_Federation/comments/81bn38/federation_heritage_sites/(comments section) (Accessed 14 July 2019).
41.https://www.reddit.com/r/NMS_Federation/comments/81bn38/federation_heritage_sites/(comments section) (Accessed 14 July 2019).

No Man's Sky: NEXT launched on 24 July 2018, and either destroyed Legacy Heritage sites or buried them out of reach under the bedrock, which cannot be excavated with current in-game tools. All that remains are the images, video, maps, text, and community dialogue surrounding the original settlements, which are now archived via the Archaeology Data Service.[42]

5.2.6. Site Reports

Method

> "All excavators have an obligation to record their findings fully and publish them quickly. In practice few do so, or at any rate did so in the past."
> —Renfrew and Bahn, 1991, p. 480

Having received permission from the Galactic Hub leadership to survey and excavate their heritage sites, one of the core elements to my archaeological method in *No Man's Sky* was to write and post immediately (and publicly) about a site that I had just finished documenting. For this case study I visited 30 abandoned bases, took 161 videos and 2,931 images, and have noted something unique to each and every base. These sites continued to surprise me throughout the survey until I reached a stopping point where an abundance of data and eventual repetition indicated I had done enough. The release of *No Man's Sky: NEXT* added final closure to the project.

I wanted to incorporate rapid reporting into this project so that the public, the player community, and other archaeologists could follow my work as-it-happened, following Renfrew and Bahn's (1991, p. 481) publication mandate to reach wider audiences. Posting the site reports on the *Archaeogaming* blog was immediately followed by the reposting of a report's link on the Hub's subreddit by Hub founder Syn1334 for the benefit of its 10,000+ subscribers. These posts would allow for members of the Galactic Hub to correct any mistakes I made in interpreting the material remains of the Legacy Hub settlements while encouraging a sharing of oral histories by the original architects of these habitations (e.g., Abundance H.Q.[43] and Mr McDillard's Pad[44]). This type of preliminary posting also followed the public engagement strategy laid out by Boellstorff et al. (2012, p. 188): "Blogs allow authors to instantaneously publish their work online and can permit useful forms of commentary and intellectual engagement. . . . For ethnographers of virtual worlds, blogs can serve to disseminate research findings with colleagues and also the communities we study." What Boellstorff, et al., do

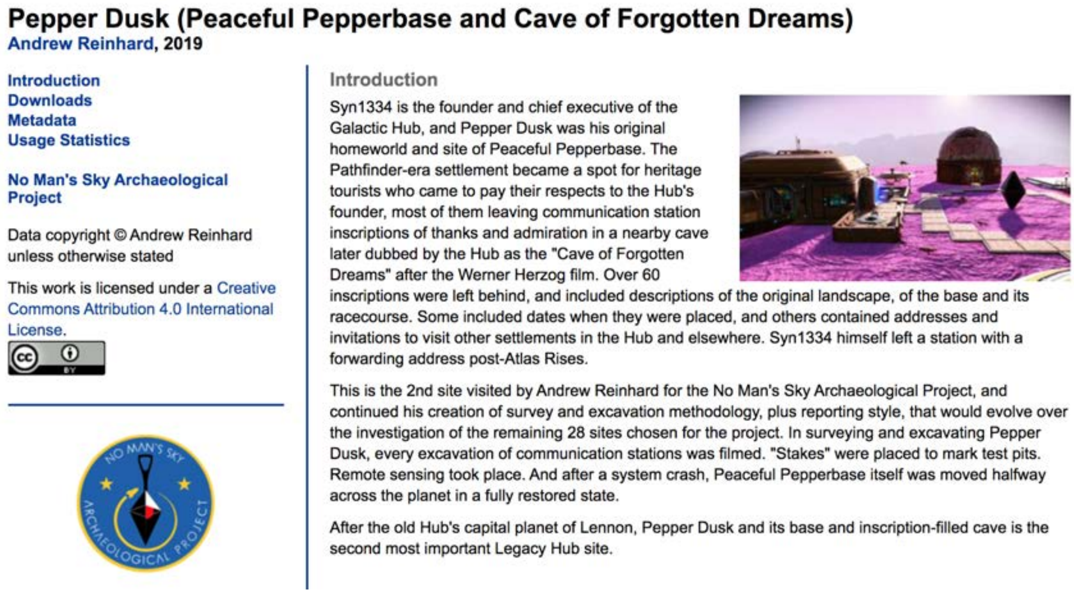
42. https://doi.org/10.5284/1056111.
43. https://doi.org/10.5284/1056622.
44. https://doi.org/10.5284/1056636.

not state, and what my blogging failed to do, was to elicit responses from my colleagues whom I had hoped would read and critique my methods so that I could consider and apply their corrections on the next site visit. Although some of the NMS Hub community did reply to the re-posts on reddit, I received no engagement whatsoever from my professional archaeological colleagues.

In writing my site reports, I wanted to integrate an engaging narrative while also providing expert-level data about each site, blending the two reporting approaches as described by Ian Hodder (1989, p. 269): 18th-century sequential storytelling of how an excavation proceeded, and a late 20th-century attention to detail about finds and context. Rapid reporting made sure that I could write up everything about a current site prior to moving on to the next one, and integrated synthetic and interpretive text, an evidence-based narrative, as well as catalogues of finds and an almanac of each environment in which I worked, paired with maps, screenshots, and videos thereby fulfilling the need to write up completed work before starting new work (Renfrew and Bahn, 2012, p. 481). Writing reports in this fashion[45]—especially with the narrative—prepares the entire project for publication as a gazeteer, and also allows for a variety of post-project articles about its paradata and methods as well as a formal write-up on the outcome of the project and what was learned about a human civilization in a synthetic environment when confronted with environmental catastrophe.

As an archaeologist in the 1990s and early 2000s, and later as the Director of Publications for the American School of Classical Studies at Athens (ASCSA) whose mandate was to publish the results of archaeological excavation of the Athenian Agora, ancient Corinth, and other affiliated sites in Greece, I have witnessed first-hand how difficult it is to report and publish archaeological work. In some instances final publication of a site occurred 50 years after the last spadeful of backfill was placed (e.g., Lerna). In other instances, competing interests, schedules, and personalities delayed final publication for years (e.g., Isthmia). Even when published, these monographs and articles were of limited use, being locked within paper pages and featuring only photographs and line drawings. The books were expensive (typically over US$150), printed in limited quantities (usually 300), and had no digital components (e.g., interactive maps, online data sets, drone video footage, etc.). Ebooks were embargoed for three years after print publication and were nothing more advanced than a simple PDF. This follows on Richard Bradley's (2006, p. 669) criticism of the current state of site reports where even when produced online, they behaved like a printed monograph (e.g., Scottish Internet Reports). In 2006, he did praise the efforts of Silchester with its interactive publication linking together various contexts and allowing the reader to draw their

45. See any site report from the list of 30 Galactic Hub sites recorded: https://archaeologydataservice.ac.uk/archives/view/nomansky_2019/site_list.cfm. Once at a site record, click the "Downloads" link to the left, and then click on the "Reports" link on the screen that appears.



Pepper Dusk (Peaceful Pepperbase and Cave of Forgotten Dreams)
Andrew Reinhard, 2019

Introduction
Downloads
Metadata
Usage Statistics

No Man's Sky Archaeological Project

Data copyright © Andrew Reinhard unless otherwise stated

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Introduction

Syn1334 is the founder and chief executive of the Galactic Hub, and Pepper Dusk was his original homeworld and site of Peaceful Pepperbase. The Pathfinder-era settlement became a spot for heritage tourists who came to pay their respects to the Hub's founder, most of them leaving communication station inscriptions of thanks and admiration in a nearby cave later dubbed by the Hub as the "Cave of Forgotten Dreams" after the Werner Herzog film. Over 60 inscriptions were left behind, and included descriptions of the original landscape, of the base and its racecourse. Some included dates when they were placed, and others contained addresses and invitations to visit other settlements in the Hub and elsewhere. Syn1334 himself left a station with a forwarding address post-Atlas Rises.

This is the 2nd site visited by Andrew Reinhard for the No Man's Sky Archaeological Project, and continued his creation of survey and excavation methodology, plus reporting style, that would evolve over the investigation of the remaining 28 sites chosen for the project. In surveying and excavating Pepper Dusk, every excavation of communication stations was filmed. "Stakes" were placed to mark test pits. Remote sensing took place. And after a system crash, Peaceful Pepperbase itself was moved halfway across the planet in a fully restored state.

After the old Hub's capital planet of Lennon, Pepper Dusk and its base and inscription-filled cave is the second most important Legacy Hub site.

Figure 5.15. Screenshot of the homepage for an example site record homepage hosted by the Archaeology Data Service (https://doi.org/10.5284/1056110). Links at the left bring the reader to Downloads (images, videos, inscriptions, and site report text), Metadata (basic site information including location and fieldwork dates), and Usage Statistics (information on visitors to this site record).

own conclusions from the data (2006, p. 669). It was therefore important for me to include as much digital data and media as possible as part of my initial reporting online and later archiving via the Open Access Archaeology Data Service platform (Fig. 5.15).

Because I was working alone, I completed the rapid-reporting process myself, which included my initial interpretations while all of the details were fresh in my mind. In the future, I anticipate that digital environments will be investigated by teams of several people. Each team member should write their own report after which they can be compared and collated into a master document, lending it a multivocality of different, possibly specialized perspectives. It was also important to me to include a narrative, not just reconstructing what might have happened at an abandoned site, but also of my own archaeological method and interpretation of what I found. These narratives within the site report give the data context, something especially useful to future researchers.

Having determined roughly how I wanted to report on the sites in this case study, I then decided on what to report. As mentioned elsewhere in this chapter, because this was in essence a salvage operation with a ticking clock, I needed to record all that I could ranging from the environment to specifics about the built heritage dotting procedurally generated landscapes. I knew that I wanted to include an excavation narrative and evidence-driven analysis of each site visited, and I also wanted to record detailed information on finds. Taking a look at a few other projects and organizations and how they organized their reports seemed worthwhile.

The Caherconnell Archaeology Field School in Ireland creates preliminary reports within four weeks of concluding the field season, posting these online right away for public consumption.[46] These reports are similar to those produced via the guidelines from the United States' Department of the Interior.[47]

Looking for further contemporary examples of archaeological site reports, I learned that Ireland's National Monuments Service's *Excavation Reports: Guidelines for Authors* recommends that each preliminary site report contain a cover page, abstract, intro, excavation, discussion/conclusion, and references (Duffy, 2006, p. 3). The next level up of reporting, the "concise report", contains more detailed information, including site name and location, site type and date, grid reference, site number, excavation license number, contact details for the excavation director, followed by dates of commencement and termination of the excavation and a brief account (500 words) of the results of the archaeological excavation. My own reporting attempted to follow this model on the Archaeology Data Service site records with a brief introduction followed by links to more detailed information. Compare the above guidelines with those from the New Hampshire Division of Historic Resources (2018), which underscores the necessity of including synthetic text as well as digital media, something these other guidelines do not mention.

While all of the above site report standards and examples cover traditional archaeological excavations, none explicitly deal with working and reporting in synthetic environments. In their "MAD-P" hard drive excavation experiment, Perry and Morgan conducted archaeological work on a digital artifact, with Phase I including the actual drive hardware and Phase II detailing the software and interface held within (Perry and Morgan, 2015). A large part of their experiment included writing and reflecting on the site report. My frustrations in archaeological report-writing echo theirs, namely that most use a "coded language" intended for an expert readership. To Perry and Morgan, site reports prove useful in:

> instilling care for process and interpretation. They can work as a meaningful pedagogical strategy, aiding in thinking through the fit between disparate data gathered during archaeological investigation. They can be used to reflexively review intellectual processes during excavation and to reevaluate

46. https://caherconnell.com/archaeology/dig-reports/ (Accessed 22 July 2019). The 2018 Preliminary Report contained: Introduction, Location, The Cashel, Research framework, Excavation aims and methodology, Artefact strategy, Excavation results, Backfilling, Finds, Samples, Discussion, Conclusion, Further work, References, Appendixes

47. https://www.nps.gov/history/local-law/arch_stnds_7.htm#results (Accessed 22 July 2019). Report elements include: description of the study area; relevant historical documentation/background research; research design; field studies as actually implemented; field observations; analyses and results; evaluation of the investigation; recommendations for updating the relevant historic contexts and planning goals and priorities; reference to related on-going or proposed treatment activities; information on the location of original data in the form of field notes, photographs, and other materials.

interpretations after the fact. They can provide a record for future researchers to understand what has been systematically destroyed through excavation (Perry and Morgan, 2015).

Other significant observations on the current state of site reports especially in the UK's gray literature were presented formally in 2017 by Alice Cattermole for Historic England and CIfA. Based on a review of 1,000 finds reports in the UK, 15 major issues plague contemporary archaeological practice:

- Despite the requirements of existing Standards and guidance and good practice advice, specialist input into project planning, project designs and WSIs is not routinely being sought.
- Details of sampling and recovery strategies are not routinely included in grey literature reports.
- Reports (including grey literature and specialist artefact reports) do not routinely include lists or quantities of material types or objects not selected for analysis or reporting, nor a statement of the rationale for excluding them.
- Specialist reports do not routinely make explicit reference to current, accepted standards or good practice guidance.
- Detailed descriptions of material types are not always present (e.g., stone types) and when they are given they do not reference formal resources, such as ceramic type series.
- Specialist reports do not routinely detail archive contents, including details of the format and content of any digital components.
- Most specialist reports do not specify when the assemblage was analysed.
- Object dimensions are not consistently included in artefact reports.
- Specialist reports are not currently indexed via OASIS/HERs[48] and there is no mechanism for uploading onto OASIS either the results of analysis or associated catalogues or datasets.
- Quantification data are not routinely presented in a standardised accessible format.
- Specialist reports do not routinely include a discussion of the assemblage in its wider context or in relation to other assemblages either from the same site or from comparative sites.
- Specialists are not routinely being credited with authorship of relevant specialist reports.
- There is great variation in the structure and content of specialist reports.
- There is currently no consistent approach towards on-site or post-excavation

48. Online AccesS to the Index of archaeological investigationS / Historic Environment Records

monitoring of artefact work by development control archaeologists, resulting in the differential application of and compliance with existing Standards and guidance.

- Awareness of current, accepted standards and guidance relating to artefact work is variable across the profession (Cattermole, 2017, pp. 1–2).

The outcome of recommendations from the study were largely for CIfA and its Finds Group to develop additional standards and guidelines and to engage in oversight over reporting, and to develop better digital asset management in support of these sites being reported upon (Cattermole, 2017, p. 2).

Reporting then became the critical issue facing me as an archaeologist documenting this type of human-settled synthetic space for the first time, especially when the likelihood of future site destruction via software update was high. I needed to decide what to incorporate into the report, how to organize the reports, and to work out the audience for the preliminary site reports, while disciplining myself as the surveyor and excavator on writing up my work promptly before moving on to the next abandoned settlement. I came up with a routine even though each report differs from the next as I experimented with presenting narrative and data (Appendix J).

Because of the high level of detail involved in visiting and documenting *NMS* bases, I forced myself into the habit of stopping after completing the archaeological investigation of a given site, updating all of the media file names, creating all the maps and plans, creating a spreadsheet for the comm station data, and then writing the whole thing up with some introductory, synthetic text, then an almanac of planetary features (flora, fauna, landscape elements, climate, etc.), followed by the actual data and commentary on those data. This would then be published for public view online at archaeogaming.com, tagged with "No Man's Sky," "Galactic Hub," and "Legacy Hub" for easy identification. Once posted, I would post the link to the @nmsarchaeology Twitter account, as well as to @archaeogaming and @adreinhard (also on Twitter) for maximum coverage.

Once I posted the site report, members of the Hub's player community would reblog, share, and save it to their own databases and wikis for future reference, seeing as I am excavating their cultural heritage and material culture. For example, the Hub heritage user, GalacticGeographic, promoted the project and began linking site reports on the Hub's public wiki on 7 May 2018.[49] My earliest preliminary excavation in the deGrasse System was picked up and shared on the Hub's reddit page in October 2017 by user 7101334, which yielded comments from others such as user kingsoverthrees, "Please keep posting these. I find this fascinating. To think someone is applying rigor-

49. https://nomanssky.gamepedia.com/index.php?title=Galactic_Hub_Project_Legacy_Region&action=history

ous scientific methodology to this game blows my mind."[50] As of this writing, the Hub's reddit has 18,900 members, ensuring a wide reach. The *NMS* archaeology project even bled over into the main reddit for the game (256,000 subscribers),[51] and led to an article on the gaming site *Kotaku*, which was read by 187,000 people (Jackson, 2017).[52] Sharing these posts with the community in real-time allowed me to test my interpretations against the memories of the players who settled in the original Hub. Frequently members of the Hub (especially their chief executive and the person in charge of "Galactic Heritage") would reply or would leave comments and questions. For example, after I posted my site report on the player base Abundance H.Q., its creator, himshieland, commented on 6 May 2018 with additional history from the time when he maintained the base:

> Wow, you've gave me feels for home. I admire and reminisce from deep in Doctinawyra galaxy. The comms you found all marked bases (home base not B&Q), two portals and a trading post (nothing to see here). Hutchbelfast was a player from Amino hub who came and settled along with the other 2 if us and for a short period there was 5 if us when Brent lived here for a few days.[53]

Field Reports Analysis

I wrote a field report for each of the 30 sites I visited in the Legacy Hub. The format and content of the reports changed over time, from daily journal entries to a more efficient style of reporting text, data, and interpretation. In hindsight, the standard, streamlined version of the report followed a template as follows, but I often strayed from the ideal organization. Regular context sheets would have helped, and can be developed for future expeditions in digital spaces. What follows is reflective of the mix of old and new writing styles as defined by Hodder (1989) while incorporating context and content of what was found on-site (and where) without falling into the problem areas as defined by the 2017 Historic England/CIfA study:

1. Site narrative: Why was this site investigated and what was interesting about it? Why should archaeologists and the wider Hub community care? I would often lead with a hook—something puzzling about the site that would later be answered by the data—taking a lesson from my background in journalism. When thinking about the site reports initially, I had not expected that nearly every site would feature something both

50. https://www.reddit.com/r/NMSGalacticHub/comments/73pasu/update_from_andrew_reinhard_of_nms_archaeological/
51. https://www.reddit.com/r/NoMansSkyTheGame/search/?q=archaeologist&restrict_sr=1
52. https://kotaku.com/archeologist-digs-into-remains-of-no-mans-sky-abandoned-1819114074
53. https://archaeogaming.com/2018/05/06/ghost-world-the-haunted-base-of-abundance-rip/

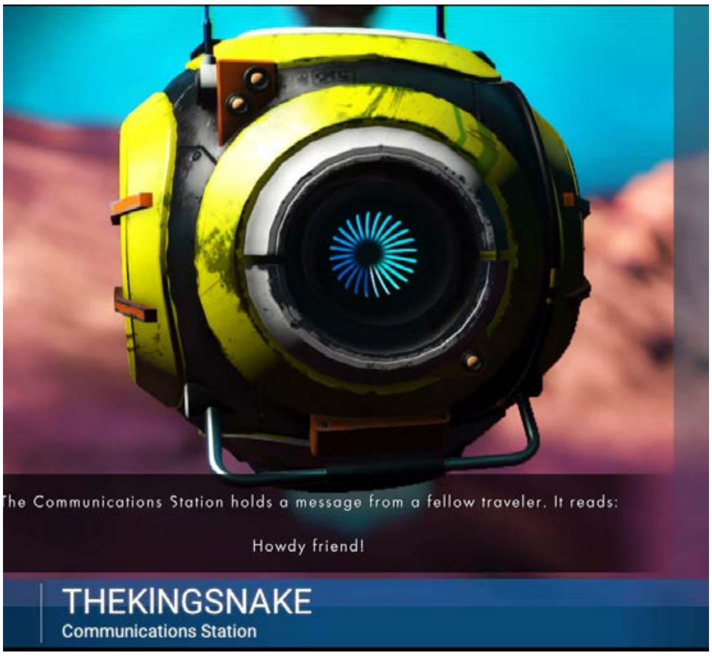


Figure 5.16. Sample communication station.

special and strange, and it seemed natural to lead off the report with that in order to grab the public's attention to draw them into the story of a site without sensationalizing it. The lead image was often of the base in its current state unless another feature was more prominent in the narrative.

2. "Anatomy": When I began my site investigations, it was unclear what data would be important, so I decided to record all that I could. The "anatomy" of the planet hosting the base includes daytime and nighttime climate, sunset/sunrise times, planet size, details of exploration (names/dates of explorers), as well as the presence/absence of flora and fauna and notable natural resources, plus notes on system-wide economy and conflict, all of which could be important in a player's decision to site a settlement. I wanted to see if I could identify patterns in the planets that were settled that might have prompted abandonment. I also wanted to log this information knowing that it might change with the deployment of v1.4 in July 2018, and I was curious to see what might change (if anything). I took screen captures of all of the above via the game's Discovery Log.

3. Landscape: I wrote descriptions of the local landscape surrounding the base, putting the base's site into a wider context, and to compare it against text and images recorded by the base's original architects and earliest guests. These descriptions also prepared me to view any changes to these planets in v1.4. I photographed the base within the landscape not only to document its location, but also to pay attention to aesthetics knowing that practicality is not the only reason people choose places upon which to live.

4. Base Description: Writing a room-by-room description of the player base enabled me to think more carefully about its construction and content, and supplemented the photos and videos I took of the base both inside and out.

5. Communication Stations: Most of the bases and worlds I visited contained one or more communication stations containing messages from the base's architect and from visiting players (Fig. 5.16). I photographed each comm station *in situ* in relation to other features and to where it sat in the landscape. I created a spreadsheet to note color, player name, message, and any special notes about the station and its location. From this data I was able to trace players' movements throughout the Hub, and could also identify trends in communication between players. On the capital planet, Lennon, the density of comm stations required me to lay out a grid to assist me in mapping, identification, and recording (Fig. 5.17a–b).

All of the field reports are a little different as I experimented with a style of reporting that would ultimately be readable by a layperson yet contain enough detail to be useful to archaeologists and to the Hub community and its leadership. In the cases of sites with massive amounts of material to collect (e.g., Lennon and Pepperdusk), I ended up keeping a journal of activities not unlike a trench notebook used over the course of a digging season. In later reports on smaller sites I settled into a routine and a report organization that had me record environmental data first, evidence of prior human exploration and occupation, communication stations (inscriptions), description of a walkthrough of a settlement, and a preliminary narrative of the site and its habitation and abandonment. The reports hosted by the Archaeology Data Service are all different, yet cover the same basics as I worked towards a more standardized format of reporting that would allow for flexibility in light of new discoveries. Standardization of reporting would also allow me (and others) to more easily identify possible trends in settlement/abandonment, and to ultimately create a gazetteer for Legacy Hub heritage tourism, a hobby already undertaken by several *NMS* players, many of whom made pilgrimages to Lennon post-evacuation. I had model reports from which to work when planning the project's survey aspect (e.g., the Eastern Korinthia Archaeological Survey) and excavation facet (e.g., the Western Argolid Research Project), but ended up creating and adapting my own reporting structure and approach, changing it site-by-site until I had a system down. It was unclear to me at the outset of how much or how little data to record, so I tried to record everything knowing the likelihood that both settlement and landscape of any site I visited would be changed/destroyed in a matter of weeks.

As of 13 September 2019, the ADS has archived the full contents of 30 site reports organized in the chronological order in which they were written, which show the evo-

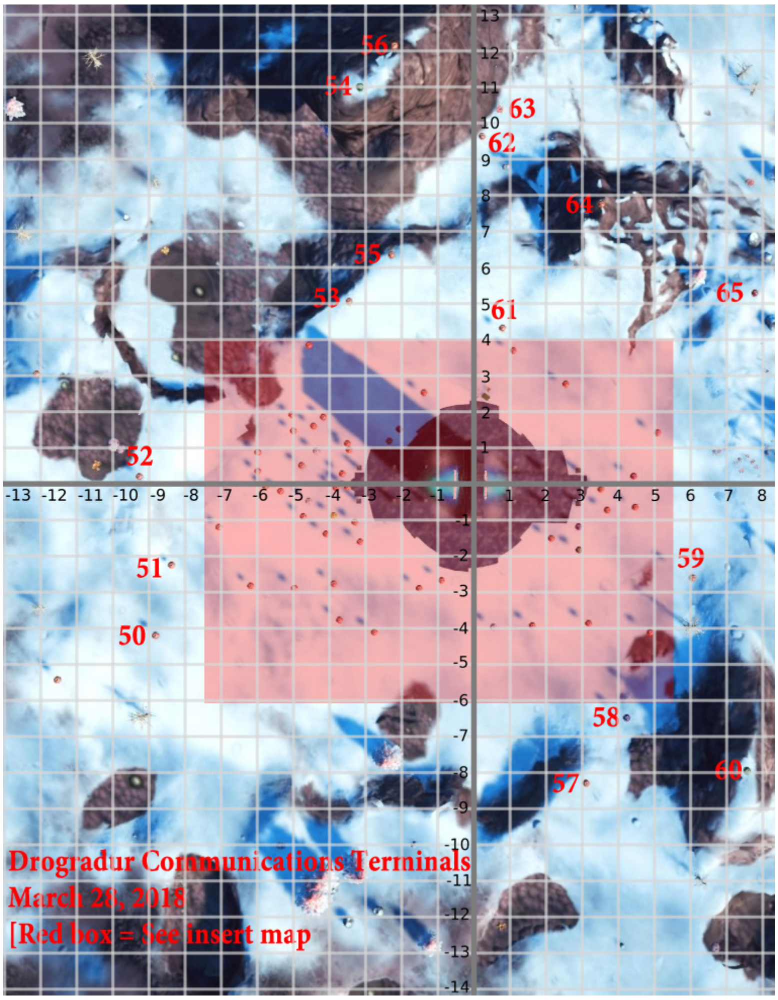
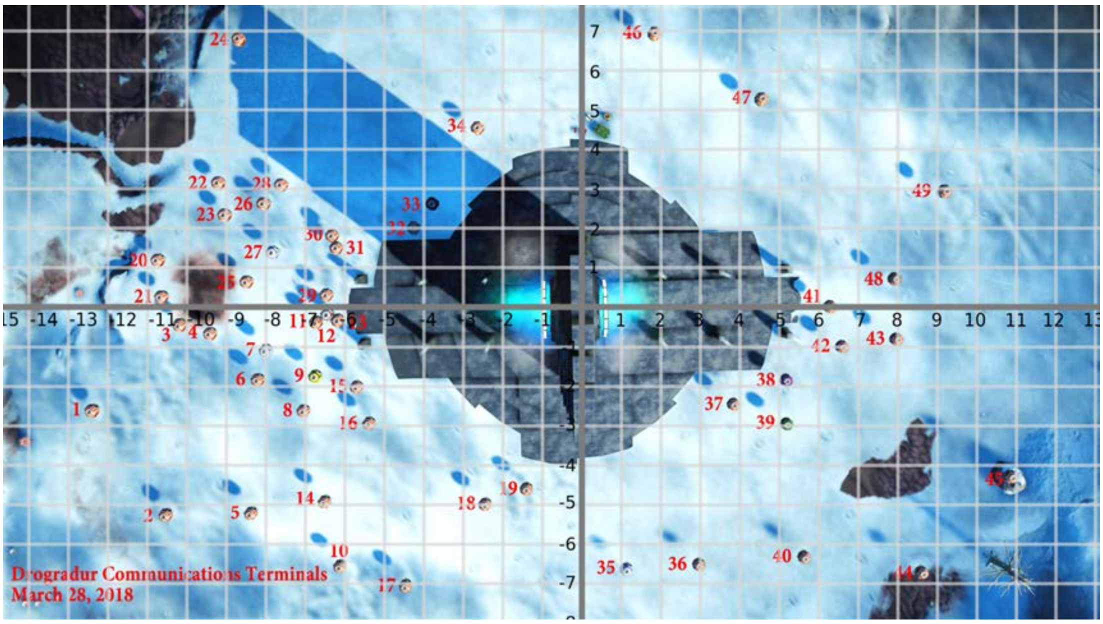


Figure 5.17a–b. Comm stations near the portal on the capital of Lennon (Drogradur NO425) with overlying grid (top). Detail of the central cluster of communication stations at Lennon's portal (bottom).



lution of my site reportage in the game.[54] See Appendix J for links to each site report and related data and media.

Summary and Conclusions on Methods

To distill my simple methodology above when documenting sites of previous human occupation in any digital space, which does not differ greatly from contermporary standard practice with sites in the natural world:

1. Discover and select a location to visit, focusing first on places with clearly defined locations that can be reached easily, working outwards from there;
2. Upon arrival, perform reconnaissance of varying degrees of granularity, from general to more detailed, using that information to determine what gets investigated first, and how;
3. Document as much as possible, but start with pen and paper to learn the environment slowly, determining how things relate to one another: mapmaking enables one to consider the general relationships of places to other places;
4. Record both general and specific images and video, with and without related data on display, because they serve two purposes: media-with-data helps us look, but media-without-data helps us see (sometimes we just need to experience a beautiful vista from the window of our house to understand why we built it here), and supplement those images and videos with verbal descriptions of what is depicted, because when we describe something, we see it differently;
5. Post/share the work as soon and as publicly as possible, which serves two functions: 1) immediately writing up a site allows one to come at the material with an intimacy derived from constant attention with every detail fresh, something that will be forgotten even as soon as the passage of a day, and 2) engaging the public encourages their attention, which can sometimes lead to observations of details one might have missed based on one's proximity to the material and the fact that the site is new to one even if it falls within one's specialty.

Regarding no. 5 above, I received the following unsolicited oral history from a player, "MrMcDillard" about a site report I posted online:[55]

> You did a great job writing up the planet description :-) As a quick info drop: This planet was once a lush, temperate, water-rich paradise. The vast ocean was

54. https://doi.org/10.5284/1056111.
55. Received 28 June 2019, after I published the 3D-printed base, Mr. McDillard's Pad, on Twitter, over one year after I posted his base's site report, which he then read. The original site report can be found at https://archaeogaming.com/2018/06/16/old-mcdillard-had-a-pad/. His oral history appears there as a comment on the post.

> dotted with large continental land masses, forming many island chains. High mountains climbed dramatically out of the deep oceans, creating a breathtaking landscape. After the update, the planet was transformed into a harsh wasteland, but with equally beautiful geological formations. As you know, our bases were all wiped after the update, but we had the option to reload our bases if we were able to find a base computer. I was committed to keeping my original base on the original planet it had been established, even if the landscape had changed. I spent weeks trekking across the planet, until I happened upon a Base Computer atop the overlook where it stands today. I couldn't be happier with the new location, although I do still miss the oceans. The comm balls mark the location of my previous base, as well as a new neighbor I had gained along the way. He didn't seem very active, so I suspect he never bothered to recover his old base. My previous base location used to be at the top of a cliff, with a view of the ocean below. Part of a larger island chain, the cliff led to a large plateau which curved in a crescent, creating an enormous bay. I hope that helps! And thank you for all your important work :-)

The takeaway from this oral history is that the digital archaeologist can compare this information against the site as it appears in the present day, and can use it to fill in any lacunae in the historical and archaeological record, complementing surveyed and excavated evidence. With archaeology of the recent past, access to living contributors is also crucial, especially with the history of digital things and environments, which while very personal and individualistic, can get lost in the sheer volume of other voices and digital constructions.

After visiting dozens of abandoned bases and homeworlds in the old Galactic Hub, I continued to refine my methodology in collecting and interpreting data. This continuous refining served to advance my techniques in investigation and recording of archaeological data in a digital space, but it also limited the ability to compare one report against another. Now that I have done this once, should I decide to continue this project in the future with later settlements in the new Hub, I will create and use a standardized template. Despite what became routine, every site continued to offer surprises, some kind of unexpected behavior emerging from the rules of the game, and the rules I set for myself as an archaeologist. What I describe is not unique to digital archaeology, or for the archaeology of synthetic worlds, but should be familiar to anyone engaging in fieldwork anywhere.

5.3. Results: General Trends in Settlement, Abandonment, and Communication in No Man's Sky

One of the goals of this case study was to document what remained of the human habitations and material culture of the original Galactic Hub in *No Man's Sky* and to interpret the abandonment process. Because *No Man's Sky* marks the first mass exodus by human players from one place to another within a synthetic environment (without abandoning that environment), it provides a unique opportunity for an archaeologist to record how people reacted to a climate-induced migration. What follows are the answers to my research questions based on my fieldwork, field reports, experience within the *NMS* environment, and communication with Hub players, especially those involved with its heritage.

5.3.1. Disaster-Driven Human Migration

In order to interpret how and why the human Galactic Hub community made their exodus post-software apocalypse, I sought to explore how and why people abandon and resettle in the natural world after suffering a major disaster. For *No Man's Sky*, this disaster fits the rubric of a "catastrophism": the "sudden, typically unpredicted natural disaster that leads to abrupt changes in a culture of lifestyle that has been stable for a long time. Following such catastrophes, an entirely new social, political or military order can emerge…." (Nur, 2008, p. 2). What happened with the overnight biome reset of the Atlas Rises update was not unlike the quick, catastrophic strike of a major earthquake. Historian Will Durant is attributed to have said in an interview with *Ladies Home Journal* (1946) that, "civilization exists by geological consent, subject to change without notice." In this quote we see a blend of earthquake science and archaeology and how one affects the other. So it is with human populations in digital built environments. Disaster ruins are created at the press of a button.[56]

When studying a disaster-caused abandonment of any place, there are several factors to consider that will help understand how a human population responded to the event: Event magnitude, event frequency, event duration, event speed of onset, areal (geographic) extent of the event, spatial dispersion of the event, temporal spacing (periodicity) of the event, time of onset of the event (Bawden and Reycraft, 2000, pp. 1–2). When applying these factors to the diaspora of the Hub population, we can plug in the following: 1) the software update affected 100% of the geographical area within *No Man's Sky*; 2) the software update event happens on average once per year (Atlas Rises in July 2017, NEXT in July 2018, and Beyond in July 2019 all reset the biomes and destroyed settlements); 3) the updates cause immediate destruction, the effects

56. See the floating settlement of Valhalla for a typical example of instant disaster ruins. https://doi.org/10.5284/1056645.

of which were felt for months afterwards; 4) the updates happen overnight. Based on these data and the fact that the universal reset repeats, Hub players and their leaders are better prepared to plan for another such event if they are given enough notice by Hello Games. The first occurrence of the reset caught everyone off-guard, much like an earthquake. The player community can now treat this "digital disaster" more like they would in planning for a hurricane, having learned from past experience.

In their work on natural disasters and archaeology, Bawden and Reycraft state that, "archaeology can no longer afford to treat ancient natural disasters as curios of the past. Its relevance lies in developing data, theory, and predictive models that deal with how increasing levels and scopes of human organization engaged environmental change. Its challenge is to provide the roots for understanding how the modern world can mitigate and survive the "superdisasters" of the new millennium" (2000, p. 223). It is possible that we can take lessons from the evidence of how players reacted to and later planned for in-game disasters, lessons that include communication between leadership and community members and the creation of pre-disaster planning documents produced well in advance of the next update. Natural disasters create disaster ruins that can give archaeologists clues as to what happened and why, and how the affected population dealt with the situation (Peiser et al., 1998).[57]

This all falls under the rubric of human geography, but there are a few differences between studying humans affected by disasters in the natural and digital worlds. In his primer on human geography, Mark Boyle states that, "there is nothing natural about natural disasters: Risk = Exposure x Vulnerability (R = E x V) (Boyle, 2015, p. 270). One can interpret this that it is not a disaster if something does not affect a human population. Boyle cites Kenneth Hewitt who demonstrated that natural hazards are always threatening but only develop into calamities when societies pursue development pathways that unwittingly increase their vulnerability (Boyle, 2015, p. 271) and then defines six ways in which social, political, and cultural processes increase the vulnerability of populations exposed to natural hazards: poverty, social exclusion, poor governance, war and violence, rapid urbanization, environmental degradation (Boyle, 2015, pp. 271–73). Looking at human populations in the natural world, one can understand how building structures away from a volcano reduces risk to those living in them, but often people of lower income or higher precarity find themselves in risky settlements because of affordability (e.g., the Grenfell Towers in London and estates like them). In *No Man's Sky*, however, all players are at 100% risk because the game collapses annually. Players have grown to accept that 100% risk as a fact of life, and are willing to

57. See this planning document for the Galactic Hub posted before the Atlas Rises update was deployed: https://www.reddit.com/r/NMSGalacticHub/comments/6trkh4/glyphs_pilgrimage_important_decisions_the/

rebuild/resettle after each software update.[58] The entire population is both exposed and vulnerable even if they are logged out of the game when disaster strikes. The question is, then, what can we learn from human populations in digital spaces who anticipate destruction? How can their society not only survive, but also thrive in such a hostile environment where loss is expected? Humans who live in flood plains adapt, and that human adaptability apparently scales into digital spaces.[59]

Also regarding disaster ruins, human populations tend to keep them around and in a ruined state to serve as instructional evidence especially to those people who have never experienced a disaster (Konuma, 2015, p. 9). These ruins, such as "disaster heritage" landmarks in Japan like the Atom Bomb Dome, part of the Hiroshima Peace Memorial, are curated as painful reminders to millions of annual visitors (Konuma, 2015, p. 15). These ruins also provide a sense of history and community (pp. 18–21). When viewing *No Man's Sky* and the destroyed player settlements in the Legacy Hub (such as Ty Beecham's Pearl Farm[60] or the Tomb of the Unknown Interloper[61]) we find the same sense of community surrounding the original human settlements within this region of the game. The ruins also serve as reminders to community members and other heritage tourists to prepare for the next software update while standing as monuments to the first reset of a human-occupied digital universe.[62]

Another major difference between migrating human populations in the natural world v. those in *No Man's Sky* was the fact that identifying and managing natural resources was easy within digital space. In *NMS*, the Hub community explored the synthetic universe for a few weeks, returned to report on what they had found, and then voted on where to resettle based on the highest concentration of livable planets and variety of resources. Because the game is truly universe-sized, there is no competition for space and resources, and no population displacement or the attendant politics in resettling a migrant population within someone else's borders (Black, 1998; Marfleet, 2006). Disaster-migration within *No Man's Sky* when compared to people fleeing war-torn countries is little more than an inconvenience, yet the players took their situation seriously and created and executed a plan to move their "tribe" with as little hardship as possible.

When dealing with abandonment of settlements in *No Man's Sky*, one must consider two facets: 1) form of abandonment, and 2) reasons for abandonment. Based on my

58. See, for example, the first iteration of King James Hova's castle, which is now in its sixth incarnation: https://doi.org/10.5284/1056640.

59. See, for example, Holly's Blue Moon Paradise, which was deconstructed and moved by player Hollyworks after the first game update reset the universe: https://doi.org/10.5284/1056621. Since that first update, she has built several new bases elsewhere in the Hub region, including a tribute to *Close Encounters of the Third Kind* in August 2018.

60. https://doi.org/10.5284/1056625.

61. https://doi.org/10.5284/1056630.

62. See the communication stations left behind by heritage tourists at the Hub's legacy capital of Lennon: https://doi.org/10.5284/1056109.

observations, I can assign one of three classes to abandoned settlements. The first class of sites is that where the base has been completely disappeared, yet communication stations remain as proof that a structure once existed (e.g., Dancing Bear, Fig. 5.18). For some players, investment in their bases necessitated that they be deconstructed and loaded onto high-capacity freighters, which would then fly to a new site in Galactic Hub 2.0. Construction of farms and other architecture is quite expensive, so in some instances it was cheaper for players to disassemble and move a base. Such is the case with player hollyworks' pearl farm[63] consisting of 16 hydroponic domes and 256 mature albumen pearl plants.

The second class contains those habitations that remain fully intact and are situated on the landscape as they were when their builder departed (e.g., Panda's, Fig. 5.19). This kind of abandonment occurred for one of two reasons: 1) the player felt it would be easier to rebuild the base in the new Galactic Hub, or more frequently 2) the player had already built newer bases elsewhere. In *No Man's Sky* (up to version 1.3), players could build multiple bases, one per system, but because of the way the game was designed, they themselves could only see their most recent, active base. Other players, however, could visit older iterations of bases now abandoned by the same player over time. My work in documenting these abandoned bases became increasingly important to the player-community as the player-builders were nostalgic for their earlier constructions.[64] The Hub's community at large viewed these earliest structures as part of their in-game cultural heritage, as evidenced by searching on the term "heritage" in the Hub's wiki, which returned not only individual sites desgnated as heritage structures, but also entries for the Galactic Heritage Archive and Legacy Heritage Archive with rules for designating sites as well as etiquette to follow when visiting heritage sites.[65]

The third class of sites contains those bases that are either buried (all or in part) or suspended in the air as evidence of a changed topography because of the Atlas Rises software update (e.g., Valhalla, Fig. 5.20a–b).

Reasons for site-abandonment vary from player to player. All chose to leave in order to be a part of the Hub's relocation and resettlement, opting to remain within the community instead of remaining alone in a wasteland. Their original homeworlds largely had been turned toxic and unlivable with poor (or absent) resources, and predatory fauna where once had been an Eden. Most players left their bases as-is, never to return. Some players (e.g., HollyWorks), deconstructed their ruined bases for raw materials to use in rebuilding their homes in the new Hub.

63. https://archaeogaming.com/2018/05/12/the-mystery-of-the-missing-pearl-farm/ (accessed 19 July 2018).

64. https://www.reddit.com/r/NMSGalacticHub/comments/70ysdl/remember_that_nms_archaeology_team_from/

65. https://nomanssky.gamepedia.com/index.php?search=heritage

Figure 5.18. A Class 1 abandoned site, "Dancing Bear", showing comm stations as evidence of the location of a player's settlement, now completely disappeared. The comm stations float in the air, which shows that the topography of the planet changed. Normally comm stations float c. 1 m above the surface, but these require a starship to visit because they are so far above the planet's current surface.

Figure 5.19. A Class 2 abandoned site, "Panda's", showing a complete player base situated in the landscape without any damage.

Figure 5.20a–b. A Class 3 abandoned site, “Valhalla”, as it was originally (top) and as it was after the Atlas Rises update (bottom). Note how the landscape changed from lush to desert and that the topography changed, which left the base suspended and disarticulated.

Figure 5.21. A communication station found at the abandoned base "Langley" indicating that the architect has relocated to the "Hilbert" region of Galactic Hub 2.0, established after the Atlas Rises update.

For those players choosing to abandon their bases *in situ*, many of these contained active hydroponic and open-air crops, which when harvested and combined could yield materials that could be sold for massive amounts of in-game currency through the galactic trade network via trade terminals also installed in abandoned player-bases. Many bases were also outfitted with starship landing pads, which allowed for safe landings and resource-free lift-offs (players normally must burn fuel for launches). Some bases also included geobays for three types of exocraft (planetary rovers) to expedite surface travel. For the old residents of the Galactic Hub, bases served two purposes: 1) a home base that could also generate a steady stream of revenue, and 2) a place for guests to visit and help themselves to expensive or rare renewable resources. The Hub community encouraged resource-sharing, enabling one another to earn wealth together, that wealth was then used to create more useful, sharable capital for generating more income for more players to share, creating a better quality of life and facilitating additional space exploration.

Other than bases, most players opted to leave behind communication stations, literal messages-in-bottles for other players to find and read (Fig. 5.21). Aside from bases, comm stations (aka "comm balls") are the only player-created artifacts able to be seen and engaged with by other players. The comm stations' colors (base and trim) can be customized, although most players chose to stay with default orange. Some of the more advanced, active players in the group opted for custom colors, making these easy to identify from world to world as I followed their Hub explorations and visits.[66] Communication stations are like single-tweet bottles for messages to other players. People who construct these are limited to a 30-character message. Not only that but the message must not contain any words, phrases, or content deemed objectionable by the community or by Hello Games at large. Players have the option of reporting inappropriate comm stations for the developer to remove.

Without exception, the hundreds of messages I found left by other players were either factual or positive (the most copious numbers of communication stations were left at Lennon,[67] Pepper Dusk,[68] and Holly's Blue Moon Paradise[69]). Factual inscriptions include player names, date of visit, and at times an address either of a base or the name of an Earth city where a player was from. Positive messages included words of thanks for farms/resources, compliments on the quality of a base's architecture, and words of welcome from the Hub community. While there were no instances of trolling within the context of the 430 comm station messages I recorded (trolling being defined as targeted player harassment), there were a few messages that related to *No Man's Sky*'s first player-war between the Galactic Hub and the upstart Empire of Hova, which was resolved by treaty and commemorated by communication stations in the system (and on the planet) where the treaty was signed. While none of the traditional kind of trolling was present in the sites I visited (and their related comm stations), examples did exist of aggression between players of different factions, specifically between the so-called Empire of Hova and the Galactic Hub, a conflict that would ultimately be resolved peacefully. Such an example was placed by Hub player art-nik on the home planet of King James Hova's empire, New Athena: "Bez-Harr will never surrender to tyranny." Granted this is not strictly trolling per se, but does indicate a message of hostility from one player to another.

At the start of my fieldwork, I naively did not anticipate that the placement of comm stations would be archaeologically important. The disposition of comm stations followed one of three options: 1) clusters encircling player-bases (e.g., Ty Beecham's Pearl Island[70]), 2) single stations noting planetary features (portals, trading posts, and other

66. This is but one example of the evidence of cultural dynamics in this case study, where meaning evolves over time. As a researcher, I first recorded color not knowing the importance of the signifier, but later site visits showed that certain players opted for certain colors to set themselves apart from those who opted for basic orange. Those players who explored the most—as evidenced by the number of comm stations they left across the Legacy Hub—tended also to have customized colors. Color served no other overt function with these messages.

67. The spreadsheet of inscriptions is here: https://archaeologydataservice.ac.uk/archives/view/nomansky_lennon_2019/downloads.cfm?archive=Spreadsheet

68. The spreadsheet of inscriptions is here: https://archaeologydataservice.ac.uk/archives/view/nomansky_pepper_2019/downloads.cfm?archive=Spreadsheet

69.The spreadsheet of inscriptions is here: https://archaeologydataservice.ac.uk/archives/view/nomansky_holly_2019/downloads.cfm?archive=Spreadsheet

70. https://doi.org/10.5284/1056625.

significant locations, as on Schrödinger's Rat Race[71]), 3) portal parties (players arrive at a planetary portal at a pre-arranged date and time to leave messages as a group to mark a specific event). The most famous portal party was the farewell party at the Galactic Hub's old capital of Lennon, which was held on 20 August 2017, immediately prior to migration.[72]

Based on archival records from the Galactic Hub's wiki[73] as well as the community's reddit,[74] the Hub's capital planet of Lennon was populated by several player-bases at the same time, something that is impossible in the Atlas Rises version of the game. A "paradise"-class planet, the mild climate and abundant resources encouraged settlement. The planet was big enough to accommodate several players without becoming overcrowded or threatening to deplete those resources. Lennon's position in the Euclid galaxy also granted it prime access to hundreds of similar worlds rich in diverse and complex flora and fauna as well as planets whose main asset was beauty. It was not uncommon for players to establish a foothold in the Galactic Hub by temporary settlement on Lennon and then leave to settle nearby systems. Lennon was a waypoint much like old St. Louis, a gateway to the West, or in this case, the stars.

Abandonment and settlement go hand-in-glove as is demonstrated in the archaeological record. When one site or area is abandoned, those displaced people often find somewhere else to settle, creating a pattern of abandonment and settlement. In the natural world, for example, the eruptions of Mt. Pinatubo in the Phillipines have a documented history of affecting populations in the Papanga and Zambales provinces (Gaillard et al., 2007, p. 234). As recently as 1991, the population continues to be redistributed because of eruptions, flooding, and government mandatory resettlement (p. 239). Cyclical resettlement based on environmental changes—in this case erosion—is also to be found in the archaeology of Jordan dating back to the Holocene (Hill, 2006, p. 6). Cyclical abandonment was more common in areas more susceptible to erosion. Areas of settlement on the more stable upland plateaus have undergone less-frequent abandonment and have experienced more continuous occupation. Hill notes that these cycles of abandonment and settlement were actually a strategy to let the soil recover prior to returning (Hill, 2006, p. 116). As soon as the landscape stopped being productive because of overuse by people, the inhabitants packed up and left only to return sometime later. Unlike disaster-driven changes in settlement, these cycles of migration are human-made and are at times intentional. With the Galactic Hub in *No Man's Sky*, one sees planned-for (and cyclical as of this writing) migration based on the forecast of a disaster created by humans on the outside of the synthetic universe.

71. https://doi.org/10.5284/1056627.
72. https://www.reddit.com/r/nomanshigh/comments/6tyvxn/the_portal_party_last_day_in_the_old_galactic_hub/ (accessed 19 July 2018).
73. https://nomanssky.gamepedia.com/Galactic_Hub_Project (accessed 19 July 2018).
74. https://www.reddit.com/r/NMSGalacticHub/ (accessed 19 July 2018).

Because the climate and topography of every world in the *No Man's Sky* universe changed literally overnight on 11 August 2017, it is impossible to tell why a player chose a specific site upon which to settle. Because 21st-century humans populated this synthetic universe, the digital archaeologist is dealing with documented (instead of prehistoric) societies, meaning that one can consult outside player resources such as the *NMS* reddit or Galactic Hub wiki. In reviewing archival photos and planetary descriptions posted on these online resources, however, one can see that players settled on planets lush with resources, planets that had agreeable weather and were free from predatory fauna. Planets with megafauna, specifically dinosaurs (affectionately known to players as "diplos") or giant teddy bears were especially desirable, as were planets with low Sentinel (patrolling bots) presence. Because the Hub community evolved into one with a citizen-science focus, settling somewhere with "space dinosaurs" became a form of prestige. Fauna in *NMS* can also be carnivorous or aggressive, which decreases the quality of life for players. Flying Sentinels can also be aggressive depending on the planet, so settling somewhere where these bots are relaxed is also desirable. Settlement followed predictably human desires of aesthetics, access to water, mountain views, and proximity to natural resources, oriented for spectacular sunsets and stellar views (e.g., Serenity Villa[75] and Asphodel[76]).

Abandonment, as described above, followed three notable trends: 1) deconstruction and relocation of a base, 2) other bases built by the player who is no longer able to see the original base, 3) base no longer accessible after the Atlas Rises v1.3 update. For those who chose to relocate via options 1 and 2, abandonment largely happened for two reasons: 1) the climate and topography changed to extreme cold, heat, or toxicity, thereby killing natural resources and making day-to-day survival nearly impossible (or certainly impractical), and 2) loss of community. The Galactic Hub's census put the original population at around 200 players by the time of Atlas Rises (the census of the New Hub is now over 400 with more players arriving daily in anticipation of the v1.4 update).[77] The community thrives together, and according to the Hub's founder and chief executive, Syn1334, only a few players remain in what is now known as the "Legacy Hub", these players largely being new arrivals to the region prior to joining up with the main group post-August 2017.

One major trend in abandonment is the tendency for the base owners to leave a communication station near their old base with a forwarding address, or simply a note that they are leaving. Compare this to notes left behind during westward migration in the United States, where families would write "GTT" on their doors in the early 1800s,

75. https://doi.org/10.5284/1056620.
76. https://doi.org/10.5284/1056641.
77. https://nomanssky.gamepedia.com/Census_-_Galactic_Hub (accessed 19 July 2018)

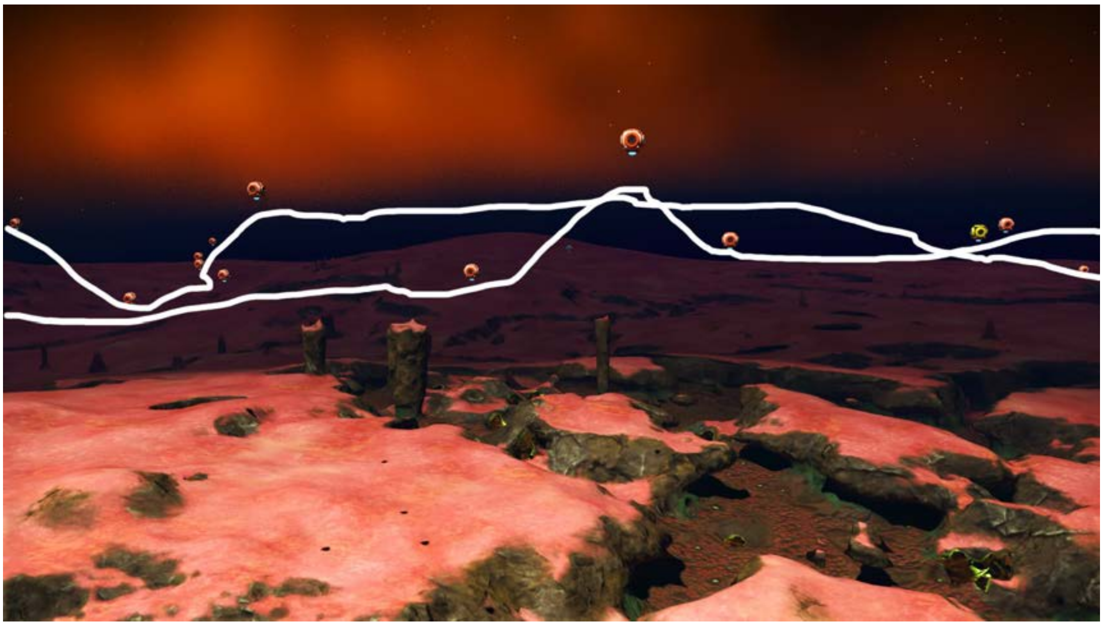


Figure 5.22. Comm station positions showing past topography at Ty Beecham's Pearl Farm.

Figure 5.23. Georeferencing of hollyworks' pearl farm on Holly's Blue Moon Paradise.

meaning "Gone to Texas" to find their fortunes when Texas was not yet a state (Hughes, 1884, p. v).

As described above, most messages were ones of greeting, ones complimenting the player on their customized base, or ones leaving information on how to reach them elsewhere in the universe, as per examples in the site reports of Lennon,[78] the Cave of Forgotten Dreams,[79] and Butter Base.[80] Some were left upon settlement, others at abandonment, but most were left by visitors taking a tour of the Hub as they traveled towards the center of the galaxy, the overarching (but not required) goal of *No Man's Sky*.

Considering the changed landscapes of planets in the Legacy Hub, in several instances I discovered communication stations and bases either buried underground

78. Inscriptions can be read here: https://archaeologydataservice.ac.uk/archives/view/nomansky_lennon_2019/downloads.cfm?archive=Spreadsheet

79. Inscriptions can be read here: https://archaeologydataservice.ac.uk/archives/view/nomansky_pepper_2019/downloads.cfm?archive=Spreadsheet

80. Inscriptions can be read here: https://archaeologydataservice.ac.uk/archives/view/nomansky_butterbase_2019/downloads.cfm?archive=Spreadsheet

Figure 5.24. In-game infoscreen showing player-discovered waypoints. Selecting a waypoint from the list shows the discoverer's gamertag and date of discovery.

or suspended in the air. Although I knew the addresses of settled Hub planets, the challenge lay in locating them. The mechanics of the game allowed for hints, icons displayed in the HUD for comm stations and bases, which in the case of buried built heritage equated to little signs stating "dig here." Their current disposition in the spring and summer of 2018 showed the original landscape (Fig. 5.22). On occasion, several comm stations would align up an invisible mountain slope or ridge, making it easier to see what a planet might have looked like. As described earlier, on a few planets I was able to conduct some exercises in georeferencing, aligning the camera to reproduce images of bases and landscapes as they were one year ago, effectively demonstrating how the landscape changed over time, and why the bases and comm stations appear as they do now (Fig. 5.23).

One other archaeological feature present within *No Man's Sky* is not created directly by the player, but rather indirectly merely through a player's presence at an abandoned site: glitches. Because of the complexity of the game's coding and algorithms, I encountered a number of glitches on the Hub's capital planet as well as elsewhere throughout the old Galactic Hub. As reported above, the game and its worlds are quite susceptible to game-saves (where a player halts their progress after a session) and "online services" (the live connection to the game's servers in Guildford). If online services are not active, player-bases will not appear for visitors, nor will comm stations or date-stamped data about on-planet discoveries such as waypoints. Dating of waypoints is crucial to understanding the history of exploration and settlement of a planet, creating a timeline of Hub-wide exploration while also setting *terminus post quem* and *terminus ante quem* for base construction, which also yields a chronology of Hub settlement (Fig. 5.24).

Saving games also induces glitches, which can disturb the archaeological context of old player-bases. As reported above, I discovered this by accident (and reproduced the issue, also by accident) early in my archaeological investigation of the Legacy Hub. For Pathfinder-era bases, many of them are locked in a ruined state, missing component parts, partially (or completely) buried, or left floating in the sky. Seeing bases in their current state provides archaeologically important information of what the world used to look like, and how bases can degrade over time once abandoned by players. Saving the game, however, while still on the ground on a legacy planet, will relocate the base to a new building site, and will also completely reconstruct it to its original design specifications as saved by the original player-builder. The first time I triggered a relocation (this happened on my second site visit, Abundance), I saved my progress on that planet, logging away so I could go to sleep. When I logged back in the following day, the comm stations surrounding the base remained, but the base had moved itself halfway across the planet, completely above ground. The second time I triggered the glitch, my Sony PlayStation 4 lost power thanks to severe weather, and when the power was restored, the base had moved itself. The original context and state of preservation were lost (although I had managed to photograph and video-record what I needed prior to the glitch). The benefit, however, was that the bases were completely restored to their original design. Players could then visit the sites not as reconstructions, but as original builds, albeit not on original sites. This is potentially (but not intentionally) misleading to players who might not know that the bases they visit are not on the original spot the builder used during the initial construction phase. As noted above, I reported to the Galactic Hub's community leadership, Syn1334 and Zaz Ariins, what I had accidentally done to the two bases, but they were happy with the outcome namely that they could finally see two of the classic structures from the Hub's earliest days.[81]

One other glitch-like behavior is present in *No Man's Sky*, and is likely present in other games and software as well. In the instances of worlds containing complex bases or several comm stations or rows of crops, the action of the game slowed down almost to a standstill. For buried bases, this slowdown in graphics and motion served as a new kind of remote sensing letting the player know that something is present under the surface. I will call this phenomenon "noise-induced discovery", the noise being the complex behavior of unseen structures detected by aberrations in player agency and movement.[82] It is another non-invasive way to identify obscured archaeological features, the noise focused on one specific area of a wider landscape.

In most of my site visits and report-writing, what I discovered and recorded matched the narrative of the original settlers of the worlds I visited in the Legacy Hub.

81. Pers. Comms. from Syn1334 and Zaz Ariins, 25 April 2018.

82. This video shows the choppy frame-rate indicative of a data-rich area in the game: https://www.youtube.com/watch?v=bBZ25AYTE0o

On at least three occasions, however, my work was supplemented through archival research that required me to revisit the sites and perform actual excavation of the bases below ground-level to uncover additional parts of these structures (e.g., Horner, Langley_83_Alpha, Sosashibukay).[83] Use of archival materials allowed me to conduct georeferencing and to supplement the narratives of these structures through reading first-hand accounts by the builders and by some of the first visitors to these sites.

On occasion my interpretations of bases were either incorrect or only partially accurate because I was missing some fundamental knowledge of the game's functionality. For example, in some cases what appeared to be a random assortment of crops planted at a hydroponic farm ended up combining to create exceptionally valuable trade goods that could be sold on the Galactic Trade Network for millions of units. Most farms were not built for subsistence, but rather as large, revenue-generating ventures that unlike capitalist, corporate farms, shared the bounty with any traveler who cared to visit and help in the harvest. This is an example of "open reciprocity" defined as "keeping no accounts because it implies a relation of permanent mutual commitment" (Graeber, 2001, pp. 219–20). In these instances, Hub community members help each other by providing cultivated resources to one another—resources that do not need human minders once planted—a kinship practice based on shared Hub citizenship.

The most notable feature of the Galactic Hub's movement of hundreds of players from one region of the galaxy to another is that it marks the first-ever catastrophic climate-induced migration of human players within a synthetic, digital space. When the atmospheres of dozens of paradise planets became unable to sustain permanent life—both plant and animal—the human population was forced to move. They moved as a community, first scouting out suitable locations and then selecting one sustainable region to share. A new charter was drawn up, a government reestablished by climate-refugees.[84]

As 24 July 2018 approached—the date of NEXT v1.4—the Hub community felt more prepared to meet any climate-related challenges, or the possible reset of the entire universe into something completely unanticipated. Hello Games hinted at the likelihood of massive, communal bases to be shared by groups of players, and at the potential for violent warfare, which might mean the invasion and destruction of a Utopia like the Galactic Hub. The Hub citizenry created a protective "space force" to patrol for incoming hostiles and to discourage them from doing harm.[85] The Hub community sees itself as peaceful, but will take up arms to protect itself if need be.

83. This continued the trend of conducting salvage/rescue work in anticipation of making all of the resulting data available for present and future research projects. These emergency excavations were not examples of preventative archaeology because there was no way to preserve the sites from the threat of annihilation by future software updates.

84. https://www.reddit.com/r/NMSGalacticHub/comments/5a4uoo/galactic_hub_project_explained/ (accessed 19 July 2018).

85. https://nomanssky.gamepedia.com/Galactic_Hub_Defense_Force (accessed 19 July 2018).

5.4. Community: How I Engaged with the Player Community, and Their Response

The Galactic Hub Project was created by player Syn1334 shortly after the initial release of *No Man's Sky* in July 2016. His stated goal for the project was to "create a hub—likely a small one—in a region in the Euclid Galaxy. A place where travelers might stay a while to explore the stars within, where 'discovery markers' would pop up everywhere when you scanned for discoveries on the in-game map. Exploring 100% of the region isn't the main goal, but might happen eventually anyway."[86] One year later after the Atlas Rises update, Syn1334 further explained the Hub and the reason for its move:[87]

> Originally located in the Rencotniijik Expanse / Rentocnii Conflux with our capital system of [HUB-G-211] Lennon, planet Drogradur, the entire civilization relocated to the Shungka Void after the Atlas Rises update. This relocation marked the beginning of the Renaissance Era in the Hub.

As the Hub's population grew, its founder and a small council of "ambassadors" codified a semi-permanent set of rules, system of governance, instructions on how to settle Hub planets, player interaction, and benefits for joining the Hub community as a citizen "interloper".[88] These rules and player-adopted form of government served the community well between Atlas Rises and the NEXT update that occurred one year later. All players were taken by surprise with the universal "biome reset" of v1.3, so when *No Man's Sky: NEXT* was announced by Hello Games on 18 May 2018, the Hub community knew that there would be a good chance that they would have to move yet again. Syn1334 created a subreddit to plan for the move based on past experience.[89] In it he outlines steps for the relocation strategy and offers instructions to community members on how to prepare for the move, leaving it up to players to decide what to do with their legacy settlements. With NEXT, Hello Games offered a way for players to "resurrect" their bases on a new homeworld, a lesson learned from the previous universal reset where unless players dismantled their homes by hand, they would become either buried or ruined.

I did not actively seek out other players as I worked, but they did find me largely through Twitter, email, and reddit. Syn1334, the founder and chief executive of the

86. https://www.reddit.com/r/NMSGalacticHub/comments/5a4uoo/galactic_hub_project_explained/ (Accessed 14 July 2019).
87. https://www.reddit.com/r/NMSGalacticHub/comments/7awyot/welcome_to_the_galactic_hub/ (Accessed 14 July 2019).
88. https://nomanssky.gamepedia.com/Galactic_Hub_Project (Accessed 14 July 2019).
89. https://www.reddit.com/r/NMSGalacticHuba/comments/6trkh4/glyphs_pilgrimage_important_decisions_the/ (Accessed 14 July 2019).

Galactic Hub reached out to me with some Hub history along with a spreadsheet of locations he had been keeping secret. These would guide my research into player settlement/abandonment in the old Hub. I was given permission to publish these in my site reports on archaeogaming.com. Player Zaz Ariins, leader of the community's Galactic Heritage project, was also cataloguing abandoned sites for the Hub's wiki and Heritage page, and we ended up sharing information. He gave me additional locations to visit, and shared my images, video, and text of the places I recorded, which have since been incorporated into the heritage lore of the Hub, via the Hub's reddit and wiki pages. The Hub community sees my work as valuable to recording the history of their initial founding, settlement, and exploration, and I have received messages of thanks from a few players. Zaz Ariins asked me to let him know where I ultimately settled at the conclusion of the project so that it could be added to the Galactic Heritage (and Legacy Hub Heritage) site gazeteer, which as of this writing it has.

Other interaction with past Hub residents was indirect, reading their earlier posts to determine locations of their old Hub bases, finding pictures of these to compare with the current state of the architecture, and to compare landscapes of the same planet pre- and post-update. The Hub's wiki and reddit pages proved to be indispensible to my work, guiding my travels, and helping me know where to look (and to understand what is now missing).

Following the example of reality television shows featuring law enforcement officers driving to various emergencies with a camera operator in the passenger seat, I managed to conduct a couple of ride-alongs on the NMSArchaeology Twitch channel,[90] netting around 10 viewers each time as I gave flyover and walking tours of player bases in the Legacy Hub. With more advance notice, and now that the project has gained positive reception, I suspect future archaeological live-streams will draw larger crowds for tours of the region even though the sites are all gone now.

The Hub's reddit community was aware of my work, and would occasionally either comment or send me direct messages with tips and corrections or requests to explore other worlds. I would occasionally link to reddit posts of players whose bases I visited (when I could derive that information).

In response to my field report on BotFodder's base on 14 June 2018, player Galactic_Geographic helpfully replied, "Not 100% sure if it's what happened, but a base like this could be built by connecting it to the core unit, then deleting the connecting pieces. Excellent article as always, a particularly strange site." Replying to my 10 June 2018 post on Sunaru2's farm, player Panthamor8 noted wryly, "Ahh the agricultural revolution…only went downhill from there."

90. Twitch.com is a free-to-use platform where anyone can share their gameplay experience live and in real-time.

Hub community members would also leave comments on my field reports on the blog. Galactic Heritage leader Zaz Ariins remarked on 23 June 2018, "Interesting read. Plenty of questions unanswered. There's another bitcoin comms suspended high in the air close to the portal on Drogradur." Helpful comments from players were not uncommon. On 8 May 2018 player gammaton32 stated, "It seems there is a typo in the note for station 15d*, you probably meant '4 comm stations near base' instead of 15. Also, players can't leave more than one comm per planet, most likely to prevent spamming. If you build a second comm the first one is deleted." Thanks to this information I was able to better understand why and how communication stations could change over time.

The leader of the Galactic Hub, Syn1334 (reddit username 7101334) responded to me immediately via a reddit direct message during my initial planning phase for this case study. I wrote to him[91] to ask for permission to conduct archaeological investigation in the Legacy Hub. He replied (used by permission), again indicative of the spirit of helpfulness of the community, and ultimately directed my to the Hub's old capital as well as Syn1334's base and the Cave of Forgotten Dreams, both of which were watershed sites surveyed quite early for the project:

> Welcome to the vacated ruins of our former home! Very glad to hear you›ve taken such an interest in it . . . . You may want to try locating abandoned bases in other systems, because only one base is visible per system (in other words, although you'll find tons of Communication Stations, you›ll only find one abandoned base on Drogradur). It›s possible my base in the Einhander or in the HUB3-G-D4 Asoiaf system could still be visible, as old bases sometimes linger. . . .You can also experience firsthand *why* we left when you visit planets like *Territorium de Caesarus*. . . . You'll actually have quite a lot to do as an archaeologist in the Legacy Region. . . . Thanks for taking the time to do this, very interested to see your results. And if you're ever looking to become Lead Archaeologist or Lead Historian of the Galactic Hub, you'd be a great candidate.

I had not expected to get a job offer or a formal invitation to join the community, and refused both, choosing to keep some personal distance from the community heritage I was studying. I was flattered by the offer, and encouraged that the Hub community had a sincere interest in what I was doing. This behavior reflects what Boellstorff et al. (2012, pp. 76–77) described in their handbook, that ethnographers "must establish the type of presence we wish to have within the worlds we are studying. . . . One of the

91. Syn1334 identified himself to me with his real name, which is male, and Zaz Ariins who knows him in the natural world referred to Syn1334 as "him." I have not reproduced his name in this thesis in order to protect his non-gaming identity.

most important steps in the participant observation process is to take care in initiating relationships with informants (establishing rapport and trust). . . . Begin by reaching out to influential members of a group (done via forms, email, or PMs). Be up front at the outset. The "raw power of authentic interest."

5.5. Reflexivity in No Man's Sky

The theory of reflexivity states that archaeological knowledge is determined by both the experience and context of the investigator. The archaeologist becomes part of the archaeological narrative through excavation and interpretation of data, and that interpretation is subject to change over time and the introduction of additional evidence and experience. I began the project with expert knowledge of video games, their history, and how they work, which likely biased my approach when compared to someone with no gaming experience attempting to undertake a similar initiative. I am also a trained field archaeologist with experience in Greece, Italy, and the United States, excavating both ancient and modern contexts. Over the course of this case study in *No Man's Sky*, my expectations and interpretations changed over the three months during which time I documented 30 Legacy Hub sites. At first, I was unsure what to expect regarding player base design, player-messages, and glitched behavior. After completing a dozen site visits, I had my method down pat, and knew roughly what would happen over the course of each visit, what the components of player-bases would likely be, what the communication stations would most likely say. The only anticipated differences were in the types of crops grown, the specific contents of messages, and that there would be at least one new significant find relating game mechanics to player construction and abandonment. Each of the 30 sites had at least one new thing to show me, revealing the underlying complexity of the game itself. That one aberration became something I could count on, even when I discovered a base where nothing appeared to be out of the ordinary. That ordinary base itself (Mother Base) became an aberration to the other 29 sites because of its very normal nature.

At the conclusion of the final site visit, I could correctly identify in a matter of seconds the nature of a particular building site, what the presence (or absence) of communication station clusters might mean, and how to avoid interfering with the site and the game so as to not corrupt a base's archaeological context. I knew where the old Hub's archival records were, where to find legacy data and images, and how that could be helpful to interpreting the ruins in their current disposition. I knew when and where to excavate, how deep I could go, and what I would likely find. I understood the tools provided to me by the PlayStation and by the game itself, developing a sensitivity on how to use them. Learning these tools and methods was little different than learning the tools and methods on my terrestrial digs. The experience was cumulative, making each visit a little more streamlined than the next, and speaks to the value of retaining experienced archaeological labor within the context of a site.

The human element of settlement and abandonment did surprise me in this game, however, after taking a step back to review the data of the 30 sites visited. One-third of the bases were farms, while the others were outposts. Of these farms, most were not for subsistence, but were rather for growing cash crops to improve the wealth of the player and the community. Many players in the Galactic Hub are industrious, and they are also generous in sharing their wealth and other resources. Players' needs in *No Man's Sky* mirror those of any migratory band of people: resources (food and materials) and shelter (from the elements and predators). The players, being human, also showed an innate curiosity, a desire to explore, and a need to share their discoveries with the greater group of people within the affinity space of the game.[92] Even in a game where the universe is the size of the actual universe, people elected to congregate together to make sense of that overwhelming space, and to help one another survive it. Natural or digital, human needs in either space appear to be the same, and that is what surprised me the most when conducting the case study, which incorporates the concept of video game ethnography as introduced by Boellstorff (2006; 2012) and the idea of new human cultures to be studied within the context of individual video games (2006, pp. 30–32) as opposed to the more general "video game culture" as defined by Adrienne Shaw (2010). "It appears likely that gaming and its associated notion of play may become a master metaphor for a range of human social relations," (Boellstorff, 2006, p. 33). This is embodied by observing and interacting with *NMS* players during the project. With video games (and to a wider extent any software application used by many people), "participatory cultures" of players emerge to "contribute information, opinions, and multimedia content to existing digital projects and, increasingly, their participation is constitutive of the project itself" (Underberg and Zorn, 2013, p. 47). This behavior is quite evident in *No Man's Sky* and its player community, where in 2019 the Galactic Hub has been retrofitted by Hello Games into the official lore of the game while players continue to ask for (and receive) software updates from the developer. The players have taken ownership of the game, and the game's architects continue to build it out to satisfy players' needs.

Boellstorff et al. argue for both the need and relevance of the ethnography of games and other "virtual worlds" such as *Second* Life: "Ethnography, an approach for studying everyday life as lived by groups of people, provides powerful resources for the study of

92. Pellicone and Ahn (2005, p. 5) describe the context of affinity spaces in the game *Minecraft*, which has a robust, networked multiplayer component where individual players and groups can share their constructions on any given game server. The "portal parties" of *NMS*—most notably the leaving party held in Lennon in August 2017—are not unlike other in-world social and ceremonial gatherings as described in the context of funerals in *World of Warcraft* in Servais (2015).

the cultures of virtual worlds. . . . We aim to study virtual worlds as valid venues for cultural practice, seeking to understand both how they resemble and how they differ from other forms of culture" (2012, p. 1). Underberg and Zorn agree with the nature of emergent human culture in digital spaces, stating that "the ubiquity and relative ease of use of computer technology has enabled new levels of empowerment for communities in managing their own self-representation" (2013, p. 26). The study of emerging human cultures in digital spaces lends itself naturally to "digital ethnography", defined by Underberg and Zorn as "a method for representing real-life cultures through combining the characteristic features of digital media with the elements of story" (2013, p. 10). The game becomes its own storytelling medium for ethnographers, and it is up to the archaeologist then to "distill the experience for the audience" (Underberg and Zorn, 2013, p. 10), something I have attempted to do through my rapid reporting in support of the project and the community of players it affects.

Community engagement via social media and messaging also proved to be a very positive experience both for me as an archaeologist and for the community at large as the culture being studied. I believe that through my transparency of purpose, immediate communication, rapid publication of preliminary data, and quick replies to questions and comments from the Hub citizens and leadership, I was able to move freely within the game and was given access to locations that might otherwise have been kept secret to the group. Through the spirit of data-sharing, I was able to get the data that I needed (and even data I did not know I needed) while at the same time assisting the community by giving them detailed information, images, and video of the places they left behind but fondly remembered. A few members of the community have approached me separately to ask to help me in my work once the multiplayer feature becomes active in v1.4, and I think it would be both fun and important to train them so that they can continue the work of documenting their own history as the community continues to grow, handing over what could be perceived as a colonial practice of archaeology to an indigenous population.

Outside of the player community and separate from this thesis, I was able to adapt the Harris Matrix for recording software versions for *No Man's Sky* (Reinhard, 2018a), which could be used for other software applications, but it remains unclear how software developers maintain their own archives (if they do at all). *NMS* developer Hello Games publicly publishes what is new in each version,[93] but other companies are not as detailed or public-facing. This detailed sharing of version information helped with the *NMS* case study to show what happened and when, and also allowed the Galactic Hub community to plan for the next catastrophic disruption of the version called "NEXT", which followed Atlas Rises as a major update and changed the climate of every planet

93. nomansky.com/release-log

in the universe while burying what was left of any Legacy Hub settlement that I had been able to study.

The key thing to remember when investigating a new digital environment is to create and follow a code of ethics (see the *NMS* ethics guidelines published in Flick et al., 2017). It is unknown what human presences will do within a procedural and persistent digital space. Extra care must be taken in the planning and execution of the initial phase of an archaeological investigation until one determines to what effect the archaeologist's agency has on the space under investigation and the other human and non-human agents within it. Research questions will likely differ between synthetic worlds, yet will share a common core of how they were created, settled, and abandoned not only by human players, but by digital cultures introduced into the game-space by the developers, or by algorithms created by developers. Based on my research for this case study, I can speculate on what those questions and answers might be. A code of ethics must underlie all of these questions before the archaeologist attempts to find the answers (Dennis, 2019).

1. How much of the human hand can be detected in procedurally generated cultures, and does that initial intervention disappear over a digital culture's iteration? With *NMS*, the procedurally generated architectural elements are designed by Hello Games staff and then uploaded into the game by way of blueprints that players can purchase with in-game currency prior to using new designs to create human-built farms, houses, and the like. The designed elements, while futuristic-looking, are standard fare, including doors, windows, walls, roofs, albeit of different styles and materials, with a variety of accoutrements that players combine to create the bespoke settlements seen in the Hub's gazeteer.[94] The game also creates procedurally generated "alien" structures and ruins that vary in size, shape, and color, yet have their own distinct architectural vocabulary. It is easy to see the differences between a structure created by a person and one created through algorithms. As games evolve, it is likely that those differences will become harder to identify as AI is trained from player behavior on how to build, learning what makes a building (from a human perspective).

2. What do digital cultures build for themselves in synthetic spaces? In *NMS* there are four artificial races of sentient beings who occupy algorithmically created structures throughout the universe. While distinct in appearance and language, these races do nothing for themselves, and merely sit and wait for human players with whom they can interact in a scripted way. Ultimately, I do believe that games will reach a point where distinct groups of non-human entities will be given agency through programming to behave collectively in ways their programmers cannot anticipate, which might include construction of functional environments. In 2019, this behavior remains to be seen in digital games.

94. https://archaeologydataservice.ac.uk/archives/view/nomansky_2019/site_list.cfm

3. Is it even possible for a human observer to detect a born-digital culture, and if so, what will that culture look like, and how will it behave? For the purposes of this case study, human-created architecture was easy to spot largely because a) humans were granted architectural elements not given to other non-player races, and b) human players often created settlements that either looked like traditional farms/houses, or paid homage to existing structures or pop culture tropes (e.g., Whole Foods grocery stores or, as in the case of Hub settlements such as Paddy's Paddock[95] or the Onsen Observatory,[96] symbols taken from Douglas Adams' *Hitchhiker* novels). Future, algorithmically created "cultures" might be difficult for humans to to detect because of their non-anthropocentric or anthropomorphic natures. Humans likely expect for other cultures to behave like other human cultures, but this discounts how non-human agents themselves behave according to their own rules, which might operate outside of human intervention (e.g., undersea life). The difference, however, between non-human cultures and born-digital cultures is that the former is not governed by human-authored code. Born-digital cultures use human-authored code as a starting point, but might ultimately drift into something undetectable by people. Again, this remains to be seen (if seen at all).

4. Will born-digital cultures ultimately have protected status or be treated like indigenous populations? One of the best outcomes of this case study is that the 30 Galactic Hub sites investigated now have a permanent home via the Archaeology Data Service. The ADS recognized the fleeting nature of these fragile digital sites and have uploaded the reports and media in an act of preservation as well as a way to share this data with Hub members and future archaeologists interested in one of the first efforts to document human settlement and abandonment in a digital environment. It is possible that UNESCO will first recognize human-created digital sites of importance, perhaps starting with major initiatives such as the Internet Archive.[97] In time, however, it may be that digital-only cultures, or cultures birthed from algorithms might rise in global importance depending on their behavior and human recognition of their importance and influence.

5. Will algorithms become a modern example of intangible heritage? In *NMS* (as in other digital built environments) code builds the space occupied by human and non-human agents. The code itself is unseen, yet causes human and non-human performance in these spaces. For something like *NMS*, which procedurally generates literally everything in the game, this code could be seen as intangible heritage, especially if it influences future development of other digital spaces. As seen in Chapter 3, the code

95. https://doi.org/10.5284/1056638.
96. https://doi.org/10.5284/1056643.
97. archive.org

for *Colossal Cave Adventure* is absolutely intangible heritage having influenced generations of coders and players.

At the conclusion of this project it became clear that there must be two methodologies in play when investigating digital sites (i.e., software): macro- and micro-. The macro-methodology can be applied to the archaeology of any piece of software, which includes understanding the context in which software is used (and who is using it to what purposes), and the context of its creation, distribution, and reception. The micro-methodologies relate to actual interaction with the software as the archaeologist-agent. Software programs differ from each other, and versions within the same software application also update their mechanics over time. While the archaeologist can ask the same research questions of any piece of software, the detailed information will be arrived at in different ways based on what the software actually does when observed from within the digital environment. Each software application studied must have its own micro-methodologies that are unique to it under the umbrella of a more general, shared set of macro-methodologies.

To return to the two major research questions stated at the outset of this chapter:

1) Did the behavior of a human population forced to migrate because of a catastrophe within the game mirror that of the natural world?

In *No Man's Sky* there was less panic and more organization than one sees in the natural world, namely because in the latter people are often fighting for their lives, making sure their needs are met (food, water, shelter). It is difficult to equate the two kinds of disasters largely because digital disasters are experienced by people of some privilege, yet each player's feeling of home and their investment of time and materials into building places of their own still carry emotional weight and are archaeologically significant. People protect what they love, and it hurts to lose those places one is close to. Players posted to reddit after each update to lament what they had lost. Player zfreakazoidz wrote that even though they had found the "perfect planet" in the new update, they "miss my old base that NMS erased."[98] Player Huntaer1 posted, "My old base. Still haven't found it yet. Oh well still have my screenshot."[99] Crashdown77 wrote, "Came back to my old home planet from version 1.38, the former paradise planet is now irradiated and everything is gone, but my exocrafts were still around hanging in the mid-air...."[100] Player MrUnnoticed posted an image captioned, "Final salute to my

98. https://www.reddit.com/r/NoMansSkyTheGame/comments/96noc9/nice_little_base_finally_found_the_perfect_planet/

99. https://www.reddit.com/r/NoMansSkyTheGame/comments/92z16v/my_old_base_still_havent_found_it_yet_oh_well/

100. https://www.reddit.com/r/NoMansSkyTheGame/comments/91wqd8/came_back_to_my_old_home_planet_from_version_138/

old foundation home," prior to leaving for a new base in the Hub.[101] These farewells to ruined bases are rarely maudlin, yet players felt enough attachment to them to post publicly about their in-game homes. After posting, they moved on and rebuilt elsewhere.

2) Did my approach to the archaeology of human occupation in a synthetic space differ that much from archaeological approaches used in the natural world?

Yes and no. I started with traditional methods with which I was familiar, and then adapted those to the environment in which I worked. It is perhaps the wrong question to consider similarities and differences between working in natural and digital spaces. The question should instead be, "how can I best answer the archaeological questions from a particular site (natural or digital), communicating those answers in a rapid and intelligible way?"

One must also realize that for humans there is no purely digital habitation. These synthetic worlds contain the fruits of digital labor, yet the human occupants remain bodily in the natural world. The digital built heritage they construct is also housed in the natural world. The digital world is blended; players talk and write outside of the confines of a game even though the subject is usually the game-as-shared-experience. Any future archaeology of digital things must consider not only the interior of digital built environments, but also the context in which they were constructed, and how people engage with software as members of affinity groups and larger user communities. These digital spaces also impact the environment of the natural world, the topic of which should be thoroughly studied: at what environmental cost do we create and sustain digital habitations? For this *No Man's Sky* case study of human settlement in a digital space it was enough to see if one could conduct meaningful archaeological research there. Future studies can go deeper.[102]

101. https://www.reddit.com/r/NoMansSkyTheGame/comments/63cmkg/final_salute_to_my_old_foundation_home/

102. On 14 August 2019, Hello Games released *No Man's Sky: Beyond*, a major update including Virtual Reality gameplay. Future research beyond this thesis should be undertaken in *NMS* to evaluate VR and archaeology mechanics.

6

Conclusions

6.1. Introduction

Based on the framework established in Chapters 1 and 2, I conducted three case studies (Chapters 3 through 5), which demonstrate the ability to do archaeological work within a variety of digital environments. This concluding chapter begins with a look at three major threads of inquiry and results shared by each of the case studies: 1) investigation, 2) interpretation, and 3) communication. Based on these three themes and the case studies that produced them, I propose several future research questions that lead towards a new, formalized research area of archaeology, which concentrates on human digital environmental culture and theoretical approaches to the digital landscapes in which people find themselves occupying both directly and indirectly. This chapter concludes with a reflection on my approach to this thesis' topic and supporting case studies, how that approach evolved, and the weaknesses and challenges that presented themselves over the course of my research.

6.2. Threads of Commonality between Case Studies

Each of the three case studies in this thesis shared several instances of commonality even though the games investigated were quite different from one another. These threads are investigation (by which I mean the act of gathering archaeological evidence in digital environments), interpretation (meaning the analysis of that evidence as well as reflections on the tools and methods I used), and communication (meaning how the evidence and its interpretations were distributed to others). The threads are further subdivided into areas of specific observations on digital archaeology, culture, and heritage. These threads are presented in the order in which many archaeologists approach material remains. They begin with an investigation of the evidence, followed by its interpretation, which is ultimately shared with others. While I appreciate the simplified—and arguably problematic—nature of this tripartite division, I believe it important because common themes emerged from my investigations of three very different digital environments using diverse, scenario-based tools, methods, and approaches.

6.2.1. Thread I: Investigation

All archaeological sites (including digital ones) are investigated and share the need for research questions, tools, and a guiding methodology for their investigations, as shown by the following six points:

Ia. All three case studies demonstrate my two underlying hypotheses that 1) archaeological methods and tools can (and should) be used to understand digital built environments (DBEs), and 2) that DBEs can be investigated archaeologically.

Colossal Cave Adventure showed that archaeological work can be conducted on software code itself in order to learn more about its creation, history of use, and impact on future generations of both people and code-based constructions. I followed standard epigraphical methodology as established for Greek and Latin inscriptions from antiquity (Bodel, 2001; Cooley, 2012) while updating my own background in Classical archaeology through the introduction of a digital suite of tools centered around the *R* statistics programming language and framework used by other archaeologists and Digital Humanities scholars. My research questions, tools, and methods reflected current archaeological practice in a non-traditional environment of code, demonstrating that an assemblage of code-artifacts can be investigated in ways similar to, for instance, the collection of Oxyrynchus papyri (Grenfell and Hunt, 1908). By conducting stylometric research into digital code, which is both machine- and human-readable, I have documented and tested tools and methods for looking not only at other code-sets, but also for any other collection of digitized texts in any language from any point in history.

Taking a completely different approach to digital heritage and archaeology, *Skyrim VR* is based on an imagined Norse heritage set in a vast landscape held within the controlled digital environment of precisely planned and designed code and graphics. This served as a proper experimental training ground for conducting traditional landscape archaeology in a 3D digital space while also asking questions about phenomenology and heritage reconstruction of environments and cultures. This opens the door to using similar tools and methods in investigating other synthetic spaces archaeologically, and includes GIS, 3D imaging/printing, and publication of those immersive spaces for people without access to that environment or to sophisticated hardware and software. By experimenting with landscape archaeology and heritage reconstructions digitally first, we can translate what we learn from digital experimentation to sites in the natural world (Morgan, 2009).

No Man's Sky proved that traditional archaeological tools and methods used in the natural world can be scaled to investigate synthetic sites and landscapes, albeit with modifications based on in-game mechanics and the realities of operating inside a space governed by manufactured physics. Human settlements and patterns of abandonment in digital environments can (and should) now be analyzed as examples of late 20th- and 21st-century archaeology in real-time as these settlements evolve. As my case study showed, if work is not conducted in synthetic worlds during periods of human habitation there, those worlds will either change or be lost within a very short time-span. Granted, archaeology generally happens after the fact, after things have changed and time has passed. We arrive too late and are left with a puzzle to recreate that is already missing pieces. With archaeology of digital things, the archaeologist can work with digital material in (or close to) real-time before change and loss occurs, and can also document that loss and change as it happens, from which trajectories of change can be modeled.

Ib. The archaeology of a digital built environment is a hardware-mediated engagement. Penetrating the screen equates to penetrating the topsoil and removing the overburden/backfill to find what lies beneath, while using peripherals (e.g. mouse, keyboard, etc.) as tools used to manipulate materials through an interface.

This point can be taken literally at first: the top layer of turf stands between the archaeologist and archaeological data. One must get through that layer to engage with what is underneath, but one can also examine the topsoil itself as another layer of data to be understood by the archaeologist. The same can be said of the screen. It is both a barrier to and a bearer of potential, and can be studied on its own as technology for mediation. One must engage with it to get to the data it displays. No matter what kind of archaeology one wishes to conduct with synthetic spaces, one must do so through the "interface" of screens, in my case studies via a flat-screen television and VR headset, and for other digital archaeologists: smartphones, computer displays, tablets.

However, any kind of excavation is not just putting spade to soil. It requires planning and permits. It often engages with politics and bureaucracy either explicitly or inadvertently. It deals with both usage rights and copyright. It always involves more than just the excavator. For my digital case studies, I faced similar issues experienced by my colleagues who work with more traditional archaeological material. I had to plan all three case studies and create the research questions that drove the planning. I had to arrange for access to the sites, in this case discovering copies of *CCA* or purchasing copies of *Skyrim VR* and *No Man's Sky*. Even then, I was never in total control of the game-sites or the technology facilitating my access to them. Hardware crashed. Games either updated or glitched. The more I worked within each digital environment, the more my thinking evolved about how to engage with the software, how to present my work, and what the results might be.

I had to select the tools to use and then learn how to use them, which included *R* and its packages for *CCA*, and the Sony PSVR hardware for working in virtual reality of *Skyrim VR*. I engaged with a community of players in *No Man's Sky*, which led to rewarding discoveries and conclusions. In planning to publish this thesis as a book or series of articles, I will need to negotiate with rightsholders of intellectual property, be it the "landowner" Hello Games (*No Man's Sky*), or individuals who have taken screen and video captures of these spaces. As shown above, the planning of digital fieldwork has much in common with more traditional fieldwork. The main difference might be, however, is that I can access digital environments whenever and wherever I like.

Ic. The games in all three case studies can be approached archaeologically with existing tools and methods, but I adapted those to the spaces I investigated. This flexibility is key, provided reflexivity accompanies their usage. The tools used differed between games. Digital archaeologists must first evaluate the site and then determine which tools are appropriate to use.

For most/all archaeological fieldwork, the archaeologist begins with the methods and tools to hand based on past personal experience as well as longstanding tradition in the discipline. However, it is not uncommon to encounter situations requiring either new tools or modification of existing ones especially when one is in a remote location (e.g., as described in Carver, 2011, regarding his evolving excavation methods at Sutton Hoo). This kind of DIY tool-making is driven by research questions and the environments in which they are deployed and reflects how humans have always adapted technology in order to work wherever they find themselves. In the case of these three case studies, however, I evaluated the tools I wished to use prior to use, checking for bias, and also ensuring that these had been vetted by others in the archaeological and Digital Humanities communities.

For *Colossal Cave Adventure* I chose *R* and various related programs to analyze code instead of traditional texts. For *Skyrim VR* I utilized *QGIS* and other programs for photogrammetry, georeferencing, and image and video capture within a virtual reality environment even though these tools had never been developed for this kind of use. It was exciting to see their potential realized, although at times the results were imperfect. Future tool-creation and modification can improve later output.

I chose each of the three games based on their unique features that made each game distinct from the other. I asked different research questions of each game, which required different tools and methods to answer. The statistical tools and epigraphic methods used in *Colossal Cave Adventure* would prove useless in *Skyrim VR* and *No Man's Sky*. I cannot conduct photogrammetry in *CCA* even though I can in the other two games. Excavation is impossible in *CCA* and *Skyrim VR*, yet the mechanics in *No Man's Sky* allow for it (although the original game's intent for this feature was not to facilitate archaeology). Despite these differences, I was able to conduct archaeological investigation in each of these games and used previously existing tools to do so even if they had not been used before in synthetic spaces. There is, however, a weakness in being one of the first to deploy digital tools within new environments. It is unclear how they will work, and the quality of data they will return. One of the benefits of working openly is that tools and methods can be evaluated by one's professional peers in real-time; unfortunately that evaluation did not happen as I expected it would. Perhaps future readers of this thesis will comment on my case studies and offer criticisms or alternate tools to use to achieve similar goals.

Id. All three case studies deal with built environments, examples of contemporary material culture, which can be studied archaeologically.

Unlike built environments in the natural world, digital built environments are constructed primarily of coded elements assembled in such a way as to produce a synthetic space in which humans can dwell, work, and play (i.e., a taskscape). Granted these DBEs are themselves products of human labor in the natural world—a kind of digital nature-culture (Latour, 1993, p. 7)—which require electricity (produced by machines and materials) and other energy sources, water, metals, plastics, all of this entangled in the creation of a space largely out of sight and out of mind when experienced by an independent user. For the purpose of this thesis, the primary focus of each of the case studies was within the synthetic environments themselves as places of human occupation, use, and abandonment.

Colossal Cave Adventure is a construction made of code punched into paper cards to be fed into a compiler and then interacted with by the user through human-readable input via hardware (keyboards and dumb terminals). Early software is literally a house of cards. Future generations of people then adopted, adapted, encroached, squatted, and constructed later iterations of that code to create a sprawling settlement of similar, networked spaces. The first examples of modding appear along with one of the first examples of the international viral spread of a code-artifact to create a culture of users based around a digital thing. Over the course of *CCA*'s history (which is still ongoing), one sees a material culture develop based on the material of code, which intersects with other communities based around computer hardware, user groups of the PDP-10 and -11, of IBM, of Spectrum, and Commodore, tribes within tribes. One can conduct digital ethnography as well as analysis of physical and coded digital media under the auspices of a single project. In 2019 many of the coders and users are likely still alive and could be approached with questions, the answers of which can be compared against the archaeological record. For this case study, I should have created a plan for the University of York's Ethics Committee to review so that I could interview various coders. When it comes time to write the journal article, I will email each of the known programmers to gain additional context about *CCA*.

Skyrim VR, itself a DBE, proved to be a model of virtual reality heritage, albeit of an imagined yet fully realized culture. Individual players inhabit millions of identical versions of this space yet share a singular nostalgia for the snow-covered, designed realm.[1] The success of this simulated environment that created a visceral sense of heritage and lore, of a place both contemporary and ancient, can lend itself to future archaeological projects engaging in cultural reconstructions and embodied experiences for users to understand at the very minimum a sense of scale.

No Man's Sky represents a new kind of DBE, a literal infinite universe inhabited by human players who can treat new worlds however they choose. One sees for the first time human-created civilizations inhabited and governed by groups of players who can choose to explore, build, and engage with a space granting complete freedom of movement. We can now see what happens when groups of people create new cultures in synthetic environments where neither space nor resources pose restrictions on creative lives. As my *NMS* case study showed, the earliest settlers of the Galactic Hub formed a functioning Utopia, which fostered individual expression in the choice and settlement of planets while also contributing to the greater good through the sharing of knowledge and resources.[2] The strength of that community manifested visually through communication stations scattered throughout the region, messages of support, praise, and thanks. Problems (and their solutions) experienced by these user groups in synthetic

1. A quick, unscientific internet search of "skyrim" and "nostalgia" returns hundreds of thousands of results on reddit alone.

2. See the constantly updated *Interloper's Handbook* produced by the Galactic Hub community as a way to welcome to players to both *NMS* and the Hub: https://nomanssky.gamepedia.com/Interloper%27s_Handbook_-_Guide_to_the_Galactic_Hub (accessed 21 September 2019).

spaces may be able to provide useful information to similar issues in the natural world where the stakes are considerably higher. For example, how well or poorly did executive management handle a disaster? How well was the community informed regarding disaster preparedness? How involved was the community in the planning process?

In *NMS*, the Galactic Hub was able to prepare for the eventuality of evacuating their current homes and relocating. The communication between the leadership and the community-at-large was both seamless and transparent. Questions were answered well in advance of the catastrophe, and a disaster-management plan was in place weeks ahead of the release of *No Man's Sky: NEXT*. Even though this is a video game culture, the leadership and planning could be considered by natural-world communities at risk from natural disasters, giving equal weight to community input on how to prepare—and survive—the next hurricane, flood, earthquake, etc.

Ie. All three case studies start with traditional archaeological questions. Each case study begins with my own experience as an archaeologist in the natural world (Classical) and then expands as I venture into the digital.

In the 1990s and 2000s I participated in a few archaeological excavations in Italy and Greece as well as in the United States. My experience with reading pottery and with reinterpreting previously dug contexts might seem like a poor foundation for conducting archaeological investigations of digital environments, but I was able to draw upon universals such as articulating research questions and research plans and adapting my methods and tools to any given site. I was able to revise my approaches to my three case studies as I worked, emerging with solid ideas of how to work with code-artifacts, with designed heritage spaces, and with human settlements in synthetic environments. I can now communicate these as baseline practices from which others can work and revise. Also, as demonstrated in my three case studies, my work with the statistics package *R*, with data visualization tool *Gephi*, with photogrammetry, with GIS, and with communication tools and methods deployed with other archaeologists, scholars, and game-specific communities can all be applied to any archaeological project regardless of its location and material. Future digital archaeology projects would benefit from the use of teams, which will bring diverse perspectives to bear on project-planning and execution, as well as internal knowledge-exchange of how to perform specialized tasks.

If. Each game I selected lends itself to different kinds of research questions in order to complete a suite of archaeological understanding of the digital spaces in which we spend much of our time and resources, both intellectual and financial. Lessons learned in/from these play-environments can possibly be applied to other digital spaces that are not as entertaining, yet still demand our presence in them each day.

This thesis uses games in its case studies as a gateway to a broader understanding of DBEs. In my personal experience it is easier to explain the intersection of archaeology and video games to non-gamers as well as non-archaeologists because of the name recognition of Lara Croft and *Tomb Raider*, or the fact that many popular games advertised online and on television include photorealistic worlds set in a historic past (e.g., *Red Dead Redemption*) or in an imagined sci-fi future (e.g., *Destiny*). In these games there are people and buildings, roads, starships, things a non-archaeologist might perceive as having some kind of archaeological use or meaning. What is perhaps less intuitive is the fact that the tools and methods used to investigate these games can be applied equally to office productivity suites, to email programs, to websites, to operating systems, and more.

Every digital thing, be it software or the hardware used to run it, is constructed and has an underlying architecture. Everything digital becomes a part of contemporary material culture. We see this in the code of *CCA* where a cavernous environment is built from words, the words of which are also constructions within the artificial language of FORTRAN, which was originally designed primarily for conducting mathematical operations. *CCA* and its versions contributed to what is now a massive community of players of adventure and role-playing games.[3] *Skyrim VR* is a designed environment, yet features a major modding community who regularly program enhancements and additions to the game, introducing new material culture into what was originally a static, synthetic space.[4] With the possibility now of 3D printing in-game artifacts, we can now generate physical artifacts from these digital spaces. In *No Man's Sky*, my research into the Galactic Hub settlements showed that human players adapted to digital environments originally architected by algorithms and made a culture around gameplay and exploration. Since this study, the Hub has grown from dozens of players to thousands.[5]

Humans experience these spaces as digital habitations and often spend many of their waking hours in them. Games are but a subset of these habitations.[6] And for those people who do not themselves possess games, software, or the hardware on which to run them, they remain enmeshed within the hyperobject of a digital-fronted global community, the Internet, and the market it affects. What we do in digital spaces absolutely affects those outside of them.

3. ifwiki.org is the major community portal for creators and readers of interactive fiction (accessed 21 September 2019). As of this writing, the group's annual interactive fiction contest is in its 25th year.

4. The *Skyrim* modding community on reddit has over 164,000 members. https://www.reddit.com/r/skyrimmods/ (accessed 21 September 2019).

5. Census results for all eras of *NMS* can be found here: https://nomanssky.gamepedia.com/Census_-_Galactic_Hub (accessed 21 September 2019).

6. In 2018, the average adult played video games six hours per week (https://www.limelight.com/resources/white-paper/state-of-online-gaming-2018/). In 2014, data research group NPD reported that 34 million players who identified as "core" (serious) gamers played video games an average of 22 hours per week (https://www.npd.com/wps/portal/npd/us/news/press-releases/the-npd-group-reports-34-million-core-gamers-spend-an-average-of-22-hours-per-week-playing-video-games/).

6.2.2. Thread II: Interpretation

Archaeological data can be interpreted both "at the trowel's edge" and post-excavation (Hodder, 2004). The following four observations underscore the similarities of interpretation of digital sites borne out of my three case studies, two of which (*Skyrim VR* and *No Man's Sky*) were created to make a profit for their developers, one large (Bethesda Softworks) and one small (Hello Games):

*IIa. Each case study yields data about different kinds of digital spaces and a different way of experiencing the synthetic, including VR 3D (*Skyrim VR*), 2D (*No Man's Sky*), and "1D" (code only*, Colossal Cave Adventure). *The archaeology of the synthetic, however, stems from an archaeology of the natural, and the problems that entails.*

When one works with code and text-output (as in *Colossal Cave Adventure*), one operates in one-dimensional space. Code is flat, yet creates a text-based world for us to comprehend and operate within. When one plays a game such as *No Man's Sky* or any equivalent software application that has a graphical user interface (GUI), we continue to live in our own four-dimensional space-time while operating within a two-dimensional digital environment of text, pictures, and graphical moving parts (or 2.5D with GIS). When one enters a "virtual" world through VR hardware, one enters a simulated three-dimensional space and operates within the rules of that environment, which can be very different from the rules of the natural world. At my desk, I am seated, but in VR, I could be floating, and my brain must hold these two conflicting states of being at the same time, negotiating this paradox. The more humans engage with evolving software, the more those same people become post-human. People and technology have co-evolved, but in the twenty-first century especially, many humans have begun to fuse with their tools (Díaz-Guardamino and Morgan, 2019; Pilsch, 2017). Perhaps this changes the nature of digital archaeology from investigating how people create and interact with digital built environments to investigating the digital-human-as-artifact. All three case studies include the human with the digital, but future work will go beyond the dualism of human-or-machine to investigate the blended sites of the post-human digital organism, something I did not anticipate originally when beginning this thesis.

As mentioned above, digitally enabled humanity currently drives the economy, climate change, and other major factors that affect the global population not just of humans, but of all living things. The digital divide widens even among residents of countries who either choose not to own (or cannot afford) digital devices and related software. By opting out (or being unable to opt in) to the digital economy these people are not left behind, but rather are swept along with the rest of humanity on digital waves of innovation and waste, which requires its own kind of archaeology. This is an archaeology of the present as the cycle of planned obsolescence and the creation of super-massive volumes of digital materials continues unabated. Games and gaming hardware being but a part of this tsunami of eventual e-waste (González-Ruibal, 2018).[7]

IIb. All three case studies are snapshots in landscape evolution. The gaming spaces evolve over time, sometimes slowly (e.g., Colossal Cave Adventure's *gradual evolution or, in the natural world, wind-erosion) and other times in punctuated leaps (e.g.,* No Man's Sky *through natural catastrophe).*

Landscapes change over time, even ones that are manufactured (i.e., software). Agents of change include environmental factors (e.g., wind, weather, animal use, plant-growth, fire, flooding, etc.) as well as human use and occupation. Because all three of this thesis' case studies are software, they are subject to forces that change their landscapes in both subtle and not-so-subtle ways. Agents of change for digital built environments can include software updates, new versions, patches, and bug-fixes all written and distributed by those responsible for the software's creation. There are other agents of change at work outside the control of software developers: bitrot (the slow degradation of code and digital files) and user-created mods (bespoke patches creating functionality and features unintended by the developers).

Most of the time, change comes slowly to software landscapes. In *Colossal Cave Adventure* the software evolved over the course of 40+ years in a kind of punctuated equilibrium as new programming languages emerged alongside new hardware and operating systems. *Skyrim VR* changed the landscape of the original *Skyrim* by adding a true 3D, immersive layer to the game, which was then patched regularly over the first year of its release (2017). *No Man's Sky* experienced the most major upheaval of the three case studies with significant software updates completely replacing climates and ecosystems while upsetting actual planetary landscapes throughout the procedurally generated universe. This kind of landscape change reflects that of catastrophic and immediate vectors such as earthquakes, volcanoes, and major storms. Also with *NMS*, its major updates included significant changes to its graphical user interface, how the player interacts with the digital space. Software, like any natural space, is always in a state of flux, never static.

IIc. All three case studies feature how humans adapt to and then mold digital spaces to their will.

7. I will take this opportunity to coin the phrase "Obsolocene" to refer to the current epoch of consumption and planned obsolescence, perhaps as a substitute for "Anthropocene."

Software changes can be affected by developers as well as other agents. Given that developers cannot plan for every possible need or want of each individual user, it is not uncommon for these users to adapt these digital spaces to their own needs. Coders creating new versions of *Colossal Cave Adventure* did so to test their programming acumen, to preserve the game for future generations, to add additional entertainment value to a beloved piece of digital heritage, and to make the game playable on a variety of operating systems over time. Players of various versions of *Skyrim* create new content, adventures, armor, weapons, houses, and more through a robust community of modders, which is supported and encouraged by the developer Bethesda, and the Steam platform hosting the game files. In *No Man's Sky* players continue to form communities, build settlements, and mold planets into usable environments for resource-collecting. This behavior is not limited to games. Users continue to create sharable macros for *Microsoft Excel* and plugins for *Adobe Creative Suite* in order to add new or improve upon old features and functions. Human tendencies do not appear to be different when it comes to modifying environments be they natural or synthetic. If anything, the digital empowers more people to create things for themselves and to participate in communities not tied to any sort of geography. Perhaps with the archaeology of digital built environments we are now post-landscape.[8] What then does that mean for archaeology without locality or place?

IId. Reconstruction of space: for some games, a gaming space (re)creates a world inside a box, while others (such as CCA*) create a world inside the mind. For archaeologists, a site can be reconstructed through publication and its supporting materials.*

People access digital worlds in *CCA*, *Skyrim VR*, and *NMS*, spaces created through code and a variety of digital assets (art and audio). All three of these games, however, are fragile. Code can be lost, just like paper archives or archaeological assemblages. Software is subject to bitrot. Games cease to run on contemporary hardware. Games hosted by companies and services such as Google Play Games can cease to be available without notice. What remains then are the video- and screen-captures, textual descriptions, archived "let's play" videos, threads on social media sites, that can all be used to reconstruct a history of use of a digital artifact or site. This is little different than archaeologists publishing their synthetic text on contexts destroyed through the act of excavation. We reassemble environments to the best of our collective abilities based on the evidence we have, evidence either obtained directly through survey/excavation, or

8. A survey of the literature did not yield any instances of "post-landscape" within an archaeological context. Just as post-humans and transhumans are people augmented with/by technology, so too are landscapes either in the natural world (landscapes modified by and adapted to technology and infrastructure), and in the synthetic (either digital depictions of natural landscapes or, as in the context of this thesis, born-digital landscapes with which human and non-human agents interact).

gathered through secondary sources to provide ancillary supporting information. The interpretation comes in organizing that evidence in logical ways both during fieldwork and after. It matters not that the fieldwork was done in digital spaces.

For *CCA*, I archived the digital evidence and data on Github as another online collection of versions plus the tools used to analyze those versions. I hope to publish this as an article, which will be supplemented with online content, for the purpose of demonstrating to the wider archaeological community that digital built environments can (and should) be investigated archaeologically. For *Skyrim VR*, this work will also be prepared as a formal archaeological article with online supporting material including 3D VR walkthroughs and printing specs and instructions for conducting photogrammetry and GIS within the digital space demonstrating how this work can be done, which might inspire others to try similar approaches to other digital environments. For *No Man's Sky*, it is likely that a book/gazeteer will evolve from the research, perhaps creating a handbook for conducting archaeology in a procedurally generated environment, which we will see more and more of over time. I suspect that ProcGen games will lend themselves to creating new cultures with their own novel material culture, cultures that should not be ignored because of their digital-only nature.

In all three cases, each game provides heritage data that can then be used for publication not only of the data but also of future applications of tools and methods used to work with that data.

6.2.3. Thread III: Communication and Production

The final set of shared characteristics from my case studies focuses on communication, which includes everything from preliminary planning to investigation and interpretation of data through to publication and other forms of public outreach. Communication happens in real-time on-site during the investigation and interpretation phases, something that includes communicating with communities where investigation takes place.

IIIa. Archaeologists must consider how they see/perceive in these digital spaces. The experiential v. what they try to communicate is a difficult bridge to build, especially when many in the audience have yet to experience a digital environment for themselves.

Communicating the nature of a site to someone who has never visited can be difficult. Archaeologists employ words and descriptors complemented by images and video as well as sound (e.g., in prehistoric landscapes) and smell (e.g., Jorvik Viking Centre). Archaeological articles, monographs, and websites do their jobs well, yet are poor substitutes for experiencing lived-in landscapes.

Digital spaces share this issue of communication and interpretation. There is a secondary problem with the digital as well: access. When conducting archaeology of software one must bear in mind that not all people have access to the software being studied (just like not all people can actually visit an archaeological site in the natural world). With software, however, one also needs the appropriate hardware in order to experience a digital built environment: gaming console, computer, virtual reality headset, etc. The equipment need not be modern. In some cases old computers or handheld devices must be used to convey the full experience of an older game or a software program that runs only in DOS. Trying to share one's interpretation of a VR site to someone who has never before experienced virtual reality is next to impossible, yet archaeologists must continue to document these spaces before they become inaccessible to anyone, even those with the appropriate hardware.[9] One workaround is to record the synthetic environment so that it is accessible to anyone with an Internet connection, a smartphone, and a Google Cardboard viewer (or similar plastic VR viewers priced at around US$5). This setup provides access to a recorded simulation of virtuality. For other, 2D spaces, images and video may be enough for those people who do not have access to the game-site being studied.

One sees similar issues with scholars unable to access articles behind paywalls, or universities unable to afford the journals their researchers need. People will either find a way to get what they need, or they will find something else. Digital archaeology is stuck in the middle (Perry and Taylor, 2018). The archaeological work must be done and must be communicated even though some people will not be able to access or benefit from the work. But the archaeologist when conducting work in digital environments must keep access and communication top-of-mind in order to reduce or remove barriers for others who do not have native access to these places.

IIIb. All three case studies required community assistance in various forms. Communication was greatly facilitated through social media, specifically Twitter (and hashtags) and reddit.

A game is not just a game, and software is not just about the programs people use. I quickly learned that in some cases I as an investigator was clearly out of my depth in what I hoped to do in each case study. I closed these lacunae by being an autodidact, but more importantly by reaching out to various user groups and communities of practice as well as game-specific communities to help me in my work. Games are at the center of vast networks of people involved in their creation, distribution, and use.

9. The digital content may not "disappear"; it will likely persist in some form somewhere, but access to that content may become more difficult over time.

For *Colossal Cave Adventure*, I did not know where to begin with the tools I needed for stylometric analysis and data visualization, but various inquiries to people in the Digital Humanities led me to *R* and its various packages. For *Skyrim VR*, I wanted to create a GIS map, to conduct photogrammetry, and to create 3D VR videos, none of which I had ever done before. Thanks to fellow digital archaeologists and to some excellent online sets of instructions and open source tools, I was able to select and use *QGIS* for mapping, *Meshlab* for photogrammetry, and *Paytube Video Converter* (and similar) for creating videos that realize the potential of VR experiences. In *No Man's Sky* I was approached by senior members of the Galactic Hub community who were able to give me coordinates to their legacy settlements, which they considered to be their cultural heritage, and I in turn was able to share with them my data and media files.

I am not proprietary about my work, and I try to be as transparent about it as I possibly can, communicating both progress and construction as I go through my social media accounts. In so doing I remain connected to various communities in a dialogue of give-and-take regarding digital archaeology and the wider Digital Humanities and their social impact. It is my hope that with the demonstrable success of my case studies thanks in no large part to these communities, that any archaeological project might do the same. The more archaeologists who take this approach, the better our discipline will become.[10] This transparency and connection community goes both ways. The community benefits from archaeological conversation by learning how to investigate and interpret its own past. They learn the approaches, methods, and tools, and can continue to evaluate their usefulness or weaknesses as they continue to document their own history and material culture. Creating a positive work environment between the archaeologist and the community can lead to future collaboration based on the goodwill, trust, and knowledge-sharing created through the initial project.

Archaeologists cannot and should not work alone or in a silo. That isolation does not serve archaeology well nor does it serve the communities that can benefit from this work, but is not without its dangers, especially to women authors and authors in the LGBTQ+ community (Cook, 2019). In the case of *NMS*, it was important for me to protect the actual identities of those players who chose to speak and work with me on this project. Although the *NMS* community is largely peaceful and inclusive, those outside of it might not respond as kindly to the work being done as evidenced by GamerGate and general online harassment and misogyny.

10. Open access publications go a long way in making archaeological research transparent and easily accessible. OA journals include *Internet Archaeology*, *Open Archaeology*, the *Journal of Computer Applications in Archaeology*, and hundreds of others (see http://www.openaccessarchaeology.org/journal-search.html#.TwcShvKbW8A).

IIIc. What can archaeologists learn from conducting archaeology in digital spaces?

Heritage-focused games, or games that incorporate lore (imagined history) into photorealistic environments, are expensive and take years to produce. They are sold commercially, and all decision-making about what a game is and does is profit-focused (Hopson, 2006). In order to realize the greatest financial returns, digital games must be products consumers are willing to pay US$60 to play, environments that are exhaustive in size and scope that engage players with one or more engaging narratives along with plenty of conflict that requires both intelligence and skill to resolve.[11]

Archaeologists are already beginning to use game engines such as *Unity* to design digital heritage experiences, and *Sketchfab* to create professional-quality reconstructions and 3D models produced through photogrammetry (for examples, see Lercari et al., 2018; Baione et al., 2018; and Dhanda et al., 2019). In some cases these artifacts can be 3D printed (Heath, 2015). The question then becomes: how can archaeologists use these digital tools and their output to communicate archaeology? In every case the archaeologist must consider the intended purpose of a digital reconstruction or immersive experience, and who is the audience? What can we learn from nearly 50 years of game design when creating synthetic representations of actual cultural heritage? The tools to be used to answer these questions are currently largely proprietary (e.g., *PhotoScan* for photogrammetry and *Cinema4D* for animation), so an effort needs to made to create, use, and promote open source software to lower barriers to access not just on the side of archaeologists, but for the public as well (see, e.g., Marchetti, et al., 2018; Watrall, 2019; Wilson and Edwards, 2015).

Many good games start with a compelling narrative driven by conflict—not necessarily violent, but rather a conflict of ideas typically in the form of puzzles (e.g., *Myst*), perceptions (e.g., *BioShock*), and the environment (e.g., survival games such as *Don't Starve*). The reconstruction or immersive heritage experience can be designed around that story. How can photogrammetry and environmental design help forward an archaeological (and therefore human) story? Is this heritage experience being built to invite people in to the site, and then what? Is the intent of a laser-scanned artifact to be published alongside synthetic text in a professional article? Planning ahead by answering these kinds of questions will save great amounts of time and money in the development process of any post-excavation project. For *CCA*, I thought initially that there would be several versions of the game to study, but only after completing the

11. For example, the best-selling games over the past three years have been *Red Dead Redemption* 2 (2018), *Call of Duty: World War II* (2017), *Call of Duty: Infinite Warfare* (2016), *Fallout* 4 (2015), and *Call of Duty: Advanced Warfare* (2014), all of which feature multi-million-dollar budgets, open worlds, and thousands of quests/missions, plus add-ons, downloadable extra content, and robust, active player communities.

data collection did I realize that the underlying purpose for bringing the game forward through time was the game's story. In *Skyrim VR*, I began the case study with the hypothesis that the designed landscape and sense of lore would drive player action and interest, something borne out by my GIS and 3D-printing work while also figuring out a way to share the VR landscape experience with others through lowest-common-denominator technology. Landscape design-by-algorithm in *No Man's Sky* also provided a cradle for the narrative of human settlement in a digital environment, which I was able to document in anticipation of rapid, preliminary publication. I expect to publish all three case studies in ways that will tie synthetic text to digital supporting matrial, and planned for that future publication by archiving data and media through Github and the Archaeology Data Service.

Returning to the intersection of human players in digital spaces, in *Colossal Cave Adventure* we have a compelling story of exploration filled with conflict and challenges that reward further progress into an imagined cave based on a real cavern system in Kentucky without the need of graphics. In *Skyrim VR*, virtual reality finally places the player into a reconstructed world based on the game series' heritage and lore, replete with ancient artifacts and structures that players can interact with, finally understanding scale. The massive open world reminds players of their humanity as they explore in an unforgiving space, experiencing it as they might have in an imagined antiquity. In *No Man's Sky*, the game's thin narrative is secondary to what players actually want to do in the game: explore. This open exploration is rewarded through the discovery of randomly placed structures, artifacts, inscriptions, and natural resources that gradually tell an evidence-based story without the need of anything scripted by the game developer. Each of the game-examples in my case studies shows that focusing on humanity first ultimately creates a successful digitally enabled experience and can be done without graphics and even without an expressly written story component. These games create a community around them, which in turn can affect future development of that game (and others like it). I see no difference in how promotion of an archaeological site can be so managed.

6.3. Human Archaeology of Digital Environments

When I first considered what this thesis might be in 2016, I originally envisioned investigating persistent, procedurally generated digital environments that were self-propagating and that created their own "machine culture" based on code and algorithms. I thought that because code-based interactive digital entertainment consisted of complex systems, that the computational complexity would give rise to heretofore-unseen emergent behavior, which would include artificial culture side-by-side with artificial intelligence. As I continued to read and select video games for my case studies, it became clear that technology has not yet arrived at a machine-only cultural singularity, meaning a culture of electronic and digital things and networks operating completely separately from human intervention, which was something at the beginning my PhD research that I had hoped to discover. While that might be on the horizon, humans and their digital technology remain inseparable in a continuous feedback loop, and it would appear that one cannot exist without the presence of the other in 2019. This current state of the field and delayed arrival of AI-created culture gives the digital archaeologist time to think through methodology, building models for others to follow and adapt.

I chose video games for this thesis on digital archaeology and heritage because of their capacity to enchant and entertain through storytelling within immersive environments. There is a transition in storytelling. Not too long ago humans would gather by a fire to hear a tale, and in the age of print they might sit by the fireside to listen to a reading. Screens are the new sources of firelight, and through them we can interact narratives in ways previous generations could only dream about. Not only were these new narratives interactive, but they became built heritage, whole new worlds to occupy filled with multiple stories, some guided by the hand of the Maker, and others by one or more people who decided to adopt a synthetic world for their own tales. Humans created these spaces for other humans to occupy, and these spaces grow, change, and are abandoned.

Even those people who cannot afford digital technology, who do not have access to that technology, or who choose not to explicitly engage with technology are impacted by its presence elsewhere (e.g., camera surveillance and facial recognition). Digital technology and the networks supporting it are hyperobjects (Morton, 2013), human-made artifacts so big as to affect the whole of humanity. These hyperobjects and their subsidiary technological artifacts require natural resources and human labor in order to sustain them, which not only puts a strain on direct users when things such as a crashed network bring productivity to a halt, but also on indirect users affected by pollution created by the production of digital things and the infrastructure needed to produce them.

If digital archaeology is to record and interpret human activity based on material evidence in both the natural and synthetic worlds, the discipline must continue to proactively create frameworks and either adapt or create tools, methods, and approaches for studying digital environments that reach far beyond those found within video games. Archaeology of the 21st century is a digital one, and it must account for the strain that the synthetic world places on the natural one. The causes and effects of such stress are both enabled and suffered by people, human agents trapped within digital systems. Digital archaeology then is not a celebration of human technological achievement, but rather serves to document electronic technology as a hallmark of our contemporary material culture and cultural heritage, for better and for worse.

6.4. Proposed Future Investigation

This section looks at the potential for future research based on the work presented here. Each case study yielded new, major avenues of future investigation that I hope will be undertaken by current/future PhD students and digital archaeologists:

6.4.1. From *Colossal Cave Adventure*

From my work with *CCA*, the results have led to new, larger questions and applications of the approaches, tools, and methods I employed. These questions and future projects go beyond video games and can be adopted for the archaeological investigation of other software types and programs. These next-steps include finding evidence of code-sharing, which will help in attributing authorship; gender studies to better understand coding culture; cultural transference of intellectual property; and code marginalia for understanding the humanity of the coders themselves and how they interacted with the programs being produced.

1. Apply text analysis tools to sets of code created in a corporate environment to determine author attribution and evidence of code-sharing. This is important because the results can help recalibrate identities of authors and co-authors of code. Atari's games for the 2600 would be a good place to start because of the finite number of games created by Atari, Inc.,[12] and this source code is widely available.[13] One could also look for evidence of code-sharing across platforms (i.e. code used in the arcade cabinet for *Centipede*, and its cartridge counterpart for the 2600.) Atari stood at the vanguard of digital gaming (both at the arcade and at home), and it is possible (but as yet not officially documented) that Atari's programmers shared code to create new games. Women engineers such as Carol Shaw helped facilitate how games appeared on-screen and assisted with the creation of games themselves (*Super Breakout* in the case of Shaw, and the coin-operated game *Centipede* by Dona Bailey), and it is possible that they were involved in uncredited roles in the development of other Atari games. Stylistic text analysis can contribute both to validating existing authorship credit while possibly dis-

12. Atari, Inc. created 136 games for the 2600. 334 other games were produced by other companies during the console's life-span. (atariage.com, accessed 18 September 2019.)
13. The most complete resource is available as open source at stella-emu.github.io (accessed 18 September 2019).

covering co-authorship or misattributed authorship of women game designers. Eighteen women programmed games for the Atari 2600, but only two worked directly for Atari, Inc., as programmers.[14]

2. Study the gender of code-authorship in an effort to determine men, women, and non-binary coders over time in various cultural and corporate environments. Who is writing the code that drives a culture, and what does a culture of coders look like? Why are coders still predominantly male,[15] and is that true across all software industries?

3. Reverse-engineer software clones (games that are alike but are made by different companies and individuals) to learn more about how intellectual property is coopted/transferred between cultures.[16] Compare that to ancient examples of reverse engineering to determine how people and processes have changed, if they have changed at all. How do people perceive digital intellectual property (IP) today, and do different cultures perceive IP differently? Was there a concept of IP in antiquity, and if so, how does it compare with modern attitudes towards ownership and copyright?

4. Study "code marginalia" to see what personal evidence programmers left behind in their commented code and the reasons behind the need to comment the code. What can we learn about a culture of coders for any given software application, and what are similarities and differences of cultures for different kinds of software development? What can we learn from the code about corporate and hobbyist environments that we don't know from other sources? Are the comments constructive, entertaining, or do they serve as apologies for badly written code (Fowler and Beck, 2019, p. 87, calls these kinds of comments "deodorant")?

6.4.2. From *Skyrim VR*

From my work in Skyrim VR, there are several further avenues to pursue with other digital environments, not just video games. Interaction with designers of open world, heritage-based VR game design could assist in engineering future heritage VR experiences; GIS and map interfaces created in (and from) digital environments can begin to create a set of mapmaking standards; photogrammetry of digital environments can also approach a set of standards not only for how to conduct 3D-scanning in digital spaces, but also can work towards a code of ethics for doing so, and for distributing the

14. atariage.com (accessed 18 September 2019).
15. According to girlswhocode.com, in 2016 women held 24% of the jobs in computing, a number that is expected to shrink.
16. For example there were over 800 different clones of the mobile phone game, *Flappy Bird* (Sherman, 2014) (https://www.digitaltrends.com/mobile/crazy-flappy-bird-clones/, accessed 18 September 2019).

results; we can also work towards affordable, accessible, quality VR output based on our work in digital environments, which will help communicate results of archaeological investigations there.

1. Take the lessons learned from the *Skyrim VR* case study and test them against other VR heritage environments. What phenomenological and haptic experiences are shared across the medium? Do these experiences differ between games, or is the VR experience universal in how the hardware mediates embodied experiences? Much research has been conducted in the past few years on virtual reality and cultural heritage (see for example Champion, 2006; Fernández-Palacios et al., 2017; Jung and tom Dieck, 2017; Tan et al. 2016). Great strides have been made in the area of heritage VR, and it is possible that studying heritage VR games (and their underlying engines) can assist in future development of their natural world counterparts, improving accessible, useful VR experiences for heritage sites through lessons learned via commercial VR game development.

2. Create a standard for mapping digital built environments using GIS, testing across other open world games as well as non-entertainment software that use graphical user interfaces (GUI). This could create a subdiscipline of "Software Topography/Topology" not only of synthetic worlds but also of any software application's GUI. These maps can track GUI changes over time and could conceivably be used by software/games developers for future GUI development.

3. In-game photogrammetry is brand new, and the steps listed in this thesis open up ways for anyone to record artifacts and environments in the round in order to export them to 3D meshes and printable things. How can we standardize photogrammetry across all digital environments and what is the archaeological potential for doing so? Video game photogrammetry traditionally refers to landscapes and artifacts that are scanned in the natural world and then imported into a game engine (Statham, 2018), but my variation goes in the opposite direction, conducting photogrammetry within a digital environment for exporting into the natural world.

4. The *Skyrim VR* case study taught me how to export 3D VR for people without access to expensive hardware or to individual games being studied. This accessibility envelope can be pushed even further for communicating end-user experiences to a wider public. How can we better communicate digital heritage findings in a multi-sensory way to a public who are not necessarily privileged with access to VR environments?

6.4.3. From *No Man's Sky*

From my work in *NMS*, a number of new research threads emerged as archaeologists continue to study the intersection of people, communities, and digital environments. Video games and the game engines used to develop them can further be used for agent-based modeling (ABM) to test hypotheses about human behavior and the environment; we can begin to explore heritage crossover between natural and synthetic spaces—and vice versa—and how that heritage is promoted by communities; digital archaeologists need to learn how to document and archive software versions and their histories while determining a curation strategy for the profusion of digital material; archaeologists can build on this case study when investigating procedurally generated digital built environments and the cultures derived from them.

1. *No Man's Sky* showed how human communities express creativity and resilience in the wake of digital catastrophe. Future research in other community games can serve as agent-based models for disasters in the natural world where investigators can learn what works (and what works better), applying lessons learned to extra-digital problems affecting flesh-and-blood people. ABM has been used in conjunction with studying climate change and public policy, but this research has been conducted outside of a video game (Lempert, 2002; Downing et al., 2000; Troost and Berger, 2013; Ch'ng and Gaffney, 2013; Ch'ng, Gaffney, and Hakvoort, 2014). Games can be used to observe patterns of human behavior through various environmental simulations, the meaning of which can be extrapolated for predicting human behavior in the wake of similar disasters in the natural world.

2. *NMS* communities created their own lore and even went so far as to create a Heritage designation for older sites to encourage tourism of their abandoned sites, which proved popular with players. What lessons can be learned from other established community games regarding heritage preservation and promotion? How are heritage practices in the natural world carrying over into the synthetic? How can these lessons extend beyond the digital?

3. How do players and developers remember the lifespan of software applications, and how are these memories and versions preserved and shared? Since its launch in 2016 *No Man's Sky* has undergone dramatic, major changes in its development, appearance, and functionality. Developer Hello Games maintains a public-facing patch log for each version, yet it is impossible to load earlier versions of the game. These versions can be remembered/shared through player testimony on sites such as reddit,[17] or through

17. https://www.reddit.com/r/NoMansSkyTheGame/ (accessed 18 September 2019).

shared screen- and video-capture.[18] Digital archaeologists must find a way to document and archive software from version to version in an effort to retain a history of development, which reflects market and industry trends as well as changes in player taste and sophistication.

4. Future archaeologists will be able to engage with purely procedurally generated environments as well as never-before-seen, algorithm-created cultures and societies in what are currently called persistent virtual worlds.[19] My work in *No Man's Sky* makes first steps into how to conduct archaeology within these spaces. Future researchers can survey and excavate other digital built environments to record the archaeological evidence of digital-only spaces and their human and non-human inhabitants.[20]

6.5. Reflections and Final Conclusion

When I began researching this thesis, I thought that I would be studying examples of machine-created culture, specifically tied to video games but with archaeological approaches, tools, and methods that would be scalable to other digital built environments. I naively did not foresee such a big intersection with actual people, instead placing technology front-and-center, moving human involvement and interaction with digital spaces to the side. I realized my mistake and my bias when selecting and developing my case studies, which showed a blending of humanity with digital space, and removed that dualism I had put in place prior to starting my degree.

For *CCA*, people were central to contributing to the popularity and longevity of a game, which itself was created from human emotion—a need for the original programmer to overcome the grief from a divorce, and to become closer to his children through digital storytelling. Human eyes and a brain were also needed to interpret and analyze the data returned from the text analysis and visualization tools, to recognize bias, and to realize when the output did not quite agree with the data sets being fed into various tools. In researching this game, the artifact of it greatly impacted millions of players through the creation of a new industry and genre of interactive digital entertainment and the growth of the lively interactive fiction (IF) community online. People created

18. For example, Wanderbot's YouTube channel (294,000 subscribers) contains at least one video from the Pathfinder era (March 2017) of *NMS* showing nearly an hour of actual gameplay footage (https://www.youtube.com/watch?v=47FdR-4M1uo, accessed 18 September 2019). The game has changed significantly since then.

19. Persistent virtual worlds are those that continue to exist, operate, and evolve without human presence or intervention. *EVE Online* is an example of a persistent virtual world. In theory, as long as at least one game server remains running, all humans could exit the game and then return in ten years' time to see the universe fully functioning, yet different.

20. Some archaeologists already have. For example, Prof. Shawn Graham of Carleton University has conducted archaeological fieldwork in *Minecraft* (http://smgprojects.github.io/ethics-of-video-games-in-archaeology/#a-playthrough-of-minecraft-as-an-archaeologist, accessed 18 September 2019).

the digital environment, which in turn inspired generations of people to create and recreate stories in synthetic space, stories that generate a human emotional response. The main weakness in my approach to this case study was not taking things far enough, namely in sharing my results with the actual people who programmed the versions I investigated. It would have been illuminating to hear if these coders were surprised by the results, and what their interpretation of my work might have been. I plan on pursuing this line of inquiry when writing my article based on this research.

With my investigation of *Skyrim VR*, people were mostly invisible, yet still responsible for the digital environment I studied. The developers built a world to encourage exploration and movement, and to advance several narratives, many of which were driven by an invented history. Additional, indirect human involvement presented itself in the questions of how to communicate VR-realized spaces to people without access to them, of how to map these spaces for others to use, and of scanning and printing intellectual property. At the outset of this case study, I was again too focused on the technology, and of the possibility of being able to make a 3D print from a 2D landscape without considering the ethics of what I was doing until after the fact. The other weakness in the planning of this case study was that I conducted my work apart from those archaeologists and heritage professionals who have worked with virtual reality and heritage spaces in the natural world, and the progress they have made in realizing (albeit with varying quality) heritage reconstructions in interactive, digital ways, as well as critiquing tools and methods. I concentrated on understanding the single world of *Skyrim VR* and what I, as an archaeologist, could do within it, failing to place that work in a wider context of other heritage VR projects at the start of my research, coming to it later during the writing-up phase. Future work in this area must recognize the goals of realizing heritage spaces digitally as well as their intended audiences.

Lastly, my efforts in *NMS* demonstrated the necessity of community inclusion in archaeological projects focused on occupied (or previously occupied) digital spaces. My initial project-planning placed me on an abandoned world, but one that still sported human interaction. Although the members of the Galactic Hub had left their capital, it was not uncommon for me to encounter heritage tourists, and I was later contacted by members of the Hub community who were curious about my work while expressing an interest in helping. This partnership helped me locate sites to survey and excavate (by permission) within the abandoned Hub region, but more importantly gathered information and media about the first settlements that could be shared by the Hub community as part of their collective history of which no physical evidence remains. The main weakness of this case study was in my underestimation of the Hub community's interest and willingness to participate. Future archaeological projects in occupied digital space must be proactive in engaging with human communities from the outset, and building a plan that involves community input throughout the project's lifespan. My initial approach was one-sided; I thought I would do the work and then hand over my data to the Hub community when finished. Instead, I should have planned (or expected) a more formal collaboration, which is what eventually happened.

When conducting archaeology of digital environments, we ignore humanity at our peril. As stated elsewhere in this thesis, digital environments are human creations. This is true even in the cases where digital spaces are created by algorithms, where the lines of code can be traced back to human sources. The fact that humanity continues to blend with the technology it creates to forge new, occasionally global, material culture, seems to validate the argument for an archaeology of digital environments. A goal of archaeology is to attempt to understand people through their interaction with things and the environment in which these things were created, used, and discarded. Archaeology considers these impacts of this entanglement not only on the landscape, but also on individuals and communities.

Contemporary archaeology must include digital built environments as examples of 20th- and 21st-century artifacts, sites, and landscapes, understood as part of the archaeological record of the recent past while preparing for an archaeology of the future. Digital archaeology currently includes the evaluation and use of digital tools and methods for all archaeological endeavors. It can now also include the archaeology of digital things and the spaces held within them. There is much work to be done as archaeologists face modern issues of mass-production, profusion of data, e-waste on a colossal scale, and the accelerated timeline upon which technological innovation and obsolescence exists. We need to consider carefully our approaches to investigating our digital habitations and heritage, testing and refining them against examples of software and the hardware than runs it, without discounting the human element that created these things, or the human communities affected by them. This thesis has taken a step in that direction.

Appendix A

Complete Narrative Text from William Crowther's Original Source Code of *Colossal Cave Adventure*

The following text contains the complete contents of advent.dat, the second of two *Colossal Cave Adventure* files coded by William Crowther in 1975. The file contains several sections called by the program itself, written in FORTRAN IV, which include narrative descriptions of places and actions, hint text, scoring, "legal" vocabulary that can be typed by the player, and "wizard hours", which can be customized by the system administrator of the mainframe computer on which the original game was played so as not to cut into staff/student productivity in the labs at Stanford University and elsewhere. The original source code was discovered in 2007 by Dr. Dennis G. Jerz, Associate Professor of English (New Media Journalism) at Seton Hill University, and is currently hosted on his personal website,[1] mirrored on co-creator Don Woods' website,[2] and is also now part of my Github archive of the *CCA* code stylometry project.[3]

NOTE: This file is divided into 12 sections, each ending in "-1" and beginnging with a section number (e.g., "1", "2", "3", etc.). I have annotated each section with a short definition of each section in brackets.

[First section begins, featuring narrative text.]

```
1
1    YOU ARE STANDING AT THE END OF A ROAD BEFORE A SMALL BRICK BUILDING.
1    AROUND YOU IS A FOREST.  A SMALL STREAM FLOWS OUT OF THE BUILDING AND
1    DOWN A GULLY.
2    YOU HAVE WALKED UP A HILL, STILL IN THE FOREST.  THE ROAD SLOPES BACK
```

1. https://jerz.setonhill.edu/intfic/colossal-cave-adventure-source-code/ (accessed January 3, 2019).
2. http://www.icynic.com/~don/jerz/ (accessed January 3, 2019).
3. https://github.com/adreinhard/cca (accessed January 3, 2019).

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2   DOWN THE OTHER SIDE OF THE HILL.  THERE IS A BUILDING IN THE DISTANCE.
3   YOU ARE INSIDE A BUILDING, A WELL HOUSE FOR A LARGE SPRING.
4   YOU ARE IN A VALLEY IN THE FOREST BESIDE A STREAM TUMBLING ALONG A
4   ROCKY BED.
5   YOU ARE IN OPEN FOREST, WITH A DEEP VALLEY TO ONE SIDE.
6   YOU ARE IN OPEN FOREST NEAR BOTH A VALLEY AND A ROAD.
7   AT YOUR FEET ALL THE WATER OF THE STREAM SPLASHES INTO A 2-INCH SLIT
7   IN THE ROCK.  DOWNSTREAM THE STREAMBED IS BARE ROCK.
8   YOU ARE IN A 20-FOOT DEPRESSION FLOORED WITH BARE DIRT.  SET INTO THE
8   DIRT IS A STRONG STEEL GRATE MOUNTED IN CONCRETE.  A DRY STREAMBED
8   LEADS INTO THE DEPRESSION.
9   YOU ARE IN A SMALL CHAMBER BENEATH A 3X3 STEEL GRATE TO THE SURFACE.
9   A LOW CRAWL OVER COBBLES LEADS INWARD TO THE WEST.
10  YOU ARE CRAWLING OVER COBBLES IN A LOW PASSAGE.  THERE IS A DIM LIGHT
10  AT THE EAST END OF THE PASSAGE.
11  YOU ARE IN A DEBRIS ROOM FILLED WITH STUFF WASHED IN FROM THE SURFACE.
11  A LOW WIDE PASSAGE WITH COBBLES BECOMES PLUGGED WITH MUD AND DEBRIS
11  HERE, BUT AN AWKWARD CANYON LEADS UPWARD AND WEST.  A NOTE ON THE WALL
11  SAYS “MAGIC WORD XYZZY”.
12  YOU ARE IN AN AWKWARD SLOPING EAST/WEST CANYON.
13  YOU ARE IN A SPLENDID CHAMBER THIRTY FEET HIGH.  THE WALLS ARE FROZEN
13  RIVERS OF ORANGE STONE.  AN AWKWARD CANYON AND A GOOD PASSAGE EXIT
13  FROM EAST AND WEST SIDES OF THE CHAMBER.
14  AT YOUR FEET IS A SMALL PIT BREATHING TRACES OF WHITE MIST.  AN EAST
14  PASSAGE ENDS HERE EXCEPT FOR A SMALL CRACK LEADING ON.
15  YOU ARE AT ONE END OF A VAST HALL STRETCHING FORWARD OUT OF SIGHT TO
15  THE WEST.  THERE ARE OPENINGS TO EITHER SIDE.  NEARBY, A WIDE STONE
15  STAIRCASE LEADS DOWNWARD.  THE HALL IS FILLED WITH WISPS OF WHITE MIST
15  SWAYING TO AND FRO ALMOST AS IF ALIVE.        A COLD WIND BLOWS UP THE
15  STAIRCASE.  THERE IS A PASSAGE AT THE TOP OF A DOME BEHIND YOU.
16  THE CRACK IS FAR TOO SMALL FOR YOU TO FOLLOW.
17  YOU ARE ON THE EAST BANK OF A FISSURE SLICING CLEAR ACROSS THE HALL.
17  THE MIST IS QUITE THICK HERE, AND THE FISSURE IS TOO WIDE TO JUMP.
18  THIS IS A LOW ROOM WITH A CRUDE NOTE ON THE WALL.  THE NOTE SAYS,
18  “YOU WON’T GET IT UP THE STEPS”.
19  YOU ARE IN THE HALL OF THE MOUNTAIN KING, WITH PASSAGES OFF IN ALL
19  DIRECTIONS.
20  YOU ARE AT THE BOTTOM OF THE PIT WITH A BROKEN NECK.
21  YOU DIDN’T MAKE IT.
22  THE DOME IS UNCLIMBABLE.
23  YOU ARE AT THE WEST END OF THE TWOPIT ROOM.  THERE IS A LARGE HOLE IN
23  THE WALL ABOVE THE PIT AT THIS END OF THE ROOM.
24  YOU ARE AT THE BOTTOM OF THE EASTERN PIT IN THE TWOPIT ROOM.  THERE IS
24  A SMALL POOL OF OIL IN ONE CORNER OF THE PIT.
25  YOU ARE AT THE BOTTOM OF THE WESTERN PIT IN THE TWOPIT ROOM.  THERE IS
25  A LARGE HOLE IN THE WALL ABOUT 25 FEET ABOVE YOU.
26  YOU CLAMBER UP THE PLANT AND SCURRY THROUGH THE HOLE AT THE TOP.
27  YOU ARE ON THE WEST SIDE OF THE FISSURE IN THE HALL OF MISTS.
28  YOU ARE IN A LOW N/S PASSAGE AT A HOLE IN THE FLOOR.  THE HOLE GOES
28  DOWN TO AN E/W PASSAGE.
29  YOU ARE IN THE SOUTH SIDE CHAMBER.
30  YOU ARE IN THE WEST SIDE CHAMBER OF THE HALL OF THE MOUNTAIN KING.
30  A PASSAGE CONTINUES WEST AND UP HERE.
31  >$<
32  YOU CAN’T GET BY THE SNAKE.
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33 YOU ARE IN A LARGE ROOM, WITH A PASSAGE TO THE SOUTH, A PASSAGE TO THE
33 WEST, AND A WALL OF BROKEN ROCK TO THE EAST. THERE IS A LARGE “Y2” ON
33 A ROCK IN THE ROOM’S CENTER.
34 YOU ARE IN A JUMBLE OF ROCK, WITH CRACKS EVERYWHERE.
35 YOU’RE AT A LOW WINDOW OVERLOOKING A HUGE PIT, WHICH EXTENDS UP OUT OF
35 SIGHT. A FLOOR IS INDISTINCTLY VISIBLE OVER 50 FEET BELOW. TRACES OF
35 WHITE MIST COVER THE FLOOR OF THE PIT, BECOMING THICKER TO THE RIGHT.
35 MARKS IN THE DUST AROUND THE WINDOW WOULD SEEM TO INDICATE THAT
35 SOMEONE HAS BEEN HERE RECENTLY. DIRECTLY ACROSS THE PIT FROM YOU AND
35 25 FEET AWAY THERE IS A SIMILAR WINDOW LOOKING INTO A LIGHTED ROOM. A
35 SHADOWY FIGURE CAN BE SEEN THERE PEERING BACK AT YOU.
36 YOU ARE IN A DIRTY BROKEN PASSAGE. TO THE EAST IS A CRAWL. TO THE
36 WEST IS A LARGE PASSAGE. ABOVE YOU IS A HOLE TO ANOTHER PASSAGE.
37 YOU ARE ON THE BRINK OF A SMALL CLEAN CLIMBABLE PIT. A CRAWL LEADS
37 WEST.
38 YOU ARE IN THE BOTTOM OF A SMALL PIT WITH A LITTLE STREAM, WHICH
38 ENTERS AND EXITS THROUGH TINY SLITS.
39 YOU ARE IN A LARGE ROOM FULL OF DUSTY ROCKS. THERE IS A BIG HOLE IN
39 THE FLOOR. THERE ARE CRACKS EVERYWHERE, AND A PASSAGE LEADING EAST.
40 YOU HAVE CRAWLED THROUGH A VERY LOW WIDE PASSAGE PARALLEL TO AND NORTH
40 OF THE HALL OF MISTS.
41 YOU ARE AT THE WEST END OF HALL OF MISTS. A LOW WIDE CRAWL CONTINUES
41 WEST AND ANOTHER GOES NORTH. TO THE SOUTH IS A LITTLE PASSAGE 6 FEET
41 OFF THE FLOOR.
42 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
43 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
44 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
45 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
46 DEAD END
47 DEAD END
48 DEAD END
49 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
50 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
51 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
52 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
53 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
54 DEAD END
55 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
56 DEAD END
57 YOU ARE ON THE BRINK OF A THIRTY FOOT PIT WITH A MASSIVE ORANGE COLUMN
57 DOWN ONE WALL. YOU COULD CLIMB DOWN HERE BUT YOU COULD NOT GET BACK
57 UP. THE MAZE CONTINUES AT THIS LEVEL.
58 DEAD END
59 YOU HAVE CRAWLED THROUGH A VERY LOW WIDE PASSAGE PARALLEL TO AND NORTH
59 OF THE HALL OF MISTS.
60 YOU ARE AT THE EAST END OF A VERY LONG HALL APPARENTLY WITHOUT SIDE
60 CHAMBERS. TO THE EAST A LOW WIDE CRAWL SLANTS UP. TO THE NORTH A
60 ROUND TWO FOOT HOLE SLANTS DOWN.
61 YOU ARE AT THE WEST END OF A VERY LONG FEATURELESS HALL. THE HALL
61 JOINS UP WITH A NARROW NORTH/SOUTH PASSAGE.
62 YOU ARE AT A CROSSOVER OF A HIGH N/S PASSAGE AND A LOW E/W ONE.
63 DEAD END
64 YOU ARE AT A COMPLEX JUNCTION. A LOW HANDS AND KNEES PASSAGE FROM THE
64 NORTH JOINS A HIGHER CRAWL FROM THE EAST TO MAKE A WALKING PASSAGE

64 GOING WEST. THERE IS ALSO A LARGE ROOM ABOVE. THE AIR IS DAMP HERE.
65 YOU ARE IN BEDQUILT, A LONG EAST/WEST PASSAGE WITH HOLES EVERYWHERE.
65 TO EXPLORE AT RANDOM SELECT NORTH, SOUTH, UP, OR DOWN.
66 YOU ARE IN A ROOM WHOSE WALLS RESEMBLE SWISS CHEESE. OBVIOUS PASSAGES
66 GO WEST, EAST, NE, AND NW. PART OF THE ROOM IS OCCUPIED BY A LARGE
66 BEDROCK BLOCK.
67 YOU ARE AT THE EAST END OF THE TWOPIT ROOM. THE FLOOR HERE IS
67 LITTERED WITH THIN ROCK SLABS, WHICH MAKE IT EASY TO DESCEND THE PITS.
67 THERE IS A PATH HERE BYPASSING THE PITS TO CONNECT PASSAGES FROM EAST
67 AND WEST. THERE ARE HOLES ALL OVER, BUT THE ONLY BIG ONE IS ON THE
67 WALL DIRECTLY OVER THE WEST PIT WHERE YOU CAN'T GET TO IT.
68 YOU ARE IN A LARGE LOW CIRCULAR CHAMBER WHOSE FLOOR IS AN IMMENSE SLAB
68 FALLEN FROM THE CEILING (SLAB ROOM). EAST AND WEST THERE ONCE WERE
68 LARGE PASSAGES, BUT THEY ARE NOW FILLED WITH BOULDERS. LOW SMALL
68 PASSAGES GO NORTH AND SOUTH, AND THE SOUTH ONE QUICKLY BENDS WEST
68 AROUND THE BOULDERS.
69 YOU ARE IN A SECRET N/S CANYON ABOVE A LARGE ROOM.
70 YOU ARE IN A SECRET N/S CANYON ABOVE A SIZABLE PASSAGE.
71 YOU ARE IN A SECRET CANYON AT A JUNCTION OF THREE CANYONS, BEARING
71 NORTH, SOUTH, AND SE. THE NORTH ONE IS AS TALL AS THE OTHER TWO
71 COMBINED.
72 YOU ARE IN A LARGE LOW ROOM. CRAWLS LEAD NORTH, SE, AND SW.
73 DEAD END CRAWL.
74 YOU ARE IN A SECRET CANYON WHICH HERE RUNS E/W. IT CROSSES OVER A
74 VERY TIGHT CANYON 15 FEET BELOW. IF YOU GO DOWN YOU MAY NOT BE ABLE
74 TO GET BACK UP.
75 YOU ARE AT A WIDE PLACE IN A VERY TIGHT N/S CANYON.
76 THE CANYON HERE BECOMES TOO TIGHT TO GO FURTHER SOUTH.
77 YOU ARE IN A TALL E/W CANYON. A LOW TIGHT CRAWL GOES 3 FEET NORTH AND
77 SEEMS TO OPEN UP.
78 THE CANYON RUNS INTO A MASS OF BOULDERS -- DEAD END.
79 THE STREAM FLOWS OUT THROUGH A PAIR OF 1 FOOT DIAMETER SEWER PIPES.
79 IT WOULD BE ADVISABLE TO USE THE EXIT.
80 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
81 DEAD END
82 DEAD END
83 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
84 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
85 DEAD END
86 DEAD END
87 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL ALIKE.
88 YOU ARE IN A LONG, NARROW CORRIDOR STRETCHING OUT OF SIGHT TO THE
88 WEST. AT THE EASTERN END IS A HOLE THROUGH WHICH YOU CAN SEE A
88 PROFUSION OF LEAVES.
89 THERE IS NOTHING HERE TO CLIMB. USE "UP" OR "OUT" TO LEAVE THE PIT.
90 YOU HAVE CLIMBED UP THE PLANT AND OUT OF THE PIT.
91 YOU ARE AT THE TOP OF A STEEP INCLINE ABOVE A LARGE ROOM. YOU COULD
91 CLIMB DOWN HERE, BUT YOU WOULD NOT BE ABLE TO CLIMB UP. THERE IS A
91 PASSAGE LEADING BACK TO THE NORTH.
92 YOU ARE IN THE GIANT ROOM. THE CEILING HERE IS TOO HIGH UP FOR YOUR
92 LAMP TO SHOW IT. CAVERNOUS PASSAGES LEAD EAST, NORTH, AND SOUTH. ON
92 THE WEST WALL IS SCRAWLED THE INSCRIPTION, "FEE FIE FOE FOO" [SIC].
93 THE PASSAGE HERE IS BLOCKED BY A RECENT CAVE-IN.
94 YOU ARE AT ONE END OF AN IMMENSE NORTH/SOUTH PASSAGE.
95 YOU ARE IN A MAGNIFICENT CAVERN WITH A RUSHING STREAM, WHICH CASCADES
95 OVER A SPARKLING WATERFALL INTO A ROARING WHIRLPOOL WHICH DISAPPEARS

95 THROUGH A HOLE IN THE FLOOR. PASSAGES EXIT TO THE SOUTH AND WEST.
96 YOU ARE IN THE SOFT ROOM. THE WALLS ARE COVERED WITH HEAVY CURTAINS,
96 THE FLOOR WITH A THICK PILE CARPET. MOSS COVERS THE CEILING.
97 THIS IS THE ORIENTAL ROOM. ANCIENT ORIENTAL CAVE DRAWINGS COVER THE
97 WALLS. A GENTLY SLOPING PASSAGE LEADS UPWARD TO THE NORTH, ANOTHER
97 PASSAGE LEADS SE, AND A HANDS AND KNEES CRAWL LEADS WEST.
98 YOU ARE FOLLOWING A WIDE PATH AROUND THE OUTER EDGE OF A LARGE CAVERN.
98 FAR BELOW, THROUGH A HEAVY WHITE MIST, STRANGE SPLASHING NOISES CAN BE
98 HEARD. THE MIST RISES UP THROUGH A FISSURE IN THE CEILING. THE PATH
98 EXITS TO THE SOUTH AND WEST.
99 YOU ARE IN AN ALCOVE. A SMALL NW PATH SEEMS TO WIDEN AFTER A SHORT
99 DISTANCE. AN EXTREMELY TIGHT TUNNEL LEADS EAST. IT LOOKS LIKE A VERY
99 TIGHT SQUEEZE. AN EERIE LIGHT CAN BE SEEN AT THE OTHER END.
100 YOU'RE IN A SMALL CHAMBER LIT BY AN EERIE GREEN LIGHT. AN EXTREMELY
100 NARROW TUNNEL EXITS TO THE WEST. A DARK CORRIDOR LEADS NE.
101 YOU'RE IN THE DARK-ROOM. A CORRIDOR LEADING SOUTH IS THE ONLY EXIT.
102 YOU ARE IN AN ARCHED HALL. A CORAL PASSAGE ONCE CONTINUED UP AND EAST
102 FROM HERE, BUT IS NOW BLOCKED BY DEBRIS. THE AIR SMELLS OF SEA WATER.
103 YOU'RE IN A LARGE ROOM CARVED OUT OF SEDIMENTARY ROCK. THE FLOOR AND
103 WALLS ARE LITTERED WITH BITS OF SHELLS IMBEDDED IN THE STONE. A
103 SHALLOW PASSAGE PROCEEDS DOWNWARD, AND A SOMEWHAT STEEPER ONE LEADS
103 UP. A LOW HANDS AND KNEES PASSAGE ENTERS FROM THE SOUTH.
104 YOU ARE IN A LONG SLOPING CORRIDOR WITH RAGGED SHARP WALLS.
105 YOU ARE IN A CUL-DE-SAC ABOUT EIGHT FEET ACROSS.
106 YOU ARE IN AN ANTEROOM LEADING TO A LARGE PASSAGE TO THE EAST.SMALL
106 PASSAGES GO WEST AND UP. THE REMNANTS OF RECENT DIGGING ARE EVIDENT.
106 A SIGN IN MIDAIR HERE SAYS "CAVE UNDER CONSTRUCTION BEYOND THIS POINT.
106 PROCEED AT OWN RISK. [WITT CONSTRUCTION COMPANY]"
107 YOU ARE IN A MAZE OF TWISTY LITTLE PASSAGES, ALL DIFFERENT.
108 YOU ARE AT WITT'S END. PASSAGES LEAD OFF IN *ALL* DIRECTIONS.
109 YOU ARE IN A NORTH/SOUTH CANYON ABOUT 25 FEET ACROSS. THE FLOOR IS
109 COVERED BY WHITE MIST SEEPING IN FROM THE NORTH. THE WALLS EXTEND
109 UPWARD FOR WELL OVER 100 FEET. SUSPENDED FROM SOME UNSEEN POINT FAR
109 ABOVE YOU, AN ENORMOUS TWO-SIDED MIRROR IS HANGING PARALLEL TO AND
109 MIDWAY BETWEEN THE CANYON WALLS. (THE MIRROR IS OBVIOUSLY PROVIDED
109 FOR THE USE OF THE DWARVES, WHO AS YOU KNOW, ARE EXTREMELY VAIN.) A
109 SMALL WINDOW CAN BE SEEN IN EITHER WALL, SOME FIFTY FEET UP.
110 YOU'RE AT A LOW WINDOW OVERLOOKING A HUGE PIT, WHICH EXTENDS UP OUT OF
110 SIGHT. A FLOOR IS INDISTINCTLY VISIBLE OVER 50 FEET BELOW. TRACES OF
110 WHITE MIST COVER THE FLOOR OF THE PIT, BECOMING THICKER TO THE LEFT.
110 MARKS IN THE DUST AROUND THE WINDOW WOULD SEEM TO INDICATE THAT
110 SOMEONE HAS BEEN HERE RECENTLY. DIRECTLY ACROSS THE PIT FROM YOU AND
110 25 FEET AWAY THERE IS A SIMILAR WINDOW LOOKING INTO A LIGHTED ROOM. A
110 SHADOWY FIGURE CAN BE SEEN THERE PEERING BACK AT YOU.
111 A LARGE STALACTITE EXTENDS FROM THE ROOF AND ALMOST REACHES THE FLOOR
111 BELOW. YOU COULD CLIMB DOWN IT, AND JUMP FROM IT TO THE FLOOR, BUT
111 HAVING DONE SO YOU WOULD BE UNABLE TO REACH IT TO CLIMB BACK UP.
112 YOU ARE IN A LITTLE MAZE OF TWISTING PASSAGES, ALL DIFFERENT.
113 YOU ARE AT THE EDGE OF A LARGE UNDERGROUND RESERVOIR. AN OPAQUE CLOUD
113 OF WHITE MIST FILLS THE ROOM AND RISES RAPIDLY UPWARD. THE LAKE IS
113 FED BY A STREAM, WHICH TUMBLES OUT OF A HOLE IN THE WALL ABOUT 10 FEET
113 OVERHEAD AND SPLASHES NOISILY INTO THE WATER SOMEWHERE WITHIN THE
113 MIST. THE ONLY PASSAGE GOES BACK TOWARD THE SOUTH.
114 DEAD END
115 YOU ARE AT THE NORTHEAST END OF AN IMMENSE ROOM, EVEN LARGER THAN THE
115 GIANT ROOM. IT APPEARS TO BE A REPOSITORY FOR THE "ADVENTURE"

115 PROGRAM. MASSIVE TORCHES FAR OVERHEAD BATHE THE ROOM WITH SMOKY
115 YELLOW LIGHT. SCATTERED ABOUT YOU CAN BE SEEN A PILE OF BOTTLES (ALL
115 OF THEM EMPTY), A NURSERY OF YOUNG BEANSTALKS MURMURING QUIETLY, A BED
115 OF OYSTERS, A BUNDLE OF BLACK RODS WITH RUSTY STARS ON THEIR ENDS, AND
115 A COLLECTION OF BRASS LANTERNS. OFF TO ONE SIDE A GREAT MANY DWARVES
115 ARE SLEEPING ON THE FLOOR, SNORING LOUDLY. A SIGN NEARBY READS: “DO
115 NOT DISTURB THE DWARVES!” AN IMMENSE MIRROR IS HANGING AGAINST ONE
115 WALL, AND STRETCHES TO THE OTHER END OF THE ROOM, WHERE VARIOUS OTHER
115 SUNDRY OBJECTS CAN BE GLIMPSED DIMLY IN THE DISTANCE.
116 YOU ARE AT THE SOUTHWEST END OF THE REPOSITORY. TO ONE SIDE IS A PIT
116 FULL OF FIERCE GREEN SNAKES. ON THE OTHER SIDE IS A ROW OF SMALL
116 WICKER CAGES, EACH OF WHICH CONTAINS A LITTLE SULKING BIRD. IN ONE
116 CORNER IS A BUNDLE OF BLACK RODS WITH RUSTY MARKS ON THEIR ENDS. A
116 LARGE NUMBER OF VELVET PILLOWS ARE SCATTERED ABOUT ON THE FLOOR. A
116 VAST MIRROR STRETCHES OFF TO THE NORTHEAST. AT YOUR FEET IS A LARGE
116 STEEL GRATE, NEXT TO WHICH IS A SIGN WHICH READS, “TREASURE VAULT.
116 KEYS IN MAIN OFFICE.”
117 YOU ARE ON ONE SIDE OF A LARGE, DEEP CHASM. A HEAVY WHITE MIST RISING
117 UP FROM BELOW OBSCURES ALL VIEW OF THE FAR SIDE. A SW PATH LEADS AWAY
117 FROM THE CHASM INTO A WINDING CORRIDOR.
118 YOU ARE IN A LONG WINDING CORRIDOR SLOPING OUT OF SIGHT IN BOTH
118 DIRECTIONS.
119 YOU ARE IN A SECRET CANYON WHICH EXITS TO THE NORTH AND EAST.
120 YOU ARE IN A SECRET CANYON WHICH EXITS TO THE NORTH AND EAST.
121 YOU ARE IN A SECRET CANYON WHICH EXITS TO THE NORTH AND EAST.
122 YOU ARE ON THE FAR SIDE OF THE CHASM. A NE PATH LEADS AWAY FROM THE
122 CHASM ON THIS SIDE.
123 YOU’RE IN A LONG EAST/WEST CORRIDOR. A FAINT RUMBLING NOISE CAN BE
123 HEARD IN THE DISTANCE.
124 THE PATH FORKS HERE. THE LEFT FORK LEADS NORTHEAST. A DULL RUMBLING
124 SEEMS TO GET LOUDER IN THAT DIRECTION. THE RIGHT FORK LEADS SOUTHEAST
124 DOWN A GENTLE SLOPE. THE MAIN CORRIDOR ENTERS FROM THE WEST.
125 THE WALLS ARE QUITE WARM HERE. FROM THE NORTH CAN BE HEARD A STEADY
125 ROAR, SO LOUD THAT THE ENTIRE CAVE SEEMS TO BE TREMBLING. ANOTHER
125 PASSAGE LEADS SOUTH, AND A LOW CRAWL GOES EAST.
126 YOU ARE ON THE EDGE OF A BREATH-TAKING VIEW. FAR BELOW YOU IS AN
126 ACTIVE VOLCANO, FROM WHICH GREAT GOUTS OF MOLTEN LAVA COME SURGING
126 OUT, CASCADING BACK DOWN INTO THE DEPTHS. THE GLOWING ROCK FILLS THE
126 FARTHEST REACHES OF THE CAVERN WITH A BLOOD-RED GLARE, GIVING EVERY-
126 THING AN EERIE, MACABRE APPEARANCE. THE AIR IS FILLED WITH FLICKERING
126 SPARKS OF ASH AND A HEAVY SMELL OF BRIMSTONE. THE WALLS ARE HOT TO
126 THE TOUCH, AND THE THUNDERING OF THE VOLCANO DROWNS OUT ALL OTHER
126 SOUNDS. EMBEDDED IN THE JAGGED ROOF FAR OVERHEAD ARE MYRIAD TWISTED
126 FORMATIONS COMPOSED OF PURE WHITE ALABASTER, WHICH SCATTER THE MURKY
126 LIGHT INTO SINISTER APPARITIONS UPON THE WALLS. TO ONE SIDE IS A DEEP
126 GORGE, FILLED WITH A BIZARRE CHAOS OF TORTURED ROCK WHICH SEEMS TO
126 HAVE BEEN CRAFTED BY THE DEVIL HIMSELF. AN IMMENSE RIVER OF FIRE
126 CRASHES OUT FROM THE DEPTHS OF THE VOLCANO, BURNS ITS WAY THROUGH THE
126 GORGE, AND PLUMMETS INTO A BOTTOMLESS PIT FAR OFF TO YOUR LEFT. TO
126 THE RIGHT, AN IMMENSE GEYSER OF BLISTERING STEAM ERUPTS CONTINUOUSLY
126 FROM A BARREN ISLAND IN THE CENTER OF A SULFUROUS LAKE, WHICH BUBBLES
126 OMINOUSLY. THE FAR RIGHT WALL IS AFLAME WITH AN INCANDESCENCE OF ITS
126 OWN, WHICH LENDS AN ADDITIONAL INFERNAL SPLENDOR TO THE ALREADY
126 HELLISH SCENE. A DARK, FOREBODING PASSAGE EXITS TO THE SOUTH.
127 YOU ARE IN A SMALL CHAMBER FILLED WITH LARGE BOULDERS. THE WALLS ARE
127 VERY WARM, CAUSING THE AIR IN THE ROOM TO BE ALMOST STIFLING FROM THE

127 HEAT. THE ONLY EXIT IS A CRAWL HEADING WEST, THROUGH WHICH IS COMING
127 A LOW RUMBLING.
128 YOU ARE WALKING ALONG A GENTLY SLOPING NORTH/SOUTH PASSAGE LINED WITH
128 ODDLY SHAPED LIMESTONE FORMATIONS.
129 YOU ARE STANDING AT THE ENTRANCE TO A LARGE, BARREN ROOM. A SIGN
129 POSTED ABOVE THE ENTRANCE READS: "CAUTION! BEAR IN ROOM!"
130 YOU ARE INSIDE A BARREN ROOM. THE CENTER OF THE ROOM IS COMPLETELY
130 EMPTY EXCEPT FOR SOME DUST. MARKS IN THE DUST LEAD AWAY TOWARD THE
130 FAR END OF THE ROOM. THE ONLY EXIT IS THE WAY YOU CAME IN.
131 YOU ARE IN A MAZE OF TWISTING LITTLE PASSAGES, ALL DIFFERENT.
132 YOU ARE IN A LITTLE MAZE OF TWISTY PASSAGES, ALL DIFFERENT.
133 YOU ARE IN A TWISTING MAZE OF LITTLE PASSAGES, ALL DIFFERENT.
134 YOU ARE IN A TWISTING LITTLE MAZE OF PASSAGES, ALL DIFFERENT.
135 YOU ARE IN A TWISTY LITTLE MAZE OF PASSAGES, ALL DIFFERENT.
136 YOU ARE IN A TWISTY MAZE OF LITTLE PASSAGES, ALL DIFFERENT.
137 YOU ARE IN A LITTLE TWISTY MAZE OF PASSAGES, ALL DIFFERENT.
138 YOU ARE IN A MAZE OF LITTLE TWISTING PASSAGES, ALL DIFFERENT.
139 YOU ARE IN A MAZE OF LITTLE TWISTY PASSAGES, ALL DIFFERENT.
140 DEAD END
-1 END

[New section begins, featuring current player locations.]

2
1 YOU'RE AT END OF ROAD AGAIN.
2 YOU'RE AT HILL IN ROAD.
3 YOU'RE INSIDE BUILDING.
4 YOU'RE IN VALLEY.
5 YOU'RE IN FOREST.
6 YOU'RE IN FOREST.
7 YOU'RE AT SLIT IN STREAMBED.
8 YOU'RE OUTSIDE GRATE.
9 YOU'RE BELOW THE GRATE.
10 YOU'RE IN COBBLE CRAWL.
11 YOU'RE IN DEBRIS ROOM.
13 YOU'RE IN BIRD CHAMBER.
14 YOU'RE AT TOP OF SMALL PIT.
15 YOU'RE IN HALL OF MISTS.
17 YOU'RE ON EAST BANK OF FISSURE.
18 YOU'RE IN NUGGET OF GOLD ROOM.
19 YOU'RE IN HALL OF MT KING
23 YOU'RE AT WEST END OF TWOPIT ROOM.
24 YOU'RE IN EAST PIT.
25 YOU'RE IN WEST PIT.
33 YOU'RE AT "Y2".
35 YOU'RE AT WINDOW ON PIT.
36 YOU'RE IN DIRTY PASSAGE.
39 YOU'RE IN DUSTY ROCK ROOM.
41 YOU'RE AT WEST END OF HALL OF MISTS.
57 YOU'RE AT BRINK OF PIT.
60 YOU'RE AT EAST END OF LONG HALL.
61 YOU'RE AT WEST END OF LONG HALL.
64 YOU'RE AT COMPLEX JUNCTION.
66 YOU'RE IN SWISS CHEESE ROOM.
67 YOU'RE AT EAST END OF TWOPIT ROOM.
68 YOU'RE IN SLAB ROOM.

71 YOU'RE AT JUNCTION OF THREE SECRET CANYONS.
74 YOU'RE IN SECRET E/W CANYON ABOVE TIGHT CANYON.
88 YOU'RE IN NARROW CORRIDOR.
91 YOU'RE AT STEEP INCLINE ABOVE LARGE ROOM.
92 YOU'RE IN GIANT ROOM.
95 YOU'RE IN CAVERN WITH WATERFALL.
96 YOU'RE IN SOFT ROOM.
97 YOU'RE IN ORIENTAL ROOM.
98 YOU'RE IN MISTY CAVERN.
99 YOU'RE IN ALCOVE.
100 YOU'RE IN PLOVER ROOM.
101 YOU'RE IN DARK-ROOM.
102 YOU'RE IN ARCHED HALL.
103 YOU'RE IN SHELL ROOM.
106 YOU'RE IN ANTEROOM.
108 YOU'RE AT WITT'S END.
109 YOU'RE IN MIRROR CANYON.
110 YOU'RE AT WINDOW ON PIT.
111 YOU'RE AT TOP OF STALACTITE.
113 YOU'RE AT RESERVOIR.
115 YOU'RE AT NE END.
116 YOU'RE AT SW END.
117 YOU'RE ON SW SIDE OF CHASM.
118 YOU'RE IN SLOPING CORRIDOR.
122 YOU'RE ON NE SIDE OF CHASM.
123 YOU'RE IN CORRIDOR.
124 YOU'RE AT FORK IN PATH.
125 YOU'RE AT JUNCTION WITH WARM WALLS.
126 YOU'RE AT BREATH-TAKING VIEW.
127 YOU'RE IN CHAMBER OF BOULDERS.
128 YOU'RE IN LIMESTONE PASSAGE.
129 YOU'RE IN FRONT OF BARREN ROOM.
130 YOU'RE IN BARREN ROOM.
-1

[New section begins, featuring valid exits out of rooms.]

3

1	2	2	44	29			
1	3	3	12	19	43		
1	4	5	13	14	46	30	
1	5	6	45	43			
1	8	63					
2	1	2	12	7	43	45	30
2	5	6	45	46			
3	1	3	11	32	44		
3	11	62					
3	33	65					
3	79	5	14				
4	1	4	12	45			
4	5	6	43	44	29		
4	7	5	46	30			
4	8	63					
5	4	9	43	30			
5	50005		6	7	45		
5	6	6					

5	5	44	46					
6	1	2	45					
6	4	9	43	44	30			
6	5	6	46					
7	1	12						
7	4	4	45					
7	5	6	43	44				
7	8	5	15	16	46			
7	595	60	14	30				
8	5	6	43	44	46			
8	1	12						
8	7	4	13	45				
8	303009		3	19	30			
8	593	3						
9	303008		11	29				
9	593	11						
9	10	17	18	19	44			
9	14	31						
9	11	51						
10	9	11	20	21	43			
10	11	19	22	44	51			
10	14	31						
11	303008		63					
11	9	64						
11	10	17	18	23	24	43		
11	12	25	19	29	44			
11	3	62						
11	14	31						
12	303008		63					
12	9	64						
12	11	30	43	51				
12	13	19	29	44				
12	14	31						
13	303008		63					
13	9	64						
13	11	51						
13	12	25	43					
13	14	23	31	44				
14	303008		63					
14	9	64						
14	11	51						
14	13	23	43					
14	150020		30	31	34			
14	15	30						
14	16	33	44					
15	18	36	46					
15	17	7	38	44				
15	19	10	30	45				
15	150022		29	31	34	35	23	43
15	14	29						
15	34	55						
16	14	1						
17	15	38	43					
17	312596		39					
17	412021		7					
17	412597		41	42	44	69		

17	27	41				
18	15	38	11	45		
19	15	10	29	43		
19	311028		45	36		
19	311029		46	37		
19	311030		44	7		
19	32	45				
19	35074		49			
19	211032		49			
19	74	66				
20	0	1				
21	0	1				
22	15	1				
23	67	43	42			
23	68	44	61			
23	25	30	31			
23	648	52				
24	67	29	11			
25	23	29	11			
25	724031		56			
25	26	56				
26	88	1				
27	312596		39			
27	412021		7			
27	412597		41	42	43	69
27	17	41				
27	40	45				
27	41	44				
28	19	38	11	46		
28	33	45	55			
28	36	30	52			
29	19	38	11	45		
30	19	38	11	43		
30	62	44	29			
31	524089		1			
31	90	1				
32	19	1				
33	3	65				
33	28	46				
33	34	43	53	54		
33	35	44				
33	159302		71			
33	100	71				
34	33	30	55			
34	15	29				
35	33	43	55			
35	20	39				
36	37	43	17			
36	28	29	52			
36	39	44				
36	65	70				
37	36	44	17			
37	38	30	31	56		
38	37	56	29	11		
38	595	60	14	30	4	5
39	36	43	23			

39	64	30	52	58	
39	65	70			
40	41	1			
41	42	46	29	23	56
41	27	43			
41	59	45			
41	60	44	17		
42	41	29			
42	42	45			
42	43	43			
42	45	46			
42	80	44			
43	42	44			
43	44	46			
43	45	43			
44	43	43			
44	48	30			
44	50	46			
44	82	45			
45	42	44			
45	43	45			
45	46	43			
45	47	46			
45	87	29	30		
46	45	44	11		
47	45	43	11		
48	44	29	11		
49	50	43			
49	51	44			
50	44	43			
50	49	44			
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50	52	46			
51	49	44			
51	50	29			
51	52	43			
51	53	46			
52	50	44			
52	51	43			
52	52	46			
52	53	29			
52	55	45			
52	86	30			
53	51	44			
53	52	45			
53	54	46			
54	53	44	11		
55	52	44			
55	55	45			
55	56	30			
55	57	43			
56	55	29	11		
57	13	30	56		
57	55	44			
57	58	46			
57	83	45			

57	84	43		
58	57	43	11	
59	27	1		
60	41	43	29	17
60	61	44		
60	62	45	30	52
61	60	43		
61	62	45		
61	100107		46	
62	60	44		
62	63	45		
62	30	43		
62	61	46		
63	62	46	11	
64	39	29	56	59
64	65	44	70	
64	103	45	74	
64	106	43		
65	64	43		
65	66	44		
65	80556		46	
65	68	61		
65	80556		29	
65	50070		29	
65	39	29		
65	60556		45	
65	75072		45	
65	71	45		
65	80556		30	
65	106	30		
66	65	47		
66	67	44		
66	80556		46	
66	77	25		
66	96	43		
66	50556		50	
66	97	72		
67	66	43		
67	23	44	42	
67	24	30	31	
68	23	46		
68	69	29	56	
68	65	45		
69	68	30	61	
69	331120		46	
69	119	46		
69	109	45		
69	113	75		
70	71	45		
70	65	30	23	
70	111	46		
71	65	48		
71	70	46		
71	110	45		
72	65	70		
72	118	49		

72	73	45			
72	97	48	72		
73	72	46	17	11	
74	19	43			
74	331120		44		
74	121	44			
74	75	30			
75	76	46			
75	77	45			
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77	75	43			
77	78	44			
77	66	45	17		
78	77	46			
79	3	1			
80	42	45			
80	80	44			
80	80	46			
80	81	43			
81	80	44	11		
82	44	46	11		
83	57	46			
83	84	43			
83	85	44			
84	57	45			
84	83	44			
84	114	50			
85	83	43	11		
86	52	29	11		
87	45	29	30		
88	25	30	56	43	
88	20	39			
88	92	44	27		
89	25	1			
90	23	1			
91	95	45	73	23	
91	72	30	56		
92	88	46			
92	93	43			
92	94	45			
93	92	46	27	11	
94	92	46	27	23	
94	309095		45	3	73
94	611	45			
95	94	46	11		
95	92	27			
95	91	44			
96	66	44	11		
97	66	48			
97	72	44	17		
97	98	29	45	73	
98	97	46	72		
98	99	44			
99	98	50	73		
99	301	43	23		
99	100	43			

100	301	44	23	11							
100	99	44									
100	159302		71								
100	33	71									
100	101	47	22								
101	100	46	71	11							
102	103	30	74	11							
103	102	29	38								
103	104	30									
103	114618		46								
103	115619		46								
103	64	46									
104	103	29	74								
104	105	30									
105	104	29	11								
105	103	74									
106	64	29									
106	65	44									
106	108	43									
107	131	46									
107	132	49									
107	133	47									
107	134	48									
107	135	29									
107	136	50									
107	137	43									
107	138	44									
107	139	45									
107	61	30									
108	95556		43	45	46	47	48	49	50	29	30
108	106	43									
108	626	44									
109	69	46									
109	113	45	75								
110	71	44									
110	20	39									
111	70	45									
111	40050		30	39	56						
111	50053		30								
111	45	30									
112	131	49									
112	132	45									
112	133	43									
112	134	50									
112	135	48									
112	136	47									
112	137	44									
112	138	30									
112	139	29									
112	140	46									
113	109	46	11	109							
114	84	48									
115	116	49									
116	115	47									
116	593	30									
117	118	49									

117 233660 41 42 69 47
117 332661 41
117 303 41
117 332021 39
117 596 39
118 72 30
118 117 29
119 69 45 11
119 653 43 7
120 69 45
120 74 43
121 74 43 11
121 653 45 7
122 123 47
122 233660 41 42 69 49
122 303 41
122 596 39
122 124 77
122 126 28
122 129 40
123 122 44
123 124 43 77
123 126 28
123 129 40
124 123 44
124 125 47 36
124 128 48 37 30
124 126 28
124 129 40
125 124 46 77
125 126 45 28
125 127 43 17
126 125 46 23 11
126 124 77
126 610 30 39
127 125 44 11 17
127 124 77
127 126 28
128 124 45 29 77
128 129 46 30 40
128 126 28
129 128 44 29
129 124 77
129 130 43 19 40 3
129 126 28
130 129 44 11
130 124 77
130 126 28
131 107 44
131 132 48
131 133 50
131 134 49
131 135 47
131 136 29
131 137 30
131 138 45

131 139 46
131 112 43
132 107 50
132 131 29
132 133 45
132 134 46
132 135 44
132 136 49
132 137 47
132 138 43
132 139 30
132 112 48
133 107 29
133 131 30
133 132 44
133 134 47
133 135 49
133 136 43
133 137 45
133 138 50
133 139 48
133 112 46
134 107 47
134 131 45
134 132 50
134 133 48
134 135 43
134 136 30
134 137 46
134 138 29
134 139 44
134 112 49
135 107 45
135 131 48
135 132 30
135 133 46
135 134 43
135 136 44
135 137 49
135 138 47
135 139 50
135 112 29
136 107 43
136 131 44
136 132 29
136 133 49
136 134 30
136 135 46
136 137 50
136 138 48
136 139 47
136 112 45
137 107 48
137 131 47
137 132 46
137 133 30

137 134 29
137 135 50
137 136 45
137 138 49
137 139 43
137 112 44
138 107 30
138 131 43
138 132 47
138 133 29
138 134 44
138 135 45
138 136 46
138 137 48
138 139 49
138 112 50
139 107 49
139 131 50
139 132 43
139 133 44
139 134 45
139 135 30
139 136 48
139 137 29
139 138 46
139 112 47
140 112 45 11
-1

[New section begins, featuring commands and vocabulary.]

4
2 ROAD
2 HILL
3 ENTER
4 UPSTR
5 DOWNS
6 FORES
7 FORWA
7 CONTI
7 ONWAR
8 BACK
8 RETUR
8 RETRE
9 VALLE
10 STAIR
11 OUT
11 OUTSI
11 EXIT
11 LEAVE
12 BUILD
12 HOUSE
13 GULLY
14 STREA
15 ROCK
16 BED

17	CRAWL
18	COBBL
19	INWAR
19	INSID
19	IN
20	SURFA
21	NULL
21	NOWHE
22	DARK
23	PASSA
23	TUNNE
24	LOW
25	CANYO
26	AWKWA
27	GIANT
28	VIEW
29	UPWAR
29	UP
29	U
29	ABOVE
29	ASCEN
30	D
30	DOWNW
30	DOWN
30	DESCE
31	PIT
32	OUTDO
33	CRACK
34	STEPS
35	DOME
36	LEFT
37	RIGHT
38	HALL
39	JUMP
40	BARRE
41	OVER
42	ACROS
43	EAST
43	E
44	WEST
44	W
45	NORTH
45	N
46	SOUTH
46	S
47	NE
48	SE
49	SW
50	NW
51	DEBRI
52	HOLE
53	WALL
54	BROKE
55	Y2
56	CLIMB
57	LOOK

57 EXAMI
57 TOUCH
57 DESCR
58 FLOOR
59 ROOM
60 SLIT
61 SLAB
61 SLABR
62 XYZZY
63 DEPRE
64 ENTRA
65 PLUGH
66 SECRE
67 CAVE
69 CROSS
70 BEDQU
71 PLOVE
72 ORIEN
73 CAVER
74 SHELL
75 RESER
76 MAIN
76 OFFIC
77 FORK
1001 KEYS
1001 KEY
1002 LAMP
1002 HEADL
1002 LANTE
1003 GRATE
1004 CAGE
1005 ROD
1006 ROD (MUST BE NEXT OBJECT AFTER "REAL" ROD)
1007 STEPS
1008 BIRD
1009 DOOR
1010 PILLO
1010 VELVE
1011 SNAKE
1012 FISSU
1013 TABLE
1014 CLAM
1015 OYSTE
1016 MAGAZ
1016 ISSUE
1016 SPELU
1016 "SPEL
1017 DWARF
1017 DWARV
1018 KNIFE
1018 KNIVE
1019 FOOD
1019 RATIO
1020 BOTTL
1020 JAR
1021 WATER

1021	H2O
1022	OIL
1023	MIRRO
1024	PLANT
1024	BEANS
1025	PLANT (MUST BE NEXT OBJECT AFTER “REAL” PLANT)
1026	STALA
1027	SHADO
1027	FIGUR
1028	AXE
1029	DRAWI
1030	PIRAT
1031	DRAGO
1032	CHASM
1033	TROLL
1034	TROLL (MUST BE NEXT OBJECT AFTER “REAL” TROLL)
1035	BEAR
1036	MESSA
1037	VOLCA
1037	GEYSE (SAME AS VOLCANO)
1038	MACHI
1038	VENDI
1039	BATTE
1040	CARPE
1040	MOSS
1050	GOLD
1050	NUGGE
1051	DIAMO
1052	SILVE
1052	BARS
1053	JEWEL
1054	COINS
1055	CHEST
1055	BOX
1055	TREAS
1056	EGGS
1056	EGG
1056	NEST
1057	TRIDE
1058	VASE
1058	MING
1058	SHARD
1058	POTTE
1059	EMERA
1060	PLATI
1060	PYRAM
1061	PEARL
1062	RUG
1062	PERSI
1063	SPICE
1064	CHAIN
2001	CARRY
2001	TAKE
2001	KEEP
2001	CATCH
2001	STEAL

2001	CAPTU
2001	GET
2001	TOTE
2002	DROP
2002	RELEA
2002	FREE
2002	DISCA
2002	DUMP
2003	SAY
2003	CHANT
2003	SING
2003	UTTER
2003	MUMBL
2004	UNLOC
2004	OPEN
2005	NOTHI
2006	LOCK
2006	CLOSE
2007	LIGHT
2007	ON
2008	EXTIN
2008	OFF
2009	WAVE
2009	SHAKE
2009	SWING
2010	CALM
2010	PLACA
2010	TAME
2011	WALK
2011	RUN
2011	TRAVE
2011	GO
2011	PROCE
2011	CONTI
2011	EXPLO
2011	GOTO
2011	FOLLO
2011	TURN
2012	ATTAC
2012	KILL
2012	FIGHT
2012	HIT
2012	STRIK
2013	POUR
2014	EAT
2014	DEVOU
2015	DRINK
2016	RUB
2017	THROW
2017	TOSS
2018	QUIT
2019	FIND
2019	WHERE
2020	INVEN
2021	FEED
2022	FILL

2023 BLAST
2023 DETON
2023 IGNIT
2023 BLOWU
2024 SCORE
2025 FEE
2025 FIE
2025 FOE
2025 FOO
2025 FUM
2026 BRIEF
2027 READ
2027 PERUS
2028 BREAK
2028 SHATT
2028 SMASH
2029 WAKE
2029 DISTU
2030 SUSPE
2030 PAUSE
2030 SAVE
2031 HOURS
3001 FEE
3002 FIE
3003 FOE
3004 FOO
3005 FUM
3050 SESAM
3050 OPENS
3050 ABRA
3050 ABRAC
3050 SHAZA
3050 HOCUS
3050 POCUS
3051 HELP
3051 ?
3064 TREE
3064 TREES
3066 DIG
3066 EXCAV
3068 LOST
3069 MIST
3079 FUCK
3139 STOP
3142 INFO
3142 INFOR
3147 SWIM
-1

[New section begins, featuring location and inventory information provided to player.]

5
1 SET OF KEYS
000 THERE ARE SOME KEYS ON THE GROUND HERE.
2 BRASS LANTERN
000 THERE IS A SHINY BRASS LAMP NEARBY.

100 THERE IS A LAMP SHINING NEARBY.
3 *GRATE
000 THE GRATE IS LOCKED.
100 THE GRATE IS OPEN.
4 WICKER CAGE
000 THERE IS A SMALL WICKER CAGE DISCARDED NEARBY.
5 BLACK ROD
000 A THREE FOOT BLACK ROD WITH A RUSTY STAR ON AN END LIES NEARBY.
6 BLACK ROD
000 A THREE FOOT BLACK ROD WITH A RUSTY MARK ON AN END LIES NEARBY.
7 *STEPS
000 ROUGH STONE STEPS LEAD DOWN THE PIT.
100 ROUGH STONE STEPS LEAD UP THE DOME.
8 LITTLE BIRD IN CAGE
000 A CHEERFUL LITTLE BIRD IS SITTING HERE SINGING.
100 THERE IS A LITTLE BIRD IN THE CAGE.
9 *RUSTY DOOR
000 THE WAY NORTH IS BARRED BY A MASSIVE, RUSTY, IRON DOOR.
100 THE WAY NORTH LEADS THROUGH A MASSIVE, RUSTY, IRON DOOR.
10 VELVET PILLOW
000 A SMALL VELVET PILLOW LIES ON THE FLOOR.
11 *SNAKE
000 A HUGE GREEN FIERCE SNAKE BARS THE WAY!
100 >$< (CHASED AWAY)
12 *FISSURE
000 >$<
100 A CRYSTAL BRIDGE NOW SPANS THE FISSURE.
200 THE CRYSTAL BRIDGE HAS VANISHED!
13 *STONE TABLET
000 A MASSIVE STONE TABLET IMBEDDED IN THE WALL READS:
000 “CONGRATULATIONS ON BRINGING LIGHT INTO THE DARK-ROOM!”
14 GIANT CLAM >GRUNT!<
000 THERE IS AN ENORMOUS CLAM HERE WITH ITS SHELL TIGHTLY CLOSED.
15 GIANT OYSTER >GROAN!<
000 THERE IS AN ENORMOUS OYSTER HERE WITH ITS SHELL TIGHTLY CLOSED.
100 INTERESTING. THERE SEEMS TO BE SOMETHING WRITTEN ON THE UNDERSIDE OF
100 THE OYSTER.
16 “SPELUNKER TODAY”
000 THERE ARE A FEW RECENT ISSUES OF “SPELUNKER TODAY” MAGAZINE HERE.
19 TASTY FOOD
000 THERE IS FOOD HERE.
20 SMALL BOTTLE
000 THERE IS A BOTTLE OF WATER HERE.
100 THERE IS AN EMPTY BOTTLE HERE.
200 THERE IS A BOTTLE OF OIL HERE.
21 WATER IN THE BOTTLE
22 OIL IN THE BOTTLE
23 *MIRROR
000 >$<
24 *PLANT
000 THERE IS A TINY LITTLE PLANT IN THE PIT, MURMURING “WATER, WATER, ...”
100 THE PLANT SPURTS INTO FURIOUS GROWTH FOR A FEW SECONDS.
200 THERE IS A 12-FOOT-TALL BEANSTALK STRETCHING UP OUT OF THE PIT,
200 BELLOWING “WATER!! WATER!!”
300 THE PLANT GROWS EXPLOSIVELY, ALMOST FILLING THE BOTTOM OF THE PIT.
400 THERE IS A GIGANTIC BEANSTALK STRETCHING ALL THE WAY UP TO THE HOLE.

500 YOU'VE OVER-WATERED THE PLANT! IT'S SHRIVELING UP! IT'S, IT'S...
25 *PHONY PLANT (SEEN IN TWOPIT ROOM ONLY WHEN TALL ENOUGH)
000 >$<
100 THE TOP OF A 12-FOOT-TALL BEANSTALK IS POKING OUT OF THE WEST PIT.
200 THERE IS A HUGE BEANSTALK GROWING OUT OF THE WEST PIT UP TO THE HOLE.
26 *STALACTITE
000 >$<
27 *SHADOWY FIGURE
000 THE SHADOWY FIGURE SEEMS TO BE TRYING TO ATTRACT YOUR ATTENTION.
28 DWARF'S AXE
000 THERE IS A LITTLE AXE HERE.
100 THERE IS A LITTLE AXE LYING BESIDE THE BEAR.
29 *CAVE DRAWINGS
000 >$<
30 *PIRATE
000 >$<
31 *DRAGON
000 A HUGE GREEN FIERCE DRAGON BARS THE WAY!
100 CONGRATULATIONS! YOU HAVE JUST VANQUISHED A DRAGON WITH YOUR BARE
100 HANDS! (UNBELIEVABLE, ISN'T IT?)
200 THE BODY OF A HUGE GREEN DEAD DRAGON IS LYING OFF TO ONE SIDE.
32 *CHASM
000 A RICKETY WOODEN BRIDGE EXTENDS ACROSS THE CHASM, VANISHING INTO THE
000 MIST. A SIGN POSTED ON THE BRIDGE READS, "STOP! PAY TROLL!"
100 THE WRECKAGE OF A BRIDGE (AND A DEAD BEAR) CAN BE SEEN AT THE BOTTOM
100 OF THE CHASM.
33 *TROLL
000 A BURLY TROLL STANDS BY THE BRIDGE AND INSISTS YOU THROW HIM A
000 TREASURE BEFORE YOU MAY CROSS.
100 THE TROLL STEPS OUT FROM BENEATH THE BRIDGE AND BLOCKS YOUR WAY.
200 >$< (CHASED AWAY)
34 *PHONY TROLL
000 THE TROLL IS NOWHERE TO BE SEEN.
35 >$< (BEAR USES RTEXT 141)
000 THERE IS A FEROCIOUS CAVE BEAR EYING YOU FROM THE FAR END OF THE ROOM!
100 THERE IS A GENTLE CAVE BEAR SITTING PLACIDLY IN ONE CORNER.
200 THERE IS A CONTENTED-LOOKING BEAR WANDERING ABOUT NEARBY.
300 >$< (DEAD)
36 *MESSAGE IN SECOND MAZE
000 THERE IS A MESSAGE SCRAWLED IN THE DUST IN A FLOWERY SCRIPT, READING:
000 "THIS IS NOT THE MAZE WHERE THE PIRATE LEAVES HIS TREASURE CHEST."
37 *VOLCANO AND/OR GEYSER
000 >$<
38 *VENDING MACHINE
000 THERE IS A MASSIVE VENDING MACHINE HERE. THE INSTRUCTIONS ON IT READ:
000 "DROP COINS HERE TO RECEIVE FRESH BATTERIES."
39 BATTERIES
000 THERE ARE FRESH BATTERIES HERE.
100 SOME WORN-OUT BATTERIES HAVE BEEN DISCARDED NEARBY.
40 *CARPET AND/OR MOSS
000 >$<
50 LARGE GOLD NUGGET
000 THERE IS A LARGE SPARKLING NUGGET OF GOLD HERE!
51 SEVERAL DIAMONDS
000 THERE ARE DIAMONDS HERE!
52 BARS OF SILVER

000 THERE ARE BARS OF SILVER HERE!
53 PRECIOUS JEWELRY
000 THERE IS PRECIOUS JEWELRY HERE!
54 RARE COINS
000 THERE ARE MANY COINS HERE!
55 TREASURE CHEST
000 THE PIRATE'S TREASURE CHEST IS HERE!
56 GOLDEN EGGS
000 THERE IS A LARGE NEST HERE, FULL OF GOLDEN EGGS!
100 THE NEST OF GOLDEN EGGS HAS VANISHED!
200 DONE!
57 JEWELED TRIDENT
000 THERE IS A JEWEL-ENCRUSTED TRIDENT HERE!
58 MING VASE
000 THERE IS A DELICATE, PRECIOUS, MING VASE HERE!
100 THE VASE IS NOW RESTING, DELICATELY, ON A VELVET PILLOW.
200 THE FLOOR IS LITTERED WITH WORTHLESS SHARDS OF POTTERY.
300 THE MING VASE DROPS WITH A DELICATE CRASH.
59 EGG-SIZED EMERALD
000 THERE IS AN EMERALD HERE THE SIZE OF A PLOVER'S EGG!
60 PLATINUM PYRAMID
000 THERE IS A PLATINUM PYRAMID HERE, 8 INCHES ON A SIDE!
61 GLISTENING PEARL
000 OFF TO ONE SIDE LIES A GLISTENING PEARL!
62 PERSIAN RUG
000 THERE IS A PERSIAN RUG SPREAD OUT ON THE FLOOR!
100 THE DRAGON IS SPRAWLED OUT ON A PERSIAN RUG!!
63 RARE SPICES
000 THERE ARE RARE SPICES HERE!
64 GOLDEN CHAIN
000 THERE IS A GOLDEN CHAIN LYING IN A HEAP ON THE FLOOR!
100 THE BEAR IS LOCKED TO THE WALL WITH A GOLDEN CHAIN!
200 THERE IS A GOLDEN CHAIN LOCKED TO THE WALL!
-1

[New section begins, featuring narrative text.]

6
1 SOMEWHERE NEARBY IS COLOSSAL CAVE, WHERE OTHERS HAVE FOUND FORTUNES IN
1 TREASURE AND GOLD, THOUGH IT IS RUMORED THAT SOME WHO ENTER ARE NEVER
1 SEEN AGAIN. MAGIC IS SAID TO WORK IN THE CAVE. I WILL BE YOUR EYES
1 AND HANDS. DIRECT ME WITH COMMANDS OF 1 OR 2 WORDS. I SHOULD WARN
1 YOU THAT I LOOK AT ONLY THE FIRST FIVE LETTERS OF EACH WORD, SO YOU'LL
1 HAVE TO ENTER "NORTHEAST" AS "NE" TO DISTINGUISH IT FROM "NORTH".
1 (SHOULD YOU GET STUCK, TYPE "HELP" FOR SOME GENERAL HINTS. FOR INFOR-
1 MATION ON HOW TO END YOUR ADVENTURE, ETC., TYPE "INFO".)
1 - - -
1 THIS PROGRAM WAS ORIGINALLY DEVELOPED BY WILLIE CROWTHER. MOST OF THE
1 FEATURES OF THE CURRENT PROGRAM WERE ADDED BY DON WOODS (DON @ SU-AI).
1 CONTACT DON IF YOU HAVE ANY QUESTIONS, COMMENTS, ETC.
2 A LITTLE DWARF WITH A BIG KNIFE BLOCKS YOUR WAY.
3 A LITTLE DWARF JUST WALKED AROUND A CORNER, SAW YOU, THREW A LITTLE
3 AXE AT YOU WHICH MISSED, CURSED, AND RAN AWAY.
4 THERE IS A THREATENING LITTLE DWARF IN THE ROOM WITH YOU!

5 ONE SHARP NASTY KNIFE IS THROWN AT YOU!
6 NONE OF THEM HIT YOU!
7 ONE OF THEM GETS YOU!
8 A HOLLOW VOICE SAYS "PLUGH".
9 THERE IS NO WAY TO GO THAT DIRECTION.
10 I AM UNSURE HOW YOU ARE FACING. USE COMPASS POINTS OR NEARBY OBJECTS.
11 I DON'T KNOW IN FROM OUT HERE. USE COMPASS POINTS OR NAME SOMETHING
11 IN THE GENERAL DIRECTION YOU WANT TO GO.
12 I DON'T KNOW HOW TO APPLY THAT WORD HERE.
13 I DON'T UNDERSTAND THAT!
14 I'M GAME. WOULD YOU CARE TO EXPLAIN HOW?
15 SORRY, BUT I AM NOT ALLOWED TO GIVE MORE DETAIL. I WILL REPEAT THE
15 LONG DESCRIPTION OF YOUR LOCATION.
16 IT IS NOW PITCH DARK. IF YOU PROCEED YOU WILL LIKELY FALL INTO A PIT.
17 IF YOU PREFER, SIMPLY TYPE W RATHER THAN WEST.
18 ARE YOU TRYING TO CATCH THE BIRD?
19 THE BIRD IS FRIGHTENED RIGHT NOW AND YOU CANNOT CATCH IT NO MATTER
19 WHAT YOU TRY. PERHAPS YOU MIGHT TRY LATER.
20 ARE YOU TRYING TO SOMEHOW DEAL WITH THE SNAKE?
21 YOU CAN'T KILL THE SNAKE, OR DRIVE IT AWAY, OR AVOID IT, OR ANYTHING
21 LIKE THAT. THERE IS A WAY TO GET BY, BUT YOU DON'T HAVE THE NECESSARY
21 RESOURCES RIGHT NOW.
22 DO YOU REALLY WANT TO QUIT NOW?
23 YOU FELL INTO A PIT AND BROKE EVERY BONE IN YOUR BODY!
24 YOU ARE ALREADY CARRYING IT!
25 YOU CAN'T BE SERIOUS!
26 THE BIRD WAS UNAFRAID WHEN YOU ENTERED, BUT AS YOU APPROACH IT BECOMES
26 DISTURBED AND YOU CANNOT CATCH IT.
27 YOU CAN CATCH THE BIRD, BUT YOU CANNOT CARRY IT.
28 THERE IS NOTHING HERE WITH A LOCK!
29 YOU AREN'T CARRYING IT!
30 THE LITTLE BIRD ATTACKS THE GREEN SNAKE, AND IN AN ASTOUNDING FLURRY
30 DRIVES THE SNAKE AWAY.
31 YOU HAVE NO KEYS!
32 IT HAS NO LOCK.
33 I DON'T KNOW HOW TO LOCK OR UNLOCK SUCH A THING.
34 IT WAS ALREADY LOCKED.
35 THE GRATE IS NOW LOCKED.
36 THE GRATE IS NOW UNLOCKED.
37 IT WAS ALREADY UNLOCKED.
38 YOU HAVE NO SOURCE OF LIGHT.
39 YOUR LAMP IS NOW ON.
40 YOUR LAMP IS NOW OFF.
41 THERE IS NO WAY TO GET PAST THE BEAR TO UNLOCK THE CHAIN, WHICH IS
41 PROBABLY JUST AS WELL.
42 NOTHING HAPPENS.
43 WHERE?
44 THERE IS NOTHING HERE TO ATTACK.
45 THE LITTLE BIRD IS NOW DEAD. ITS BODY DISAPPEARS.
46 ATTACKING THE SNAKE BOTH DOESN'T WORK AND IS VERY DANGEROUS.
47 YOU KILLED A LITTLE DWARF.
48 YOU ATTACK A LITTLE DWARF, BUT HE DODGES OUT OF THE WAY.
49 WITH WHAT? YOUR BARE HANDS?
50 GOOD TRY, BUT THAT IS AN OLD WORN-OUT MAGIC WORD.
51 I KNOW OF PLACES, ACTIONS, AND THINGS. MOST OF MY VOCABULARY
51 DESCRIBES PLACES AND IS USED TO MOVE YOU THERE. TO MOVE, TRY WORDS

51 LIKE FOREST, BUILDING, DOWNSTREAM, ENTER, EAST, WEST, NORTH, SOUTH,
51 UP, OR DOWN. I KNOW ABOUT A FEW SPECIAL OBJECTS, LIKE A BLACK ROD
51 HIDDEN IN THE CAVE. THESE OBJECTS CAN BE MANIPULATED USING SOME OF
51 THE ACTION WORDS THAT I KNOW. USUALLY YOU WILL NEED TO GIVE BOTH THE
51 OBJECT AND ACTION WORDS (IN EITHER ORDER), BUT SOMETIMES I CAN INFER
51 THE OBJECT FROM THE VERB ALONE. SOME OBJECTS ALSO IMPLY VERBS; IN
51 PARTICULAR, "INVENTORY" IMPLIES "TAKE INVENTORY", WHICH CAUSES ME TO
51 GIVE YOU A LIST OF WHAT YOU'RE CARRYING. THE OBJECTS HAVE SIDE
51 EFFECTS; FOR INSTANCE, THE ROD SCARES THE BIRD. USUALLY PEOPLE HAVING
51 TROUBLE MOVING JUST NEED TO TRY A FEW MORE WORDS. USUALLY PEOPLE
51 TRYING UNSUCCESSFULLY TO MANIPULATE AN OBJECT ARE ATTEMPTING SOMETHING
51 BEYOND THEIR (OR MY!) CAPABILITIES AND SHOULD TRY A COMPLETELY
51 DIFFERENT TACK. TO SPEED THE GAME YOU CAN SOMETIMES MOVE LONG
51 DISTANCES WITH A SINGLE WORD. FOR EXAMPLE, "BUILDING" USUALLY GETS
51 YOU TO THE BUILDING FROM ANYWHERE ABOVE GROUND EXCEPT WHEN LOST IN THE
51 FOREST. ALSO, NOTE THAT CAVE PASSAGES TURN A LOT, AND THAT LEAVING A
51 ROOM TO THE NORTH DOES NOT GUARANTEE ENTERING THE NEXT FROM THE SOUTH.
51 GOOD LUCK!
52 IT MISSES!
53 IT GETS YOU!
54 OK
55 YOU CAN'T UNLOCK THE KEYS.
56 YOU HAVE CRAWLED AROUND IN SOME LITTLE HOLES AND WOUND UP BACK IN THE
56 MAIN PASSAGE.
57 I DON'T KNOW WHERE THE CAVE IS, BUT HEREABOUTS NO STREAM CAN RUN ON
57 THE SURFACE FOR LONG. I WOULD TRY THE STREAM.
58 I NEED MORE DETAILED INSTRUCTIONS TO DO THAT.
59 I CAN ONLY TELL YOU WHAT YOU SEE AS YOU MOVE ABOUT AND MANIPULATE
59 THINGS. I CANNOT TELL YOU WHERE REMOTE THINGS ARE.
60 I DON'T KNOW THAT WORD.
61 WHAT?
62 ARE YOU TRYING TO GET INTO THE CAVE?
63 THE GRATE IS VERY SOLID AND HAS A HARDENED STEEL LOCK. YOU CANNOT
63 ENTER WITHOUT A KEY, AND THERE ARE NO KEYS NEARBY. I WOULD RECOMMEND
63 LOOKING ELSEWHERE FOR THE KEYS.
64 THE TREES OF THE FOREST ARE LARGE HARDWOOD OAK AND MAPLE, WITH AN
64 OCCASIONAL GROVE OF PINE OR SPRUCE. THERE IS QUITE A BIT OF UNDER-
64 GROWTH, LARGELY BIRCH AND ASH SAPLINGS PLUS NONDESCRIPT BUSHES OF
64 VARIOUS SORTS. THIS TIME OF YEAR VISIBILITY IS QUITE RESTRICTED BY
64 ALL THE LEAVES, BUT TRAVEL IS QUITE EASY IF YOU DETOUR AROUND THE
64 SPRUCE AND BERRY BUSHES.
65 WELCOME TO ADVENTURE!! WOULD YOU LIKE INSTRUCTIONS?
66 DDIGGING WITHOUT A SHOVEL IS QUITE IMPRACTICAL. EVEN WITH A SHOVEL
66 PROGRESS IS UNLIKELY.
67 BLASTING REQUIRES DYNAMITE.
68 I'M AS CONFUSED AS YOU ARE.
69 MIST IS A WHITE VAPOR, USUALLY WATER, SEEN FROM TIME TO TIME IN
69 CAVERNS. IT CAN BE FOUND ANYWHERE BUT IS FREQUENTLY A SIGN OF A DEEP
69 PIT LEADING DOWN TO WATER.
70 YOUR FEET ARE NOW WET.
71 I THINK I JUST LOST MY APPETITE.
72 THANK YOU, IT WAS DELICIOUS!
73 YOU HAVE TAKEN A DRINK FROM THE STREAM. THE WATER TASTES STRONGLY OF

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73 MINERALS, BUT IS NOT UNPLEASANT.  IT IS EXTREMELY COLD.
74 THE BOTTLE OF WATER IS NOW EMPTY.
75 RUBBING THE ELECTRIC LAMP IS NOT PARTICULARLY REWARDING.  ANYWAY,
75 NOTHING EXCITING HAPPENS.
76 PECULIAR.  NOTHING UNEXPECTED HAPPENS.
77 YOUR BOTTLE IS EMPTY AND THE GROUND IS WET.
78 YOU CAN'T POUR THAT.
79 WATCH IT!
80 WHICH WAY?
81 OH DEAR, YOU SEEM TO HAVE GOTTEN YOURSELF KILLED.  I MIGHT BE ABLE TO
81 HELP YOU OUT, BUT I'VE NEVER REALLY DONE THIS BEFORE.  DO YOU WANT ME
81 TO TRY TO REINCARNATE YOU?
82 ALL RIGHT.  BUT DON'T BLAME ME IF SOMETHING GOES WR......
82                    --- POOF!! ---
82 YOU ARE ENGULFED IN A CLOUD OF ORANGE SMOKE.  COUGHING AND GASPING,
82 YOU EMERGE FROM THE SMOKE AND FIND....
83 YOU CLUMSY OAF, YOU'VE DONE IT AGAIN!  I DON'T KNOW HOW LONG I CAN
83 KEEP THIS UP.  DO YOU WANT ME TO TRY REINCARNATING YOU AGAIN?
84 OKAY, NOW WHERE DID I PUT MY ORANGE SMOKE?....        >POOF!<
84 EVERYTHING DISAPPEARS IN A DENSE CLOUD OF ORANGE SMOKE.
85 NOW YOU'VE REALLY DONE IT!  I'M OUT OF ORANGE SMOKE!  YOU DON'T EXPECT
85 ME TO DO A DECENT REINCARNATION WITHOUT ANY ORANGE SMOKE, DO YOU?
86 OKAY, IF YOU'RE SO SMART, DO IT YOURSELF!  I'M LEAVING!
90 >>> MESSAGES 81 THRU 90 ARE RESERVED FOR "OBITUARIES". <<<
91 SORRY, BUT I NO LONGER SEEM TO REMEMBER HOW IT WAS YOU GOT HERE.
92 YOU CAN'T CARRY ANYTHING MORE. YOU'LL HAVE TO DROP SOMETHING FIRST.
93 YOU CAN'T GO THROUGH A LOCKED STEEL GRATE!
94 I BELIEVE WHAT YOU WANT IS RIGHT HERE WITH YOU.
95 YOU DON'T FIT THROUGH A TWO-INCH SLIT!
96 I RESPECTFULLY SUGGEST YOU GO ACROSS THE BRIDGE INSTEAD OF JUMPING.
97 THERE IS NO WAY ACROSS THE FISSURE.
98 YOU'RE NOT CARRYING ANYTHING.
99 YOU ARE CURRENTLY HOLDING THE FOLLOWING:
100 IT'S NOT HUNGRY (IT'S MERELY PININ' FOR THE FJORDS).  BESIDES, YOU
100 HAVE NO BIRD SEED.
101 THE SNAKE HAS NOW DEVOURED YOUR BIRD.
102 THERE'S NOTHING HERE IT WANTS TO EAT (EXCEPT PERHAPS YOU).
103 YOU FOOL, DWARVES EAT ONLY COAL!  NOW YOU'VE MADE HIM *REALLY* MAD!!
104 YOU HAVE NOTHING IN WHICH TO CARRY IT.
105 YOUR BOTTLE IS ALREADY FULL.
106 THERE IS NOTHING HERE WITH WHICH TO FILL THE BOTTLE.
107 YOUR BOTTLE IS NOW FULL OF WATER.
108 YOUR BOTTLE IS NOW FULL OF OIL.
109 YOU CAN'T FILL THAT.
110 DON'T BE RIDICULOUS!
111 THE DOOR IS EXTREMELY RUSTY AND REFUSES TO OPEN.
112 THE PLANT INDIGNANTLY SHAKES THE OIL OFF ITS LEAVES AND ASKS, "WATER?"
113 THE HINGES ARE QUITE THOROUGHLY RUSTED NOW AND WON'T BUDGE.
114 THE OIL HAS FREED UP THE HINGES SO THAT THE DOOR WILL NOW MOVE,
114 ALTHOUGH IT REQUIRES SOME EFFORT.
115 THE PLANT HAS EXCEPTIONALLY DEEP ROOTS AND CANNOT BE PULLED FREE.
116 THE DWARVES' KNIVES VANISH AS THEY STRIKE THE WALLS OF THE CAVE.
117 SOMETHING YOU'RE CARRYING WON'T FIT THROUGH THE TUNNEL WITH YOU.
117 YOU'D BEST TAKE INVENTORY AND DROP SOMETHING.
118 YOU CAN'T FIT THIS FIVE-FOOT CLAM THROUGH THAT LITTLE PASSAGE!
119 YOU CAN'T FIT THIS FIVE-FOOT OYSTER THROUGH THAT LITTLE PASSAGE!
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120 I ADVISE YOU TO PUT DOWN THE CLAM BEFORE OPENING IT. >STRAIN!<
121 I ADVISE YOU TO PUT DOWN THE OYSTER BEFORE OPENING IT. >WRENCH!<
122 YOU DON'T HAVE ANYTHING STRONG ENOUGH TO OPEN THE CLAM.
123 YOU DON'T HAVE ANYTHING STRONG ENOUGH TO OPEN THE OYSTER.
124 A GLISTENING PEARL FALLS OUT OF THE CLAM AND ROLLS AWAY. GOODNESS,
124 THIS MUST REALLY BE AN OYSTER. (I NEVER WAS VERY GOOD AT IDENTIFYING
124 BIVALVES.) WHATEVER IT IS, IT HAS NOW SNAPPED SHUT AGAIN.
125 THE OYSTER CREAKS OPEN, REVEALING NOTHING BUT OYSTER INSIDE. IT
125 PROMPTLY SNAPS SHUT AGAIN.
126 YOU HAVE CRAWLED AROUND IN SOME LITTLE HOLES AND FOUND YOUR WAY
126 BLOCKED BY A RECENT CAVE-IN. YOU ARE NOW BACK IN THE MAIN PASSAGE.
127 THERE ARE FAINT RUSTLING NOISES FROM THE DARKNESS BEHIND YOU.
128 OUT FROM THE SHADOWS BEHIND YOU POUNCES A BEARDED PIRATE! "HAR, HAR,"
128 HE CHORTLES, "I'LL JUST TAKE ALL THIS BOOTY AND HIDE IT AWAY WITH ME
128 CHEST DEEP IN THE MAZE!" HE SNATCHES YOUR TREASURE AND VANISHES INTO
128 THE GLOOM.
129 A SEPULCHRAL VOICE REVERBERATING THROUGH THE CAVE, SAYS, "CAVE CLOSING
129 SOON. ALL ADVENTURERS EXIT IMMEDIATELY THROUGH MAIN OFFICE."
130 A MYSTERIOUS RECORDED VOICE GROANS INTO LIFE AND ANNOUNCES:
130 "THIS EXIT IS CLOSED. PLEASE LEAVE VIA MAIN OFFICE."
131 IT LOOKS AS THOUGH YOU'RE DEAD. WELL, SEEING AS HOW IT'S SO CLOSE TO
131 CLOSING TIME ANYWAY, I THINK WE'LL JUST CALL IT A DAY.
132 THE SEPULCHRAL VOICE ENTONES, "THE CAVE IS NOW CLOSED." AS THE ECHOES
132 FADE, THERE IS A BLINDING FLASH OF LIGHT (AND A SMALL PUFF OF ORANGE
132 SMOKE). . . . AS YOUR EYES REFOCUS, YOU LOOK AROUND AND FIND...
133 THERE IS A LOUD EXPLOSION, AND A TWENTY-FOOT HOLE APPEARS IN THE FAR
133 WALL, BURYING THE DWARVES IN THE RUBBLE. YOU MARCH THROUGH THE HOLE
133 AND FIND YOURSELF IN THE MAIN OFFICE, WHERE A CHEERING BAND OF
133 FRIENDLY ELVES CARRY THE CONQUERING ADVENTURER OFF INTO THE SUNSET.
134 THERE IS A LOUD EXPLOSION, AND A TWENTY-FOOT HOLE APPEARS IN THE FAR
134 WALL, BURYING THE SNAKES IN THE RUBBLE. A RIVER OF MOLTEN LAVA POURS
134 IN THROUGH THE HOLE, DESTROYING EVERYTHING IN ITS PATH, INCLUDING YOU!
135 THERE IS A LOUD EXPLOSION, AND YOU ARE SUDDENLY SPLASHED ACROSS THE
135 WALLS OF THE ROOM.
136 THE RESULTING RUCKUS HAS AWAKENED THE DWARVES. THERE ARE NOW SEVERAL
136 THREATENING LITTLE DWARVES IN THE ROOM WITH YOU! MOST OF THEM THROW
136 KNIVES AT YOU! ALL OF THEM GET YOU!
137 OH, LEAVE THE POOR UNHAPPY BIRD ALONE.
138 I DARESAY WHATEVER YOU WANT IS AROUND HERE SOMEWHERE.
139 I DON'T KNOW THE WORD "STOP". USE "QUIT" IF YOU WANT TO GIVE UP.
140 YOU CAN'T GET THERE FROM HERE.
141 YOU ARE BEING FOLLOWED BY A VERY LARGE, TAME BEAR.
142 IF YOU WANT TO END YOUR ADVENTURE EARLY, SAY "QUIT". TO SUSPEND YOUR
142 ADVENTURE SUCH THAT YOU CAN CONTINUE LATER, SAY "SUSPEND" (OR "PAUSE"
142 OR "SAVE"). TO SEE WHAT HOURS THE CAVE IS NORMALLY OPEN, SAY "HOURS".
142 TO SEE HOW WELL YOU'RE DOING, SAY "SCORE". TO GET FULL CREDIT FOR A
142 TREASURE, YOU MUST HAVE LEFT IT SAFELY IN THE BUILDING, THOUGH YOU GET
142 PARTIAL CREDIT JUST FOR LOCATING IT. YOU LOSE POINTS FOR GETTING
142 KILLED, OR FOR QUITTING, THOUGH THE FORMER COSTS YOU MORE. THERE ARE
142 ALSO POINTS BASED ON HOW MUCH (IF ANY) OF THE CAVE YOU'VE MANAGED TO
142 EXPLORE; IN PARTICULAR, THERE IS A LARGE BONUS JUST FOR GETTING IN (TO
142 DISTINGUISH THE BEGINNERS FROM THE REST OF THE PACK), AND THERE ARE
142 OTHER WAYS TO DETERMINE WHETHER YOU'VE BEEN THROUGH SOME OF THE MORE
142 HARROWING SECTIONS. IF YOU THINK YOU'VE FOUND ALL THE TREASURES, JUST
142 KEEP EXPLORING FOR A WHILE. IF NOTHING INTERESTING HAPPENS, YOU
142 HAVEN'T FOUND THEM ALL YET. IF SOMETHING INTERESTING *DOES* HAPPEN,

142 IT MEANS YOU’RE GETTING A BONUS AND HAVE AN OPPORTUNITY TO GARNER MANY
142 MORE POINTS IN THE MASTER’S SECTION. I MAY OCCASIONALLY OFFER HINTS
142 IF YOU SEEM TO BE HAVING TROUBLE. IF I DO, I’LL WARN YOU IN ADVANCE
142 HOW MUCH IT WILL AFFECT YOUR SCORE TO ACCEPT THE HINTS. FINALLY, TO
142 SAVE PAPER, YOU MAY SPECIFY “BRIEF”, WHICH TELLS ME NEVER TO REPEAT
142 THE FULL DESCRIPTION OF A PLACE UNLESS YOU EXPLICITLY ASK ME TO.
143 DO YOU INDEED WISH TO QUIT NOW?
144 THERE IS NOTHING HERE WITH WHICH TO FILL THE VASE.
145 THE SUDDEN CHANGE IN TEMPERATURE HAS DELICATELY SHATTERED THE VASE.
146 IT IS BEYOND YOUR POWER TO DO THAT.
147 I DON’T KNOW HOW.
148 IT IS TOO FAR UP FOR YOU TO REACH.
149 YOU KILLED A LITTLE DWARF. THE BODY VANISHES IN A CLOUD OF GREASY
149 BLACK SMOKE.
150 THE SHELL IS VERY STRONG AND IS IMPERVIOUS TO ATTACK.
151 WHAT’S THE MATTER, CAN’T YOU READ? NOW YOU’D BEST START OVER.
152 THE AXE BOUNCES HARMLESSLY OFF THE DRAGON’S THICK SCALES.
153 THE DRAGON LOOKS RATHER NASTY. YOU’D BEST NOT TRY TO GET BY.
154 THE LITTLE BIRD ATTACKS THE GREEN DRAGON, AND IN AN ASTOUNDING FLURRY
154 GETS BURNT TO A CINDER. THE ASHES BLOW AWAY.
155 ON WHAT?
156 OKAY, FROM NOW ON I’LL ONLY DESCRIBE A PLACE IN FULL THE FIRST TIME
156 YOU COME TO IT. TO GET THE FULL DESCRIPTION, SAY “LOOK”.
157 TROLLS ARE CLOSE RELATIVES WITH THE ROCKS AND HAVE SKIN AS TOUGH AS
157 THAT OF A RHINOCEROS. THE TROLL FENDS OFF YOUR BLOWS EFFORTLESSLY.
158 THE TROLL DEFTLY CATCHES THE AXE, EXAMINES IT CAREFULLY, AND TOSSES IT
158 BACK, DECLARING, “GOOD WORKMANSHIP, BUT IT’S NOT VALUABLE ENOUGH.”
159 THE TROLL CATCHES YOUR TREASURE AND SCURRIES AWAY OUT OF SIGHT.
160 THE TROLL REFUSES TO LET YOU CROSS.
161 THERE IS NO LONGER ANY WAY ACROSS THE CHASM.
162 JUST AS YOU REACH THE OTHER SIDE, THE BRIDGE BUCKLES BENEATH THE
162 WEIGHT OF THE BEAR, WHICH WAS STILL FOLLOWING YOU AROUND. YOU
162 SCRABBLE DESPERATELY FOR SUPPORT, BUT AS THE BRIDGE COLLAPSES YOU
162 STUMBLE BACK AND FALL INTO THE CHASM.
163 THE BEAR LUMBERS TOWARD THE TROLL, WHO LETS OUT A STARTLED SHRIEK AND
163 SCURRIES AWAY. THE BEAR SOON GIVES UP THE PURSUIT AND WANDERS BACK.
164 THE AXE MISSES AND LANDS NEAR THE BEAR WHERE YOU CAN’T GET AT IT.
165 WITH WHAT? YOUR BARE HANDS? AGAINST *HIS* BEAR HANDS??
166 THE BEAR IS CONFUSED; HE ONLY WANTS TO BE YOUR FRIEND.
167 FOR CRYING OUT LOUD, THE POOR THING IS ALREADY DEAD!
168 THE BEAR EAGERLY WOLFS DOWN YOUR FOOD, AFTER WHICH HE SEEMS TO CALM
168 DOWN CONSIDERABLY AND EVEN BECOMES RATHER FRIENDLY.
169 THE BEAR IS STILL CHAINED TO THE WALL.
170 THE CHAIN IS STILL LOCKED.
171 THE CHAIN IS NOW UNLOCKED.
172 THE CHAIN IS NOW LOCKED.
173 THERE IS NOTHING HERE TO WHICH THE CHAIN CAN BE LOCKED.
174 THERE IS NOTHING HERE TO EAT.
175 DO YOU WANT THE HINT?
176 DO YOU NEED HELP GETTING OUT OF THE MAZE?
177 YOU CAN MAKE THE PASSAGES LOOK LESS ALIKE BY DROPPING THINGS.
178 ARE YOU TRYING TO EXPLORE BEYOND THE PLOVER ROOM?
179 THERE IS A WAY TO EXPLORE THAT REGION WITHOUT HAVING TO WORRY ABOUT
179 FALLING INTO A PIT. NONE OF THE OBJECTS AVAILABLE IS IMMEDIATELY
179 USEFUL IN DISCOVERING THE SECRET.

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180 DO YOU NEED HELP GETTING OUT OF HERE?
181 DON’T GO WEST.
182 GLUTTONY IS NOT ONE OF THE TROLL’S VICES.  AVARICE, HOWEVER, IS.
183 YOUR LAMP IS GETTING DIM.  YOU’D BEST START WRAPPING THIS UP, UNLESS
183 YOU CAN FIND SOME FRESH BATTERIES.  I SEEM TO RECALL THERE’S A VENDING
183 MACHINE IN THE MAZE.  BRING SOME COINS WITH YOU.
184 YOUR LAMP HAS RUN OUT OF POWER.
185 THERE’S NOT MUCH POINT IN WANDERING AROUND OUT HERE, AND YOU CAN’T
185 EXPLORE THE CAVE WITHOUT A LAMP.  SO LET’S JUST CALL IT A DAY.
186 THERE ARE FAINT RUSTLING NOISES FROM THE DARKNESS BEHIND YOU.  AS YOU
186 TURN TOWARD THEM, THE BEAM OF YOUR LAMP FALLS ACROSS A BEARDED PIRATE.
186 HE IS CARRYING A LARGE CHEST.  “SHIVER ME TIMBERS!” HE CRIES, “I’VE
186 BEEN SPOTTED!  I’D BEST HIE MESELF OFF TO THE MAZE TO HIDE ME CHEST!”
186 WITH THAT, HE VANISHES INTO THE GLOOM.
187 YOUR LAMP IS GETTING DIM.  YOU’D BEST GO BACK FOR THOSE BATTERIES.
188 YOUR LAMP IS GETTING DIM.  I’M TAKING THE LIBERTY OF REPLACING THE
188 BATTERIES.
189 YOUR LAMP IS GETTING DIM, AND YOU’RE OUT OF SPARE BATTERIES.  YOU’D
189 BEST START WRAPPING THIS UP.
190 I’M AFRAID THE MAGAZINE IS WRITTEN IN DWARVISH.
191 “THIS IS NOT THE MAZE WHERE THE PIRATE LEAVES HIS TREASURE CHEST.”
192 HMMM, THIS LOOKS LIKE A CLUE, WHICH MEANS IT’LL COST YOU 10 POINTS TO
192 READ IT.  SHOULD I GO AHEAD AND READ IT ANYWAY?
193 IT SAYS, “THERE IS SOMETHING STRANGE ABOUT THIS PLACE, SUCH THAT ONE
193 OF THE WORDS I’VE ALWAYS KNOWN NOW HAS A NEW EFFECT.”
194 IT SAYS THE SAME THING IT DID BEFORE.
195 I’M AFRAID I DON’T UNDERSTAND.
196 “CONGRATULATIONS ON BRINGING LIGHT INTO THE DARK-ROOM!”
197 YOU STRIKE THE MIRROR A RESOUNDING BLOW, WHEREUPON IT SHATTERS INTO A
197 MYRIAD TINY FRAGMENTS.
198 YOU HAVE TAKEN THE VASE AND HURLED IT DELICATELY TO THE GROUND.
199 YOU PROD THE NEAREST DWARF, WHO WAKES UP GRUMPILY, TAKES ONE LOOK AT
199 YOU, CURSES, AND GRABS FOR HIS AXE.
200 IS THIS ACCEPTABLE?
201 THERE’S NO POINT IN SUSPENDING A DEMONSTRATION GAME.
-1
```

[New section begins, featuring transitions between locations.]

```
7
1    3
2    3
3    8    9
4    10
5    11
6    0
7    14   15
8    13
9    94   -1
10   96
11   19   -1
12   17   27
13   101  -1
14   103
15   0
16   106
```

17 0 -1
18 0
19 3
20 3
21 0
22 0
23 109 -1
24 25 -1
25 23 67
26 111 -1
27 35 110
28 0
29 97 -1
30 0 -1
31 119 121
32 117 122
33 117 122
34 0 0
35 130 -1
36 0 -1
37 126 -1
38 140 -1
39 0
40 96 -1
50 18
51 27
52 28
53 29
54 30
55 0
56 92
57 95
58 97
59 100
60 101
61 0
62 119 121
63 127
64 130 -1
-1
8
1 24
2 29
3 0
4 33
5 0
6 33
7 38
8 38
9 42
10 14
11 43
12 110
13 29
14 110
15 73

```
16   75
17   29
18   13
19   59
20   59
21   174
22   109
23   67
24   13
25   147
26   155
27   195
28   146
29   110
30   13
31   13
-1
```

[New section begins, featuring transitions between locations.]

```
9
0    1    2      3      4      5      6      7      8      9      10
0    100  115    116    126
2    1    3      4      7      38     95     113    24
1    24
3    46   47     48     54     56     58     82     85     86
3    122  123    124    125    126    127    128    129    130
4    8
5    13
6    19
7    42   43     44     45     46     47     48     49     50     51
7    52   53     54     55     56     80     81     82     86     87
8    99   100    101
9    108
-1
```

[New section begins, featuring scoring information at the game's conclusion.]

```
10
35   YOU ARE OBVIOUSLY A RANK AMATEUR.  BETTER LUCK NEXT TIME.
100  YOUR SCORE QUALIFIES YOU AS A NOVICE CLASS ADVENTURER.
130  YOU HAVE ACHIEVED THE RATING: "EXPERIENCED ADVENTURER".
200  YOU MAY NOW CONSIDER YOURSELF A "SEASONED ADVENTURER".
250  YOU HAVE REACHED "JUNIOR MASTER" STATUS.
300  YOUR SCORE PUTS YOU IN MASTER ADVENTURER CLASS C.
330  YOUR SCORE PUTS YOU IN MASTER ADVENTURER CLASS B.
349  YOUR SCORE PUTS YOU IN MASTER ADVENTURER CLASS A.
9999 ALL OF ADVENTUREDOM GIVES TRIBUTE TO YOU, ADVENTURER GRANDMASTER!
-1
```

[New section begins, featuring scoring data.]

```
11
2    9999        10     0      0
3    9999        5      0      0
4    4    2      62     63
```

```
5   5   2   18   19
6   8   2   20   21
7   75  4   176  177
8   25  5   178  179
9   20  3   180  181
-1
```

[New section begins, featuring “Wizard Hours”.]

```
12
1  A LARGE CLOUD OF GREEN SMOKE APPEARS IN FRONT OF YOU.  IT CLEARS AWAY
1  TO REVEAL A TALL WIZARD, CLOTHED IN GREY.  HE FIXES YOU WITH A STEELY
1  GLARE AND DECLARES, “THIS ADVENTURE HAS LASTED TOO LONG.”  WITH THAT
1  HE MAKES A SINGLE PASS OVER YOU WITH HIS HANDS, AND EVERYTHING AROUND
1  YOU FADES AWAY INTO A GREY NOTHINGNESS.
2  EVEN WIZARDS HAVE TO WAIT LONGER THAN THAT!
3  I’M TERRIBLY SORRY, BUT COLOSSAL CAVE IS CLOSED.  OUR HOURS ARE:
4  ONLY WIZARDS ARE PERMITTED WITHIN THE CAVE RIGHT NOW.
5  WE DO ALLOW VISITORS TO MAKE SHORT EXPLORATIONS DURING OUR OFF HOURS.
5  WOULD YOU LIKE TO DO THAT?
6  COLOSSAL CAVE IS OPEN TO REGULAR ADVENTURERS AT THE FOLLOWING HOURS:
7  VERY WELL.
8  ONLY A WIZARD MAY CONTINUE AN ADVENTURE THIS SOON.
9  I SUGGEST YOU RESUME YOUR ADVENTURE AT A LATER TIME.
10 DO YOU WISH TO SEE THE HOURS?
11 DO YOU WISH TO CHANGE THE HOURS?
12 NEW MAGIC WORD (NULL TO LEAVE UNCHANGED):
13 NEW MAGIC NUMBER (NULL TO LEAVE UNCHANGED):
14 DO YOU WISH TO CHANGE THE MESSAGE OF THE DAY?
15 OKAY.  YOU CAN SAVE THIS VERSION NOW.
16 ARE YOU A WIZARD?
17 PROVE IT!  SAY THE MAGIC WORD!
18 THAT IS NOT WHAT I THOUGHT IT WAS.  DO YOU KNOW WHAT I THOUGHT IT WAS?
19 OH DEAR, YOU REALLY *ARE* A WIZARD!  SORRY TO HAVE BOTHERED YOU . . .
20 FOO, YOU ARE NOTHING BUT A CHARLATAN!
21 NEW HOURS SPECIFIED BY DEFINING “PRIME TIME”.  GIVE ONLY THE HOUR
21 (E.G. 14, NOT 14:00 OR 2PM).  ENTER A NEGATIVE NUMBER AFTER LAST PAIR.
22 NEW HOURS FOR COLOSSAL CAVE:
23 LIMIT LINES TO 70 CHARS.  END WITH NULL LINE.
24 LINE TOO LONG, RETYPE:
25 NOT ENOUGH ROOM FOR ANOTHER LINE.  ENDING MESSAGE HERE.
26 DO YOU WISH TO (RE)SCHEDULE THE NEXT HOLIDAY?
27 TO BEGIN HOW MANY DAYS FROM TODAY?
28 TO LAST HOW MANY DAYS (ZERO IF NO HOLIDAY)?
29 TO BE CALLED WHAT (UP TO 20 CHARACTERS)?
30 TOO SMALL!  ASSUMING MINIMUM VALUE (45 MINUTES).
31 BREAK OUT OF THIS AND SAVE YOUR CORE-IMAGE.
32 BE SURE TO SAVE YOUR CORE-IMAGE...
-1
0
```

Appendix B

Complete FORTRAN IV Code from William Crowther's Original Source Code of *Colossal Cave Adventure*

The following text contains the complete FORTRAN IV source code of *Colossal Cave Adventure* programmed by William Crowther in 1975. The original source code was discovered in 2007 by Dr. Dennis G. Jerz, Associate Professor of English (New Media Journalism) at Seton Hill University, and is currently hosted on his personal website,[1] mirrored on co-creator Don Woods' website,[2] and is also now part of my Github archive of the *CCA* code stylometry project.[3]

```
C ADVENTURES
        IMPLICIT INTEGER(A-Z)
        REAL RAN
        COMMON RTEXT,LLINE
        DIMENSION IOBJ(300),ICHAIN(100),IPLACE(100)
        1 ,IFIXED(100),COND(300),PROP(100),ABB(300),LLINE(1000,22)
        2 ,LTEXT(300),STEXT(300),KEY(300),DEFAULT(300),TRAVEL(1000)
        3 ,TK(25),KTAB(1000),ATAB(1000),BTEXT(200),DSEEN(10)
        4 ,DLOC(10),ODLOC(10),DTRAV(20),RTEXT(100),JSPKT(100)
        5 ,IPLT(100),IFIXT(100),QUIP(100)

C READ THE PARAMETERS

        IF(SETUP.NE.0) GOTO 1
        SETUP=1
        KEYS=1
        LAMP=2
        GRATE=3
        ROD=5
        BIRD=7
```

1. https://jerz.setonhill.edu/intfic/colossal-cave-adventure-source-code/ (accessed January 3, 2019).
2. http://www.icynic.com/~don/jerz/ (accessed January 3, 2019).
3. https://github.com/adreinhard/cca (accessed January 3, 2019).

```
      NUGGET=10
      SNAKE=11
      FOOD=19
      WATER=20
      AXE=21
      DATA(QUIP(I),I=1,9)/50,51,64,66,67,68,69,49,79/
      DATA(JSPKT(I),I=1,16)/24,29,0,31,0,31,38,38,42,42,43,46,77,71
      1 ,73,75/
      DATA(IPLT(I),I=1,20)/3,3,8,10,11,14,13,9,15,18,19,17,27,28,29
      1 ,30,0,0,3,3/
      DATA(IFIXT(I),I=1,20)/0,0,1,0,0,1,0,1,1,0,1,1,0,0,0,0,0,0,0,0/
      DATA(DTRAV(I),I=1,15)/36,28,19,30,62,60,41,27,17,15,19,28,36
      1 ,300,300/
      DO 1001 I=1,300
      STEXT(I)=0
      IF(I.LE.200) BTEXT(I)=0
      IF(I.LE.100)RTEXT(I)=0
1001  LTEXT(I)=0
      I=1
      CALL IFILE(1,’TEXT’)
1002  READ(1,1003) IKIND
1003  FORMAT(G)
      GOTO(1100,1004,1004,1013,1020,1004,1004)(IKIND+1)
1004  READ(1,1005)JKIND,(LLINE(I,J),J=3,22)
1005  FORMAT(1G,20A5)
      IF(JKIND.EQ.-1) GOTO 1002
      DO 1006 K=1,20
      KK=K
      IF(LLINE(I,21-K).NE.’ ‘) GOTO 1007
1006  CONTINUE
      STOP
1007  LLINE(I,2)=20-KK+1
      LLINE(I,1)=0
      IF(IKIND.EQ.6)GOTO 1023
      IF(IKIND.EQ.5)GOTO 1011
      IF(IKIND.EQ.1) GOTO 1008
      IF(STEXT(JKIND).NE.0) GOTO 1009
      STEXT(JKIND)=I
      GOTO 1010
1008  IF(LTEXT(JKIND).NE.0) GOTO 1009
      LTEXT(JKIND)=I
      GOTO 1010
1009  LLINE(I-1,1)=I
1010  I=I+1
      IF(I.NE.1000)GOTO 1004
      PAUSE ‘TOO MANY LINES’
1011  IF(JKIND.LT.200)GOTO 1012
      IF(BTEXT(JKIND-100).NE.0)GOTO 1009
      BTEXT(JKIND-100)=I
      BTEXT(JKIND-200)=I
      GOTO 1010
1012  IF(BTEXT(JKIND).NE.0)GOTO 1009
      BTEXT(JKIND)=I
      GOTO 1010
1023  IF(RTEXT(JKIND).NE.0) GOTO 1009
      RTEXT(JKIND)=I
```

```
        GOTO 1010
1013    I=1
1014    READ(1,1015)JKIND,LKIND,(TK(L),L=1,10)
1015    FORMAT(12G)
        IF(JKIND.EQ.-1) GOTO 1002
        IF(KEY(JKIND).NE.0) GOTO 1016
        KEY(JKIND)=I
        GOTO 1017
1016    TRAVEL(I-1)=-TRAVEL(I-1)
1017    DO 1018 L=1,10
        IF(TK(L).EQ.0) GOTO 1019
        TRAVEL(I)=LKIND*1024+TK(L)
        I=I+1
        IF(I.EQ.1000) STOP
1018    CONTINUE
1019    TRAVEL(I-1)=-TRAVEL(I-1)
        GOTO 1014

1020    DO 1022 IU=1,1000
        READ(1,1021) KTAB(IU),ATAB(IU)
1021    FORMAT(G,A5)
        IF(KTAB(IU).EQ.-1)GOTO 1002
1022    CONTINUE
        PAUSE 'TOO MANY WORDS'

C TRAVEL = NEG IF LAST THIS SOURCE + DEST*1024 + KEYWORD

C COND  = 1 IF LIGHT,  2 IF DON T ASK QUESTION

1100    DO 1101 I=1,100
        IPLACE(I)=IPLT(I)
        IFIXED(I)=IFIXT(I)
1101    ICHAIN(I)=0
        DO 1102 I=1,300
        COND(I)=0
        ABB(I)=0
1102    IOBJ(I)=0
        DO 1103 I=1,10
1103    COND(I)=1
        COND(16)=2
        COND(20)=2
        COND(21)=2
        COND(22)=2
        COND(23)=2
        COND(24)=2
        COND(25)=2
        COND(26)=2
        COND(31)=2
        COND(32)=2
        COND(79)=2
        DO 1107 I=1,100
        KTEM=IPLACE(I)
        IF(KTEM.EQ.0)GOTO 1107
        IF(IOBJ(KTEM).NE.0) GOTO 1104
        IOBJ(KTEM)=I
        GO TO 1107
```

```
1104    KTEM=IOBJ(KTEM)
1105    IF(ICHAIN(KTEM).NE.0) GOTO 1106
        ICHAIN(KTEM)=I
        GOTO 1107
1106    KTEM=ICHAIN(KTEM)
        GOTO 1105
1107    CONTINUE
        IDWARF=0
        IFIRST=1
        IWEST=0
        ILONG=1
        IDETAL=0
        PAUSE 'INIT DONE'

1       CALL YES(65,1,0,YEA)
        L=1
        LOC=1
2       DO 73 I=1,3
        IF(ODLOC(I).NE.L.OR.DSEEN(I).EQ.0)GOTO 73
        L=LOC
        CALL SPEAK(2)
        GOTO 74
73      CONTINUE
74      LOC=L

C DWARF STUFF

        IF(IDWARF.NE.0) GOTO 60
        IF(LOC.EQ.15) IDWARF=1
        GOTO 71
60      IF(IDWARF.NE.1)GOTO 63
        IF(RAN(QZ).GT.0.05) GOTO 71
        IDWARF=2
        DO 61 I=1,3
        DLOC(I)=0
        ODLOC(I)=0
61      DSEEN(I)=0
        CALL SPEAK(3)
        ICHAIN(AXE)=IOBJ(LOC)
        IOBJ(LOC)=AXE
        IPLACE(AXE)=LOC
        GOTO 71
63      IDWARF=IDWARF+1
        ATTACK=0
        DTOT=0
        STICK=0
        DO 66 I=1,3
        IF(2*I+IDWARF.LT.8)GOTO 66
        IF(2*I+IDWARF.GT.23.AND.DSEEN(I).EQ.0)GOTO 66
        ODLOC(I)=DLOC(I)
        IF(DSEEN(I).NE.0.AND.LOC.GT.14)GOTO 65
        DLOC(I)=DTRAV(I*2+IDWARF-8)
        DSEEN(I)=0
        IF(DLOC(I).NE.LOC.AND.ODLOC(I).NE.LOC) GOTO 66
65      DSEEN(I)=1
        DLOC(I)=LOC
```

```
        DTOT=DTOT+1
        IF(ODLOC(I).NE.DLOC(I)) GOTO 66
        ATTACK=ATTACK+1
        IF(RAN(QZ).LT.0.1) STICK=STICK+1
66      CONTINUE
        IF(DTOT.EQ.0) GOTO 71
        IF(DTOT.EQ.1)GOTO 75
        TYPE 67,DTOT
67      FORMAT(' THERE ARE ',I2,' THREATENING LITTLE DWARVES IN THE
        1  ROOM WITH YOU.',/)
        GOTO 77
75      CALL SPEAK(4)
77      IF(ATTACK.EQ.0)GOTO 71
        IF(ATTACK.EQ.1)GOTO 79
        TYPE 78,ATTACK
78      FORMAT(' ',I2,' OF THEM THROW KNIVES AT YOU!',/)
        GOTO 81
79      CALL SPEAK(5)
        CALL SPEAK(52+STICK)
        GOTO(71,83)(STICK+1)
81      IF(STICK.EQ.0) GOTO 69
        IF(STICK.EQ.1)GOTO 82
        TYPE 68,STICK
68      FORMAT(' ',I2,' OF THEM GET YOU.',/)
        GOTO 83
82      CALL SPEAK(6)
83      PAUSE 'GAMES OVER'
        GOTO 71
69      CALL SPEAK(7)

C PLACE DESCRIPTOR

71      KK=STEXT(L)
        IF(ABB(L).EQ.0.OR.KK.EQ.0)KK=LTEXT(L)
        IF(KK.EQ.0) GOTO 7
4       TYPE 5,(LLINE(KK,JJ),JJ=3,LLINE(KK,2))
5       FORMAT(20A5)
        KK=KK+1
        IF(LLINE(KK-1,1).NE.0) GOTO 4
        TYPE 6
6       FORMAT(/)
7       IF(COND(L).EQ.2)GOTO 8
        IF(LOC.EQ.33.AND.RAN(QZ).LT.0.25)CALL SPEAK(8)
        J=L
        GOTO 2000

C GO GET A NEW LOCATION

8       KK=KEY(LOC)
        IF(KK.EQ.0)GOTO 19
        IF(K.EQ.57)GOTO 32
        IF(K.EQ.67)GOTO 40
        IF(K.EQ.8)GOTO 12
        LOLD=L
9       LL=TRAVEL(KK)
        IF(LL.LT.0) LL=-LL
```

```
      IF(1.EQ.MOD(LL,1024))GOTO 10
      IF(K.EQ.MOD(LL,1024))GOTO 10
      IF(TRAVEL(KK).LT.0)GOTO 11
      KK=KK+1
      GOTO 9
12    TEMP=LOLD
      LOLD=L
      L=TEMP
      GOTO 21
10    L=LL/1024
      GOTO 21
11    JSPK=12
      IF(K.GE.43.AND.K.LE.46)JSPK=9
      IF(K.EQ.29.OR.K.EQ.30)JSPK=9
      IF(K.EQ.7.OR.K.EQ.8.OR.K.EQ.36.OR.K.EQ.37.OR.K.EQ.68)
      1 JSPK=10
      IF(K.EQ.11.OR.K.EQ.19)JSPK=11
      IF(JVERB.EQ.1)JSPK=59
      IF(K.EQ.48)JSPK=42
      IF(K.EQ.17)JSPK=80
      CALL SPEAK(JSPK)
      GOTO 2
19    CALL SPEAK(13)
      L=LOC
      IF(IFIRST.EQ.0) CALL SPEAK(14)
21    IF(L.LT.300)GOTO 2
      IL=L-300+1
      GOTO(22,23,24,25,26,31,27,28,29,30,33,34,36,37)IL
      GOTO 2
22    L=6
      IF(RAN(QZ).GT.0.5) L=5
      GOTO 2
23    L=23
      IF(PROP(GRATE).NE.0) L=9
      GOTO 2
24    L=9
      IF(PROP(GRATE).NE.0)L=8
      GOTO 2
25    L=20
      IF(IPLACE(NUGGET).NE.-1)L=15
      GOTO 2
26    L=22
      IF(IPLACE(NUGGET).NE.-1) L=14
      GOTO 2
27    L=27
      IF(PROP(12).EQ.0)L=31
      GOTO 2
28    L=28
      IF(PROP(SNAKE).EQ.0)L=32
      GOTO 2
29    L=29
      IF(PROP(SNAKE).EQ.0) L=32
      GOTO 2
30    L=30
      IF(PROP(SNAKE).EQ.0) L=32
      GOTO 2
```

```
31      PAUSE 'GAME IS OVER'
        GOTO 1100
32      IF(IDETAL.LT.3)CALL SPEAK(15)
        IDETAL=IDETAL+1
        L=LOC
        ABB(L)=0
        GOTO 2
33      L=8
        IF(PROP(GRATE).EQ.0) L=9
        GOTO 2
34      IF(RAN(QZ).GT.0.2)GOTO 35
        L=68
        GOTO 2
35      L=65
38      CALL SPEAK(56)
        GOTO 2
36      IF(RAN(QZ).GT.0.2)GOTO 35
        L=39
        IF(RAN(QZ).GT.0.5)L=70
        GOTO 2
37      L=66
        IF(RAN(QZ).GT.0.4)GOTO 38
        L=71
        IF(RAN(QZ).GT.0.25)L=72
        GOTO 2
39      L=66
        IF(RAN(QZ).GT.0.2)GOTO 38
        L=77
        GOTO 2
40      IF(LOC.LT.8)CALL SPEAK(57)
        IF(LOC.GE.8)CALL SPEAK(58)
        L=LOC
        GOTO 2

C DO NEXT INPUT

2000    LTRUBL=0
        LOC=J
        ABB(J)=MOD((ABB(J)+1),5)
        IDARK=0
        IF(MOD(COND(J),2).EQ.1) GOTO 2003
        IF((IPLACE(2).NE.J).AND.(IPLACE(2).NE.-1)) GOTO 2001
        IF(PROP(2).EQ.1)GOTO 2003
2001    CALL SPEAK(16)
        IDARK=1
2003    I=IOBJ(J)
2004    IF(I.EQ.0) GOTO 2011
        IF(((I.EQ.6).OR.(I.EQ.9)).AND.(IPLACE(10).EQ.-1))GOTO 2008
        ILK=I
        IF(PROP(I).NE.0) ILK=I+100
        KK=BTEXT(ILK)
        IF(KK.EQ.0) GOTO 2008
2005    TYPE 2006,(LLINE(KK,JJ),JJ=3,LLINE(KK,2))
2006    FORMAT(20A5)
        KK=KK+1
        IF(LLINE(KK-1,1).NE.0) GOTO 2005
```

```
      TYPE 2007
2007  FORMAT(/)
2008  I=ICHAIN(I)
      GOTO 2004

C K=1 MEANS ANY INPUT

2012  A=B
      JTWO=0
      GOTO 2021
2010  JSPK=QUIP(K)
      GOTO 5200
2009  JSPK=54
5200  CALL SPEAK(JSPK)
2011  JVERB=0
      JOBJ=0
      JTWO=0
2020  CALL GETIN(JTWO,A,TWOWD,B)
      K=70
      IF(A.EQ.'ENTER'.AND.(B.EQ.'STREAM'.OR.B.EQ.'WATER'))GOTO 2010
      IF(A.EQ.'ENTER'.AND.JTWO.NE.0)GOTO 2012
2021  IF(A.NE.'WEST')GOTO 2023
      IWEST=IWEST+1
      IF(IWEST.NE.10)GOTO 2023
      CALL SPEAK(17)
2023  DO 2024 I=1,1000
      IF(KTAB(I).EQ.-1)GOTO 3000
      IF(ATAB(I).EQ.A)GOTO 2025
2024  CONTINUE
      PAUSE 'ERROR 6'
2025  K=MOD(KTAB(I),1000)
      KQ=KTAB(I)/1000+1
      GOTO (5014,5000,2026,2010)KQ
      PAUSE 'NO NO'
2026  JVERB=K
      JSPK=JSPKT(JVERB)
      IF(JTWO.NE.0)GOTO 2028
      IF(JOBJ.EQ.0)GOTO 2036
2027  GOTO(9000,5066,3000,5031,2009,5031,9404,9406,5081,5200,
      1 5200,5300,5506,5502,5504,5505)JVERB
      PAUSE 'ERROR 5'
2028  A=TWOWD
      B=' '
      JTWO=0
      GOTO 2023
3000  JSPK=60
      IF(RAN(QZ).GT.0.8)JSPK=61
      IF(RAN(QZ).GT.0.8)JSPK=13
      CALL SPEAK(JSPK)
      LTRUBL=LTRUBL+1
      IF(LTRUBL.NE.3)GOTO 2020
      IF(J.NE.13.OR.IPLACE(7).NE.13.OR.IPLACE(5).NE.-1)GOTO 2032
      CALL YES(18,19,54,YEA)
      GOTO 2033
2032  IF(J.NE.19.OR.PROP(11).NE.0.OR.IPLACE(7).EQ.-1)GOTO 2034
      CALL YES(20,21,54,YEA)
```

```
        GOTO 2033
2034    IF(J.NE.8.OR.PROP(GRATE).NE.0)GOTO 2035
        CALL YES(62,63,54,YEA)
2033    IF(YEA.EQ.0)GOTO 2011
        GOTO 2020
2035    IF(IPLACE(5).NE.J.AND.IPLACE(5).NE.-1)GOTO 2020
        IF(JOBJ.NE.5)GOTO 2020
        CALL SPEAK(22)
        GOTO 2020
2036    GOTO(2037,5062,5062,9403,2009,9403,9404,9406,5062,5062,
        1 5200,5300,5062,5062,5062,5062)JVERB
        PAUSE ‘OOPS’
2037    IF((IOBJ(J).EQ.0).OR.(ICHAIN(IOBJ(J)).NE.0)) GOTO 5062
        DO 5312 I=1,3
        IF(DSEEN(I).NE.0)GOTO 5062
5312    CONTINUE
        JOBJ=IOBJ(J)
        GOTO 2027
5062    IF(B.NE.’ ‘)GOTO 5333
        TYPE 5063,A
5063    FORMAT(‘  ‘,A5,’ WHAT?’,/)
        GOTO 2020
5333    TYPE 5334,A,B
5334    FORMAT(‘ ‘,2A5,’ WHAT?’,/)
        GOTO 2020
5014    IF(IDARK.EQ.0) GOTO 8
        IF(RAN(QZ).GT.0.25) GOTO 8
5017    CALL SPEAK(23)
        PAUSE ‘GAME IS OVER’
        GOTO 2011
5000    JOBJ=K
        IF(JTWO.NE.0)GOTO 2028
        IF((J.EQ.IPLACE(K)).OR.(IPLACE(K).EQ.-1)) GOTO 5004
        IF(K.NE.GRATE)GOTO 502
        IF((J.EQ.1).OR.(J.EQ.4).OR.(J.EQ.7))GOTO 5098
        IF((J.GT.9).AND.(J.LT.15))GOTO 5097
502     IF(B.NE.’ ‘)GOTO 5316
        TYPE 5005,A
5005    FORMAT(‘ I SEE NO ‘,A5,’ HERE.’,/)
        GOTO 2011
5316    TYPE 5317,A,B
5317    FORMAT(‘ I SEE NO ‘,2A5,’ HERE.’/)
        GOTO 2011
5098    K=49
        GOTO 5014
5097    K=50
        GOTO 5014
5004    JOBJ=K
        IF(JVERB.NE.0)GOTO 2027
5064    IF(B.NE.’ ‘)GOTO 5314
        TYPE 5001,A
5001    FORMAT(‘ WHAT DO YOU WANT TO DO WITH THE ‘,A5,’?’,/)
        GOTO 2020
5314    TYPE 5315,A,B
5315    FORMAT(‘ WHAT DO YOU WANT TO DO WITH THE ‘,2A5,’?’,/)
        GOTO 2020
```

```
C CARRY

9000    IF(JOBJ.EQ.18)GOTO 2009
        IF(IPLACE(JOBJ).NE.J) GOTO 5200
9001    IF(IFIXED(JOBJ).EQ.0)GOTO 9002
        CALL SPEAK(25)
        GOTO 2011
9002    IF(JOBJ.NE.BIRD)GOTO 9004
        IF(IPLACE(ROD).NE.-1)GOTO 9003
        CALL SPEAK(26)
        GOTO 2011
9003    IF((IPLACE(4).EQ.-1).OR.(IPLACE(4).EQ.J)) GOTO 9004
        CALL SPEAK(27)
        GOTO 2011
9004    IPLACE(JOBJ)=-1
9005    IF(IOBJ(J).NE.JOBJ) GOTO 9006
        IOBJ(J)=ICHAIN(JOBJ)
        GOTO 2009
9006    ITEMP=IOBJ(J)
9007    IF(ICHAIN(ITEMP).EQ.(JOBJ)) GOTO 9008
        ITEMP=ICHAIN(ITEMP)
        GOTO 9007
9008    ICHAIN(ITEMP)=ICHAIN(JOBJ)
        GOTO 2009

C LOCK, UNLOCK, NO OBJECT YET

9403    IF((J.EQ.8).OR.(J.EQ.9))GOTO 5105
5032    CALL SPEAK(28)
        GOTO 2011
5105    JOBJ=GRATE
        GOTO 2027

C DISCARD OBJECT

5066    IF(JOBJ.EQ.18)GOTO 2009
        IF(IPLACE(JOBJ).NE.-1) GOTO 5200
5012    IF((JOBJ.NE.BIRD).OR.(J.NE.19).OR.(PROP(11).EQ.1))GOTO 9401
        CALL SPEAK(30)
        PROP(11)=1
5160    ICHAIN(JOBJ)=IOBJ(J)
        IOBJ(J)=JOBJ
        IPLACE(JOBJ)=J
        GOTO 2011
9401    CALL SPEAK(54)
        GOTO 5160

C LOCK,UNLOCK OBJECT

5031    IF(IPLACE(KEYS).NE.-1.AND.IPLACE(KEYS).NE.J)GOTO 5200
        IF(JOBJ.NE.4)GOTO 5102
        CALL SPEAK(32)
        GOTO 2011
5102    IF(JOBJ.NE.KEYS)GOTO 5104
        CALL SPEAK(55)
        GOTO 2011
```

```
5104    IF(JOBJ.EQ.GRATE)GOTO 5107
        CALL SPEAK(33)
        GOTO 2011
5107    IF(JVERB.EQ.4) GOTO 5033
        IF(PROP(GRATE).NE.0)GOTO 5034
        CALL SPEAK(34)
        GOTO 2011
5034    CALL SPEAK(35)
        PROP(GRATE)=0
        PROP(8)=0
        GOTO 2011
5033    IF(PROP(GRATE).EQ.0)GOTO 5109
        CALL SPEAK(36)
        GOTO 2011
5109    CALL SPEAK(37)
        PROP(GRATE)=1
        PROP(8)=1
        GOTO 2011

C LIGHT LAMP

9404    IF((IPLACE(2).NE.J).AND.(IPLACE(2).NE.-1))GOTO 5200
        PROP(2)=1
        IDARK=0
        CALL SPEAK(39)
        GOTO 2011

C LAMP OFF

9406    IF((IPLACE(2).NE.J).AND.(IPLACE(2).NE.-1)) GOTO 5200
        PROP(2)=0
        CALL SPEAK(40)
        GOTO 2011

C STRIKE

5081    IF(JOBJ.NE.12)GOTO 5200
        PROP(12)=1
        GOTO 2003

C ATTACK

5300    DO 5313 ID=1,3
        IID=ID
        IF(DSEEN(ID).NE.0)GOTO 5307
5313    CONTINUE
        IF(JOBJ.EQ.0)GOTO 5062
        IF(JOBJ.EQ.SNAKE) GOTO 5200
        IF(JOBJ.EQ.BIRD) GOTO 5302
        CALL SPEAK(44)
        GOTO 2011
5302    CALL SPEAK(45)
        IPLACE(JOBJ)=300
        GOTO 9005
5307    IF(RAN(QZ).GT.0.4) GOTO 5309
        DSEEN(IID)=0
```

```
      ODLOC(IID)=0
      DLOC(IID)=0
      CALL SPEAK(47)
      GOTO 5311
5309  CALL SPEAK(48)
5311  K=21
      GOTO 5014

C EAT

5502  IF((IPLACE(FOOD).NE.J.AND.IPLACE(FOOD).NE.-1).OR.PROP(FOOD).NE.0
      1 .OR.JOBJ.NE.FOOD)GOTO 5200
      PROP(FOOD)=1
5501  JSPK=72
      GOTO 5200

C DRINK

5504  IF((IPLACE(WATER).NE.J.AND.IPLACE(WATER).NE.-1)
      1 .OR.PROP(WATER).NE.0.OR.JOBJ.NE.WATER) GOTO 5200
      PROP(WATER)=1
      JSPK=74
      GOTO 5200

C RUB

5505  IF(JOBJ.NE.LAMP)JSPK=76
      GOTO 5200

C POUR

5506  IF(JOBJ.NE.WATER)JSPK=78
      PROP(WATER)=1
      GOTO 5200
      END

      SUBROUTINE SPEAK(IT)
      IMPLICIT INTEGER(A-Z)
      COMMON RTEXT,LLINE
      DIMENSION RTEXT(100),LLINE(1000,22)

      KKT=RTEXT(IT)
      IF(KKT.EQ.0)RETURN
999   TYPE 998, (LLINE(KKT,JJT),JJT=3,LLINE(KKT,2))
998   FORMAT(20A5)
      KKT=KKT+1
      IF(LLINE(KKT-1,1).NE.0)GOTO 999
997   TYPE 996
996   FORMAT(/)
      RETURN
      END

      SUBROUTINE GETIN(TWOW,B,C,D)
      IMPLICIT INTEGER(A-Z)
      DIMENSION A(5),M2(6)
      DATA M2/"4000000000,"20000000,"100000,"400,"2,0/
```

```
6       ACCEPT 1,(A(I), I=1,4)
1       FORMAT(4A5)
        TWOW=0
        S=0
        B=A(1)
        DO 2 J=1,4
        DO 2 K=1,5
        MASK1="774000000000
        IF(K.NE.1) MASK1="177*M2(K)
        IF(((A(J).XOR."201004020100).AND.MASK1).EQ.0)GOTO 3
        IF(S.EQ.0) GOTO 2
        TWOW=1
        CALL SHIFT(A(J),7*(K-1),XX)
        CALL SHIFT(A(J+1),7*(I-6),YY)
        MASK=-M2(6-K)
        C=(XX.AND.MASK)+(YY.AND.(-2-MASK))
        GOTO 4
3       IF(S.EQ.1) GOTO 2
        S=1
        IF(J.EQ.1) B=(B.AND.-M2(K)).OR.("201004020100.AND.
        1 (-M2(K).XOR.-1))
2       CONTINUE
4       D=A(2)
        RETURN
        END

        SUBROUTINE YES(X,Y,Z,YEA)
        IMPLICIT INTEGER(A-Z)
        CALL SPEAK(X)
        CALL GETIN(JUNK,IA1,JUNK,IB1)
        IF(IA1.EQ.'NO'.OR.IA1.EQ.'N') GOTO 1
        YEA=1
        IF(Y.NE.0) CALL SPEAK(Y)
        RETURN
1       YEA=0
        IF(Z.NE.0)CALL SPEAK(Z)
        RETURN
        END
```

Appendix C

Installation and Use of Software Tools for the *CCA* Case Study

1. Digital Tools for CCA

Because people design software, these programs carry an inherent bias based on the people behind their creation. While the actual bias might be obscure, the researcher must still hold this in the back of the mind when evaluating data either produced or interpreted by the software being used. It is also a good idea to know who is behind the software tools one is using in one's research. Even though bias might be present in the software tools employed in research, if it is acknowledged and accounted for, the outcomes can provide more information to add to the conclusions of the research, perhaps leading to new, unanticipated research questions. For complete transparency, I used the following software applications in this case study and briefly note here each program's purpose and who created it:

1.1. R

R is a statistics programming environment and language largely replacing *S* as the modern standard for data analysis and statistical computing. Originally written by Ross Ihaka (statistical computing) and Robert Gentleman (bioinformatics) of the University of Auckland in 1993, *R* is now overseen by various international consortia and user groups (including *R*-Ladies to promote gender diversity in the *R* community), has its own peer-reviewed journal, and a curated open source archive (CRAN) for user-created, mission-specific packages based on an *R* backbone. This open source community (like other open source groups) self-polices and vets *R* code and packages.

1.2. Stylo for R

Stylo was created in August 2015 by Maciej Eder (Institute of Polish Language, Polish Academy of Sciences), Jan Rybicki (Institute of English Studies, Jagiellonian University), and Mike Kestemont (Department of Literature, Antwerp University), for the purpose of using *R* to determine authorship attribution through stylometric analysis.

1.3. TextReuse

Lincoln Mullen developed *TextReuse* for *R* in 2015 as a way to measure similarity among documents and detecting passages that have been reused between them. Mullen currently holds a dual appointment at George Mason University as Assistant Professor in the Department of History and Art History, and Director of Computational History at GMU's Roy Rosenzweig Center for History and New Media. Originally created to compare 19th-century legal documents, *TextReuse* can be applied to any corpus of documents to see what (and how much) text was borrowed, shared, or plagiarized.

1.4. Textnets

Chris Bail is an Associate Professor of Sociology and Public Policy at Duke University where he also directs the Polarization Lab. His *Textnets* package for *R* allows one to detect and visualize networks of documents and authors based on the examination of a corpus of texts.

1.5. Gephi

The *Gephi* application was created in 2010 by students at the University of Technology of Compiègne in France, which is now managed by the non-profit Gephi Consortium and open source user community. The program is a network analysis and visualization tool further developed over several years by additional students at the annual Google Summer of Code event.

1.6. ExifTool

ExifTool allows users to extract metadata from a variety of files, largely digital images. It was created in 2005 by Phil Harvey of Queens University's (Canada) Department of Physics, who currently manages its imaging project for the Sudbury Neutrino Observatory.

2. Installation and Use of Non-Stylometric Software Tools

2.1. ExifTool

ExifTool can be installed and run from the Terminal (Mac) or Console (Windows). One can use this tool to read all available metadata for any kind of file (not just images) through a simple, typed command:

```
exiftool -all [filename without the brackets]
```

For example, to see the creation date of Crowther's original advent.dat data file given to Don Woods in 1977/8, open the Terminal/Console, navigate to the directory storing the file, and then type:

```
exiftool -all advent.dat
```

Pressing the Enter/Return key will retrieve the file metadata.

2.2. CHECKSUM

To run a checksum in the Terminal on Mac OS, type the following, and then drag the file to check directly onto the Terminal window, pressing Return afterwards:

```
shasum —a 256
```

Repeat with the file(s) you wish to compare to the original. If the numbers match, they are clones (Fig. 20). If not, the non-original files differ in some way.

For Windows operating systems, users may need to download either an MD5 or SHA utility in order to complete the checksum investigations.

3. How to Install and Use the Stylometric/Text Analysis Tools

The following steps illustrate how to conduct text analysis of code in *R* and then visualize them with *Gephi*. These steps are for Mac OSX, and will differ slightly for people using other platforms. Part 2 below details the results obtained through following these processes.

3.1. Stylo[1]

Step 1: Prepare the corpus. For *CCA*, I opened the files that I wanted to analyze in a simple text editor and then re-saved the files as .txt. To make it easy to read the results, I named each file after its author (e.g., crowther.txt). I then placed all of the .txt files into a folder labeled "corpus". Note that because I was working with three sets of files (code, data, and ReadMe), I had three separate "corpus" directories.

Step 2: Download and install *R* from www.r-project.org. Follow the instructions in the "Getting Started" section. Once installed, launch the *R* app.

Step 3: Download and install *Stylo for R* from sites.google.com/site/computationalsty-listics/stylo. Follow the installation instructions provided on that page (Steps 1.1 and 1.2).

Step 4: Run *Stylo*. After launching the *R* app, type the following at the prompt and then press the Return key (always press Return to run the line of code that you typed):

```
library(stylo)
```

Next, set the working directory where the results will ultimately be saved, without the brackets, substituting your own information for what is inside the brackets:

```
setwd("/Users/[your user name on your computer]/[filepath to the
directory containing the corpus folder]")
```

For example, I typed:

```
setwd("/Users/andrew/desktop/colossalcavereadme")
```

Now you can run *Stylo* by typing:

```
stylo()
```

A window will open that gives you options to describe the nature of your data and how you would like it to appear.

1. I posted these steps online for anyone to follow, but to date none have done so. My Github repository (https://github.com/adreinhard/cca) contains these steps, plus the tools to use and the data to use them on should anyone wish to either reproduce or challenge my results.

Input & Language windowpane: Select "plain text" for input, and "Other" for language.
Features windowpane: Accept the default settings.
Statistics windowpane: Accept the default settings.
Sampling: Accept the default settings.
Output: Accept the default settings.

Press the "OK" button, and in a few moments some files will appear in the directory holding your corpus folder. One of these files is a .csv file that can be opened in a spreadsheet program containing the stylometric analysis results of the documents in the corpus folder, which can be reviewed and interpreted prior to data visualization. To exit *Stylo*, type:

```
q()
```

3.2. TextReuse

Step 1: Prepare the corpus. You can use the same .txt files in the same corpus folder created in *Stylo* Step 1 above.

Step 2: Download and install *TextReuse*. Launch the *R* app and type the following at the prompt:

```
install.package("textreuse")
```

As above with *Stylo*, set the working directory where the results will ultimately be saved, without the brackets, substituting your own information for what is inside the brackets:

```
setwd("/Users/[your user name on your computer]/[filepath to the directory containing the corpus folder]")
```

For example, I typed:

```
setwd("/Users/andrew/desktop/colossalcavereadme")
```

Then type:

```
library(textreuse)
```

Now you can run *TextReuse* by typing the following few lines of code (below is what I typed for my project), pressing Return after reaching the end of this snippet:

```
dir <- ("corpus")
corpus <- TextReuseCorpus(dir = dir, meta = list(title = "Colos-
sal Cave Adventure"), tokenizer = tokenize_ngrams, n = 7)[2]
```

Now type, pressing Return after each line:

```
corpus
names(corpus)
comparisons <- pairwise_compare(corpus, jaccard_similarity)
comparisons
pairwise_candidates(comparisons)
df <- pairwise_candidates(comparisons)
View(df)
write.csv(comparisons, file="textreuse-comparisons.csv")
```

This will create a .csv file containing a table of data about which documents borrowed how much text from other documents in the corpus folder. One can read and interpret the data now, or can move on to data visualization with *Gephi* (see below).

3.3. Textnets

Step 1: Prepare the corpus of files. Unlike *Stylo* and *TextReuse*, *Textnets* requires that all data to be analyzed be grouped in a single CSV (comma-delimited spreadsheet) file. For example, for *CCA*'s ReadMe files, I created a two-column spreadsheet with column headings of "ReadMe_Name" (the name I assigned to a *CCA* version) and "ReadMe_Data" (copy-pasted text from an entire ReadMe file for a version of *CCA*). Create one CSV file per corpus of texts to analyze.

Step 2: Download and install *Textnets*. Launch the *R* app and type the following at the prompt, pressing the Return key after each line:

```
library(devtools)
install_github("cbail/textnets")
```

2. Note that "n = 7" indicates that every seventh word is compared between documents; this number can be set higher or lower depending on one's needs.

Step 3: As above with *Stylo*, set the working directory where the results will ultimately be saved, without the brackets, substituting your own information for what is inside the brackets:

```
setwd("/Users/[your user name on your computer]/[filepath to the directory containing the corpus folder]")
```

For example, I typed:

```
setwd("/Users/andrew/desktop/colossalcavereadme")
```

Then type:

```
library(textnets)
```

Now you can run *Textnets* by typing the following few lines of code (below is what I typed for my project), pressing Return after reaching the end of each snippet. The first line tells *Textnets* where to find your CSV file and that the file has column headers and is comma-delimited:

```
ReadMe <- read.csv(file="[path to the CSV]/ReadMe.csv", header = TRUE, sep=",")
```

To ingest your CSV data into the text analysis tool, type the following lines, pressing the Return key after the final line:

```
prepped_readme <- PrepText(ReadMe, groupvar = "ReadMe_Name", textvar = "ReadMe_Data", node_type = "groups", tokenizer = "words", pos = "all", remove_stop_words = FALSE,
compound_nouns = TRUE))
```

To generate the data for visualization, type:

```
readme_text_network <- CreateTextnet(prepped_readme)
```

Unlike *Stylo* and *TextReuse* the *Textnets* package does its own data visualization. To generate the graph, type:

```
VisTextNet(readme_text_network, label_degree_cut = 0)
```

When the graph appears, choose File, Save As… from the menu and save it as a PDF.[3]

3.4. Data Visualization with Gephi

Follow these steps to create a graph based on the .csv files returned from both *Stylo* and *TextReuse*:

Step 1: Prepare the .csv files. While the .csv files can be visualized as-is, they may benefit from a bit of data reformatting from a table to a list that will better define the "edges" (links) between "nodes" (.txt files that underwent text analysis). To do this, first download and install a Visual Basic macro, "table2list.xla", from michael.wordpress.com/2009/03/12/convert-excel-tables-to-lists/.[4] Open a .csv file containing your data, then open the Visual Basic editor from within the spreadsheet application, and run the macro. Re-save and close the .csv file. Repeat for your other .csv files.

Step 2: Download and install the *Gephi* data visualization program from gephi.org. Launch *Gephi*.

Step 3: Create a graph based on a .csv file of text-analyzed data by first selecting "File" from the menu, and then "Import Spreadsheet."

Once the spreadsheet has been uploaded to *Gephi* and nodes and edges appear in the Overview window, do the following:

Activate the Statistics pane and select "Run" for Eigenvector in the Node Overview section.

In the window that appears, choose "Undirected" and then OK.

Close the Eigenvector window after it opens.

In the Appearance panel, choose the Circles icon, then Nodes and then Ranking and select Eigenvector Centrality from the drop-down list.

3. In this example, I used "ReadMe" because it reflects my data. Change "ReadMe" to whatever your CSV and columns of data are named.

4. A macro is a miniature program written to do a single, specific task. Spreadsheet programs such as Microsoft Excel allow users to create and use macros, which are written in the Visual Basic programming language for which Microsoft embeds an editor in its suite of Office programs. Because the Internet is susceptible to link rot, I have placed a copy of the table2list.xla macro in the stable repository for this case study: https://github.com/adreinhard/cca.

Set Min size to 5 and Max size to 40. Select "Apply."
In the Statistics pane run the Modularity option in the Network Overview section. Accept the defaults and select OK.

Close the Modularity Report window after it opens.

In the Appearance panel, choose the Art icon, then Nodes and Partition, and select Modularity Class. Select Apply.

At the bottom of the screen, choose the T icon.

Open the Data Laboratory window and select the "Copy data to other column" button. Choose ID and then Label, and press OK.

Return to the Overview window.

Use the Font Size slider to reduce the size of the labels.

In the Layout pane, choose ForceAtlas 2 from the drop-down list. Run it. Change Gravity to 5. Run the change.

Select Expansion from the drop-down list. Run it.

Select Fruchterman Reingold from the drop-down list. Run it. Stop it.

Select Noverlap from the drop-down list. Run it.

Select Label Adjust from the drop-down list. Run it.

In the Filters pane, choose Edge Weight (the thickness of the lines connecting the dots/nodes) from the Edges Library. Drag Edge Weight into the Queries pane below. Change the slider to read something between statistically significant numbers, and press the Filter button.[5] Press the Stop button.

Open the Preview window and tick the box for "Show Labels." Click the "Refresh" button to view the final graph. Export to .svg, .png, or .pdf by selecting the "Export" button at the bottom of the window.

5. For example, data falling within a range below .01 (on a scale of 0 to 1) would not be statistically significant, and can be filtered out of the final visualization.

Appendix D

Results of Running Stylo Against Narrative Data Sets

Weight of 6 (4 sets)

bhch0565	well0550
cox_0350	daim0350
kine0350	wood0350
malm0350	malm1000

Weight of 5 (8 sets)

anon0501	oska0551
arna0440-linux	arna0440-source
cox_0350	lumm0350
ekma0350	kine0350
gill0350	wood0350
goet0350	kint0350
kenw0350	plot0350
wood0430	wood043b

Weight of 4 (4 sets)

daim0350	lumm0350
goet0350	ticm0350
kenw0550	vane0560
long0500	oska0551

Weight of 3 (17 sets)

anon0501	arna0660
anon0501	long0500
arna0440-dos	arna0440-linux
arna0660	arna0770
arna0660	plat0550
arna0770	mcdo0551
beck0500	kenw0550
CROW0000	russ0000
ekma0350	gill0350
ekma0350	wood0350
kenn0000	lumm0350
kenn0000	pohl0350
kenn0000	whin0450
kint0350	ticm0350
munk0430	wood0430
nels0350	oska0551
plot0350	vane0560

Weight of 2 (18 sets)

anon0501	bhch0565
anon0501	nels0350
anon0501	well0550
arna0440-dos	arna0440-source
arna0660	long0500
arna0770	munk0430
beck0500	mcdo0551
beck0500	plot0350
bhch0565	malm1000
cox_0350	kenn1000
CROW0000	lumm0350
gill0350	kine0350
lumm0350	pohl0350
lumm0350	russ0000
munk0430	wood043b
oska0551	malm0350
oska0551	plat0550
pohl0350	whin0450

Weight of 1 (26 sets)

anon0501	gill0350
anon0501	plat0550
arna0440-dos	beck0500
arna0440-linux	beck0500
arna0440-source	beck0500
arna0660	munk0430
arna0770	wood0430
beck0500	vane0560
bhch0565	long0500
cox_0350	CROW0000
cox_0350	pohl0350
cox_0350	russ0000
daim0350	kenn1000
gill0350	long0500
gill0350	munk0430
gill0350	wood0430
goet0350	oska0551
goet0350	wood0350
kenw0550	mcdo0551
kint0350	wood0350
long0500	nels0350
long0500	well0550
lumm0350	whin0450
malm0350	kint0350
malm1000	oska0551
ticm0350	wood0350

Appendix E

Results of Running TextReuse Against Narrative Data Sets

Weight = 100% (10 sets)

long0500	anon0501
arna0440-linux	arna0440-dos
arna0440-source	arna0440-dos
arna0440-source	arna0440-linux
CROW0000	russ0000
kenn0000	pohl0350
kint0350	ticm0350
munk0430	wood0430
munk0430	wood043b
wood043b	wood0430

Weight = 90–99% (10 sets)

ekma0350	kine0350 (99%)
cox_0350	daim0350 (99%)
daim0350	lumm0350 (99%)
gill0350	wood0350 (98%)
daim0350	kenn0000 (96%)
daim0350	pohl0350 (96%)
cox_0350	kenn0000 (96%)
cox_0350	pohl0350 (96%)
kenn0000	lumm0350 (95%)
lumm0350	pohl0350 (95%)

Weight = 80–89% (5 sets)

kenn0000	whin0450 (88%)
pohl0350	whin0450 (88%)
daim0350	whin0450 (86%)
cox_0350	whin0450 (86%)
lumm0350	whin0450 (85%)

Weight = 70–79% (11 sets)

kine0350	wood0350 (75%)
ekma0350	wood0350 (75%)
oska0551	vane0560 (75%)
gill0350	kine0350 (74%)
gill0350	ekma0350 (74%)
anon0501	oska0551 (71%)
long0500	oska0551 (71%)
kine0350	kint0350 (71%)
kine0350	ticm0350 (71%)
ekma0350	kint0350 (71%)
ekma0350	ticm0350 (71%)

Weight = 60–69% (4 sets)

kint0350	wood0350 (63%)
ticm0350	wood0350 (63%)
gill0350	kint0350 (62%)
gill0350	ticm0350 (62%)

Weight = 50–59% (8 sets)

munk0430	wood0350 (58%)
wood0350	wood0430 (58%)
wood0350	wood043b (58%)
gill0350	munk0430 (58%)
gill0350	wood0430 (58%)
gill0350	wood043b (58%)
anon0501	vane560 (57%)
long0500	vane0560 (57%)

Weight = 40–49% (35 sets)
Weight = 30–39% (32 sets)

Weight = 20–29% (40 sets)
Weight = 10–19% (0 sets)
Weight = 0–9% (0 sets)

Appendix F

Results of Running Stylo Against ReadMe Files

Weight = 6 (5 sets)

arna0660	arna0770
bree_xxx	gerr0000
ekma0350	kine0350
kenw0550	well0550
kinm0551	kint0350

Weight = 5 (3 sets)

arna0550	arna0660
gasi0350	muno0370
olss0551	oska0551

Weight = 4 (8 sets)

arna0550	arna0770
arna0550	pict0551
bree_xxx	kenw0550
cox_0350	ticm0350
gasi0350	yong_xxx
king0350	plat0550
king0350	well0550
kinm0551	ticm0350

Weight = 3 (27 sets)
Weight = 2 (32 sets)
Weight = 1 (39 sets)

Appendix G

Results of Running TextReuse Against ReadMe Files

100% (3 sets)

blac0350	supn0350
kenn0000	pohl0350
kind0430	munk0430

90% (3 sets)

arna0550	arna0660 (93%)
arna0660	arna0770 (92%)
arna 0550	arna0770 (90%)

70% (2 sets)

kenw0550	well0550 (75%)
ekma0350	kine0350 (70%)

Appendix H

Instructions for Using Software Tools for In-Game Photogrammetry, VR Recording, and GIS

1. In-Game Photogrammetry

It is possible to scan items from within a digital environment in order to create 3D models that can ultimately be printed. These are the steps I followed to print an artifact I scanned, creating something in the natural world that only existed previously in the synthetic.

Step 1: In-Game Photogrammetry
For this experiment, I selected an "ancient Nord pickaxe" in my player inventory in *Skyrim* (Fig. 4.14). Its handle is incised with vine-like decoration. In order to scan it for printing, I needed to have my avatar approach a flat surface in the game's environment (e.g., a wall or the side of a hill) in order to guarantee a featureless, black background, which is not unlike a finds photographer using a black velvet backdrop to create a defined silhouette. Because the game's data-windows are translucent, trying to scan inventory in the middle of a field for example would create a lighter, textured background that would interfere with the 3D rendering tool used later in tis process. Once flush with the wall, I opened my inventory screen and selected the item to scan, in this case a pickaxe (for archaeology). On my handheld PS4 controller, I started recording video (double-tap of the Share button). I then activated the zoom feature (right trigger or R2 button) to make the pickaxe fill the screen. Next I rotated the pickaxe on the Y-axis a few times, and repeated with the X-axis by using the right stick, maintaining consistent pressure to assure that the rotation speed is constant. This action mirrors what happens when one uses a turntable to support an object for photogrammetry. Once I rotated the

pickaxe I released the R2 button and then stopped the video recording with a double-tap of the Share button. I then exported the MP4 movie file to a USB drive through the PS4's Picture Gallery area.

Step 2: Rendering the 3D Image

I extracted the MP4 file from my USB drive onto my computer, and then navigated to a free online file conversion utility that split the MP4 moving image into dozens of JPG files. For this example, I used *FileZigZag* (filezigzag.com), but there are other free online tools and standalone software apps that work as well (e.g., *ffmpeg*). Once I had the JPGs, I imported them into the open source regard3D app, which analyzed the collection of images to produce OBJ and MTL files for cleanup prior to printing (Fig. 4.15).

Note: Because the Skyrim pickaxe was recorded in VR, the resulting 3D image was curved. *Skyrim VR* projects its images onto a curved surface, and that curve is reflected in the imported image files. Also, even though an artifact is recorded in-the-round through rotation, *regard3d* treats the final scan as a curved, uniface image and not as a true 3D object. The resulting 3D printed artifact reflects this instead of presenting a true 3D object. It is as yet unclear to me if this will happen in other games/environments, if this issue is unique to VR, or if this an issue with the software.

Step 3: Cleaning and Printing the Artifact

Most 3D scans (Fig. 4.16) need to be touched up before they are printed, eliminating any digital "cruft." Cleaning can be done with the tools (vertice select and vertice delete) in the open source app *Meshlab*. Once the 3D model was cleaned, I saved it and brought it to a Makerspace for printing (Fig. 4.17).

2. Creating a VR Tour in *Skyrim VR*

One of the more difficult things about conducting archaeological investigation within a digital environment is being able to communicate what that space looks like and how to interact with it. The following steps detail how to record a walk through a digital landscape in *Skyrim VR* that can be shared with people who do not have access to the game or to expensive VR hardware.

Step 1: Recording the Walk

I knew where I wanted the walk to begin and end, and headed to the starting point to begin recording video (double-tap of the Share button on the PS4 controller). As I conducted the walk, I tried to be mindful that any turn of my head would be recorded.

Keeping my head still resulted in a better and more stable experience for the viewer. Once I reached the end of my walk, I paused for a few seconds and then stopped the recording. The pause is important so as not to jar the viewer with an abrupt stop to the walk. I saved the MP4 video to a USB drive and transferred the file to my computer.

Step 2: Converting the Walk from 2D to 3D VR

The MP4 video recorded through the VR headset results in a 2D film that must undergo conversion to regain its immersive, 3D feel. There are several conversion tools available online as well as conversion apps that handle a variety of video formats. For this example, I chose to use *PavTube Video Converter*. Its simple interface allowed me to import my MP4 video and then choose "side-by-side 3D video MP4" as an option. The resulting file contained stereoscopic 3D VR video (with audio) that could then be uploaded to Wordpress, YouTube VR, or for Google Cardboard users for free access (Fig. 4.18). Viewers can now experience what I did on my walk, which will help them as they read the associated synthetic text about that particular survey.[1]

3. Creating 360º Panoramic and Spherical Photos to Share with the Public

Another option for sharing in-game VR experiences with people is to create still images in the round. The following instructions explain how to make 360º panoramic and spherical photos from images captured within digital environments such as *Skyrim VR*.

Step 1: Capture the Environment

Sometimes it is important to show someone what a place looks like from where you are standing, whether it is outside in the world or inside a structure. Filming panoramas or 3D VR images in the natural world requires a special omnidirectional camera, although Google Cardboard Camera is now available as a free 360 VR-recording app for use with a smartphone. Unfortunately, games often limit the player to a single perspective and require the use of that to create an image. To make a panorama or spherical image in *Skyrim VR* for this case study, I found a place to stand, and then began recording video (double-tap of the Share button on the PS4 controller). I slowly turned in one direction using the controller's right stick. After completing the turn, I stopped recording the video, and then saved it to a USB drive. I copied the MP4 video file onto a computer.

1. Before and after videos can be accessed through https://archaeogaming.com/2018/01/20/skyrim-vr-sharing-a-walk-to-rorikstead/ (accessed 7 February 2018).

Step 2: Preparing the Image Files

I navigated to a free online file conversion utility that split the MP4 moving image into dozens of JPG files. As with the photogrammetry example above, I used *FileZigZag* (filezigzag.com), but there are other free online tools and standalone software apps that work as well. I saved the JPGs to a folder.

Step 3: Create the 360 VR image

I opened *Photoshop* (or one could also use the open source *Gimp* app). Note that to create a 3D VR spherical image, one needs *Photoshop* CS6 Extended or Creative Cloud. One can, however, create 360 panoramas in *Photoshop* CS5 or higher. I chose File, Automate . . . , then Photomerge . . . . For a 360 panoramic image, I chose the Cylinder option (for a 360 spherical image, one can choose the Spherical option). I ticked the box for "Blend images together" but left the other boxes unticked. I clicked the Browse button to locate the folder containing the JPGs from Step 2 and selected all the files. I clicked OK to begin the creation of the 360 image (note that the more files one has the longer the process takes to complete). I saved the resulting 360 panoramic image as a JPG (Fig. 4.19). This could now be uploaded to Google Cardboard or to Wordpress.com for embedding in a blogpost, or to any other site using free WebVR technology. Anyone using a smartphone and inexpensive VR headset can access the 360 panoramic image, which places them where the archaeologist was initially, at which point they can view the image by moving their head or turning their entire body around to see more of the vista.[2]

Step 3a: To enable the 360 image as Spherical 3D, once the spherical image has rendered in *Photoshop*, one can use the 3D menu option to enable the 3D functionality and then save the image as a TIFF, JPG, or PNG file, which can then be uploaded to any number of websites including Wordpress blogs/sites, YouTube VR, Google Cardboard, and others for free, easy viewing.

Note: Success with *Photoshop's* Automerge feature varies on the game and the environment being filmed. I experimented with *No Man's Sky* with good results right away. *Skyrim VR*, however, confused the Automerge algorithms resulting in one-dimensional Mobius strips containing images from the recorded panorama. An alternate panoramic-creation method is to place several images side-by-side in Photoshop, aligning the edges by hand, then flattening the image to save as a JPG, which is what I ultimately did for the *Skyrim VR* test.

2. Examples of my *Skyrim VR* panoramas can be found at: https://archaeogaming.com/2018/01/20/creating-3600-panoramic-and-spherical-photos-from-within-skyrim-vr/ (accessed 7 February 2018).

4. Making GIS Maps of Digital Environments

Mapping digital environments serves the same purpose of creating and using maps for traditional archaeological spaces. The archaeologist needs to be able to indicate locations of sites and features as well as findspots. The instructions below detail how I created a map of a region in *Skyrim VR* using *QGIS* and an underlying base map separated into SVG layers for different landscape features.

Software Used

I used the following software programs for Mac OSX as I created a usable GIS map:

Adobe *Illustrator* CS5—I used this program to open and manipulate the original topographic map's multi-layered SVG file.

Inkscape v0.92—This open source application opens SVG files and can convert them to DXF (*AutoCAD*) files, which includes line art and data points.

QGIS v2.18—*QGIS* is the open source version of *ArcGIS*, which allowed me to import DXF files as individual layers tied to specific classes of map features (e.g., ruins, camps, caves, etc.) and then export those for other GIS applications.

Procedure

1. Preparing the Map—I was able to find a high-quality topographic map of Skyrim created by NexusMods user "T Cook" published as a CC0 (public domain) scalable vector graphic (SVG) file (Fig. 4.21).[3] Vector graphics can be enlarged without losing image clarity unlike their more static TIFF, JPG, and PNG counterparts. I opened the SVG file in Adobe *Illustrator* CS5 and then opened the Layers panel. Cook had created individual layers for each class of map feature. After much trial-and-error I discovered that I could get usable results in *QGIS* if I saved multiple SVG files, each with only a single map feature layer (e.g, ruins.svg showing only ruin locations in Skyrim). I saved a total of 30 SVG files. Once the layers were saved separately, I updated each one in Illustrator by deconstructing the individual elements in each sub-map. In order to get data points to appear in *QGIS*, I had to use *Illustrator* to ungroup the collection of ruins (for example), and then I had to dissociate each plotted ruin location with its ruin icon (Fig. 4.22). Doing this step allowed me to import the icons and the data points as separate layers, which *QGIS* would later display as either dots or shapes. NOTE: If one tries

3. https://www.nexusmods.com/skyrim/mods/36159/ (accessed 7 February 2018).

to import a multilayered SVG file into *QGIS* directly, the data points will all appear in a single layer making it impossible to differentiate between features.

2. Converting the Map Layers—Adobe *Illustrator* CS5 does not have an export feature that can produce readable data by GIS software. I had to use a middleman, *Inkscape*, to convert the map layers to something *QGIS* could use. I opened each SVG file in *Inkscape* and then chose the Save As function to save each SVG file as an *AutoCAD* Drawing Exchange Format (DXF) file (Fig. 4.23). This conversion process recognized the features in the SVG layer files as data points, allowing them to be plotted in *QGIS* in the final step (see below).

3. Importing to *QGIS*—I created a new GIS file in *QGIS* and then dragged each DXF layer file onto the blank white "mapboard" to begin drawing the map. With every import the map grew in both size an complexity, ultimately revealing the rich topographic landscape of the original map along with actual data points tied to map symbols for everything from burials to lighthouse locations with the ability to turn layers on or off depending on the research questions being asked (Fig. 4.24).

Appendix I

Online Resources Created for the *No Man's Sky* Archaeological Project

Twitter: https://twitter.com/nmsarchaeology
Twitch: https://www.twitch.tv/nmsarchaeology
YouTube: https://www.youtube.com/channel/UC3ZbxHWZIr4kCYxgyNQErcw
Archaeology Data Service archive: https://archaeologydataservice.ac.uk/archives/view/nomansky_2019/

Appendix J

List of *No Man's Sky* Data, Metadata, Media, and Site Reports (5 April–6 July 2018)

The following list records the names, dates, and locations of sites recorded during the survey and excavation of the 30 Legacy Hub settlements in *No Man's Sky*. All data, metadata, media, and site reports have been ingested into the Archaeology Data Service (ADS) platform for archival purposes and to make this information available as Open Access to researchers, *No Man's Sky* Galactic Hub community members, other archaeologists, and the general public.

No Man's Sky Archaeological Project Parent Record

The DOI for the *No Man's Sky* Archaeological Project's parent record is: https://doi.org/10.5284/1056111

No Man's Sky Archaeological Project Site Records

1. Lennon (Old Galactic Hub Capital)
   5 April 2018, https://doi.org/10.5284/1056109
2. Pepper Dusk (Peaceful Pepperbase and The Cave of Forgotten Dreams)
   29 April 2018, https://doi.org/10.5284/1056110
3. Abundance (Abundance H.Q.)
   6 May 2018, https://doi.org/10.5284/1056622
4. Horner ("Tohoulvaldou"-Außenposten)
   8 May 2018, https://doi.org/10.5284/1056630

5. Holly's Blue Moon Paradise (Dancing Bear Base)
   12 May 2018, https://doi.org/10.5284/1056621
6. Hova Rises (Bez-Harr Embassy)
   17 May 2018, https://doi.org/10.5284/1056623
7. Hesperides (Beecham's Pearl Island)
   19 May 2018, https://doi.org/10.5284/1056625
8. Elebor (Longitude Base)
   19 May 2018, https://doi.org/10.5284/1056646
9. Asphodel (The Birdcage)
   20 May 2018, https://doi.org/10.5284/1056641
10. Lajodanssysl (ButterBase 1.3)
    22 May 2018, https://doi.org/10.5284/1056632
11. New Athena (Grand Castle of Hova v1)
    26 May 2018, https://doi.org/10.5284/1056640
12. Inuya (Mortham base)
    27 May 2018, https://doi.org/10.5284/1056644
13. Nohash Patieme (Neptune Acquisitions Inc)
    27 May 2018, https://doi.org/10.5284/1056639
14. Red Death (Radar Rat Race)
    1 June 2018, https://doi.org/10.5284/1056627
15. Verikondor (Sanctuary)
    1 June 2018, https://doi.org/10.5284/1056628
16. Sojaunnedy Kibits (Binoscopes Pad)
    12 June 2018, https://doi.org/10.5284/1056629
17. Onsifi (BotFodder's Base)
    14 June 2018, https://doi.org/10.5284/1056626
18. GlassShop (Hiviehale Outpost)
    15 June 2018, https://doi.org/10.5284/1056631
19. Arpinsarypov (Mother Base)
    15 June 2018, https://doi.org/10.5284/1056642
20. Marvel (Mr McDillard's Pad)
    16 June 2018, https://doi.org/10.5284/1056636
21. Eslachlan Kayham (Panda's)
    16 June 2018, https://doi.org/10.5284/1056634
22. Langley_83_Alpha (Gemini Outpost)
    20 June 2018, https://doi.org/10.5284/1056637
23. Meridian (Meridian Village)
    20 June 2018, https://doi.org/10.5284/1056635

24. Caoimhe (Paddy's Paddock)
    21 June 2018, https://doi.org/10.5284/1056638
25. Ahibahcal Anai (Onsen Portal Observatory)
    21 June 2018, https://doi.org/10.5284/1056643
26. Pr (Kogiirouk Outpost)
    22 June 2018, https://doi.org/10.5284/1056624
27. Bluegrass Planet (Serenity Villa)
    3 July 2018, https://doi.org/10.5284/1056620
28. Bluegrass Moon (Dwrigger-Drle Outpost)
    4 July 2018, https://doi.org/10.5284/1056619
29. Vaguileochi (TEC FLB Valhalla)
    5 July 2018, https://doi.org/10.5284/1056645
30. Sosashibukay (Heart of Sosashibukay)
    6 July 2018, https://doi.org/10.5284/1056633

Glossary

Augmented Reality (AR): A way of enhancing the natural world through a layer of personal technology (e.g., smartphone) providing data not normally available through one's unassisted senses. In digital heritage, for example, one can see the Parthenon in 2019 without its roof, but when viewing the building through one's phone during a site visit, a hypothetical AR app could superimpose a roof atop it.

Avatar: Player-driven character in a video game, serving as a player's digital proxy within a game-world.

Bitrot: A slow deterioration of software performance over time or its diminishing responsiveness such that the software eventually becomes faulty, unusable, or otherwise called "legacy" and in need of upgrade. (Definition from Wikipedia, https://en.wikipedia.org/wiki/Software_rot).

Breaks in Presence (BiP): Unexpected interruptions in augmented or virtual reality that immediately bring the user out of a technology-assisted experience. Coined by Stu Eve (Eve, 2012a).

Checksum: A method of verifying file identities by comparing unique numeric identifiers assigned to them by the computer upon creation.

Code Archaeology: A combination of epigraphical, material, and contextual evidence used to understand the underpinnings of software, their biographies, and their histories of use.

Colossal Cave Adventure**:** The first digital interactive text game created for the computer, which gave birth to interactive fiction and the adventure/role-playing video game industry. Created by Will Crowther in 1975.

Communication Station / Comm Station / Comm Ball: Player created/deposited inscriptions contained within levitating spheres in *No Man's Sky*. Unlike the proverbial messages-in-bottles, communication stations remain where placed.

Complexity: The notion that things and actions are composed of co-functioning independent parts that when taken together produce behavior(s) based on rules governing both the whole and its parts. See emergent behavior.

Console: Hardware specifically designed for digital gameplay (e.g., Atari 2600, Xbox, PlayStation, etc.).

Controller: Any handheld device that affects action within a digital game.

Digital Artifact: 1) A glitch in a software program; 2) An example of digital material culture (i.e., something "born" digital that exists only in synthetic space).

Digital Built Environments (DBEs): Constructions of programming code and other assets created for human and/or non-human use (i.e., software).

Embodied GIS: Locative geographic information system in which the observer is present in a landscape to experience phenomena based on location. Coined by Stu Eve (Eve, 2012a). For example, one could walk along Hadrian's Wall and learn through a mobile app about points of interest based on one's current exact location while at the same time experiencing weather, wind, scent, temperature, and the topography of the immediate landscape.

Emergent behavior: In complex systems, behaviors (both expected and unexpected) produced by rules governing individual parts in those systems as well as rules governing the whole composed of those parts.

EXIF data: Exchangeable Image File format information embedded in all media files. While traditionally used by photographers to determine the camera used to take a photo, focal length, exposure time, etc., EXIF data can also be used to understand other file information, specifically time- and date-stamps and other user information such as name and location.

Feature creep: Extra functionality added to a software program outside of the scope of the original design specification.

Galactic Hub: Semi-permanent settlement and name for a collective of *No Man's Sky* players dedicated to exploring an infinite procedural universe.

Glitch: An obvious break in a software experience often manifested visually.

Haptics: Sensory-perception hardware (headset, gloves, suit, etc.) worn by a user in order to experience augmented or virtual reality via feedback of physical phenomena.

HDMI: Abbreviation for high-definition media input, HDMI indicates a suite of matching hardware and software used to deploy media of exceptional high fidelity.

Head-Up Display (HUD): Actual or virtual hardware upon which visual data display via digital projection.

Installation media: Portable, physical artifact containing a small software program used to transfer and set up a larger software program. In the past, these have been 5.25" floppy disks, 3.5" diskettes, CDs, DVDs, and sometimes USB memory devices. All of these would have contained some variety of executable installation file (e.g., .dmg, .exe, .msi, etc.) that would instruct the computer or console on how to extract and install a software application.

Interactive fiction: A story that enables the reader to choose a path through the narrative. In print, the *Choose Your Own Adventure* series popularized interactive fiction. Games such as *Colossal Cave Adventure* created text-only narratives in a digital space for players to navigate. The open source platform *Twine* is one example of a contemporary space that allows for the creation of new interactive stories.

Machine-Created Culture: 1) A digital group of things invested with artificial intelligence created through algorithms that exhibit traditionally accepted characteristics of a discrete culture (shared beliefs, practices, creative output, material expressions, such as those created by and exhibited in the game *Ultima Ratio Regum*, by Mark R. Johnson); 2) A condition of human-abdicated agency in which a person relies on instruction and cues from electronic entities rather than on one's own notion of freewill.

Natural World: For the purposes of this thesis, the natural world is that which can be experienced/perceived directly without digital assistance.

No Man's Sky: Digital space exploration game notable for its attempt at creating a universe of biodiverse planets, flora, fauna, built heritage, language, and landscapes through procedural generation. Created by Hello Games in 2016.

Noise-induced discovery: Software-based phenomenon where complex behavior (noise) of unseen structures/routines are detected by aberrations in player agency and movement. This is a non-invasive way to identify obscured archaeological features in software, the noise focused on one specific area of a wider landscape.

Possibility space: Coined by Will Wright, creator of SimCity (1989) and the following Sims franchise, this term reflects places in a game (or the game itself) where anything can happen to a player. The game architecture is built: what will happen within that built environment? Also called a "possibility landscape."

Post-human: A description of people who use technology as a figurative extension of themselves. For example, smartphones can be considered to be post-human technology because they enable people through instant recovery of information. See Trans-human.

Post-landscape: Just as post-humans and transhumans are people augmented with/by technology, so too are landscapes either in the natural world (landscapes modified by and adapted to technology and infrastructure), and in the synthetic (either digital depictions of natural landscapes or, as in the context of this thesis, born-digital landscapes with which human and non-human agents interact). A survey of the literature did not yield any instances of "post-landscape" within an archaeological context.

Procedural generation: Method of creating and populating digital environments through algorithms.

ReadMe file: Typically a simple text (TXT) file created by the author of a software program, which can contain information on installation, usage, creation history, and copyright.

Role-playing game (RPG): A type of entertainment where players adopt personas (typically of the fantasy variety) in order to engage with a fantastic milieu while in character. RPGs exist in both print and digital forms.

***Skyrim VR*:** Based on *Elder Scrolls* V: *Skyrim* (Bethesda, 2011), the virtual reality edition (2017) translated the popular game into an immersive experience based on a fictionalization and appropriation of Nordic heritage.

Stylometry: A form of text analysis that identifies authorship of unknown/disputed texts by comparing these with an established corpus of text where the author is known.

Synthetic World: For the purposes of this thesis, the synthetic world is that which can only be experienced when facilitated by technology, specifically spaces accessed through screens. Also known as "synthetic space."

Trans-human: A description of people who use technology as a literal extension of themselves. For example, one can embed communication electronics subcutaneously, merging the synthetic with the natural.

Trolling: Targeted harassment against a player where the harasser is typically anonymous.

Virtual Reality (VR): Technology-facilitated experience in which the user feels fully immersed in a digital space.

Voxel: A three-dimensional pixel often containing data and/or instructions/rules for procedural generation.

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