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Engaging the Virtual Landscape: Toward an Experiential Approach to Exploring Place Through a Spatial Experience Engine

Susan J. Bergeron
West Virginia University

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Susan J. Bergeron

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Trevor M. Harris, Ph.D., Chair
Anne K. Knowles, Ph.D.
Kenneth C. Martis, Ph.D.
Crandall A. Shifflett, Ph.D.
Timothy A. Warner, Ph.D.

Department of Geology and Geography

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Abstract

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The utilization of Geographic Information Systems (GIS) and other geospatial technologies in historical inquiry and the humanities has led to a number of projects that are exploring digital representations of past landscapes and places as platforms for synthesizing and representing historical and geographic information. Recent advancements in geovisualization, immersive environments, and virtual reality offer the opportunity to generate digital representations of cultural and physical landscapes, and embed those virtual landscapes with information and knowledge from multiple GIS sources. The development of these technologies and their application to historical research has opened up new opportunities to synthesize historical records from disparate sources, represent these sources spatially in digital form, and to embed the qualitative data into those spatial representations that is often crucial to historical interpretation.

This dissertation explores the design and development of a serious game-based virtual engine, the Spatial Experience Engine (SEE), that provides an immersive and interactive platform for an experiential approach to exploring and understanding place. Through a case study focused on the late nineteenth-century urban landscape of Morgantown, West Virginia, the implementation of the SEE discussed in this dissertation demonstrates a compelling platform for building and exploring complex, virtual landscapes, enhanced with spatialized information and multimedia. The SEE not only provides an alternative approach for scholars exploring the spatial turn in history and a humanistic, experiential analysis of historical places, but its flexibility and extensibility also offer the potential for future implementations to explore a wide range of research questions related to the representation of geographic information within an immersive and interactive virtual landscape.

Dedication

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Chapter 1 Introduction

Understanding the interplay of space and place is a core theme in the discipline of geography. Exploring the concept of place and the ways in which we define and give meaning to places has been the focus of a large body of literature (Hubbard, Kitchen, and Valentine eds. 2004; Cresswell 2004; Tuan 1977; Relph 1976; Buttimer, 1976; Massey 1997; Casey 1993). Concepts about sense of place, place-making, and place identity have also attracted scholars across multiple disciplines beyond geography, including philosophy, history, landscape archaeology, cultural heritage, and other humanities disciplines (Withers 2009; Ethington2007; Puren et al. 2006; Cresswell 2004). While such research has explored a broad range of topics related to place, the relationship between place and human experience is a common theme.

Within the field of geography, the humanistic geographer Yi-Fu Tuan has been one of the more influential scholars on space and place, arguing that place is more than just a location within space – it is place as lived, experienced space. By ascribing meanings to such locations, we essentially create a sense of place (Tuan 1977). Since the processes of place-making and sense of place are individualistic and experiential in nature, approaches to studying these concepts in geography and other fields often center on phenomenological approaches that emphasize experiential and subjective approaches (Harris et al. 2011; Cresswell 2004; Bergeron 2004). Within the culturally and socially produced landscape, places can be identified that have meaning to individuals and groups through their perceptions or actions (Tilley 1994). It is this sense of place, and the perceptions and experiences that are bound up in the symbolism of landscape that give meaning to place and that provides a key to understanding how people form attachments to the spaces they inhabit. To identify and interpret these meanings and their role in the human understanding of place, scholars must be able to experience places in a way that is similar to previous inhabitants (Tilley 1994; Bergeron 2004).

Experiencing place in ways similar to earlier peoples raises important questions about how we explore such humanistic and geographical concepts of place within the context of the past. If one of the most important aspects of an experiential approach to place is to appreciate how people perceive and experience landscapes that they construct and move through, then the study of historical, or even prehistoric, places and landscapes becomes highly problematic. Not only do these landscapes no longer exist in the forms in which they were experienced by the culture that produced them, but the cultures themselves have disappeared or changed. Consequently, it would be impossible to accurately reconstruct and experience past cultural landscapes in ways in which earlier cultures did. Humanistic geographers would argue that our shared human characteristics can give us an affinity for people far removed from ourselves (Tuan 1977). Tilley, for example, argues that while the experience of place and landscape is an individual one, our common humanity allows us to share similar experiences of the same place and still feel a shared sense of place (Tilley 1994; Bergeron 2004; Harris et al. 2011).

The increasing utilization of Geographic Information Systems (GIS) and geospatial technologies not only in the sciences and social sciences but also the humanities has also contributed to a deeper exploration and examination of digital representations of place and past landscapes. Much of this work has been in historical GIS and, until recently, focused on mapping, gazetteers, and the development of spatial databases, such as the Great Britain Historical GIS (Gregory and Southall 2002; Gregory 2000). Such project-driven applications have leveraged the data processing and spatial analytical capabilities of GIS, but do not stray far from the comfort zone of traditional GIS to explore the many other challenges inherent in utilizing geospatial technologies to address research questions in history and more broadly in the humanities. However, this intersection of GIS and humanist disciplines has also spurred some researchers to challenge the use of GIS and other digital tools and to move geospatial technologies and thinking beyond a heavily science and social science focus and to investigate new avenues of research within the geohumanities and spatial humanities (Dear et al. 2011; Bodenhamer, Corrigan, and Harris 2010).

Recent advancements in GIScience, including the areas of geovisualization, immersive environments, and virtual reality now offer researchers the opportunity to generate digital representations of cultural and physical landscapes, and to embed virtual landscapes with information and knowledge from multiple data sources. The development of these hybrid technologies and their application to landscape research has enabled historical records to be synthesized from disparate sources and for them to be spatially represented in digital form, and embedded with qualitative data that is so crucial to historical interpretation (Harris, Bergeron and Rouse 2011). In addition, a number of conceptual questions have arisen that raise broader issues about the linkages between history, geography, and GIScience, and especially the notion of place and the understanding of past places. The increasing awareness of GIS and geospatial technologies has certainly contributed to a growing interest in the ’spatial turn‘ in history and other humanities disciplines, and a growing number of scholars recognize that a spatial perspective can offer significant insight into historical and broader humanities research questions (Fisher and Mennel eds. 2010; Arias 2010; Warf and Arias eds. 2008; Finnegan 2008; Doorn 2005; Leander and Sheehy eds. 2004).

Applying an experiential approach to landscape analysis can be problematic when a place or landscape is inaccessible for direct experiential field work. However, within the last few years a number of developments within the fields of GIScience and computer science have broadened the possibilities for harnessing the power of the computer to generate virtual representations that arguably provide a more intuitive way to incorporate qualitative aspects of space and place within an experiential framework. (Harris, Bergeron and Rouse 2011; Champion 2011; Germanchis, Cartwright and Pettit 2007; Brown, Kidner and Ware 2002). The increasing availability of relatively inexpensive advanced graphics technologies are now moving us far beyond the static two-dimensional map and providing researchers with the tools to not only generate nearly photorealistic three-dimensional virtual landscapes, but also incorporate realistic light and textures. Creating a sense of immersion through the generation of such life-like virtual landscape features, combined with camera perspectives and navigation that mimic human perceptions of movement through space are key elements in generating a sense of presence that allows virtual users to feel as if they are experiencing a real landscape experience.

Utilizing computer functionality pioneered by the video game industry, sound and other sensory input that help foster a deeper sense of immersion can now be more readily incorporated within such landscapes, and a user’s experiences of place and landscape are thus greatly enhanced: in effect such a platform can be seen as the beginnings of a sensual GIS (Gillings and Goodrick 1996). In addition, the advanced graphics functionality of gaming environments allows for the modeling of water movement, weather, and other physics-based aspects of the virtual environment that are important components in creating a sense of user interactivity and immersion. While these graphical rendering and process modeling capabilities have significantly improved the virtual reconstructions of places and landscapes, an immersive and interactive platform for exploring an experiential approach to place must have additional capabilities to integrate the sources and interpretations of humanistic inquiry that inform such work.

In order to provide access to the sources of humanistic information that are vital to telling the story of a past place, multimedia sources such as photographs and other historical documents, and audio and video can be embedded within the immersive virtual landscape and then accessed through user interaction with features in the reconstruction, such as individual building models (Harris *et al*., 2011). These qualitative data sources are essential components in the reconstruction and interpretation of historical landscapes, and yet are difficult to represent in traditional GIS. Computer and video games now routinely feature extensive virtual worlds with recognizable geography and real-world behaviors, and the ability to achieve a high level of realism is a key element in the commercial success of such games.

It is within this growing body of GIScience and humanities scholarship related to the application of GIS and advanced geovisualization tools to humanistic and historical inquiry that this dissertation research is situated. The goal of this research is to explore how GIS and gaming-based geovisualization techniques can be utilized to develop a platform for the virtual exploration and experience of space and as a mechanism for understanding place. This goal will be accomplished through the completion of six objectives:

1. Review the relevant literature in the following areas of scholarship:
    - Examine the relevant fields in GIS, geovisualization, serious gaming, and advanced graphical display environments. Examine concepts of place as explored in geography and history
    - Review developments in spatial, digital and visual history
    - Review the work in Historical GIS and current research trends

2. Explore the conceptual, epistemological and technical challenges that arise when integrating GIS, geovisualization and virtual reality in the creation of an immersive virtual environment that can serve as a platform for exploring the experience of place

3. Create a GIS-based approach to virtual landscape reconstruction and the examination of place

4. Design a serious game-based method for representing place and landscape within a virtual environment

5. Implement a game-based platform for virtual landscape reconstruction using the early twentieth-century urban landscape of Morgantown, West Virginia as a case study

6. Evaluate and assess the design, implementation, and effectiveness of a spatial experience engine as a platform for experiencing place.

To this end, this dissertation focuses on the design and implementation of an immersive and interactive virtual landscape reconstruction as a platform for exploring an experiential approach to understanding places and landscapes. To gain a deeper understanding of the challenges and research questions related to this work, a brief review of the literature related to the concepts of place and sense of place within the discipline of geography, and how geographers, historians, and other scholars have sought to understand these concepts is pursued This body of literature also includes work related to the use of computing as a tool in historical landscape research as well as to current trends in digital and visual history, which give valuable insight into how digital technologies are being utilized to represent past landscapes linked to multimedia and interactive platforms..

This dissertation research is also informed by literature within GIScience related to the representation of space and place through GIS, geovisualization, virtual landscape reconstruction, and virtual reality. In addition, this research also discusses how the conceptual and methodological challenges inherent in developing an experiential approach to reconstructing and interpreting historical and cultural landscapes through the use of immersive and interactive virtual environments. Following this literature review, the implementation of a GIS-based approach to an immersive virtual reconstruction of landscape is explored, discussed and evaluated utilizing consumer GIS and modeling software applications to generate the landscape and to embed GIS-sourced multimedia within it. The discussion of a GIS-based approach, including the technical limitations of the GIS software in achieving the performance and functionality requirements of an immersive and interactive virtual landscape, provides a valuable background for the design and development of a new platform for immersive and interactive virtual landscapes.

The dissertation specifically focuses on the design and development of a virtual landscape platform built on state-of-the-art video game technology and interactive techniques that can be utilized to apply an experiential approach to place. This game-based approach led to the development of a spatial experience engine that can build immersive and interactive virtual landscapes and embed historical and humanities information within the landscape without sacrificing the sense of immersion and presence felt by the user.

The implementation of a prototype spatial experience engine is demonstrated through a case study reconstruction of the late nineteenth and early twentieth century urban landscape of Morgantown, West Virginia that incorporates game-based functionality designed to foster a deeper sense of immersion and interaction. The elements of this Virtual Morgantown application are discussed in some detail, as well as the performance and stability of the completed prototype. As this study focused on the conceptual and methodological challenges in the design and prototype development of a spatial experience engine, selected multimedia and other information related to Morgantown's urban and historical landscape were embedded within the immersive scene, though a full-scale historical place analysis was outside the scope of this study.

The dissertation concludes with a discussion evaluating the effectiveness of the spatial experience engine as an immersive and interactive platform for virtual landscape reconstruction and as a tool for the experiential exploration of past places. Such platforms can be evaluated in several areas of performance: 1) technical performance and stability; 2) user experience; 3) content and scholarship; and 4) effectiveness as a platform for an experiential approach to place. Since the goal of this research was the design and development of a stable, working prototype, the focus of evaluation on technical performance and user experience is emphasized, as these criteria are crucial factors in fostering and maintaining an immersive experience within the virtual environment.

Chapter 2 Geography, History, and the Experience of Place

Space and place are central concepts in the study of geography, and many geographers have wrestled with the task of defining these intertwined concepts (Cresswell 2004). At its most basic level, a place is a location within space, and "[w]hen humans invest meaning in a portion of space and then become attached to it in some way (naming is one such way) it becomes a place" (Cresswell 2004: 10). Within geography, place is much more than just a location: "Place is how we make the world meaningful and the way we experience the world… It has been one of the central tasks of human geography to make sense of it" (Cresswell 2004: 12). This is no easy task, however, as place can have multiple meanings, from everyday usage that signifies a location with some connection or meaning, to a description of a person or object's location within a hierarchy or structure, one's 'proper' place (Cresswell 2004). Scholars across a range of disciplines, from geographers to philosophers, have explored the meaning of place and its importance to humanity (Cresswell 2004; Casey 1997; Tuan 1977; Relph 1976).

While definitions of place may vary, one of the most important concepts for this research is the notion that a place is defined through the meanings given to it by people as they form an attachment to a particular location and express that connection in many possible ways (Withers 2009; Cresswell 2004). Placemaking has been part of human behavior throughout history, and by seeking to identify and understand the meanings that people give to a place, geographers and others can gain an understanding of the relationships between people and the world they inhabit. This attachment is often referred to as a 'sense of place,' the ways in which humans form and express emotional attachment to a place (Cresswell 2004). While integral to understanding the relationships between people and the world they move through and inhabit, undertaking the study of places and sense of place is a challenging task.

Humanist geography and the experience of place

In the 1970s, renewed interest in space and especially place, as lived experiences, became the focus of a movement that has been characterized as humanistic geography (Tuan 1976; Cresswell 2004; Withers 2009). This movement grew out of a disenchantment with quantitatively-oriented spatial science which focused on abstract mathematical generalizations of space (Withers 2009). Through the work of Yi-Fu Tuan, Anne Buttimer, Edward Relph and others, the notion of place as a central concept in understanding the relationship between humans and their environment, primarily through experience and perception, became generally accepted (Tuan 1977; Buttimer 1976; Relph 1976; Adams, Hoelscher, and Till 2001). For Tuan, the individual's relationship with the world around them, their being-in-the-world, was at the heart of any understanding of place, and the larger networks of places that is space. In addition, Tuan argued that aspects of human experience, while highly individualistic, are also based on biological and cognitive traits that are common to everyone (Tuan 2001). His discussion of the development of human perceptions of space and place, from our infancy to adulthood, highlights the notion that while humans may live in and experience a myriad of environments throughout the world, we still possess innate traits as humans that allow us to share aspects of our experiences of space and place.

One of the most difficult aspects of applying this humanistic perspective in the study of place lies in developing and implementing methods and methodology for carrying out such research. The type of approach most often associated with humanistic geography is an experiential one, which relies on individual description and reflection of the object under study. A number of humanistic geographers looked to the work of philosophers whose work has centered around existential phenomenology, such as Heidegger's concept of being-in-the-world (Entrikin 1976). Relph especially argued for an experiential approach to understanding place, or a "phenomenology of place" (Relph 1976; Withers 2009). At its heart, phenomenology is the study of human experience through observation and interpretation. There are a number of schools of thought within phenomenology as a philosophical pursuit, but one of the key elements that they all share is some notion that one must experience phenomena in order to understand them (Entrikin 1976). However, as Tuan deftly noted, "Experiences are slighted or ignored because the means to articulate them or point them out are lacking" (Tuan 1977, 2001). It is this very point that drives the research goal and methodology of this dissertation.

Place and Landscape

In the related fields of cultural landscape analysis and landscape archaeology, the importance of the role of space and place in past landscapes has been taken up by a number of scholars, including Christopher Tilly. In his *A Phenomenology of Landscape* (1994), Tilley argues that in archaeology space is not absolute, but is a medium for action. Consequently, space is socially produced, and as such is only meaningful in relation to human activity and agency. In this context, landscape "is an anonymous sculptural form always already fashioned by human agency, never completed, and constantly being added to, and the relationship between people and it is a constant dialectic and process of structuration: the landscape is both medium *for* and outcome *of* action and previous histories of action. Landscapes are experienced in practice, in life activities." (Tilley 1994: 23).

Tilley further argues that the real key to understanding past landscapes lies in the notion of a sense of place. Within culturally and socially produced landscapes, we identify certain places that have meaning to individuals and groups through perceptions or actions: "People are immersed in a world of places which the geographical imagination aims to understand and recover – places as contexts for human experience, constructed in movement, memory, encounter and association." (Tilley 1994: 15) Consequently, the perceptions and experiences that are bound up in the visual symbols of that place, provide an invaluable key to understanding how we interpret and give meaning to the space we inhabit.

In her work on Stonehenge, Bender (1999) argues that landscapes, and the spaces and places within them, are not static, passive entities, but rather are constructed, mediated, and contested. Consequently, even in the consideration of a prehistoric landscape such as Stonehenge, there is "the need to mesh an understanding of embodied landscapes with a political landscape of unequal power relations." (Bender 1999: 38). As Tilley argues:

> Experiencing places in the landscape involves taking as much account of the landscape in which the place is embedded, its relationship with its physical and topographical context, as of the place itself. Throughout, we assume that what makes the place significant is its relationship with other 'natural' and 'cultural' places. We are thus concerned with the dialectics of place and surroundings. Methodologically, this requires sensing place from without and from within from a variety of vantage points and

> pathways. No adequate understanding of the social and cultural geography of a place can be achieved without considering its relationship with others and experiencing its situation in the landscape at a human scale requiring moving and walking through and exploring its surroundings. (Tilley 2004, 221)

Bender notes that prehistoric peoples likely experienced landscape in a similar fashion, filtering their experience through embedded meanings and relations that reflected their own social and cultural interactions. Thus, any experience or perception of space and place will carry with it the observer's own worldview, as well as social, cultural, and political meanings that have been layered upon the landscape.

The individualistic nature of perception and experience presents a very difficult task for those who would try to generate digital representations of spaces and places that are defined by cultural, behavioral or experiential characteristics. If, for example, a landscape is experienced by each person in his or her own unique way, how then can another person truly share that experience? Even if, as Tuan argues (Tuan 2001), our shared human heritage can create experiences that are similar to those of others who have inhabited or experienced a landscape, each experiences are individual and cannot be replicated by another person.

Furthermore, the difficulties inherent in gaining meaning from a cultural landscape and its embedded spaces and places through experience and perception become more pronounced when the focus shifts to historic or prehistoric landscapes. Not only do the cultures and peoples no longer exist, but the 'realities' of the landscapes and places that they inhabited and experienced have also changed and been altered by subsequent physical, cultural, and social processes. It is likely impossible to accurately reconstruct and experience previous cultural landscapes in the same way earlier cultures did, since not only can we never know with certainty that we have replicated the physical landscape features, we cannot access the accumulated and embedded social and cultural experiences and meaning that earlier peoples brought to their experience of space and place (Tuan 2001; Bender 1999; Bergeron 2004).

History and place

Within the last decade, attention has been drawn to the 'spatial turn' in a number of disciplines, including the social sciences, history, and the humanities. The notion of a 'spatial turn' implies that space is increasingly recognized as an integral part influencing human behavior, and examining and understanding the role of space should be an important component of research (Doorn 2005). How, then, can the 'spatial turn' in history be characterized? Perhaps at its most basic level, the spatial turn represents a conscious move toward adopting a spatial perspective toward understanding the past and conducting historical research. It is a recognition that space is an important factor in understanding human behavior and processes. The spatial turn can be seen in a number of different aspects of historical research, from the development of historical GIS to the awareness and incorporation of space and place as important components of human behavior, to the exploration of space as an active agent in creating and mediating history, as in spatial history (White 2010; Withers 2009; Doorn 2005; Carter 1987)

The concept of place and of understanding place, then, can be seen as an important focus not only in geography, but also in history. Baker (2003: 219) argues that "historical geography is fundamentally concerned with place synthesis, not with spatial analysis." and that "historical geography highlights the historical specificity of particular places" (2003: 220). As Edward Casey (1997: ix) argues, "Whatever is true for space and time, this much is true for place: we are immersed in it and could not do without it. To be at all – to exist in any way – is to be somewhere, and to be somewhere is to be in some kind of place. Place is as requisite as the air we breathe, the ground on which we stand, the bodies we have. We are surrounded by places. We walk over and through them. We live in places, relate to others in them, die in them. Nothing we do is unplaced." Consequently, by understanding past places we can gain insight into people themselves.

Gaddis (2002) argues that the study of the past can be seen through the spatial metaphor of landscape: "For if you think of the past as a landscape, then history is the way we represent it, and it's that act of representation that lifts us above the familiar to let us experience vicariously what we can't experience directly: a wider view." (Gaddis 2002: 5). History can also be seen as a form of mapping, Gaddis suggests, sharing with cartography a focus on representing rather than replicating reality. In order to represent reality, whether in the past or present, both cartographers and historians must distill the experiences that are necessary to create these representations (Gaddis 2002).

In his recent essay entitled "Placing the Past: 'Groundwork' for a Spatial Theory of History", historian Philip J. Ethington (2007) also makes the argument for a spatial perspective in understanding history when he states in his précis that "All human action *takes* and *makes* place. The past is a set of places made by human action. History is a map of these places." (Ethington 2007: 465). To support this assertion, Ethington surveys the work of modern philosophers such as Heidegger, Dilthey, and Simmel and their conceptualizations of time and space, as well as the work of Lefebrve and Casey on space and place. Ethington then proposes a cartographic approach to the study of history, whereby places of the past are referred to as *topoi*, from the Greek noun *topos*, or "place." These *topoi* can be mapped onto a topological framework that relates places with other places throughout time. History, then "is the map of past. Its elemental units are *topoi*. In my latest vintage of this term, *topos* signifies the intersection of (lived) place-time and (natural) spacetime." (Ethington 2007: 483-485). By making the concept of *topoi* the central element of historical study, Ethington is arguing for a practice of history that has much in common with historical geography's focus on historical place analysis.

Ethington's provocative essay, published in the journal *Rethinking History* (2007), was met with a number of responses and commentaries, including several published in the same issue of the journal. In his response, Edward Casey (2007) lauds Ethington's work, but seeks to explore the argument further by focusing on the notion of boundaries, "because they demonstrate so tellingly that history occurs as place: which is nothing less than Ethington's primary thesis." Casey further elaborates that "*boundaries are where places happen.* If history is to occur as place, then it will do so most effectively in the boundaries that belong to places." (Casey 2007: 509). However, Casey goes on to argue against Ethington's notion that the practice of writing history must focus on places and suggests that "[i]t is sufficient if the role of place is tacitly acknowledged as the source of historical actions themselves. For this acknowledgement to be effective, they need not be singled out as such." (Casey 2007: 510). Thus, Casey agrees with Ethington's overall argument for the central role of place in history, but suggests that it need not be an explicit part of the historian's argument.

Spatial History and Place

The recognition of space and place as important interpretive concepts for history is not just a recent phenomenon, as the French Annales school of thought in mid-20th century broke with previous traditions of historiography by arguing for a focus on social and economic themes as well as more traditional political history and biography (Knowles 2008b; Forster 1978). Fernand Braudel, a leading Annales historian, developed the *longue durée* approach, which focused on the long, slow effects of space, environment, and changing technology to explain the course of history through long-term cycles, rather than the short-term political and military events that were the traditional focus of historical writing (Iggers 2005; Forster 1978).

While the Annales school considered space and place to be integral parts of a total history, spatial history goes a step beyond simply recognizing and applying a spatial perspective in historical research and analysis, and focuses on the active role of space in shaping history and how such a role can be interpreted. Thomas (2004) argues that spatial history seeks to offer multiple perspectives on the past and reject empirical positivism. The theoretical framework of spatial history, then, is grounded in the movements, both in history and geography, related to postmodernist, post-structuralist, Marxist and other social critiques that argue against the positivist, empirical perspective, and hold instead that there is no one true account, or narrative; rather there are many pasts (Fulbrook 2002; Thomas 2004; Knowles 2001).

One of the most well-known examples of spatial history, Paul Carter's *The Road to Botany Bay: An Essay in Spatial History* (1987) explores the spatial history of

Australia's early settlement through the use of a medley of primary sources, including journals, letters, maps, and personal accounts of convict escapes. He argues that the activities surrounding the exploration and colonization of Australia reflect the active attempts by its settlers, including convicts, to create a meaningful world out of the unknown. Carter focuses on the episode of an escape to Botany Bay to show how conceptions of space that are recorded in historical sources, such as the contrast between how the 'road' to Botany Bay actually would have looked and how it was seen both by imperial authorities and by the convicts themselves, can tell us a great deal about how space is used to define and shape history (Carter 1987, Thomas 2004).

Carter's (1987) focus on telling the story of Australia's settlement through the experiences of its settlers is an important aspect of understanding historical space and place. His focus on spatial history as a counterpoint to imperial history is only one perspective on how a recognition of space as a lived phenomenon can bring new voices to the historical discourse. Recent studies in spatial history have addressed a broad range of topics, from the early industrial development of the British city of Sheffield in the nineteenth century to the development of modern Russia, and African history (Griffiths 2005; Bassin, Ely, and Stockdale eds 2010; Howard and Shain eds. 2005). While these case studies employ a broad range of perspectives and methodologies under the umbrella of spatial history, they share a focus on examining issues of space and place as social construct and lived experience.

The term spatial history is also being applied to studies that bring a spatial perspective to history through the use of computer mapping and spatial analysis technologies, such as GIS. These studies are focused more on utilizing GIS and mapping technologies to bring new insights to historical research questions, such as railway development, and the development of the city of Tokyo through time by examining the role of space as an explanatory factor (Schwartz, Gregory, and Thevénin 2011; White 2010; Siebert 2000). In this sense, they share a commonality with the spatial history studies mentioned above, but this new use of the term 'spatial history' is more to denote the methods used, and does not connote the same theoretical perspective as the spatial histories of postcolonial historians such as Paul Carter, for example.

Digital and Visual History

A parallel trend with the development of spatial history has been an increasing awareness and adoption of computing hardware and software as tools in historical research. Computing as a tool in historical research and analysis goes back much further than the development of historical GIS. As early as the late 1940s and early 1950s, a few American historians were making use of early IBM punch card technology to record and synthesize large historical data sets. In the 1960s and 1970s, the rise of quantitative history paralleled the movement toward social history, as a number of young historians utilized computer-based statistical analyses to generate quantitatively-based interpretations of historical processes (Thomas 2005; Staley 2002a). Within the last decade, historians' use of computing has broadened to encompass a variety of technologies and interests, including database development, internet resources and online collaboration, electronic texts, and virtual environments (Anderson and Tedd 2005) However, while the opportunities presented by new digital technologies have continued to evolve, their use by historians for the research, interpretation, and presentation of history has not expanded beyond a fairly small group of enthusiasts (Anderson and Tedd 2005; Ayers 1999).

A number of historians who have embraced the potential of computing and digital technologies as tools for historical research have also recognized the importance of leveraging computer and Internet technology as a means of sharing historical data and results. For example, The United States Library of Congress' *American Memory Project* (http://memory.loc.gov/ammem/index.html) is a large-scale example of digital history that offers access to a range of digital source collections, coupled with interpretive material. Users can browse the collections in their own way, and are not bound to a linear narrative experience. Such digital archives have much in common with parallel developments in digital humanities in general, such as the creation of large digital archive projects like Project Muse (http://muse.jhu.edu/).

Although digital history need not have a visual or even spatial component, many scholars are combining these perspectives to create more comprehensive presentations, such as Edward Ayers often-cited *Valley of the Shadow* project (http://valley.vcdh.virginia.edu/) or Ray's Salem Witch Trials project (http://www2.iath.virginia.edu/salem/home.html). Ayers *Valley of the Shadow* is a powerful example of the use of multimedia exploring conceptions of space and place in a historical context. In examining the experiences of two communities in the Shenandoah Valley, one Northern, one Southern before, during, and after the Civil War Ayers used multimedia, textual sources, and maps, to create a digital archive enabling users to explore the sources and construct their own narrative path through the historical record of these places. While each user's experience with the *Valley of the Shadow* website will be unique, they will share aspects of that experience with other users who will explore the same content. Consequently, while the non-linear aspect of the site's design means that each user will assemble the components of their experience into a unique narrative, the historians can still be reasonably confident that the information they wish to convey about the past will be viewed by users at some point.

In his *Computers, Visualization, and History*, Staley (2002a) delves into an aspect of computers utilization that extends beyond simple use as digital assistants for compiling and organizing historical research but rather examines the "methodological and philosophical implications of the use of computer visualizations by historians as a vehicle of scholarly thought and communication." (2002a: 3) He argues that while digital history projects are gaining a broader acceptance among historians who are comfortable working with digital technologies, mainstream historical research, as with many academic disciplines, is still focused on textual modes of communicating knowledge and the use of computers is mainly "to laterally transfer textual culture from paper to screen." (Staley 2002a: 3). Staley defines a visual history as one that utilizes visualization as a key element in representing and conveying the historian's knowledge of the past (Staley 2002). In a more recent work on defining a heuristic for evaluating such visual presentations of historical knowledge, Staley offers an "appeal to historians to view themselves as more than just writers, to expand the range of media in which they work, to think of themselves as information designers." (Staley 2007: 25)

For example, a number of case studies in visual history focus on images from the past, such as Quanchi's (1997) work on historical photograph collections related to the Pacific Islands, or Fleming and Luskey's (1993) research on photographic images of

Native Americans. In a case study utilizing a visual publishing format in the online version of the journal *History and Computing*, Staley (2002b) focuses not only visual images as historical evidence, but also explores visual presentation of his scholarly work through a graphic article that presents images from Germany's 20th century history in a sequential fashion, as a kind of visual narrative. Staley suggests that "[t]his visual article is an experiment in sequential art as a rich and expressive form of historical narrative. My goal here is to suggest ways that professional historians might communicate to each other through this visual medium." (Staley 2002b).

In a more recent work, Staley (2006) looks again at issues related to visual art and its representation of historical information through an examination of a series of illustrations done for an influential text on world history. In arguing that historians are often dismissive of visual images as representations of knowledge, Staley contends that "Most historians continue to believe that 'serious history' is written history. Diagrams, charts, and other visual images are distractions from the 'real history' historians locate in the text." (Staley 2006: 384). He goes on to note that the illustrations from the world history text are examples of cognitive art, as defined by Edward Tufte, and "have long been a part of the representation of knowledge in scientific and technical disciplines." (Staley 2006: 285). In arguing for the legitimacy of visual images and other media representations as mechanisms for representing historical knowledge, Staley lays the groundwork for utilizing similar visual modes of communicating historical information through other means, such as the immersive virtual platform that is the subject of this dissertation.

In a similar vein, Shifflett argues that visual history and digital scholarship, especially through visualization, can become powerful tools for historical analysis and "it is when researchers use a variety of visualization, animation, and auditory tools and techniques as the primary means of analyses and presentation that [they] will make visualization history's new frontier." (Shifflett 2007: 59). Through the example of *Virtual Jamestown,* Shifflett demonstrates how this new historical methodology might work using visualizations such as virtual reality recreations of elements of the human and natural landscape of early 17th century Jamestown, Virginia. In addition, visual primary historical sources, such as John Smith's 1612 Map of Virginia have been visualized using modern digital cartography (*Virtual Jamestown*, 2011).

More recently, as noted above, spatial history has become identified with digital history, historical GIS and other computer-based efforts to explore the past. In his short essay "What is Spatial History?" Richard White of the Spatial History Project at Stanford University describes their work as

> operating outside normal history practice in five ways. First, our projects are collaborative. … Second, while many of our presentations involve language and texts, our main focus is on visualizations, and by visualizations I mean something more than maps, charts or pictures. Third, these visualizations overwhelmingly depend on digital history. … Fourth, these projects are open-ended: everything – both tools and data – becomes part of a scholarly commons to be added to, subtracted from, reworked and recombined. The final, and most critical aspect of our departure from professional norms, is our conceptual focus on space.
> (White 2010: 1)

Examples of the Spatial History Project include mapping and visualizing the spatial relationships in Voltaire's correspondences as part of the larger Mapping the Republic of Letters project (Nyaosi 2010), the expansion of railroads and their role in shaping the American West (Shnayder 2010), and visualizing 19th century land speculation in Fresno County, California (Ormsby 2010).

Although perhaps still far from the mainstream viewpoint, an increasing number of historians, and scholars in other humanities disciplines, are exploring these new digital, spatial, and visual modes in conducting historical research and representing knowledge about the past (Censer and Hunt 2005; Thomas and Ayers 2003; Staley 2002a, 2002b). In addition, this awareness and acceptance of computing and its utility in scholarly research has also helped scholars in history and other disciplines recognize the potential of a broader range of digital technologies, such as GIS.

The literature areas discussed in this chapter may be rooted in different disciplines, but they converge in a number of important ways, and provide an intriguing intersection for the consideration of historical place analysis within the context of digital environments. The humanistic geographers' focus on the concept of place as lived experience, coupled with the work of scholars in history and related fields who focus on understanding landscapes and the places within them, raise important questions about how we can explore an experiential approach to historical place analysis. In addition, the parallel trends of spatial history and digital and visual history also offer potential methods and mechanisms through which we can represent the unique information that offer insights into the experiential aspects of place. In the following chapter, a discussion of developments in GIS, historical GIS, and virtual reality will examine the challenges in developing an experiential approach to historical place analysis that leverages recent developments in computer graphics and other technologies.

Chapter 3 Historical GIS, virtual reality, and an experiential approach to place

Paralleling these other developments in the use of computing technologies in historical research, the adoption of GIS as a tool in historical research, which has come to be known as historical GIS, had its beginning in a number of projects in the 1980s and 1990s, and within the last decade has continued to develop rapidly (refs). Early uses of GIS for historical scholarship focused on developing spatial databases and the mapping of historical places and changing administrative boundaries (Knowles ed 2000; Gregory and Healey 2007). In addition, a number of scholars in related fields, such as archaeology, have also incorporated GIS mapping and analysis into their work (Harris 2002, 2000; Wheatley and Gillings 2002; Lock ed 2000).

In addition to numerous individual research projects utilizing GIS in historical research, scholars in several countries quickly recognized the potential of GIS to digitize and synthesize spatial data sets at the national level. The development of national historical GIS projects have focused on the daunting task of mapping administrative boundaries over time, and on generating spatial databases of demographic, economic, and social data. Perhaps the most successful of these efforts to date has been the Great Britain Historical GIS (GBHGIS), which is the culmination of years of effort to create a spatial database of census and vital records, and other data from the 1800s to the 1970s (Gregory and Southall 1998; Gregory and Ell 2005; Gregory and Healey 2007). The GBHGIS is now available for scholars to utilize in historical and historical geographic research, and a number of studies have already been completed (Gregory 2000; Gregory and Southall 2002). Other national historical GIS efforts, such as the NHGIS for the United States, the

China Historical GIS, and the Netherlands Historical GIS, are in various stages of development, with the focus on creating reliable spatial databases of historical statistics and changing administrative boundaries over time that can be utilized by scholars as tools in historical studies (Knowles 2005).

A further series of initiatives have leveraged digital mapping and GIS technologies for historical research centered on the development of digital cultural atlases, such as the Electronic Cultural Atlas Initiative (ECAI) (http://www.ecai.org/). This collaborative project began in 1997 when a group of scholars brought together by Lewis Lancaster began the work of developing a dynamic digital cultural atlas that could link disparate projects on a wide range of historical, cultural heritage, and humanities topics (Knowles 2005; Buckland and Lancaster 2004). By leveraging GIS and internet technologies, the ECAI initiative sought to create a platform where scholars could share data sets, visualizations, and other information on a range of humanities topics. A significant part of the ECAI platform is TimeMap, a mapping and visualization software package developed by the Archaeological Computing Lab (ACL) at the University of Sydney as a tool for handling spatiotemporal data (Zerneke et al. 2006; Wilson 2001; Johnson 1999). Through a partnership between ACL and ECAI, one of the goals of developing TimeMap was to provide scholars with a digital platform for mapping, displaying, and working with spatiotemporal data. The success of the ECAI community of scholars in leveraging platforms like TimeMap to create a portal for cultural atlases and other digital storehouses of cultural data can be seen in the wide range of projects linked to the ECAI website, and the growing bibliography of publications that demonstrate the scholarly contributions of these projects (ECAI 2011).

Since the mid-1990s David Rumsey, an avid collector of historical maps, has been a leader in developing techniques and software for digitizing and making his collection of maps freely available online (http://www.davidrumsey.com/). In addition to over 27,000 maps available to users around the world through the David Rumsey Map Collection website, there are also custom map and GIS viewers to access the content and to perform limited analytical functions (Rumsey 2011). Just as with the national historical GIS projects, and with ECAI, the goal of the David Rumsey online collection is to develop and provide access to digital historical resources and spatial data sets that can be utilized by scholars in historical research.

As historical GIS has developed as a subdiscipline within the last decade, there has been a growing body of scholarly work utilizing GIS for a variety of historical topics, from the development of Victorian railways and population change in 19th century Britain (Schwartz 1999), to mapping the history of Russian administrative boundaries (Merzliakova and Karimov 2001). In 2000, *Social Science History* devoted a special issue to historical GIS, with an introduction by Anne K. Knowles, and a spectrum of papers illustrate yet again the great variety of uses of GIS in historical investigation. These ranged from Tokyo's spatial history, the use of GIS in print culture studies, and an analysis of China's historical demography (Knowles 2000; Siebert 2000; MacDonald and Black 2000; Skinner et al. 2000). Another important work to showcase historical GIS applications was *Past Time, Past Place: GIS for History* (2002), edited by Anne K. Knowles. The projects discussed within the book included utilizing GIS to study redlining in mid-20th-century Philadelphia, a historical GIS of the American Dust Bowl, and mapping British population history (Hillier 2002; Cunfer 2002; Gregory and Southall 2002).

Knowles' most recent collection of historical GIS scholarship, *Placing History: How Maps, Spatial Data, and GIS Are Changing Historical Scholarship* (2008), includes contributions that not only demonstrate the power of GIS as a tool in historical research, but also explore how GIS fits into historical scholarship (Bodenhamer 2008) and how historical GIS might continue to develop as a subfield (Knowles, Hillier, and Balstad 2008). Indeed, the book concludes with an agenda of sorts for the future of historical GIS, highlighting the potential of GIS and geospatial technologies as well as some of the criticisms leveled against the use of GIS by historians that must be addressed (Knowles, Hillier, and Balstad 2008). Here the authors argue that historical GIS projects should strive to focus on analysis and interpretation, and suggest that historical GIS is "most compelling when spatial questions are central to the research, rather than afterthoughts that produce a map or two at the end of a project." (Knowles, Hillier, and Balstad 2008: 269).

A number of projects in historical GIS have also sought to integrate the mapping and analytical functions of GIS with research questions and qualitative data sets that are reflective of the humanistic nature of historical inquiry. For example, Harris and Rouse (2000) explored the use of viewshed analysis of Native American mounds in the Ohio Valley to derive possible relationships between the placement of cultural features and symbolic meanings within a past cultural landscape. In similar vein, Knowles'(2008) work focusing on the Gettysburg Civil War battlefield examined an important historical question – what could General Robert E. Lee and other Union and Confederate officers actually see from various vantage points on the battlefield, and how did that intervisibility impact their decisions during the battle? By utilizing historical maps and other sources, coupled with modern GIS data and analytical techniques and especially viewshed analysis, Knowles was able to generate a visualization of the areas that could be seen from the Confederate commanders' vantage points at various crucial times during the three-day battle, and thereby offer additional insight into the visual information that guided their decisions (Knowles 2008).

While historical GIS scholarship to date has covered a wide range of projects from the development and utilization of spatial historical data sets, to mapping and visualizing historical information, to historical analyses based on GIS functionality, the focus remains on methodologies that generate social science-based results and conclusions. Indeed, when arguing for the future research agenda of historical GIS, scholars in the field have emphasized analysis and interpretation of results derived from GIS processes, such as spatial statistical analyses or viewshed analyses (Knowles 2008; Gregory and Healey 2007). However, other researchers have explored the development of historical GIS has a platform for synthesizing and integrating historical resources and allowing users to explore the history of a place through its representation within the layers of the GIS.

Extending Historical GIS

A number of scholars working within historical GIS have also focused on integrating qualitative historical information into GIS without necessarily converting such sources into quantifiable features or data sets (refs). One area of focus is the use of multimedia embedded within a traditional GIS platform as a method for spatializing qualitative data and incorporating materials into a GIS (refs). Such sources become part of the spatial database within the Historical GIS and a key component in visualizing and exploring information, rather than reduced to input variables in a GIS process. For example, Harris and Rouse (2000) demonstrated the use of embedded multimedia in an Internet-based GIS project within the Electronic Cultural Atlas Initiative. By utilizing the GIS as a platform, and incorporating historical photos and drawings, audio interviews with historians, and even video of the current mound environment, the researchers created a contextual GIS that represented not only aspects of the past landscape of the Moundsville and Grave Creek Mound area, but also some sense of modern cultural and social meanings layered onto the prehistoric landscape.

There are a number of other examples of the use of spatial multimedia as a method for integrating qualitative historical sources within a GIS framework. Giordano's work on multimedia historical GIS illustrates this work through the visualization of change on Nantucket Island (Giordano and Buckley 2004). Other scholars have demonstrated the use of multimedia GIS for projects as wide-ranging as the historical documentation of Ottoman fortresses on the Dardanelles (Guney and Celik 2004) to the development of urban neighborhoods in twentieth century Morgantown, West Virginia (Harris et al. 2003). The use of spatial multimedia integrated within a historical GIS framework enables researchers to explore historical landscape interpretation based on the qualitative aspects of place and experience.

Representing Space and Place in GIS

More generally, representing space and place within GIS is of central importance in the social sciences and especially the humanities. The quantitative and positivist roots of GIS favors representations of space that are absolute, such as the familiar two-dimensional Cartestian plane of x, y coordinates. Data that cannot be easily translated into such Cartesian forms become problematic. For example, notions of relative produced space, such as perceptions of fear across an urban landscape or gendered perceptions of landscape, may have fuzzy boundaries that cannot easily be translated into digital forms and incorporated into a GIS (Bell and Reed 2004; Hubbard et al. 2004).

In order to effectively utilize GIS to address questions of space and place, then, researchers must address the challenges of incorporating the qualitative data sources that are often crucial. A wide range of primary sources are qualitative in nature, such as paintings, drawings, photographs, oral histories, and text descriptions of places or events. More recent historical sources can also include audio, video, and film. While there is often a wealth of spatial information within these sources, from landscape paintings that depict a place to travelogues that describe a place, that spatial component can be difficult to assign to a discrete location required by the data models used to represent information within the GIS (Harris, Bergeron, and Rouse 2011).

Representing qualitative data sources, such as local knowledge, was a major focus of the research that arose out of the GIS and Society debates in Geography in the 1990s, and became a key concept in the development of Public Participatory GIS (PPGIS) and later Participatory GIS (PGIS) (Sieber 2006). Researchers recognized that the quantitatively-driven, expert GIS was much more adept at incorporating, displaying and analyzing data that were readily converted to the recognizable data entities of point, line, polygon, or raster pixels. As a result, Harris and Weiner (1998, 2002) and others investigated ways to incorporate local knowledge into a Community-Integrated GIS for land reform in South Africa. By spatializing local knowledge from mental maps and other ethnographic sources, the researchers were able to incorporate qualitative local knowledge into a GIS and to generate a more balanced view of space and embedded places within the Kiepersol area (Harris and Weiner 1998, 2002; Weiner et al. 2002).

As PGIS has developed, much of the research focus has been on community empowerment and advocacy, and on methods to integrate local community knowledge into GIS to support community voices in the decision making process (Sieber 2006). By continuing to develop methods for incorporating local and indigenous knowledge into GIS, PGIS researchers are exploring ways to integrate multiple forms of information including qualitative data into a GIS framework. Dunn (2007: 616) argued that a "Participatory GIS celebrates the multiplicity of geographical realities rather than the disembodied, objective and technical 'solutions' which have tended to characterize many conventional GIS applications." While PGIS work is not historical in nature, the conceptual frameworks and methods developed through this initiative can inform research into historical and humanities spatial research.

A further field to grow out of the PGIS work is the recent focus on Qualitative GIS. Much of this work is focused on developing methods to merge qualitative data into quantitative methods for conducting spatial analysis in GIS (Jung and Elwood 2010; Kwan and Ding 2008). In the edited volume *Qualitative GIS: A Mixed Methods*

Approach (2009b), Cope and Elwood argue for a mixed-methods approach to qualitative GIS, whereby qualitative research methods in human geography are adapted for, and extended by, integrating them into a GIS (Cope and Elwood 2009a).

While social science research that is mainly focused on modeling and processes might struggle with the appropriate and effective use of spatial analysis and GIS, the humanities provide an even greater challenge, largely due to fundamental differences in theoretical frameworks, data sources, and methodologies. Focused as it is on qualitative, humanist data sources, the humanities have differing epistemologies that sits uncomfortably with the positivist driven GIS. While it may be relatively simple to represent physical features such as rivers, point locations, or administrative boundaries within the GIS, the data that drive much of humanities research does not fit easily into the traditional GIS vector and raster data models. Not least humanists, social scientists, and scientists differ considerably in the way which they pursue and undertake research (Harris et al. 2011)

Experiencing place through virtual reality

One of the most promising avenues of research in terms of representing place and landscape within GIScience is geovisualization, especially landscape reconstruction and modeling and virtual reality (Ervin and Hasbrouk 2001) Numerous projects have sought to utilize increasingly powerful graphics computing environments to model and display 3D representations of historical landscapes, often in conjunction with museum applications and cultural heritage projects (Trapp et al. 2010; Bergeron et al. 2007; Severson 2001; Harris and Rouse 2011; Cremer et al. 2000).

The goal of developing such compelling virtual environments is not simply to provide to a realistic simulation of a landscape or place, but to help the user achieve a sense of ‘presence’ within that digital world. The concept of ‘presence’ is familiar to many humanities scholars and computer scientists, but has multiple meanings within other disciplines (Egges et al. 2007; McMahan 2003). At its most basic level, presence is the user’s perception that they have been transported from the real world and are actually ‘present’ in the virtual world in some way (Sadowski and Stanney 2002). This effect can be achieved through a number of hardware and software elements within the virtual environment that combine to create a sense of immersion and interaction or engagement that leads to the feeling of presence (McMahan 2003).

Janet Murray offers a compelling argument for the potential of virtual worlds for the development of compelling immersive virtual environments that can evoke a sense of place, in her seminal work *Hamlet on the Holodeck* (1997). In describing the potential power of computer-generated representations, Murray explains the unique characteristics of the computer that can be harnessed in creating virtual landscapes: “Digital environments are procedural, participatory, spatial, and encyclopedic. The first two properties make up most of what we mean by the vaguely used word *interactive*; the remaining two properties help to make digital creations seem as explorable and extensive as the actual world, making up much of what we mean when we say that cyberspace is *immersive*.” (Murray 1997: 71) To generate virtual environments that will allow users to move beyond passive viewing, compelling levels of both immersion and interaction must be achieved through a combination of computing power and informed design that leverage the unique properties of digital environments.

For the development of immersive historical landscape reconstructions, achieving a sense of presence can be an important component in conveying the qualitative aspects of meaning that make a place unique. If users can become immersed within a virtual landscape to the extent that they perceive themselves as being present within the landscape, the experience of exploring and interacting with the virtual environment can, in fact, foster a sense of place. By augmenting the virtual reconstruction with embedded spatial multimedia that provides additional information about various additional aspects of the landscape, it is possible to enhance the user’s experience without undermining the perception of being present within a virtual world.

To explore the design and development of an immersive virtual landscape capable of providing a platform for an experiential approach to exploring and understanding past places, a number of approaches are possible. The first approach involves extending existing GIS and geovisualization functionality to generate a virtual reconstruction that incorporates complex landscape elements, such as 3D models of structures and vegetation. In addition to graphical landscape features, the GIS-based virtual environment will also require camera navigation that allows a user to explore the landscape from a first-person perspective. The GIS-based approach will also require the availability of software customization tools to develop functionality for embedding spatial multimedia and other functions that foster immersion and interactivity. The following chapter discusses the design and implementation of a GIS-based virtual landscape reconstruction, utilizing a historical urban landscape as a case study.

Chapter 4 A GIS-based approach to immersive virtual landscapes

The previous chapter discussed the potential for an immersive virtual landscape reconstruction as a platform for exploring an experiential approach to understanding historical places and landscapes. The development of such a platform can be a daunting task, especially for domain experts in history or other humanities disciplines who are unfamiliar with computer software customization and development. However, for researchers who are well-versed in standard GIS software, a number of tools and development environments are readily available to design and test prototype applications and extensions. Consequently, initial efforts in this research to develop such a system focused on extending standard GIS interfaces and functions to incorporate mechanisms for visualizing and exploring a virtual historical landscape, building on previous work in this area (Harris and Rouse 2001; Bergeron 2004).

Morgantown, West Virginia case study

The main goal of the case study was to develop and implement a virtual reconstruction of a historical landscape using GIS data and 3D models that could be used as a platform for exploring that landscape. After consideration of several possible case study sites, the late nineteenth century urban landscape of Morgantown, West Virginia was selected as a case study. A number of factors contributed to the selection of the Morgantown case study, including 1) Access to the Sanborn Fire Insurance Maps as a base layer for reconstructing the town's building footprint and street layout; 2) Access to GIS data sets for reconstructing the terrain and water features: 3) Access to a large collection of primary and secondary historical sources related to late nineteenth century Morgantown and the surrounding region, including historical photographs; and 4) the close proximity of the case study allowed easy access for data collection and quality checking of the completed virtual terrain and models.

The city of Morgantown, located on the Monongahela River in north central West Virginia, was established in 1785 when Zackquill Morgan laid out lots on 50 acres of his land between the river and Deckers Creek (Figure 4.1). Morgantown was an ideal location to take advantage of north-south travel routes along the Monongahela River, and have access to nearby natural resources such as timber, coal, and iron. To service the needs of settlers in the new territory, a number of small industries were established by local entrepreneurs. Mills were built at several points along Decker’s Creek and other waterways, and a number of foundries and iron works were established along Decker's Creek and the Cheat River to exploit local iron deposits (Core, 1979). The new settlement of Morgantown acquired a tannery, pottery kiln, stores, taverns, and other business enterprises centered in the area just north of Deckers Creek and east of the Monongahela River. As the town became more prosperous, settlement spread outward from the original planned town to areas east and south of Deckers Creek, especially after the construction of a turnpike from Morgantown to Fairmont (Callahan 1926; Core 1979).

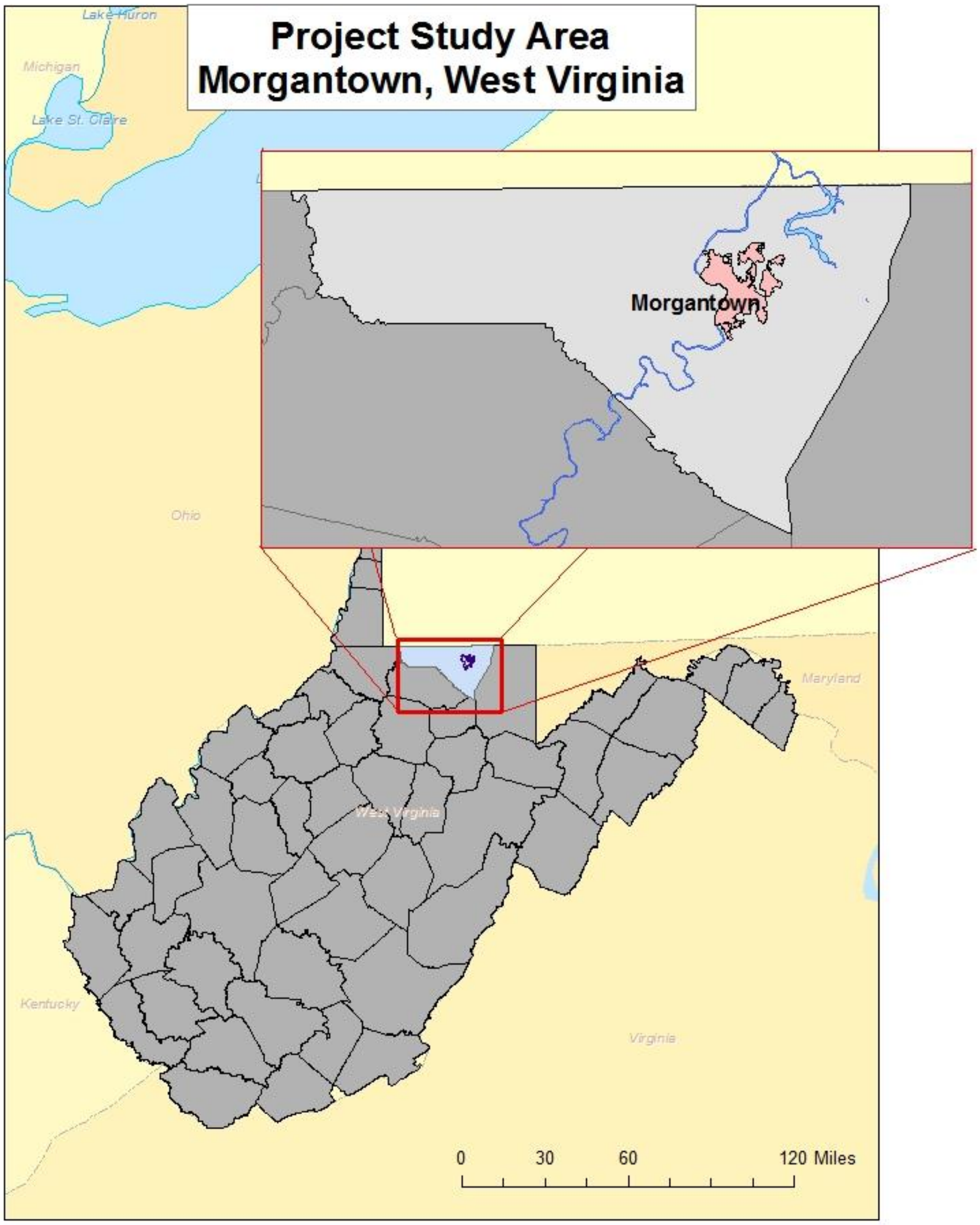

Figure 4.1. Project study area - Morgantown, WV

Between the1880s and the 1920s, Morgantown experienced rapid economic growth and increased prosperity associated with the industrial revolution in West Virginia, and its riverfront became the industrial heart of the city. A number of glass factories were established along the Monongahela River and the main railroad line linked the mills, warehouses and other industries already located there. In addition, the rapid growth of the coal and gas industries in the region spurred industrial development, and the rapid influx of capital and banking (Mazgaj 1997). In a few short decades, Morgantown was transformed from a relatively small agricultural center to a successful regional industrial and commercial center. In more recent years, many of these structures have been lost as the city has undergone urban regeneration.

Design Considerations for the Virtual Morgantown reconstruction

The initial GIS-based Virtual Morgantown reconstruction was designed around the utilization of an existing GIS platform with 2.5D/3D visualization capabilities, and extending those capabilities to incorporate functionality that would provide a greater sense of immersion and presence. The GIS-based Virtual Morgantown design was centered around an existing GIS software platform, ESRI's ArcGIS, and its 3D visualization module, ArcScene. ArcScene is a 3D viewer application embedded within the ArcGIS platform, and provides out-of-the-box functionality to add and display GIS data layers in 2.5D. ArcScene provides simple navigation tools that allow the user to fly over a 2.5D scene, as well as zoom and explore the scene in a simulated 'walking' mode.

The physical landscape of the Virtual Morgantown reconstruction was developed from GIS data layers for elevation, ground cover, and hydrography. Elevation data was derived from a LIDAR data set for Morgantown, West Virginia acquired in 2002. The raw LIDAR elevation points were converted into an ESRI GRID raster data set with 2-meter pixel resolution to generate a bare earth surface for the downtown Morgantown area. Although the raw LIDAR data could provide a finer resolution DTM, the elevation raster was generated at 2-meter resolution in order to maintain an optimal file size for the output raster. The LIDAR elevation dataset represents modern-day topography, but since the study area's urban character was already well developed by 1900, many portions of the downtown have retained the same building footprints and street alignments as the current urban landscape (Sanborn 1899).

Once the topographic layer was completed, building footprints, lots, and street surfaces were digitized from the Sanborn Company's 1899 fire insurance maps for Morgantown, West Virginia. (Sanborn1899). Each Sanborn sheet was georeferenced using modern reference imagery, and separate vector polygon layers were digitized for street layout, lot boundaries, and building footprints (Figure 4.1). Using these layers as a reference, shapefiles were digitized to provide locations for trees, and for street furniture, such as streetlights The most complex portion of the ArcScene Virtual Morgantown project was the construction and placement of 3D models representing the built structures including houses, commercial buildings, outbuildings, railroad, and the suspension bridge spanning the Monongahela River. The first step in this process was the digitization of individual building footprints as polygon shapefiles, utilizing the ArcMap editing

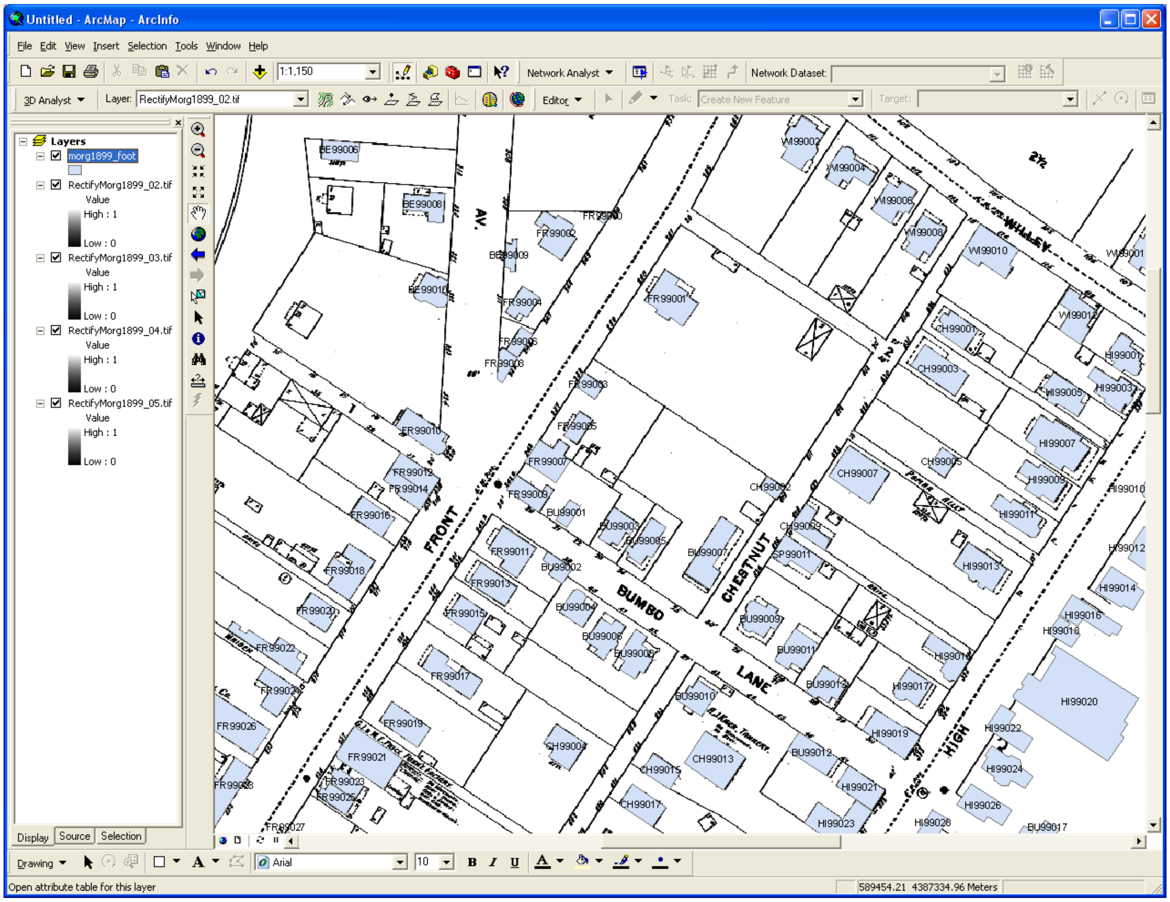

Figure 4.2. Detail of digitized building footprints

environment. Each building footprint was digitized as a single polygon, and assigned a unique identifier in the “BuildingID” attribute field. An alphanumeric code was used to generate this identifier, where the first two digits represented a two-letter abbreviation for the street name, followed by a two-digit abbreviation for the year of the Sanborn map set, and a three-digit identifier for an individual structure. For example, FR99001 would denote a structure on Front Street (FR), with a footprint digitized from the 1899 Sanborn (99), and its individual identifier is 001.

The 3D building models were then individually generated in @Last Software’s SketchUp Pro 5.0 (now Google SketchUp). To construct each model, the unique footprint polygon was exported as a separate shapefile in order to utilize SketchUp's Shapefile Importer. The Shapefile Importer preserved spatial orientation information, which simplified placement of the completed models. Once the footprint was successfully imported into the SketchUp environment, the building outline was digitized as the base for the model, and the shell of the building was constructed. SketchUp 5.0 provided a library of textures that could be applied to the render the models and to simulate materials such as wood and brick, as well as paint colors (Figure 4.2). Each building's textures were determined by available information about that structure, including historical and modern photographs, Sanborn symbology, text descriptions, other sources, or extant buildings of similar type and age. In addition to material textures, SketchUp's component libraries provided pre-built windows, doors, and other architectural elements that could be applied to the building models.

Once the 3D building models were completed in Sketchup, they were imported into the ArcScene virtual landscape. Due to the large number of structure models, over 400, a number of methods were explored for loading and displaying the 3D models without overwhelming the ArcScene program. Associated attribute information for each model also had to be maintained within the virtual scene. Consequently, the most common method for importing and displaying 3D models within the ArcScene environment, as a multipatch graphic, was not viable for the Virtual Morgantown project. A new workflow for loading and displaying the 3D models was developed, utilizing a point shapefile to store point locations for the centroid of each building and with a BuildingID field to store each model's unique identifier. With this method, relevant information for each building is stored within the shapefile's attribute field, and editing and analysis could be performed on selected features when necessary. To display the models themselves, the ArcGIS custom style gallery functionality was utilized, which allows the user to assign custom 2D or 3D symbols to a feature within a shapefile or feature class.

A new custom style gallery was created within the ArcGIS Style Manager, with each feature's BuildingID used as the identifier. Then, each 3D model was imported into the Style Gallery as a 3D Marker symbol. The buildings were checked for errors and adjusted to the appropriate scale if necessary. A unique identifier was assigned. (Figure 4.3). The same procedure was used to upload models for streetlights, and for individual

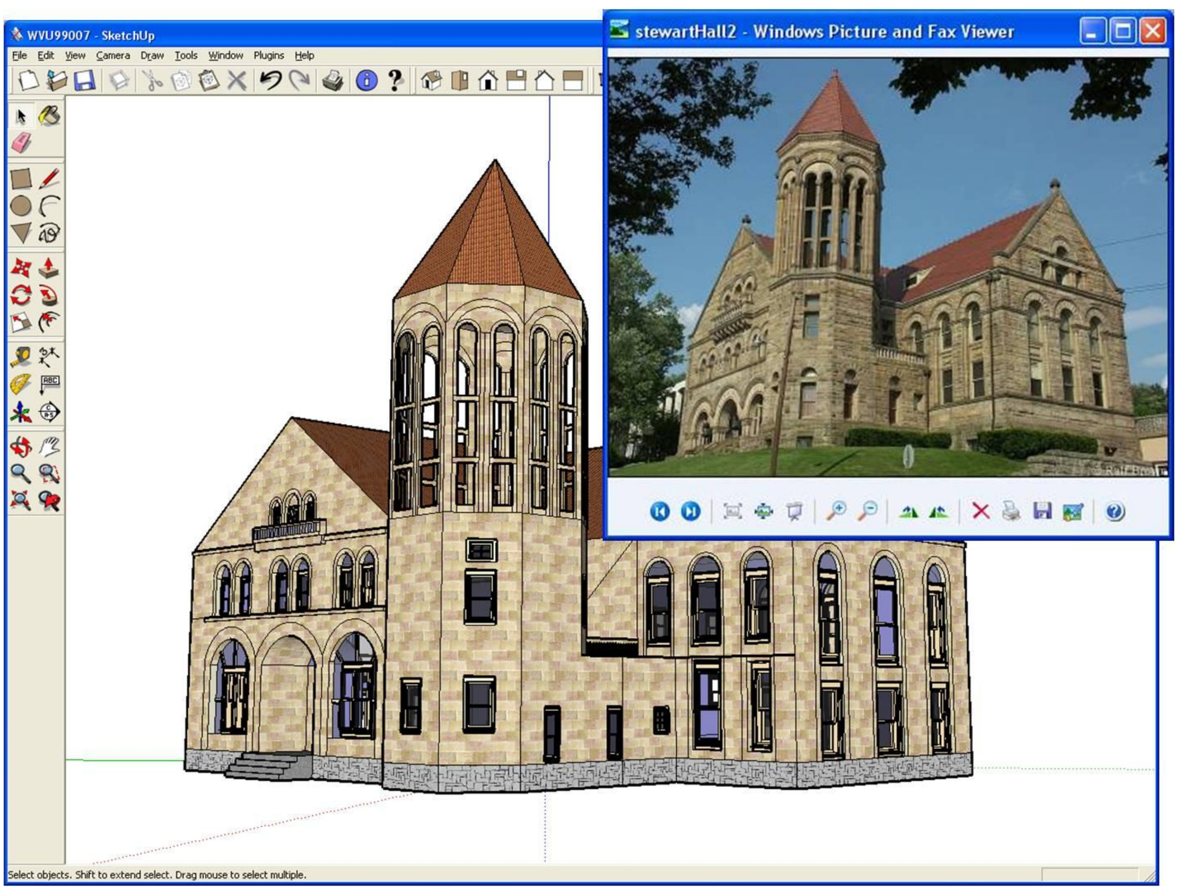

Figure 4.3. Textured building model

tree species models within the Vegetation shapefile. Once the custom style galleries were completed, they were used to load and display the 3D models within any ArcScene project that contained the building centroid shapefile as a layer.

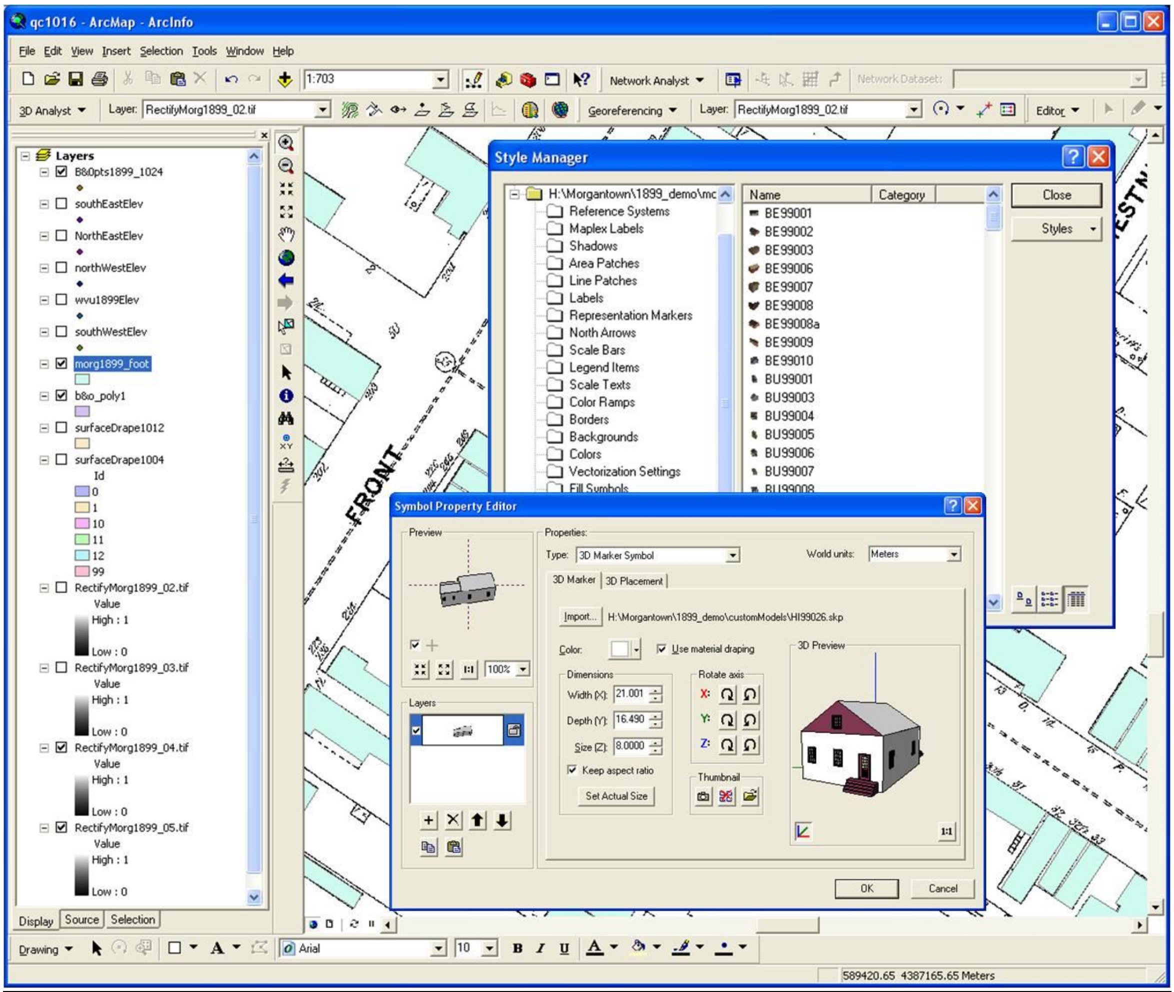

Figure 4.4. Adding a 3D model to custom ArcGIS style gallery

Building the Virtual Morgantown landscape

Once the GIS layers and custom style galleries for 3D models and vegetation were completed, the layers were loaded into the ArcScene environment to generate the full virtual landscape scene. The first step was to load and to set the 3D display properties for the raster terrain layer. The raster ground surface texture layer was then added and ground cover texture properties were set. The 3D point shapefiles for trees, and street furniture were added and each layer's custom 3D style gallery was imported to load and render the 3D models (Figure 4.4). Finally, the 3D building model shapefiles were added, and the custom style gallery imported to load and render the buildings and other structures (Figure 4.5).

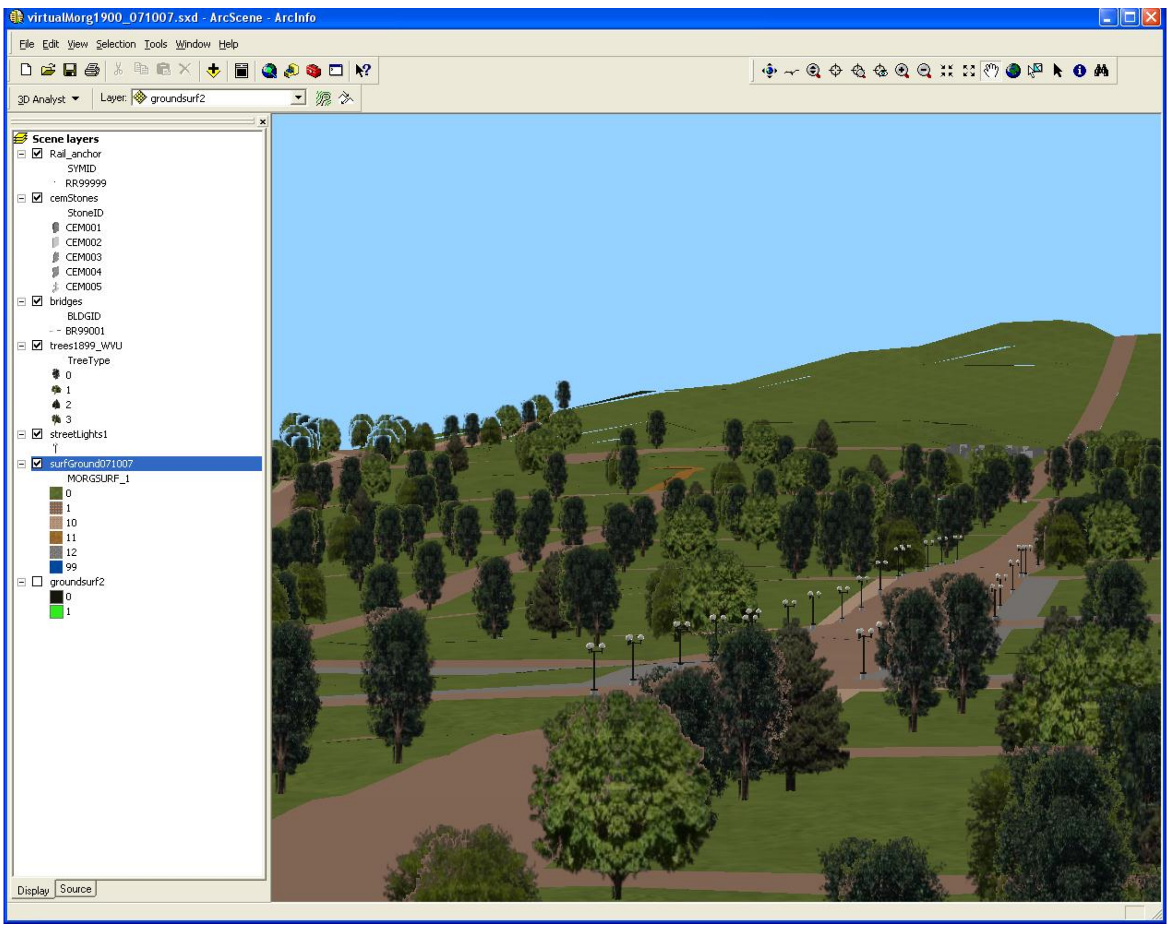

Figure 4.5. Terrain, vegetation, and street furniture in ArcScene

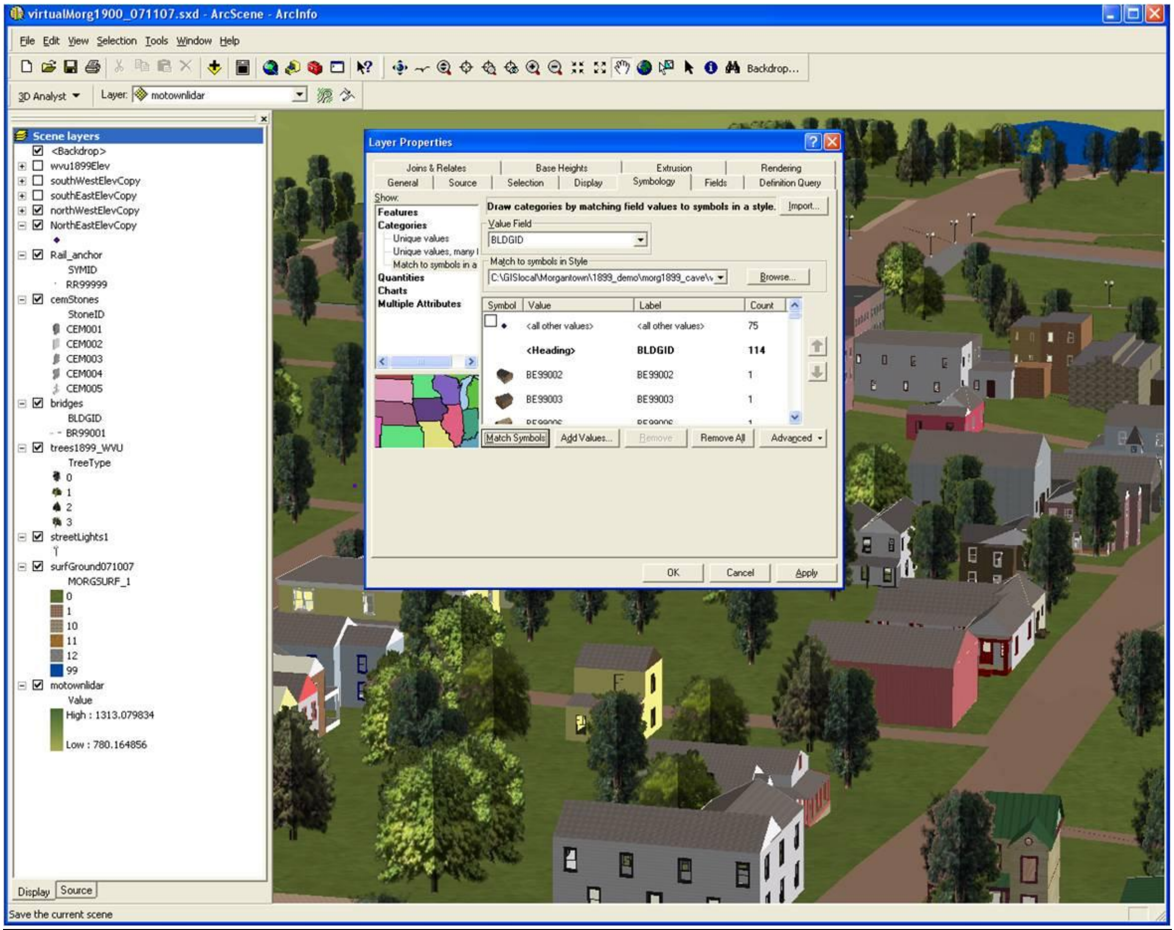

Figure 4.6. Loading custom 3D building models in ArcScene

The completed ArcScene virtual landscape was then quality-tested to check for the accuracy of elevation values for each feature within the virtual landscape to be certain that each model intersected the terrain at the appropriate height and did not float above the terrain or render too far beneath the surface. Adjustments to elevation values were made as necessary. This proved to be a time-consuming task, as minor differences in height that would not be readily apparent in a typical flyover view became quite prominent at ground level. Each model was also checked for errors and rendering issues, and corrected if necessary. Once the final adjustments and scene properties were set, the Virtual Morgantown project was saved as an ArcScene document (Figure 4.6).

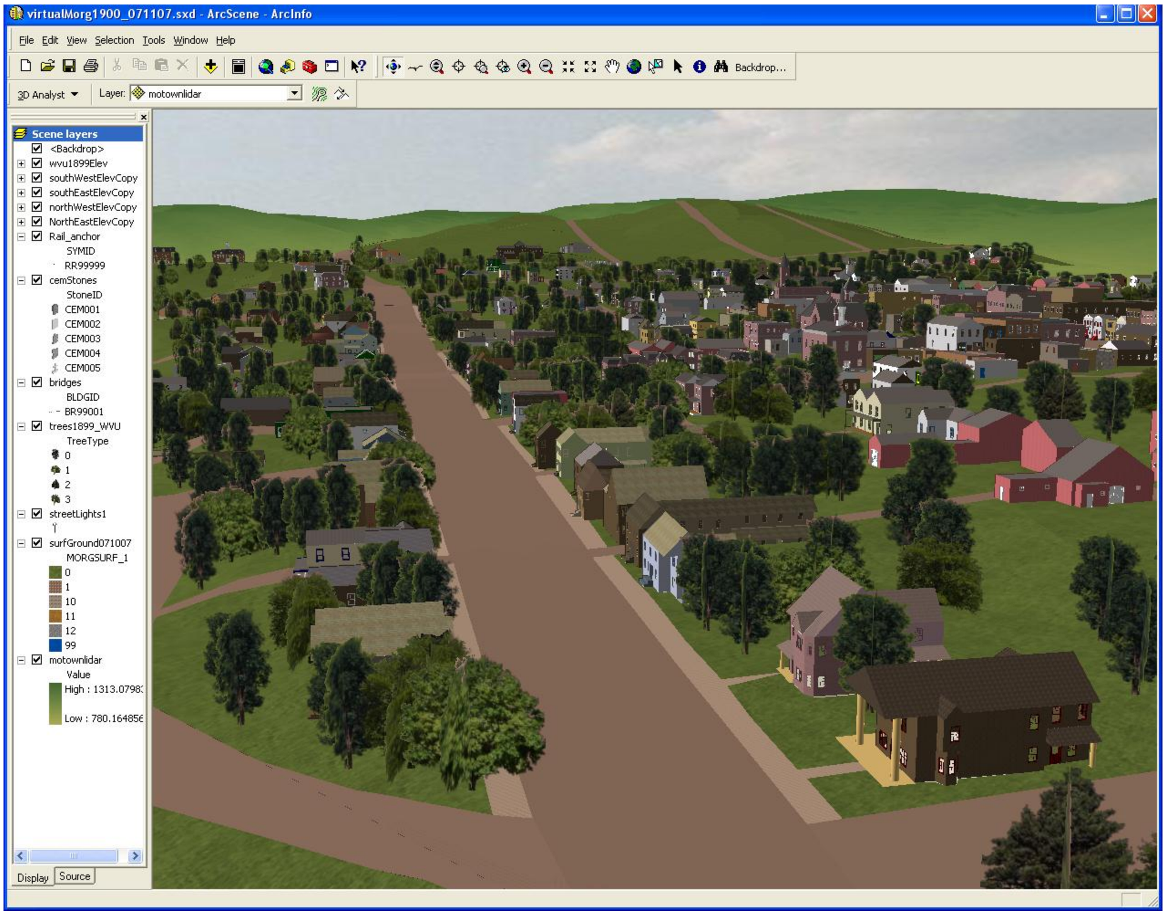

Figure 4.7. Detail view of completed Virtual Morgantown in ArcScene

Spatializing historical information

The completed ArcScene reconstruction of the early twentieth century downtown Morgantown landscape offers a detailed, scalable visualization of the physical and urban landscape and allows users to explore individual elements of that landscape utilizing the navigation tools of the ArcScene interface. However, the standard ArcScene platform does not allow for the integration of additional media and information that are an important part of understanding the historical landscape of Morgantown. Consequently, additional custom functionality was required in order to provide users with spatialized multimedia within an ArcScene virtual landscape.

Developing custom ArcScene functionality

To embed additional information about Morgantown's historical landscape as digital media within the virtual landscape, the existing functionality of ArcScene was enhanced through the development of a custom extension to allow the display of spatialized multimedia within the ArcScene viewer interface. Although ESRI's ArcGIS software offers a powerful suite of GIS and visualization tools, ESRI recognizes that users across a broad spectrum of disciplines have different needs and requirements. Consequently, the ArcGIS software can be customized and extended through a suite of development tools and code libraries called ArcObjects. The ability to create custom functionality using ArcObjects was an important factor in utilizing the platform for designing and implementing a GIS-based virtual landscape reconstruction.

To develop a mechanism for the display of embedded spatial multimedia within the Virtual Morgantown scene, a custom ArcScene extension was developed based on Microsoft's Visual Studio application development environment and the Visual Basic coding language. These development tools readily interface with the ArcGIS environment, and offer numerous resources to aid developers in writing custom functionality. Custom ArcGIS applications and extensions can be tested within the development environment without corrupting the GIS installation.

The custom 3D Info extension for Virtual Morgantown was designed around the concept of a pop-up window as the main display mechanism for embedded spatial multimedia, such as text, photographs, audio, and video. Written in Visual Basic coding language and embedded within the ArcScene interface, the 3D Info extension can be utilized by any project with the appropriate data layers. When the extension is enabled,

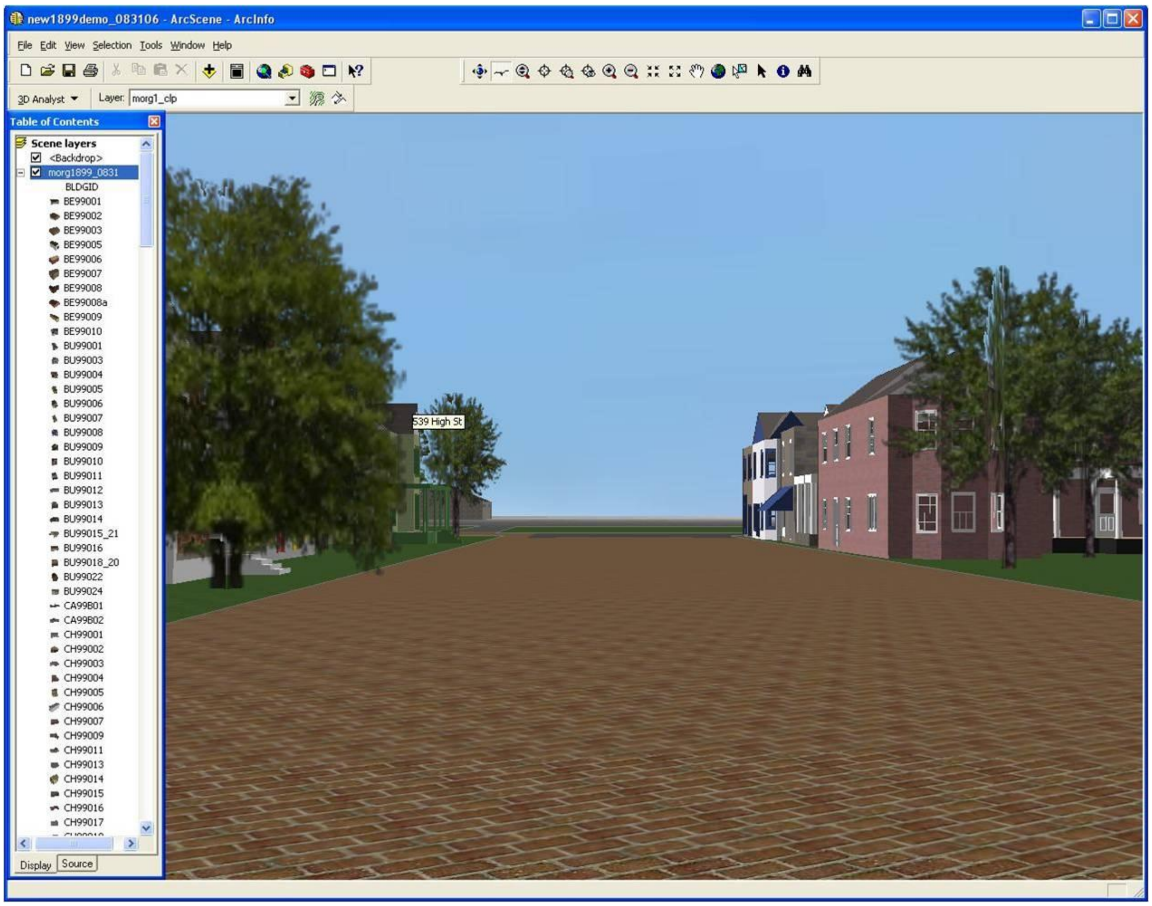

Figure 4.8. Pop-up Info window displaying text

the user simply approaches a feature of interest, such as a building, and an info window pop-up occurs within the 3D scene and displays attribute information and digital media related to that feature is made available (Figures 4.7-4.9). The info window is triggered utilizing a buffered distance around the feature and around the virtual camera that controls the user's viewpoint. When the camera buffer intersects the feature buffer, a collision is detected and this triggers the display of the popup window. Collision detection is one of the most basic event triggers in 3D graphics applications.

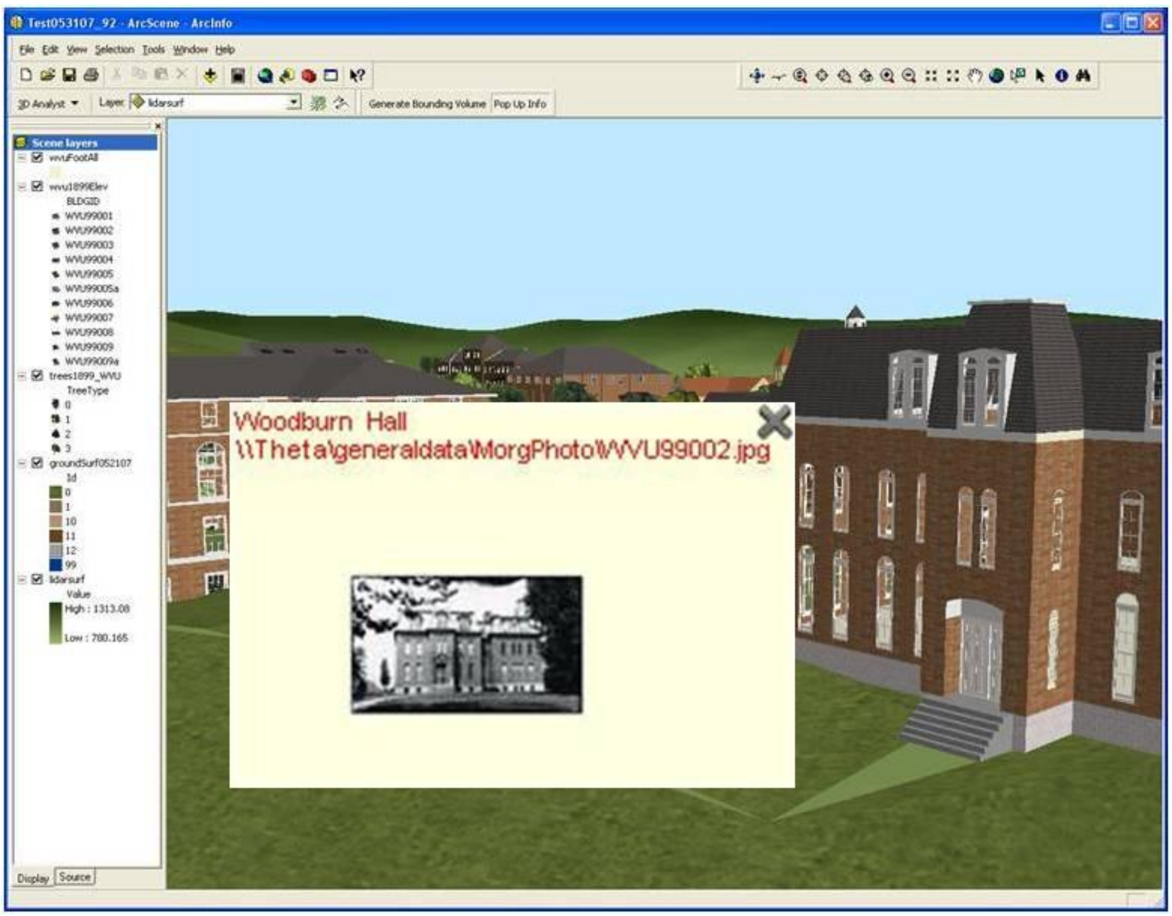

Figure 4.9. Pop-up Info window displaying historical photo

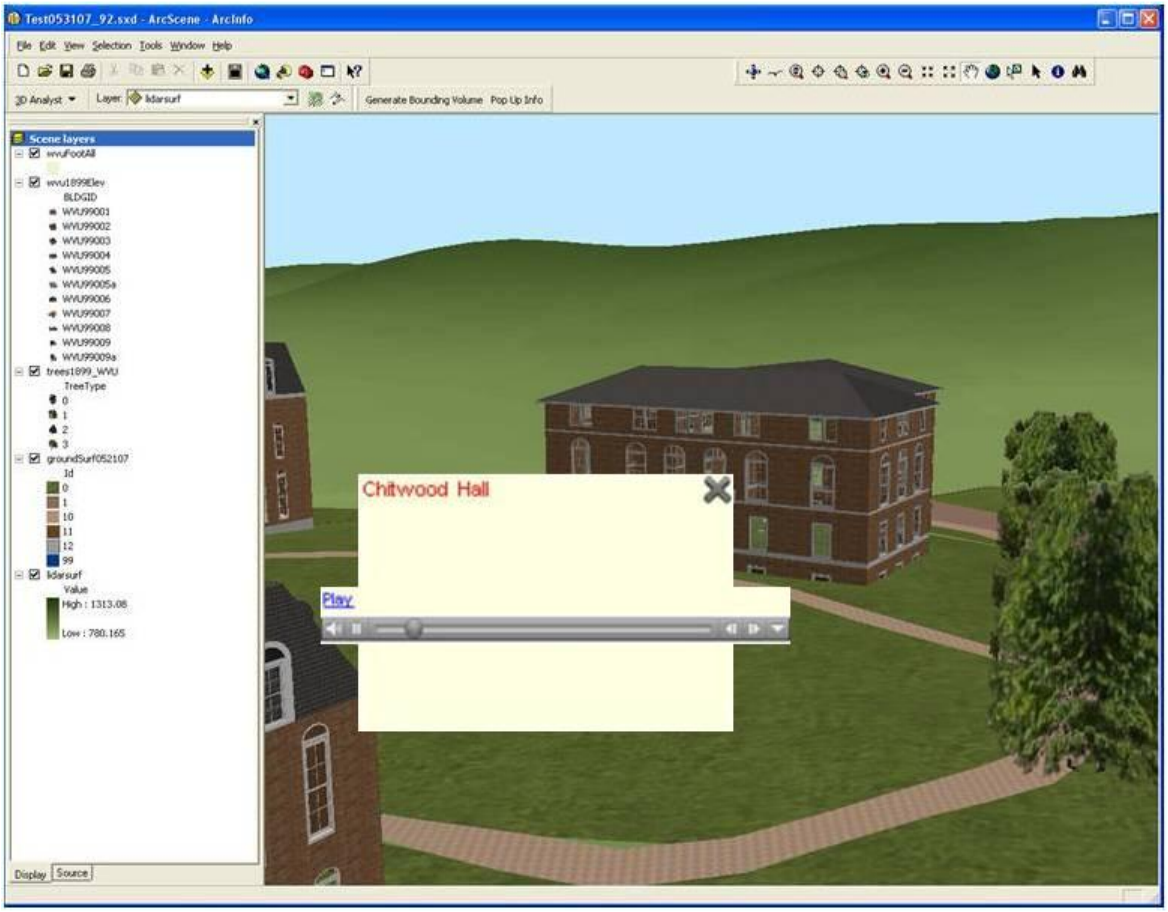

Figure 4.10. Pop-up Info window showing embedded audio clip

Assessing the GIS-based virtual reconstruction

The completed Virtual Morgantown ArcScene project was successful in demonstrating that mainstream GIS software functionality could be utilized and extended to generate a virtual reconstruction of a historical landscape. The completed scene allowed users to explore the digital landscape either by flying overhead in a bird's eye camera view, or by a ground-level first-person camera perspective. As users navigated through the scene in either mode, they were able to access multimedia at selected points that offered additional information about the historical urban landscape of Morgantown.

The goal of the project was to develop an immersive virtual landscape that could utilize representations of natural and human-made landscape features, coupled with realistic navigation and interaction, to foster a sense of immersion within the virtual landscape. While the first iteration of the Virtual Morgantown project demonstrated the potential of a GIS-based approach as a platform for building and exploring a virtual landscape reconstruction, a number of issues became apparent during testing of the completed scene. The Virtual Morgantown scene was able to convey some sense of the physical and cultural characteristics of the early twentieth century Morgantown landscape, but the level of immersion and interactivity was severely hampered by both hardware and software limitations related to the GIS environment. The number of features rendered within the virtual landscape, including over 400 structures, the associated vegetation and the physical topography proved taxing to the ArcScene viewer, and this greatly limited the speed and performance of navigation within the full scene. Any degradation or latency in scene display or navigation immediately impacts the immersive experience for a user. Such was the case here.

These limitations were readily apparent when testing began on the full virtual landscape, and several procedures were developed to minimize the software issues and allow the Virtual Morgantown project to run. During the loading process, the ArcScene environment loads and renders symbols for each layer at the same time, and would become unstable if too many custom symbols were loaded all at once. In addition, the Virtual Morgantown project load time was nearly 20 minutes in its first iteration, much longer than typical ArcScene documents.

To alleviate these issues, the building layer was divided into five separate smaller shapefiles, Northwest, Northeast, Southwest, Southeast, and the West Virginia University campus to reduce the number of custom 3D symbols that any one layer would need to load. In addition, the scene document was saved with the 3D building layers turned off. This allowed ArcScene to load and render the terrain, ground surface, and vegetation layers first. Then, the four building layers were turned on one at a time, allowing the 3D symbols to load and render in much smaller batches.

The performance limitations of the ArcScene environment also impacted the navigation of the virtual landscape as the ArcScene viewer was limited in its ability to quickly and smoothly render the scene as the camera view changed. Since a seamless movement is a critical aspect of creating a sense of immersion within a virtual environment, the rendering performance issues within ArcScene considerably limited the effectiveness of a complex virtual reconstruction. When the GIS-based Virtual Morgantown was tested within a collaborative CAVE Virtual Reality environment (Figure 4.11), users offered positive verbal feedback on the overall impression of the virtual landscape, but readily noted the issues with navigation and rendering lag.

The CAVE is a virtual reality platform that is designed to increase the sense of immersion by utilizing large screens to surround the user with the visual elements of the virtual landscape. The effect is further enhanced by the use of hardware and software functionality that simulates a 3D perspective to place the user within the virtual scene. Audio and other sensory input can also add to the sense that the user is immersed within a virtual world (Cruz-Neira, Sandin, and DeFanti 1993). The CAVE environment, then, is an excellent test bed for virtual reconstructions such as the GIS-based Virtual

Morgantown, as it not only provides users with a number of visual and sensory aids to help foster a sense of immersion, but those same cues also allow users to easily discern aspect of a virtual scene that detract from the immersive quality of the experience.

Figure 4.11 GIS-based Virtual Morgantown in CAVE

Alternative visualization platforms

To improve the virtual Morgantown and to overcome some of the deficiencies noted above, a series of alternative geovisualization platforms were explored that might substitute for the ArcScene engine. Within the last five years, a number of technologies have built upon traditional GIS-based visualizations in the form of virtual globes, the most well-known example being Google Earth (Google 2010). Built around a small desktop rendering and viewing application for data streamed via the Internet, Google Earth incorporates many of the tools and ideas discussed in the previous chapters, but does have significant limitations as a tool for an experiential approach to historical landscapes. Like other virtual globe applications, Google Earth is built around a top-down perspective, so users can begin with a full zoom-out view of the Earth and zoom-in to areas of interest, with the level-of-detail becoming finer as the area displayed becomes smaller (Figure 4.12). However, Google Earth is designed to be navigated by flying over

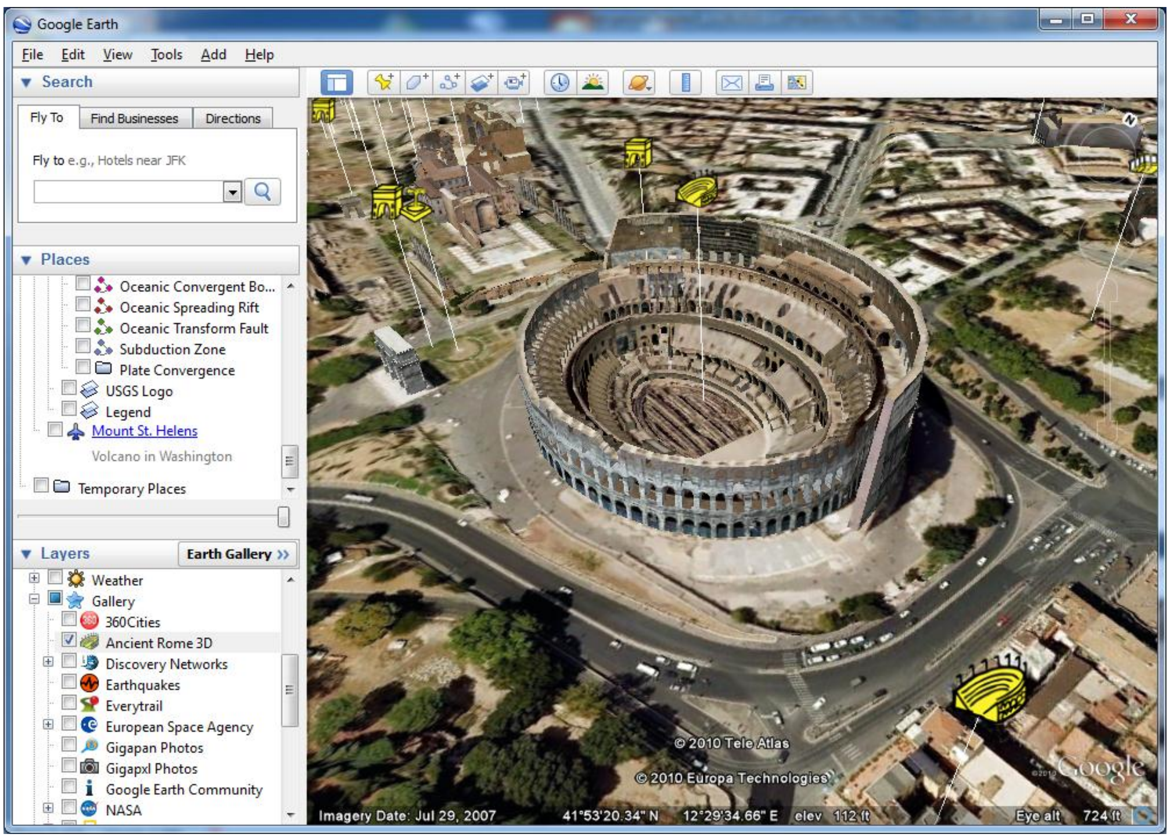

Figure 4.12. Detail of Google Earth showing 3D model of Roman Coliseum

the landscape and if a user were to zoom in close enough to try to simulate a walking experience through a place they would notice that the landscape elements are very coarsely rendered and do not provide a realistic visual representation of the landscape (Figure 4.13).

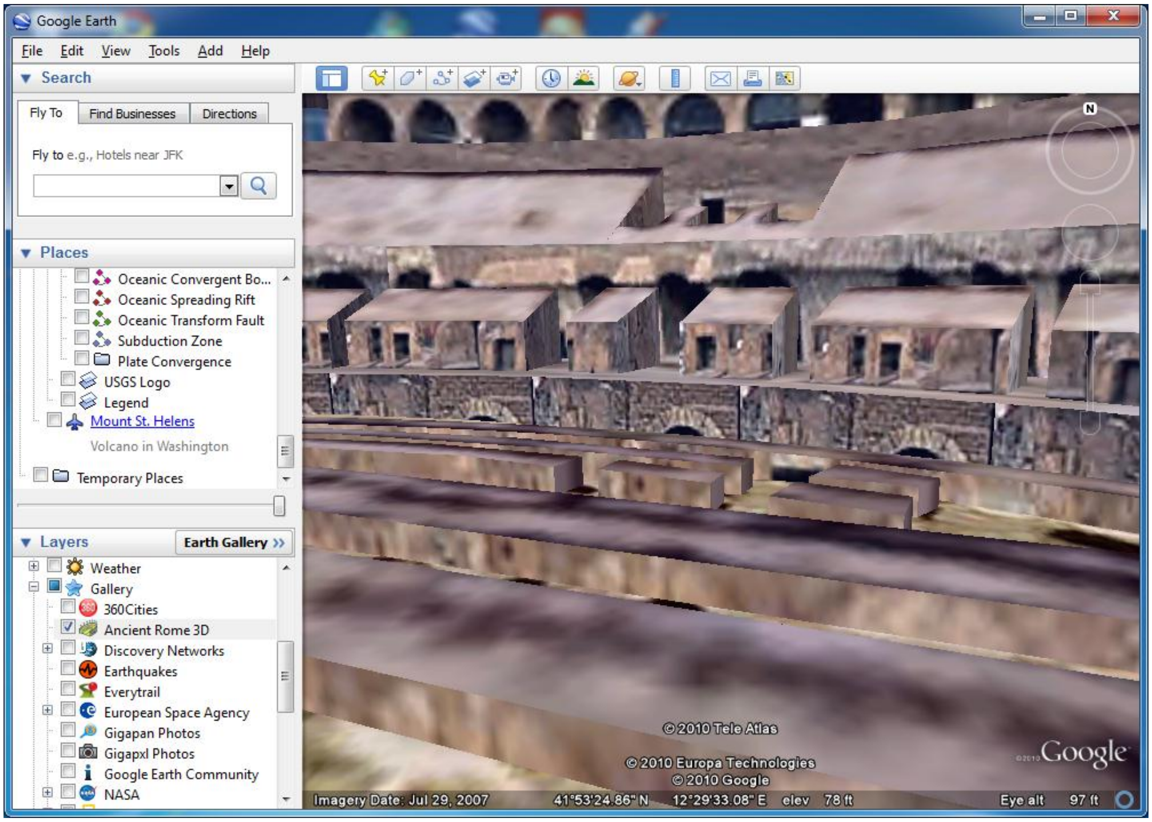

Figure 4.13. Full zoom of Google Earth Roman Coliseum model showing blurred textures

Google Earth and other virtual globe applications have also demonstrated a number of ways in which multimedia information can be spatialized and embedded within a virtual landscape. A number of projects focused on historical landscapes have utilized Google Earth's KML format to create spatialized multimedia, providing users with additional information that helps provide details about locations that can contribute to evoking a sense of place. For example, the Nez Perce Historical Trail project includes locations related to the US cavalry's campaign against the Nez Perce Indians during the summer of 1877, as well as other historical events in the Nez Perce's history such as their encounter with Lewis and Clark (fs.usda.gov/npnht). When a user clicks on an icon for a location along the trail, they may see text descriptions of the location's significance as well as embedded multimedia such as photographs of the location (Figure 4.14).

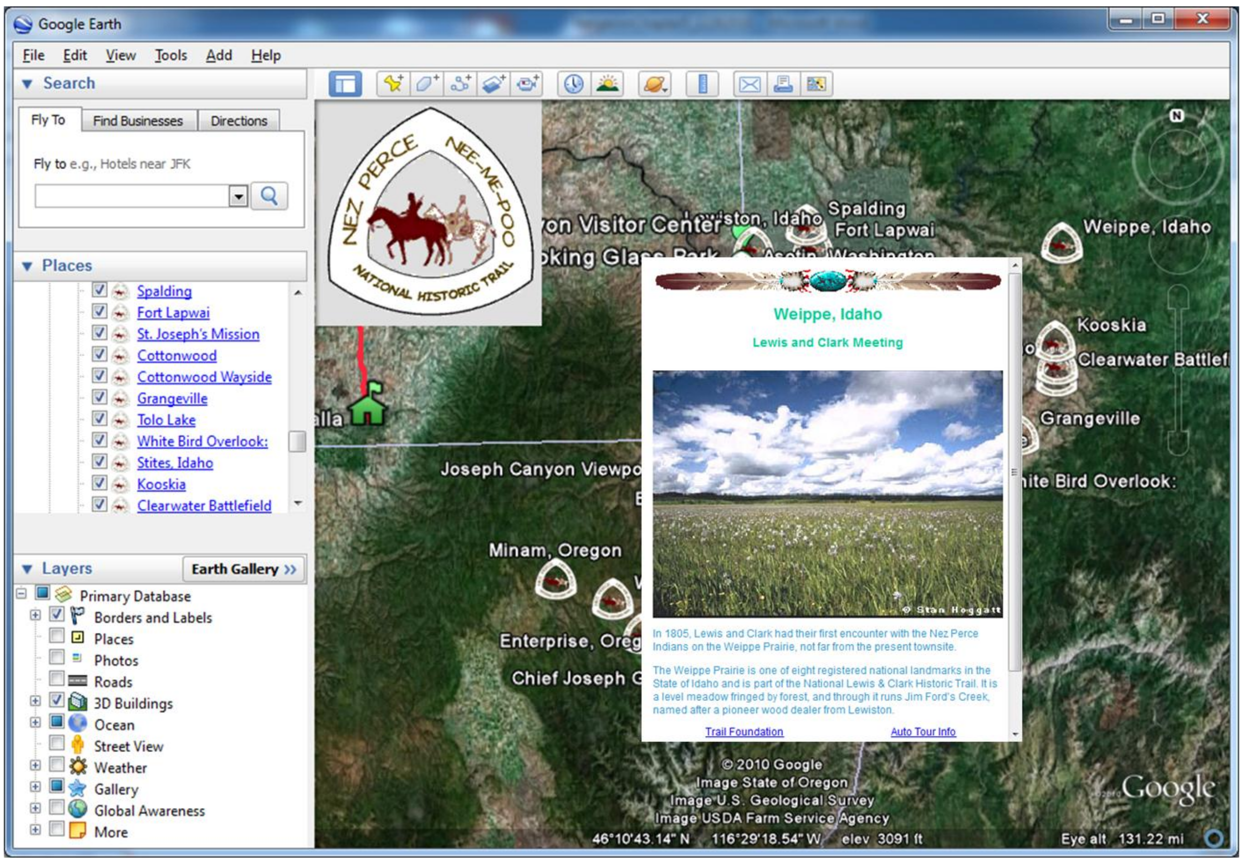

Figure 4.14. Screen Capture of Nez Perce Historical Trail content in Google Earth

There are now a number of examples of projects that utilize Google Earth and Google SketchUp, as well as other virtual globe technologies, to model historical structures and landscapes with tagged embedded multimedia and associated information, such as hyperlinks to websites (http://www.ritsumei.ac.jp/acd/cg/lt/geo/coe/; While these projects are an important resource for audiences to virtually explore landscapes that they could not physically visit, they are limited by Google Earth's technology and cannot provide the level of immersion and interaction that more advanced game-based technologies can offer. Serious gaming engines were thus examined as a possible virtual geovisualization platform.

Chapter 5 – A serious game-based approach to virtual landscapes

Although video games have long been seen as entertainment for children and young adults, a growing field is focused on utilizing the concepts and technology of the gaming industry to develop applications for training, simulation, and education across a range of industries and fields. Known as “serious games,” these initiatives represent cutting-edge efforts to bring the latest computer graphics hardware and software, including virtual reality, to users in government, education, and industry who are often engaged in specialized and even potentially dangerous training and simulation exercises. The term ‘games’ or ‘gaming’ is in fact a misnomer here, and has contributed to a diminished respect for the potential of serious gaming approaches in education and research. In reality, the graphics, speed, and real-time rendering of complex environments provide powerful tools for representing real-world elements and processes. For example, agencies that engage in risky training can benefit greatly from realistic, immersive game environments that simulate high-stress, real-world situations without putting trainers or trainees at personal risk of injury. Serious gaming is also gaining support and funding as the current generation of young gamers mature and enter the workforce in a wide range of fields that utilize advanced technology. Since many are already familiar with video games and gaming worlds, serious games can be an effective training tool in the workplace, as well as in the classroom (Aldrich 2009).

Increasingly, educators and researchers in a number of disciplines are thus recognizing the potential power of videogame technology as tools for representing and conveying knowledge, and for decision making (Corbett and Wade2005; Shepherd and

Bleasedale-Shepherd 2009; Champion 2011) . For some, however, the term “serious games” is problematic, as the reference to games seems to undermine the sense of academic rigor and scholarship that is a crucial component of the development of such applications. In addition, while some researchers incorporate the mechanisms of gameplay, such as goal-oriented or competitive tasks, within their projects others focus on aspects of gaming technologies that are not strictly ‘game’ theory-based, such as advanced graphics and physics for virtual world-building. Consequently, not all uses of the technology behind video gaming are actually games (Champion 2011; Aldrich 2009). To better characterize the application of gaming technology in non-game applications, new terms such as ‘Immersive Simulation’ are being coined to describe these efforts to utilize the advanced graphical, navigation, interaction, and physics simulation capabilities developed for video games, without necessarily creating actual game scenarios (Aldrich 2009).

The key aspect of these technologies is to provide compelling immersive visual experiences. In addition to representing increasingly realistic virtual landscapes with realistic ground object surface textures and lighting, gaming environments also enable researchers and scholars to build highly interactive interfaces without sacrificing performance, and with relatively inexpensive and readily available consumer computing hardware. Users of these systems can be immersed in a virtual world landscape and use powerful game-based first-person perspective navigation tools and camera perspectives. Utilizing the same game functionality sounds, smells, and other sensory input that would be part of such landscapes can also be added such that users can *experience* phenomena that in combination creates a powerful sense of place. These sensory inputs can be augmented through the ability of gaming environments to model water movement, weather, and other physics-based aspects of the virtual world that are important components in contributing to a sense of interactivity and immersion (Mach and Petschek 2006).

As a result of these gaming advances, a number of recent historical projects now utilize the advanced visual graphics and interactive technologies that are modeled on state-of-the-art online gaming and virtual world environments, such as Second Life or World of Warcraft (Linden Labs 2010; Blizzard 2010). These immersive virtual reconstructions of historical landscapes offer rich visual and interactive experiences by drawing heavily on videogame technology with their high-resolution graphics and interactive elements that are so readily familiar to videogame players. Perhaps one of the most impressive applications of this technology in a historical project is IBM's *Beyond Space and Time: the Virtual Forbidden City* (IBM 2010), which recreates the historical and cultural landscape of China's Forbidden City in Beijing. The Forbidden City, as the home of China's imperial family and court, was for centuries only accessible to a few Chinese and outsiders. Today, the Forbidden City is an important cultural monument and portions of the complex are open to visitors as a museum.

However, even though the Forbidden City and its outstanding architecture and cultural artifacts are accessible to visitors, experiencing the Forbidden City in person is beyond the reach of most people. To share the rich cultural heritage of China's imperial past with the rest of the world, IBM partnered with the Chinese government and scholars to develop a virtual reconstruction of the Forbidden City, which was accessible via the Internet and onsite in Beijing (this site has recently been taken down and is no longer accessible). The Internet application is based on a lightweight desktop application which renders the virtual world, while data is streamed real-time over the World Wide Web (Figure 5.1).

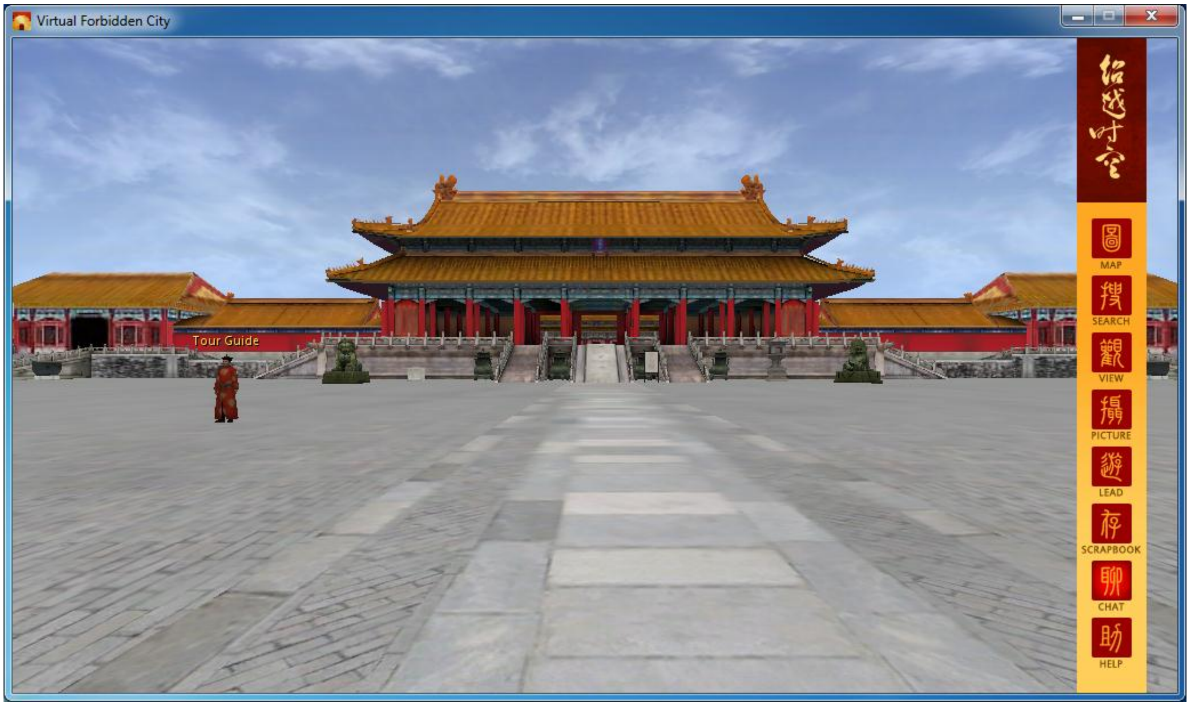

Figure 5.1. Screen Capture of Virtual Forbidden City 3D virtual landscape

The Virtual Forbidden City simulation moves beyond rendering a virtual landscape, and provides interactive elements to foster the user's sense of immersion and presence. For example, when a user virtually visits the Forbidden City for the first time, they are asked to select an avatar to represent them as they navigate the virtual space. This avatar, which can be male or female, is dressed in historical Chinese attire, a design characteristic to help the user feel familiarized within the virtual landscape by taking on the physical characteristics of people who actually inhabited the Forbidden City in its past (Figure 5.2).

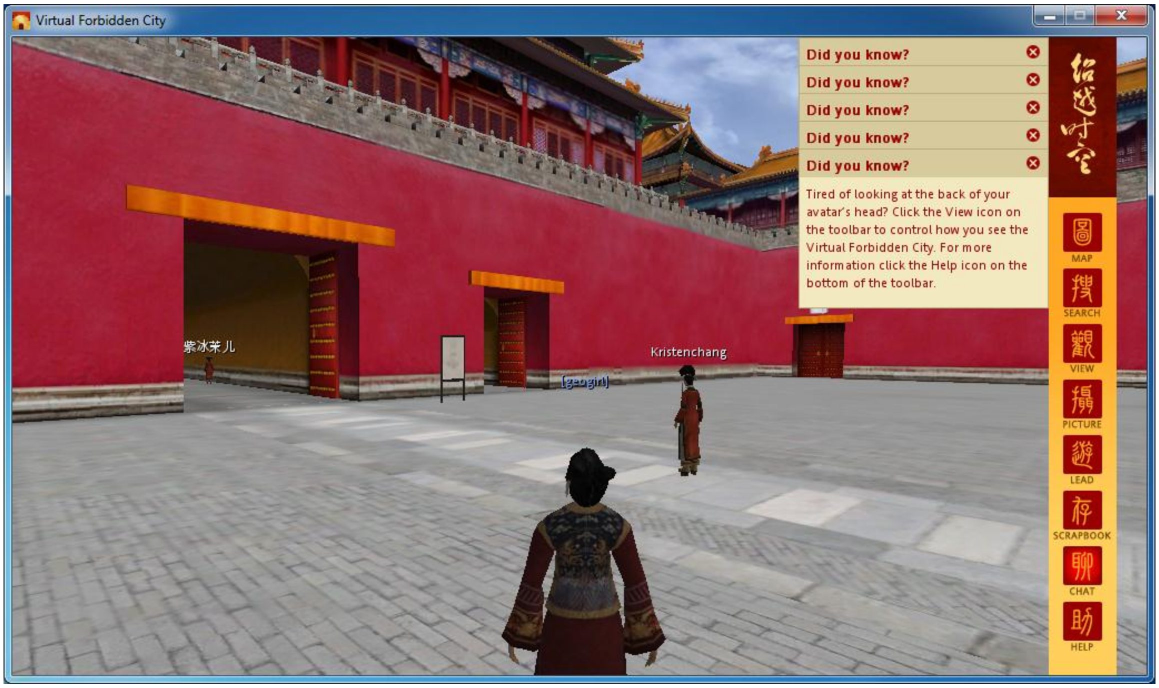

Figure 5.2. Screen capture of avatar in Virtual Forbidden City

In addition to its impressive recreation of the physical fabric of the Forbidden City, the Virtual Forbidden City also incorporates embedded media and information within the virtual scenes through the use of a heads-up display and other navigation tools. These elements allow the user to access additional information about the elements of the landscape or place as they navigate through the virtual environment.

Design Considerations for a Spatial Experience Engine

In addition to content then, a compelling immersive virtual environment for exploring reconstructed historical landscapes and places must meet a number of operational requirements in both design and implementation. Such a spatial experience engine must render high-resolution visual graphics quickly and smoothly, with no evidence of performance lag that can negatively impact a user's sense of immersion. In addition, a spatial experience engine should be capable of simulating other elements of the real world within the virtual environment, such as flowing water and other physics-based systems.

Gaming engines offer significant technological improvements over geovisualization platforms offered by traditional GIS software. These gaming engines, especially those that support a first person camera perspective, are designed to provide an intuitive user interface that permits users to view and interact within the virtual world and to feel that they are actually immersed in that world. The success of many commercial games depends heavily on this sense of immersion and presence. The navigation functionality utilized by gaming engines is mostly standardized in the industry, allowing users to develop general game skills that are transferable across a broad range of gaming and simulation platforms. The spatial data handling capability of GIS however still underpins the ability of the visualization to receive and display meaningful data content to the user.

The game 'engine' is thus critical to these systems. In computer software terminology, the engine comprises the software components that drive the functionality of a program, and provides graphics rendering, collision detection, timing, and user input. The 'engine' encapsulates the functionality that can be implemented across multiple applications. Simply put, a game engine is the software engine designed to support the development of video games (J. Gregory 2009). The engine provides interchangeable code for executing the functionality of a game, and is designed to be utilized across multiple gaming platforms that possess similar core functionality though with differing data input, design elements, and perhaps user interfaces. Examples of leading commercial 3D game engines include the Unreal engine, the Torque engine, and the Unity engine (Epic Games 2011; Garage Games 2011; Unity Technologies 2011). These, and other software game engines, have been used to develop both commercial 3D video games and independent research projects.

While there are advantages to utilizing existing commercial and open source 3D game engines in designing and implementing a spatial experience engine, there are limitations to the use of these existing turn-key engines. Most of these products are proprietary and very expensive to acquire and implement, requiring expert programming support, and the payment of licensing fees. Customized functionality can also be difficult and time-consuming to develop. Consequently, it was determined that the most effective solution for this project would be the design and implementation of a custom built spatial experience engine geared toward the functionality outlined above and as a platform for an experiential approach to exploring issues of historical place.

The design of the spatial experience engine focused on developing functionality in four core areas: 1) Rendering high-resolution and visually compelling virtual landscapes, that included terrain, vegetation, cultural elements, and physics-based dynamic systems such as weather and water movement; 2) Provide seamless and smooth, real-time navigation for a first-person camera perspective to enhance the user’s sense of immersion and presence; 3) Develop an event-driven functionality that included collision detection and provided a mechanism for interacting with elements of the virtual landscape and could trigger responses when the user was in close proximity to objects; and 4) Incorporate information representation and presentation within the immersive simulation, such as spatial multimedia, Heads-Up Display (HUD), and virtual tour guides. Each of these functionality areas are discussed more fully below.

Chapter 6 Developing the Spatial Experience Engine Functionality

A number of design insights were thus gained from the development and use of ArcScene and from a review of serious gaming engines. One of the most important features of an effective spatial experience engine is the ability to render both simple and complex landscape elements with a high degree of realism, without sacrificing speed and performance. To perform this critical function, the graphics rendering functions must be able to calculate changes in viewing angles and positions at many iterations per second, and redraw thousands or even millions of polygons accordingly in order to maintain a nearly seamless viewing experience for the user. This functionality is a core part of video gaming coding frameworks, and is a primary strength for utilizing game-based platforms over other visualization platforms such as GIS. GIS-based virtual landscapes often suffer from significant performance lag issues and unstable platforms. The design architecture for rendering and viewing graphics in these non-gaming systems was not optimized for real-time movement over a highly-detailed landscape, and the requirements for such reconstructions invariably overtaxed the computer hardware resources. By utilizing a serious game engine framework that is optimized for high performance graphics rendering, the spatial experience engine can be designed to handle large complex landscape data sets while maintaining appropriate performance levels.

To provide a realistic visual experience to the user, the rendering functionality of the spatial experience engine must handle complex texture mapping, as well as critical lighting and shading elements. Texture maps are image elements that are applied to the surface of a graphics shape or polygon and provide additional colors and visual features.

These texture maps are often utilized in 3D applications to give models and other landscape elements a realistic or visually appealing appearance. Texture mapping uses multiple layers of information embedded within an image and is often used to add elements such as a weathered or dirty appearance to the surface of a model. For this reason, texture mapping requires advanced graphics processing capabilities which are readily available in most recent game platforms but must be implemented in customized engines. The ability to create visual effects using changing light and shading elements also contributes markedly to the level of realism in rendering elements within the virtual landscape. Changing ambient light conditions can provide important immersive clues such as simulated time of day or changing seasons, and point lighting can be used to simulate man-made light sources within a landscape (J. Gregory 2009; Ervin and Hasbrouck 2001).

An immersive simulation environment that is dynamic is another major element in a compelling virtual landscape, and it is important for the spatial experience engine to incorporate functionality that can simulate the physics of a moving, changing physical environment. For example, when water is present in a virtual construction, it is important to simulate the natural movements of flowing water or wave action, in order to give the water a sense of realism. Likewise, the movements of clouds, smoke, and weather elements such as rain or snow can be simulated using physics-based particle systems (J. Gregory 2009). As a user explores the virtual landscape, these systems lend a sense of ambient movement and realism to the simulation that mirrors the dynamic nature of the real world and reinforces the sense of presence within an immersive environment.

In addition to the ability to simulate movement in a dynamic environment, it is important that the spatial experience engine have timing functionality: the ability for the immersive simulation, once started, to update as the user explores and interacts with the scene. This timing functionality is obviously an essential element common to 3D gaming platforms, and the application of those functions to the spatial experience engine will overcome a major shortcoming of the GIS-based approach to virtual landscape reconstruction. The ability to automatically advance time while the immersive simulation is running, and to move back and forth along a timeline offers a unique opportunity to represent and explore temporal issues within a spatial experience engine.

Navigating the Virtual Landscape

Within any virtual environment, the model that best simulates how visual elements are displayed on the computer screen and updated as the user explores the virtual landscape is that of a movie or video camera. The viewing perspective is rendered as if the camera is the user, and the controls, such as a game controller or keyboard, enable the user to move or to view the landscape or other visual elements while stationary. This interface model is used for most visualization applications, from data visualization to geovisualization to 3D immersive virtual environments and video games (J. Gregory 2009; Aldrich 2009; Ervin and Hasbrouck 2001).

A further key element in creating a compelling immersive virtual environment is the user’s experience in navigating and exploring the landscape through this camera perspective interface. Since we perceive our world in a first-person perspective, looking out and around us, it is essential that the spatial experience engine similarly and effortlessly provide this functionality. With traditional GIS and geovisualization technologies, this is a difficult task as these applications are designed with an interface that provides the user with a privileged top-down view. This top-down viewpoint often starts well above the landscape, giving the user an omniscient perspective that is outside or exogenous to the landscape itself. The user must zoom to ground level and, as with Google Earth, often a graphical display that was compelling from far away cannot maintain the high resolution rendering that may be required for achieving a deeper sense of immersion at close range. Google Earth's interface provides a good example of this issue, as the imagery overlays and 3D building models look impressive as the user flies over the landscape but become blurred and less distinct as the 'camera' approaches the ground surface.

By utilizing a gaming engine approach designed around a first-person camera perspective, the spatial experience engine overcomes the issues of a top-down 2D perspective. The spatial experience engine interface here is built around a first-person viewpoint, as if the user was at ground level walking through a virtual landscape. Only those parts of the scene that are visible to the user's viewpoint are rendered on the display, and the user must explore and navigate the virtual landscape in the same ways that he or she would use in wayfinding through a real environment. Consequently, this first-person perspective enhances the sense of immersion and presence that the user experiences when exploring a virtual landscape.

Interacting in the Virtual Landscape

Although the visual aspects of the virtual landscape are key components in creating a sense of immersion, the ability of a spatial experience engine to provide user feedback and to interact with the user is also crucial. Two types of interaction functionality are important within the virtual environment, and both are accomplished in the spatial experience engine via standard video game functions and collision detection. To reiterate, collision detection tests are performed many times per second as the user moves through a virtual landscape, and events are triggered by the user's proximity to, or collision with, a particular location or object in the virtual space.

The first major type of interaction with a virtual scene is through feedback when a user comes into close proximity to objects within the landscape. The expectation is that these objects will provide similar feedback as their real-world analogues. For example, as a user approaches a building in the virtual scene, the expectation will be that the object is solid and the user will not be able to pass through it. Or, as the user explores the landscape, he or she will not be allowed to navigate below the ground surface. If a collision with a proximity buffer is detected, the camera location will be reset to prevent further forward motion toward the object. This simple functionality is important to help maintain a sense of real-world behavior within the immersive virtual landscape.

The second type of interaction also utilizes collision detection and is focused on active interaction with specific objects that can provide information or otherwise enhance the user's experience. For example, as a user approaches an object or feature with associated information, the collision detection can trigger an appropriate response, such as displaying pop-up media, displaying an avatar, or playing an audio or video clip. This functionality provides information to the user while he or she is exploring the virtual landscape, without the need to pause or exit the simulation and break the sense of immersion.

Presenting humanities information in the virtual landscape

The key component of the Spatial Experience Engine that takes it beyond simply visualizing a virtual landscape reconstruction, and that addresses the goal of representing humanities information in such an immersive environment is the ability to embed multimedia within the simulation. This is accomplished in two ways through: 1) pop-up multimedia that display when the user is within close proximity to the location of the media's subject; and 2) textual and multimedia that is presented via a Heads-Up Display (HUD) which can display both continuous information or spatialized multimedia in specific locations.

The pop-up media functionality is modeled after information presentation mechanisms in a number of geovisualization applications such as Google Earth, as well as GIS-based systems discussed in the previous chapter. Digital humanities data such as historical photographs, images of primary sources, text descriptions, audio, or video can be assigned to specific locations relevant to their subject. As a user explores the immersive virtual landscape and approaches a location with relevant information, the multimedia can be displayed as a vertical billboard tied to that location. The billboard can rotate as the user changes camera orientation. Once a user moves away from the feature, the pop-up is closed. This passive method of displaying spatial multimedia requires no action on the user's part other than propinquity, and should not significantly lessen the user's sense of immersion and presence within the virtual landscape.

The second information presentation mechanism within the spatial experience engine is the implementation of a Heads-Up Display (HUD) that can be toggled on and off by the user. The HUD is essentially a partially transparent overlay that displays information but still allows the user to see and explore the virtual landscape behind it. This technique is a common information display platform in videogames, and is easily recognizable to game players. Unlike the pop-ups, the HUD can be displayed continuously, with information updating and changing as the user moves through the virtual landscape. Information displayed on the HUD can include real-time location coordinates, help messages, an overview map to aid navigation, and spatialized multimedia. When using the HUD, the display of these multimedia resources is still spatialized, and will be triggered only when the user is within close proximity to a subject. However, the media is displayed as part of the HUD framework and does not appear to be embedded within the landscape itself.

Each of these information presentation methods has advantages and disadvantages. By developing the spatial experience engine to accommodate both types of presentation, specific projects can be customized with methods that best represent the humanities information that the project designers are seeking to convey.

Application Framework

The final design feature and component for the spatial experience engine is the overall structure of the application, and its primary user interface. The application structure of the spatial experience engine incorporates basic elements of many videogame and simulation applications, and is designed around the concept of screens. The application is made up of a series of screens that are combined in a specific sequence for each individual project. There are different types of screens, and each acts as a 'container' for particular functions. For example, a menu screen contains the functionality to display a menu and trigger events when menu items are selected.

Following the model of a videogame level or stage (J. Gregory 2009; Aldrich 2009), most of the functionality of the immersive simulation itself is contained within a single screen, which includes the rendering of the virtual landscape graphics, interaction, updating, and timing. This screen-based framework enables the spatial experience engine to be highly customizable, as almost any number of screens can be added to the sequence. For example, additional virtual landscape screens could be added to an application to display other virtual landscape reconstructions that can be accessed via menu selections or other input. Other screens that display information or help for the user, or that trigger other functionality, can be loaded and accessed as needed through events triggered within the main simulation screen.

For each project, the appropriate spatial experience engine screens are added to the application, and placed in the correct sequence when the application runs. However, all applications should start with a Title Screen that identifies the title of the immersive simulation, and provides a Start prompt. The user then navigates through a series of information and option screens, which will provide additional information about the immersive simulation and offer the opportunity to customize settings if applicable. The display of background information through such screens is relatively intuitive, and even those users with no prior familiarity with video games should be able to advance through the screens with little difficulty.

Following these information screens, a user will be presented with the Main Menu screen, which offers menu choices to enter the immersive simulation, the view options and settings, or allows an exit from the program. When a user selects the option to enter the virtual world, the simulation loop begins and the virtual world screen is loaded and displayed. This sequence is visualized in the flow diagram below (Figure 6.1). This screen is the container for the immersive simulation while it is running, and all the functionality of the spatial experience engine can be accessed from this simulation screen. This overall design allows the spatial experience to be customizable and extensible, as designers can modify and replace the simulation screen at any time to

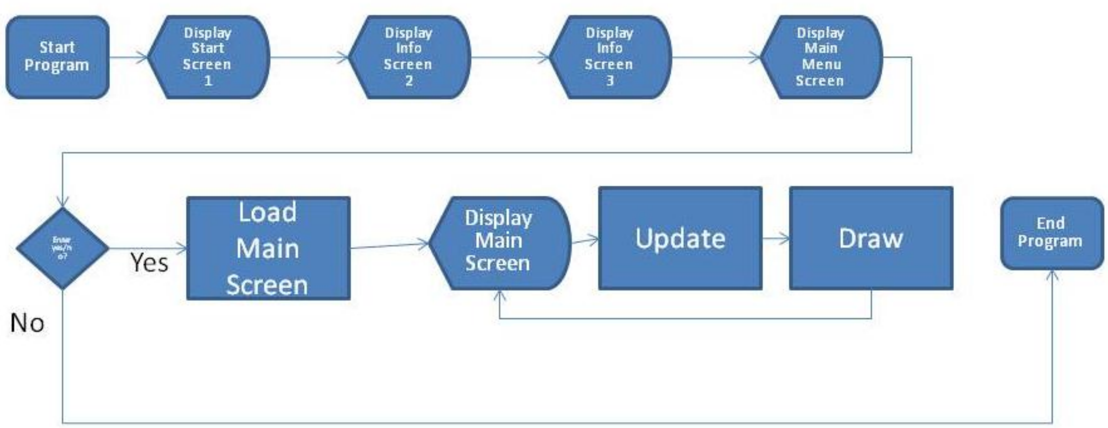

Figure 6.1. Design flow chart for Spatial Experience Engine

implement another virtual landscape reconstruction, or can add new simulation screens and broaden the landscapes or time periods that can be visualized within each implementation.

The design of the spatial experience engine outlined above incorporates both functionality from traditional geovisualization and landscape reconstruction, and state-of-the-art serious gaming and immersive simulation functionality. By leveraging the hardware optimization capabilities and functionality of game engine technology, the spatial experience engine can render compelling visual landscape reconstructions with dynamic physics-based behaviors. In addition, building on previous work that embeds and displays information within virtual landscapes, the spatial experience engine can demonstrate how such information can be presented within an immersive virtual environment.

Chapter 7 Virtual Morgantown – Implementing the Spatial Experience Engine

To fully leverage the desired game-based graphics and interaction functionality, it was necessary to select a free serious gaming development environment that provided access to code frameworks and libraries that would support the development and implementation of the spatial experience engine. A wide range of options were researched, from open source graphics rendering engines such as the Object-oriented Graphics Rendering Engine (OGRE) and the Virtual Terrain Project, to commercially developed game engines such as the widely popular Quake and Unreal engines (J. Gregory 2009). Unreal, for example, offers a wide range of tools for prototyping and developing comprehensive game-based functionality beyond graphics rendering, allowing players of the game and others to create "mods" of the game levels with custom terrain, features, and functionality (J. Gregory 2009).

While game engines have been utilized for academic research in landscape visualization by geographers and others (Germanchis *et al*. 2007; Champion 2007; Teichmann 2009), there are limitations to their use in the development of a spatial experience engine for this research that precluded their selection as a development platform. Utilization of most of these development tools and code libraries requires extensive programming experience, generally based on the C++ language. For researchers not versed in such coding environments, the implementation of these tools can be extremely time-consuming and costly if additional expert programming assistance is required. In addition, some engines, such as the Pro version of Unity 3, require paid licensing to access all the development features (Unity Technologies 2011). Finally, the goal of building a spatial experience engine that provides for the embedding of spatialized multimedia and other specialized interactive functions was best served by the development of a custom engine that could be extended and shared for use in a wide range of projects.

In 2007, Microsoft released XNA Game Studio, a set of free development tools designed to broaden the base of independent video games that could be deployed on both the Windows PC platform and the XBox gaming console system. XNA Game Studio is designed to be implemented within Microsoft's free Visual C# Express development environment (Microsoft, 2010). Its code libraries are built on the Microsoft .NET framework, thereby allowing integration across multiple .NET compatible languages and code libraries, including Esri's ArcGIS Engine development libraries (Grootjans 2009; Esri 2010). A rich collection of education resources, including white papers, tutorials, and sample code, are also available to developers utilizing the XNA Framework via the XNA Creators Club (http://creators.xna.com) along with a flourishing online developer community.

The spatial experience engine was built on the basic Microsoft XNA game template released with XNA Game Studio 3.1 (Microsoft 2009). This template allows for the rapid prototyping of basic functionality for an immersive virtual landscape simulation, and includes a comprehensive catalog of resources to aid inexperienced and non-professional programmers to develop a stable, functioning application that is capable of matching the performance levels of mainstream video games. The game framework structure allows each portion of the virtual landscape, including physical and cultural landscape features, embedded interactive functionality, and physics systems to be designed and implemented as separate components which can be added to the application as needed. This framework also allows the spatial experience engine to be customized as needed for individual landscape reconstructions, and the engine can be extended and updated as new functionality becomes available within the .NET and XNA code libraries.

Spatial Experience Engine architecture

The spatial experience engine application developed for this research implements a basic video game architecture with information screens displaying in sequence upon startup, followed by a menu screen which allows a user to enter the virtual landscape simulation. Once the user selects the option to enter the virtual world, the simulation loop begins. The virtual landscape components and interactive elements are loaded into the main screen, and the full immersive simulation is displayed for the user to begin exploring and interacting with the virtual scene.

During the user's session within the immersive simulation, the main screen performs two primary functions: *Draw* and *Update*. These functions are part of the basic XNA functionality and occur many times per second, as the user's changing camera position is updated and the graphics are redrawn based on the user's new position. Because of the speed of this redraw, the resulting view for the user is a nearly seamless sense of movement through the landscape. In addition to camera updates, the *Update* function also controls collision detection and tests for any necessary interactive elements based on the user's changing location or state. For example, if the user's camera location is within a previously defined proximity buffer of a multimedia resource, the collision detection will trigger the function that allows that resource to be viewed or played. The immersive simulation continues in a recursive loop until the user chooses to end the session by pressing the appropriate button to bring up the *Exit* menu screen. If the exit is confirmed, the program will be ended.

When the main loop of the application begins, the main screen is loaded with each component within the virtual landscape and the display elements are drawn on the screen. The terrain, water, and sky are generated first, and the initial camera properties are set. The remaining visual elements of the virtual landscape, vegetation and structure models, are referenced via XML files containing the appropriate identifier, location and associated matrix information, and display tag for each model. This allows the spatial experience engine to be easily customized and updated when models are added or removed.

Virtual Landscape Elements

The first step in developing the virtual landscape is the design and code implementation of the terrain rendering module. There is an extensive body of literature within computer science on the design and implementation of graphical representations of terrain and topography and addresses issues related to efficiency, performance, accuracy of representation, and level of detail. Each of these issues must be considered when developing a terrain model for an immersive virtual environment, because the terrain is the base layer upon which all other elements are built.

For the implementation of the spatial experience engine, the terrain renderer was designed as a component within the overall application structure, and can be updated as needed when more efficient or better performing architectures are developed. The current implementation is built on a quadtree structure, which generates the terrain at multiple levels of detail. The terrain values are read from a raster containing elevation values. In order to create a more visually realistic terrain, textures based on photos of land cover types are applied to the terrain faces. Three basic ground cover types were implemented in this immersive simulation: grass, dirt, and brick (Figure 7.1). In addition to the ground cover types, additional landcover features were also added to enhance the simulation of the physical environment, including water and vegetation.

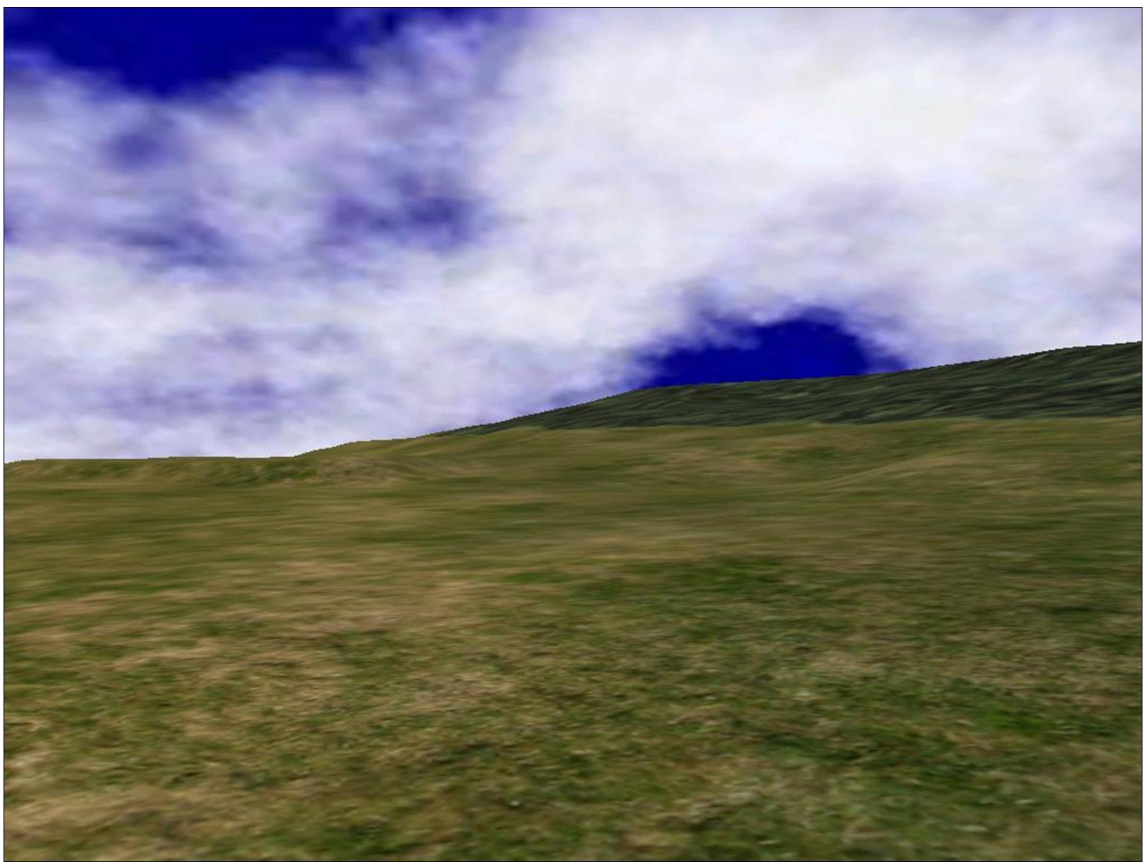

Figure 7.5. Detail of textured terrain

To maintain performance and speed, the water component within the spatial experience engine uses a pixel blending technique that simulates the visual effect of flowing or moving water that is reflecting and refracting light (Grootjans 2009). This effect is achieved by combining pixel values for a base water color, a sky color, the texture color for the terrain beneath the water, wave direction and strength, and light source location and direction. The resulting surface is a compelling simulation of moving water and contributes to the creation of a seemingly dynamic ambient environment (Figure 7.2).

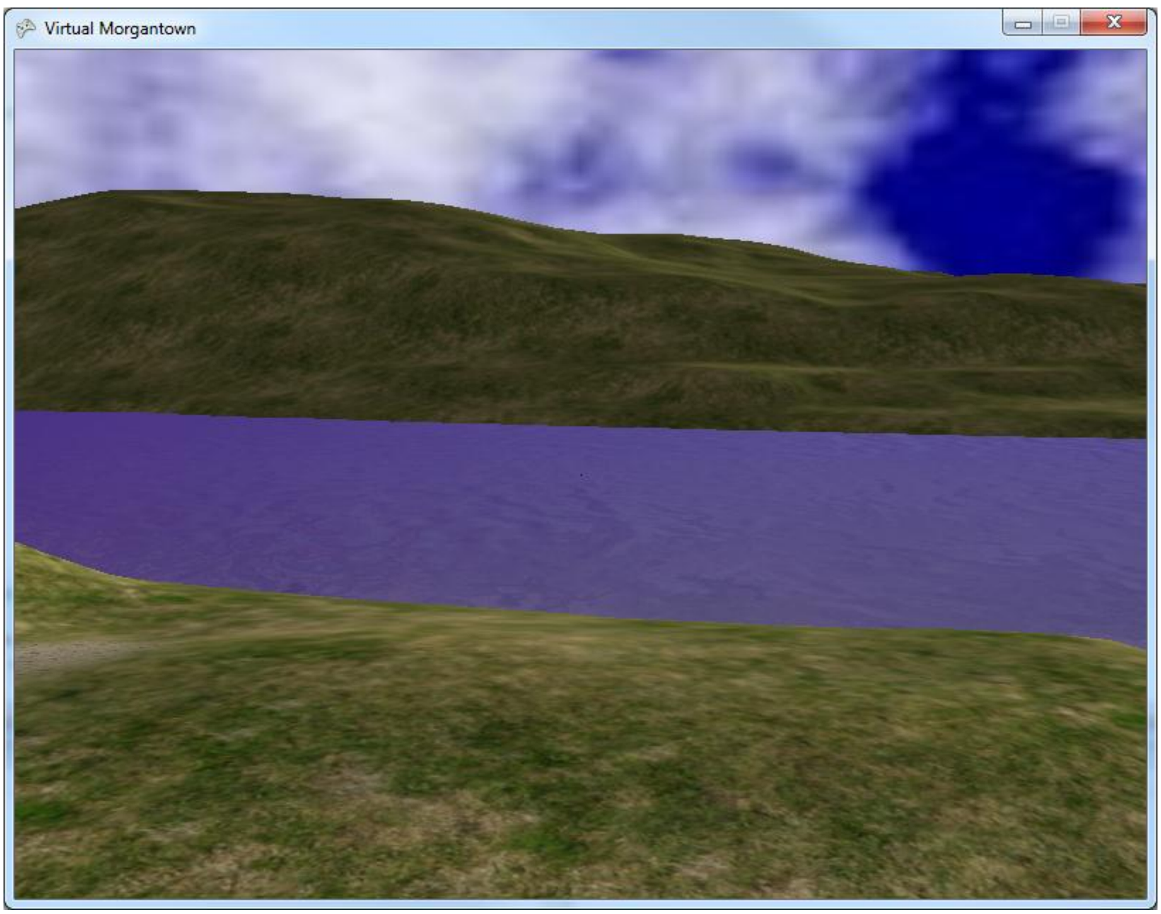

Figure 7.6. Detail of simulated moving water

The base vegetation model consists of three types of trees. Each tree model was built using a low-cost software application called TREEMagik, which provided a quick method for generating a textured tree model that could be exported in the DirectX native .x format and easily imported into the XNA environment (Figure 7.3). The tree models include an animation loop, which allows the branch and leaf elements of the models to move in a pattern that simulates wind blowing through the trees. This functionality is another element that aids in creating a sensation of movement and helps to increase the feeling of immersion.

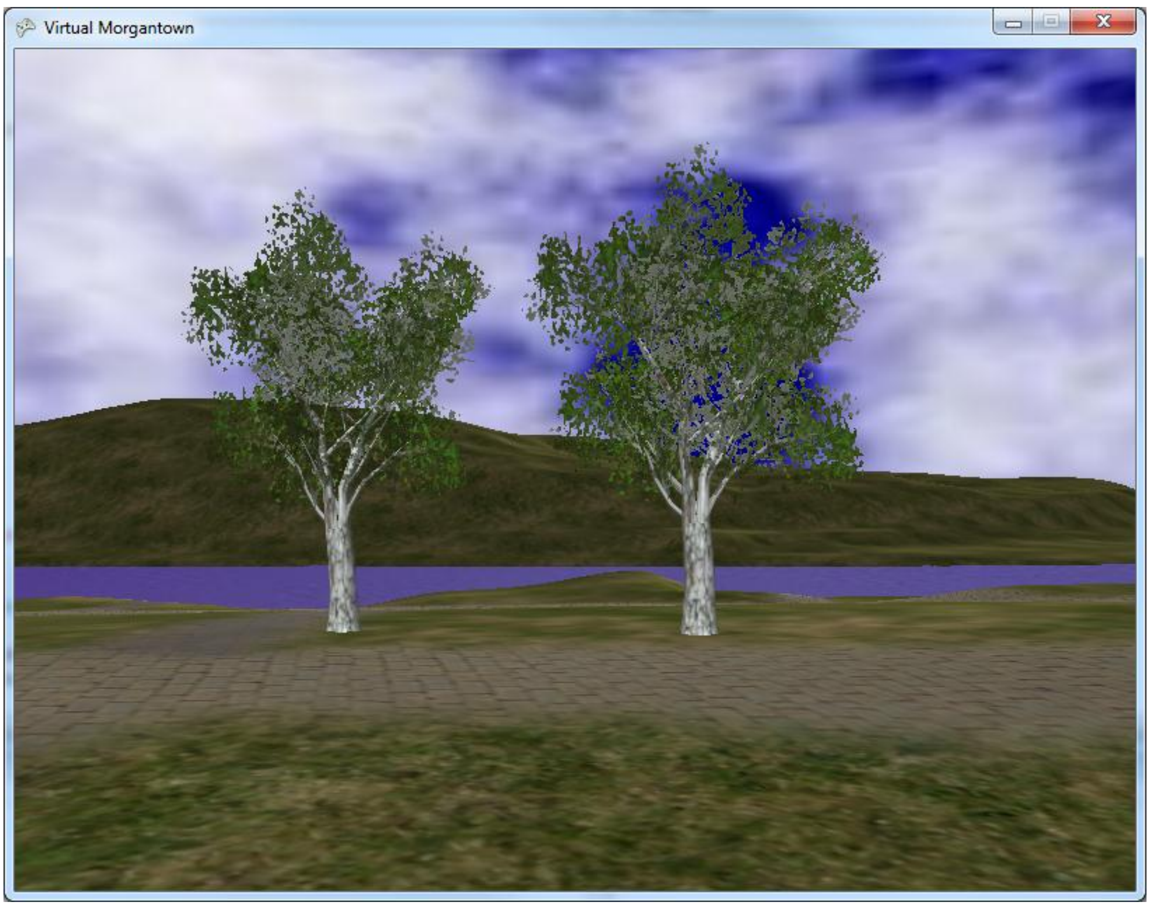

Figure 7.7. Detail of animated tree model

A powerful component that contributes significantly to compelling immersive virtual environments is the use of dynamic physics-based particle systems that can simulate dynamic real-world phenomena such as weather or smoke. These systems deepen the sense of immersion and presence by providing the user with a sense of ambient movement, as in the real world. When augmented with audio, for example the sound of falling rain, such physics systems can provide powerful evocations of scenes. Several modules were developed within the spatial experience engine to provide such physics functionality, and were used in rain and snow modules, and a module for generating smoke (Figure 7.4).

Figure 7.4. Snow particle system generating snow in virtual scene

Structures and the Built Environment

One of the most important elements of any immersive simulation is the representation of the cultural features of a historical landscape or place, including buildings and other structures such as bridges. The models representing these features were based on the original SketchUp models generated for the GIS-based landscape reconstruction of Morgantown. Approximately 400 structure models, including a suspension bridge, are included within the demonstration immersive simulation.

While it was possible to utilize the existing 3D models generated for the GIS-based ArcScene virtual landscape, the game-based spatial experience engine required that each model be edited for accuracy and efficient design, as unnecessary polygons within the models have a negative impact on performance. In addition, the spatial experience engine allows for the rendering of high-resolution, photo realistic textures, and a number of the house models were upgraded with new textures to take advantage of this added capability (Figure 7.5).

Once each model had been edited, the SketchUp file was exported to the native DirectX graphics file format (*.x), and imported into the XNA environment. As noted above, each model's reference information, including location, scale, rotation, and display ID, were stored in an XML file, allowing the models to be loaded via a recursive loop function. The XML reference file also provides some editing flexibility, as models can be added or removed from the list without the need to change other functions within the application.

Figure 7.5. Screen capture of photo-textured 3D building models

User Interface and Interactive Functionality

One of the most important elements of any immersive virtual environment is the user interface, the mechanisms by which a user interacts with the simulation. At the basic hardware level, the user interface consists of a display device, such as a computer monitor or projection screen, and one or more input devices, such as a mouse and keyboard or a joystick or game controller (Pedersen 2003).

The main user interface of the spatial experience engine is a series of screens that display information to the user and react to user input. The immersive simulation itself is essentially designed as a screen, with the primary function of displaying the virtual landscape and handling the user's navigation and interaction with the simulation. Since the overall application runs as a chained series of screens, these can be added or removed easily, giving the spatial experience engine flexibility for a wide range of customizable project types. This screen system, as noted above, is a standard architecture in video game design, and should be readily familiar to many game users (Grootjans 2009; J. Gregory 2009; Pedersen 2003).

For most computer applications, the main tools for interaction with the system and for navigation within it are the mouse and keyboard. These hardware devices allow the user to input the appropriate information required by the application to complete the various functions. Within the virtual environment, the keyboard and mouse can still be used as input devices for interacting with the system: from entering a name or other information, to utilizing keys for navigation or selecting menu items. However, many users already familiar with console-based videogames are quite comfortable using the game controller, and the spatial experience engine is designed with the controller as the primary input device.

For video game developers, an important component of a successful virtual world game is a mechanism that provides users with relevant information about the context of the immersive simulation, how to navigate through the virtual world, and identifies available options for customizing the user experience. Within the spatial experience engine, information screens were created to introduce the user to the virtual scene, and in the case of the Virtual Morgantown case study provided a historical context for the virtual landscape the user was about to enter. In addition, help screens also provide information on using the controller for navigating and interacting within the immersive simulation.

The ability to interact with elements in the virtual landscape is key to creating a compelling sense of presence for the user. In order for a user to experience the virtual landscape or place, there must be an ability to interact with features within the landscape that in turn generates a response or feedback in some form (Champion 2011; Murray 1997). To provide users with multimedia information without requiring them to exit the immersive environment, the spatial experience engine allows historical photographs, audio, and video elements to be displayed when a user navigates to an area where additional information is available. As the user approaches, the collision detection functionality triggers a pop-up display with the media source. As the user continues to explore the vicinity, the pop-up rotates so that it can be viewed from multiple angles (Figure 7.6). By spatializing these multimedia and tying their display to a specific location within the virtual landscape, important source materials can be more directly linked and contextualized within the virtual scene.

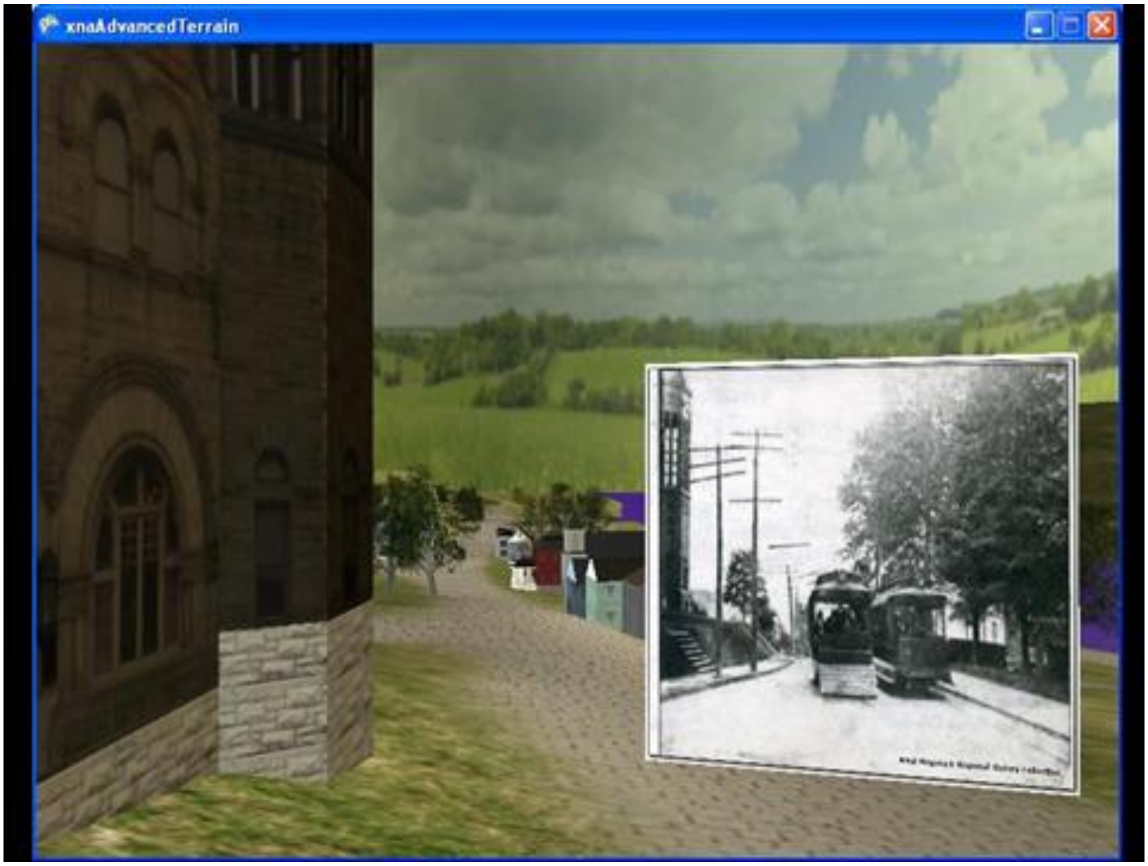

Figure 7.6. Screen capture of embedded spatial multimedia

The basic design elements of the spatial experience engine's HUD are fairly minimalistic, but could be easily customized for individual projects. The HUD displays general information in the lower left corner and locational information in the lower right corner. As the user approaches a multimedia resource, the resource is displayed in the lower center of the HUD, and associated text is displayed to the left. The HUD is able to display both still images and video (Figure 7.7).

Figure 7.7. Screen capture of HUD with spatial multimedia

Within many 3D gaming environments and virtual world applications, the use of virtual representations of people as a conduit for conveying information to users is a common tool, and easily recognized by users who are familiar with such games. The desire to interact with virtual human representations is intuitive, and even inexperienced game players quickly understand that such virtual informants possess useful information that enhances the experience of the immersive simulation.

A simple demonstration of the virtual informant was developed, although this functionality can be readily expanded and customized for other projects. As a user approaches the virtual informant, collision detection triggers an audio clip and this can offer the user any type of information from a greeting to a textual description of a nearby feature or assist in navigating the virtual landscape. The complexity of the virtual informant model is also highly customizable as well, from a simple static 3D human model to an animated figure that is capable of multiple interactions (Figure 7.8).

Figure 7.8. Screen capture of virtual informant

The Virtual Morgantown case study

To test the design elements outlined for the spatial experience engine, a prototype application was built that utilizes the late 19th-century urban landscape of Morgantown, West Virginia. This case study was selected for a number of reasons. First, by using the same late 19th-century timeframe and area as the GIS-based virtual reconstruction of historical Morgantown, it is possible to directly compare the functionality, performance, and usability of the spatial experience engine platform with the alternative GIS approach. Second, as with the ArcScene virtual Morgantown, there are readily available GIS data sets for generating the physical landscape features of the Morgantown area and other elements of the virtual reconstruction. Third, the close physical proximity of the extant urban landscape of Morgantown allowed for data collection of photographs and other information necessary for generating and rendering 3D models of structures and other cultural features. Finally, readily accessible historical collections, including photographs, primary and secondary sources, and local museum collections, provided content for embedded spatial multimedia and other interactive elements.

Once the basic development was completed on the XNA spatial experience engine platform, the initial stages of the serious game-based Virtual Morgantown implementation followed a similar workflow to the previously completed GIS-based virtual reconstruction. GIS elevation data for the downtown Morgantown area was utilized to generate the terrain module for the XNA immersive simulation, which was successfully implemented and tested before moving on to the water and vegetation landscape features. The flowing water and physics-based weather particle systems were implemented next, and the physical landscape portion of the Virtual Morgantown immersive simulation was tested for performance and stability.

Following the successful completion of testing for the physical landscape modules within the Virtual Morgantown simulation, the structures and built environment features were processed and loaded into the spatial experience engine platform. While the 3D structure models originally developed for the GIS-based virtual Morgantown landscape were used in the XNA implementation, nearly all of the over 400 models had to be edited and tested to meet the more stringent graphical requirements of the game-based environment. When the processing and loading of updated 3D models was completed, the immersive simulation was again tested for performance and stability.

Once all development and testing was completed on the physical and cultural landscape features of the Virtual Morgantown virtual scene, the interactive elements of the immersive simulation were implemented. These included demonstrations of 1) the spatial experience engine’s embedded multimedia functionality using historical photographs of Morgantown that displayed when a user approaches specific locations; 2) the HUD functionality using a simple display that provided a user’s location, instructions on navigating the scene, and displayed multimedia when the user approached specific locations; and 3) two virtual informants represented by 3D models of a human with an associated audio clip that provided general information about the Morgantown area around the virtual informant. Final testing for performance and stability was successfully conducted following the implementation of the interactive spatial experience engine functionality, and the Virtual Morgantown spatial experience engine prototype was complete.

The Virtual Morgantown immersive simulation represents a working prototype of the spatial experience engine, and demonstrates the visual graphics rendering, first-person navigation, physics-based systems, and interaction functionality identified as key components of such an engine. By combining traditional GIS and geovisualization functionality with videogame technologies and methods using game engine architecture, the spatial experience engine offers a platform for visualizing and representing both geographic and qualitative data contextualized through the spatiality offered by the scene. More importantly, the spatial experience engine leverages videogame functionality to provide an immersive virtual environment that enables users to explore and experience the virtual landscape. In the following chapter, the Virtual Morgantown spatial experience engine prototype will be discussed with respect to how well it performs as a platform for applying an experiential approach to exploring concepts of place and sense of place within past landscapes.

Chapter 8 The Spatial Experience Engine and an Experiential Approach to Place Analysis: review, evaluation, and prospect

Review: Toward a Spatial Experience Engine

This research set out to explore how the combination of GIS and virtual environments could be utilized as a platform for an experiential approach to the study of place and landscape. The study began with a focus on a GIS approach to virtual landscape reconstruction based on ESRI's ArcScene. The limitations of ArcScene in terms of graphical display, object constraints and system latency, combined to diminish the critical experiential aspects of immersion and interaction on which this phenomenological approach depended. As a result, the research agenda developed to examine other approaches to virtual world reconstruction, and MS XNA was adapted as the framework around which the case study of Virtual Morgantown was formed as a prototype immersive simulation platform.

The developing body of literature on the use of GIS in historical landscape analysis and now more broadly within the humanities, has produced an early body of work focused in the areas of digital atlases and the mapping and analysis of quantitative historical information. This emphasis has evolved as experience, practice, and understanding has grown. The early projects rightly played to the strengths of mainstream GIS software and methods, which heavily favor the development of digital spatial data sets and mapping. As the spatial turn has evolved within a number of disciplines, and knowledge and practice has grown, so a number of projects now utilize more of the GIS functionality along with geovisualization and related geospatial technologies to address not only historical analyses but broader humanist studies in the spatial humanities.

Concomitantly, conceptual questions and challenges concerning the merging of a positivist technology with humanistic inquiry and the representation of spatial knowledge within humanities scholarship have arisen. Central to the challenges facing the GIS community is the very nature of humanities information itself which tends to be qualitative and challenging to integrate within a GIS that is designed to digitize, store, and render the real world in the form of the spatial primitives of points, lines, polygons, and pixels. Perhaps the most challenging issue concerns adapting a technology formed in the image of the scientific method to humanist traditions and humanities scholarship which so often centers around individual inquiry and the nuanced interpretation of sources to the lessening of quantitative measures or spatial science analysis. In this study, geovisualization and immersive virtual environments were explored as way of bridging the powerful technological tools of GIScience with the nuanced, experiential, and humanist approaches of the humanities scholar through a spatial experience engine.

To this end, this dissertation explored the use of Virtual GIS through commercial GIS software and subsequently through serious gaming engines as an approach to reconstructing and interpreting place and landscapes. Virtual Morgantown focused on the development of a virtual reconstruction of the past urban landscape of Morgantown, West Virginia, initially within ESRI’s ArcScene environment, and subsequently using XNA. GIS data layers were developed and merged with terrain data and 3D models of the urban infrastructure were generated in SketchUp 5.0. To test the concept and viability of embedding spatialized multimedia within the virtual reconstruction, historical data sets in the form of Sanborn Fire Insurance maps, historical photograph collections, and secondary sources on the history of late 19th and early 20th century Morgantown were utilized to develop the virtual reconstruction of Morgantown's past urban landscape. The building footprints were created from the Sanborn fire insurance maps, and embedded within a terrain model based on DEM. Vegetation and street furniture were generated for downtown Morgantown c.1900 which, along with several GIS data layers, were imported into ArcScene to form the core of the virtual landscape platform. A custom ArcObjects extension was developed to display information such as photos and media in the form of pop-up windows within the ArcScene viewer.

Although the ArcScene landscape reconstruction was a powerful visualization tool for illustrating the layout and features of the late 19th-century urban landscape of Morgantown, it was not an ideal platform for generating the two main components of compelling digital environments: interactivity and immersion. The 3D visualization capabilities of the ArcScene environment were limited by its software architecture, which was designed to allow users to display and broadly navigate over 3D datasets in a top-down bird's-eye perspective. In addition, the architecture of the ArcScene module, although customizable, was not designed to integrate embedded spatial multimedia and this created a number of challenges in the development process. While limited success was achieved in utilizing ArcObjects to create multimedia display pop-ups, this customization further limited an already slow and unstable ArcScene performance. Furthermore, the critical elements of system interactivity and immersion were severely impeded by system latency and this only compounded the problems in achieving an experiential 'presence' in the virtual world. Accordingly, a significant and unexpected change of course was embarked on to develop an alternative virtual environment that more closely achieved the ambitious goals set forth in the dissertation objectives.

The resulting XNA-based spatial experience engine incorporates functionality drawn from traditional GIS, geovisualization, and landscape reconstruction, and combines it with state-of-the-art videogame functionality. By leveraging the hardware optimization capabilities and functionality of game engine technology, the spatial experience engine renders compelling visual landscape reconstructions with physics-based behaviors that simulate the dynamic nature of real-world processes and enhance the sense of immersion and presence felt by a user exploring the virtual scene. In addition, the spatial experience engine is capable of embedding multimedia representations within an immersive and interactive virtual environment.. The goal of such integration is to combine the immersive simulation of physical and cultural elements of a virtually-reconstructed place with other humanistic sources of information that enhance the all-important experience of that place.

The prototype Virtual Morgantown case study was developed on the spatial experience engine platform as a custom application of a game-based coding framework, Microsoft's XNA Game Studio. The leveraging of videogame industry standard graphics, physics, and interactive functionality considerably improved the performance and utility of the virtual scene and came markedly closer to the intended goals of an immersive and experiential framework. The spatial experience engine prototype was built on the historical, GIS, and multimedia data generated for the previously completed GIS-based Morgantown project and included historical maps, photographs, and secondary sources. GIS data sets that included high-resolution graphics for physical landscape elements such as terrain, water and vegetation, and 3D structure models for the built environment were also imported into the XNA spatial experience engine platform to complete the rendering of the physical and cultural elements of the virtual landscape.

Drawing on the greater capabilities of the XNA platform, physics-based particle systems were developed that enabled moving particles, such as smoke, rain, and snow, to be displayed. These additions contributed greatly to the immersive experience because movement provides an ambient environment within the virtual landscape, and increases the user's sense of immersion and presence by simulating the dynamic real-world processes that humans experience daily. Finally, to allow users to interact more easily and intuitively with the media embedded in the features of the virtual landscape, several interactive mechanisms were implemented in the Virtual Morgantown prototype including a heads-up display drawn at the base of the screen that allows users to view text, photos, audio, and video information. The embedded spatial multimedia displays as pop-up billboards within the urban scene. Virtual avatars provide additional audio information when users approach them within the landscape scene and with a greater emphasis on artificial intelligence, which is beyond the scope of this study, could have been made capable of holding a 'conversation' based on key words or phrases.

The Virtual Morgantown immersive simulation represents a working prototype and implementation of the spatial experience engine concept, and demonstrates the visual graphics rendering, first-person navigation, physics-based systems, and interactive functionality that are key components of an experiential engine. By combining traditional GIS and geovisualization functionality with videogame technologies and methods using game engine architecture, the spatial experience engine provides a platform for visualizing and representing both geographic information and embedded humanities information. More importantly, the spatial experience engine leverages videogame functionality to provide an immersive virtual environment that offers users the virtual opportunity to explore and experience aspects of landscape and place in late 19^{th}-century Morgantown.

Evaluation and prospect

There is, as yet, no fully developed body of literature that even begins to address best practices for the evaluation and assessment of game-based immersive virtual environments in geographical or humanities scholarship and especially those platforms designed as experiential portals to place analysis. Indeed, few applications have even been built and this considerably limits the knowledge base upon which to develop evaluation procedures (Champion 2011). The process of designing, implementing, and using a virtual environment requires evaluation and assessment on a number of levels. Such evaluations can include a wide range of design criteria, technical performance specifications, content assessment, and usability measures, as well as user experience assessments. In addition, the intended experiential nature of the system demands individual as well as group assessments and the interdisciplinary nature of the work entail that evaluation methods and criteria for each of these metrics must come from a wide range of disciplines, including computer science, human-computer interaction, GIScience, geography, and domain and content experts. Consequently, a full evaluation of the Spatial Experience Engine across all levels of design and implementation is especially challenging and probably requires an entire study in its own right.

For this study, the evaluation has focused on the technical performance and user experience, as these elements are crucial to effectively generate a sense of immersion, interaction, and presence, irrespective of the specific content within the immersive simulation. When evaluating the technical performance of software applications, quality assessment must be undertaken on a number of levels. At the macro level, the application must start and stop without errors and without destabilizing the operating system or other applications. Within the application itself, the overall navigation must be smooth, and perform without errors. The user interface design for the application should follow accepted software engineering design principles, and provide users with an aesthetically pleasing, efficient, error-free, and flexible experience.

In terms of technical performance, a graphics-intensive immersive simulation application such as the SEE must be able to maintain minimum performance levels in order to ensure that the virtual environment provides the user with an experience that is as visually and interactively 'realistic' as possible. Consequently, evaluation testing must include performance benchmarks for the speed and frequency with which the SEE is able to update the scene, known as the frame rate which must be above 30 frames per second in order for the immersive environment to appear seamless to the user. Visually perceptible lags will negatively impact the user experience, and are not acceptable in advanced game-based applications (J. Gregory 2009). To this end, the technical performance was conducted and evaluated throughout the development process, from debugging the code to testing against performance benchmarks. Improvements and enhancements were continually made to improve the many elements of system performance as outlined above.

The completed SEE prototype, as opposed to the ArcScene implementation, certainly performed well above minimum requirements for a virtual environment to maintain an immersive and interactive user experience. The system also maintained stability throughout the testing period. The additional input of expert users from computer science, serious gaming programming, and GIS helped verify and improve system performance and stability within the application throughout the study. Beyond technical performance, it is much more difficult to assess and evaluate the utilization of the Spatial Experience Engine as a platform for an constructing and experiencing aspects of place. In this regard, the user experience is a unique but key component of the SEE. Researchers who have conducted testing on user experiences within virtual reality and other immersive environments have generally focused either on technical evaluation through quantitative assessments of physiological responses from users in the immersive environment or on questionnaire-based post-experience assessment (Champion 2011; Sutcliffe and Gault 2004).

Evaluating individual experience can be difficult in such immersive simulations, as the real-time assessment of achieving a sense of presence and immersion in a scene is so often difficult to assess (Champion 2011). However, the feedback of users of the SEE from a number of informal demonstrations and academic presentations has been extremely positive on a number of key fronts, As the main goal of this study was to explore the design and implementation of a geovisualization and immersive simulation platform that enabled researchers to experience a virtual landscape reconstruction and access embedded humanities information within the immersive scene, no comprehensive user testing was conducted as part of the research. However, many users of the SEE provided considerable anecdotal feedback and insight into the use of the system. Furthermore, the Virtual Morgantown SEE prototype was installed as a permanent exhibit in the Morgantown local history museum and this has provided an additional opportunity for the application to be tested by non-expert users in an informal setting and to obtain feedback through a comment sheet.

An examination of the comments from users of the Virtual Morgantown immersive simulation and from visitors to the museum suggests not only a fascination for the innovative presentation of historical materials but of the intuitive navigation and sense of presence in the scene. Indeed, many commented about ‘enjoying’ the experience. In addition, knowledgeable local residents pointed to specific elements of the virtual historical landscape to which they added insight and information or which they found sufficiently compelling to want to learn more about it. Users generally found navigation within the virtual scene to be intuitive, especially with use, and several users commented that they would like to see the project expanded to include more of the historical urban landscape of Morgantown so that they could continue to explore it virtually.

One of the most important aspects of the SEE is its ability to render and display elements within the virtual environment, not only from a technical perspective but also from an aesthetic or ‘realistic’ perspective. Interestingly, although considerable effort went into using extensive resources to ensure the accuracy of the street scene and rendering of the buildings, it is suggested here that verisimilitude is not an essential goal of such a project. This is a contentious issue in Virtual Reality for it could be argued that this single issue has sidetracked the entire field into a somewhat barren siding from which it is trying to escape. While visual ‘reality’ in a scene is achieved through an accurate rendition of a feature or scene, it is not the quintessential determinant for achieving a sense of presence or immersion. Landscape elements must be visually compelling to create a sense of realism, and interactive functions within the immersive environment must behave as expected or the sense of immersion and presence will be lost. However, users are quite adept at accepting a scene without the need for extreme visual accuracy, as long as the interactive and feedback within that virtual world behaves as it would in a real-world analog. In several instances, box shapes without rendered exteriors were created to demonstrate earlier or later developments in the urban fabric and users found no problem interpreting these forms or accepting them as part of the virtual scene. It seems that interaction, navigation, and immersion within a scene, however coarse the scene is rendered, often has greater impact on a user’s sense of presence than extreme verisimilitude of the rendered image.

The completed Virtual Morgantown prototype implementation of the spatial experience engine clearly demonstrates the capability and utility of game-based graphics and physics engines in developing immersive virtual landscape reconstruction platforms, and its potential as a platform for experiential place analysis. The flexibility of the spatial experience engine allows for the deployment of virtual reconstructions for any time period or location for which data is available in digital form. This latter point is no small issue for gaps or silences in the data have far reaching implications for platforms such as this. While considerable latitude is possible using text or prose to position an argument or describe possible situations or explain outcomes, such leeway is not available to the same degree in visual systems such as this. It is ironic that maps are generally seen to be objective and 'real', yet virtual reconstructions are often held suspect without the same degree of rigorous assessment.

With a working prototype in hand, it would now be possible to further explore a number of research questions raised during this project. One of the most compelling questions for future work is the notion of knowledge representation and its relationship to the ways in which users experience and navigate through the virtual landscape. Constructing and evaluating spatial narratives based on, and derived from, a phenomenological, experiential use of virtualized landscapes promises considerable potential benefits and insight into understanding or explaining places, events, and processes. By constructing spatial narratives as part of the research process, scholars are able to embed the components of such narratives in the actual visual form and spatialized multimedia of the virtual place. Further exploration of such new methods of knowledge representation offers a great deal of promise for geographers, historians, and humanities scholars.

Conclusion

This work contributes to the growing body of GIScience literature that seeks to extend the capabilities of GIS and geovisualization technologies and methods to explore research questions in a range of disciplines as well as within geography. This dissertation explores a number of issues related to the design, development, and implementation of advanced game-based virtual landscapes. The use of immersive and interactive virtual environments in representing geographic information and the construction of place and space raises important questions related to representation and the re-creation of place within virtual worlds. The spatial experience engine demonstrates how gaming technologies might be utilized in geographical research to create immersive and interactive virtual landscapes that enable scholars and the public to explore an experiential approach to landscape and place reconstruction and analysis.

Despite optimism that experiencing place through a spatial experience engine is potentially very rewarding, further research is clearly necessary in order to assess the effectiveness of the system in specific domain areas. The focus of this study has been on understanding the complexities, strengths, limitations, and approaches to providing advanced simulation environments such as the spatial experience engine and the ways in which the system represents and enables the exploration of space and place. The ability for future scholars to now apply the system in differing domain areas is exciting, for it is only through these grounded studies that a true evaluation of the spatial experience engine will emerge.

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