Algorithmic Architecture in Virtual Spaces

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ABSTRACT

Much of the recent interest in virtual worlds has focused on using the immersive properties of virtual worlds to recreate an experience like that of interacting face to face with other participants. This thesis instead focuses on how we can use the distinctive properties of virtual spaces to create experiences native to virtual worlds. I present two projects that have different perspectives on this concept. The first project—*Information Spaces*—demonstrates how visualization of behavior in a 3d meeting space can augment the meeting process and provide participants new behavioral ways to communicate. The second project—**space*— is an abstract 2d virtual platform for prototyping and experimenting with virtual world experiences that provides a structure for changing properties of the virtual space to influence people's behavior in that space.

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Chapter 1

INTRODUCTION

Over the past twenty years, the prospect of visiting a virtual world different from our own world has moved from being strictly the domain of imagination to being widely accessible. What started as worlds accessed through typed commands and presented as text have evolved into rich graphical and sensorial experiences that are rapidly becoming commonplace. The promise of virtual worlds has always been somewhat revolutionary. Virtual worlds might, for example, suppress the prejudices of offline society by hiding identity information, breaking down the boundaries of distance, and making experiences broadly accessible that might not otherwise be feasible. Perhaps we could even build a new virtual society, one that is better than our own. These utopian visions are attractive precisely because the urge to grow beyond the confines of everyday experience is so strong.

In practice, though, virtual worlds have quite a bit farther to go before they can meet any of these expectations. While some of the more pragmatic aspects of the promise of virtual worlds are accessible, the loftier goals—truly removing the prejudices of offline society, for example—remain out of reach. The research I describe here demonstrates why it is a useful first step to give virtual world designers the ability to control what aspects of someone's identity are part of their representation in the world. In some parts of a virtual world, you might want everyone to look the same, while in others showing how talkative people are is more appropriate. I will show that by designing virtual worlds in which spaces have a broad range of algorithmic properties, we start to create virtual spaces that move beyond simply recreating physical spaces and instead harness the nature of virtual space to create new kinds of interactions that give designers opportunities to address the broad promise of virtual worlds.

Central to my approach is a desire to create interactions in virtual spaces that don't simply mimic our face-to-face interactions. Hollan and Stornetta (1992) argued that computer mediated communication had two basic paths: recreating the experience of being face to face (which they describe as the "being there" strategy) and using the mediated nature of the communication to augment the experience in some way ("beyond being there"). The heart of their approach is to consider physical space as just another medium that should be judged for its appropriateness to specific tasks like one might choose between email and a letter. Instead of focusing on physical space as the best environment for all interactions, they suggest that there are some domains in which mediated interactions can do much better than simply aspiring to recreate the experience of being face to face.

In much the same way, I argue that we should not simply build virtual spaces with the same basic rules of physical space. Rather, we should take advantage of the unique properties of virtual space to build experiences that are better in particular ways than interacting face to face might be. By no means am I suggesting that virtual worlds can be better than face-to-face communication in all respects. Instead, I think there are aspects of virtual worlds that make it possible to build virtual experiences that we couldn't easily have face to face, and that it is in these design spaces where we can start to fulfill the promise of virtual worlds.

My primary goal in this work is to explore the relationship between the functionality of virtual spaces and the social interactions that take place within them. The working hypothesis that guides my process is that by making virtual spaces both more responsive to the actions that take place within them, and by controlling changes of agency and appearance of avatars, we much more effectively support specific activities carried out there. In the process, I will discuss and illuminate some more general questions:

> How does virtual space differ from physical space?
>
> How should we understand the role of representation in virtual worlds?
>
> How can we build virtual spaces that have some of the same expressive richness of physical spaces?

To answer these questions, I discuss two major projects. The first, called *Information Spaces*, works within the constraints of an existing virtual world platform to create a social space centered on decision-making and consensus building. Using this project, I will show how an avatar's mere coordinate position in a virtual space can be significantly augmented by techniques that aggregate and display avatar behavior over time. This, in turn, can give participants a new vocabulary for expressing how they feel about the issue being discussed. The second project, called **space*, demonstrates a virtual world that takes advantage of freshly conceived algorithmic enhancements to greatly facilitate the design of social spaces, a highly challenging task in existing virtual world platforms. Using this platform, I will show how changing the basic assumptions of the physical world opens up exciting new possibilities that approach our goal of making virtual spaces that go *Beyond Being There*. To contextualize these projects, I will illustrate the intellectual etymologies of virtual environments through a discussion of virtual worlds in games, literature, and academic research.

Chapter 2

BACKGROUND

2.1 TERMINOLOGY

In the literature, there is a range of terminology related to virtual worlds. Each name tends to exaggerate a specific aspect of virtual worlds. For instance, Castronova avoids the phrase "virtual world" and instead writes about "synthetic worlds" (Castronova 2005). This is an appropriate distinction to make for his work because he is primarily concerned with how money, influence, and identity move between physical and virtual worlds. His argument is that there isn't much that is "virtual" about virtual worlds—because so many aspects of the physical world move easily into the virtual, he argues it is more apt to describe these worlds as "synthetic". While I wholeheartedly agree with his analysis of the nature of the boundaries between the so-called "real" and "virtual", this work is not focused on that aspect, and using his vocabulary is not appropriate.

Historically, early virtual environment systems like *MASSIVE* (C. Greenhalgh & S. Benford 1995) were described as "collaborative virtual environments", which accentuates their interest in creating specific interaction spaces for collaborative multi-user activity. This work is closer to mine in its focus, but describing the environments as 'collaborative' is a bit limiting. I think the implications of this work are not just about collaboration.

There are numerous other terms like "Massively Multiplayer Online Game" (MMOG) and "Multi-User Dungeon" (MUD). These terms describe specific classes of game worlds, and the approach to algorithmic architecture described here is not specific to games.

Instead of these more specific terms, I have settled on using "virtual world" (when talking about the platform itself and the connection of virtual environments in that world) and "virtual environment" (when talking about a specific space in a larger virtual world). I use this to describe a superset of worlds that includes all the kinds of worlds described by the different terms I have laid out in this section. In a very general sense they all share certain key characteristics like persistence, synchronous embodied interaction, and (usually) some sort of spatiality, and using a very general term to describe them all seems appropriate.

In contrast to "virtual", I use the phrase "physical world" for those spaces that are not mediated by technology. The physical world is where face-to-face interactions take place, follows the laws of physics, etc. I avoid the "real" and "virtual" distinction because the implication that the virtual is somehow less than real is not true. Mediated experiences are different than unmediated ones, but experiences that take place in a virtual world are not necessarily less emotionally meaningful than other non-mediated experiences we have. There is a significant body of work that demonstrates this, most notably (Dibbell 1999) and (Turkle 1997). More recently, Wagner James Au has described it in *Second Life* (Au 2008).

2.2 TYPOLOGIES OF VIRTUAL WORLDS

We are in the middle of an explosion in the market for virtual worlds. Long a niche entertainment medium, virtual worlds for a huge variety of domains have sprung up in the last five years and attained major commercial success. A brief survey of worlds in use today provides a sense of the variety (game-world subscriber counts from (Woodcock n.d.))[1]:

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[1] Subscriber numbers are notoriously hard to pin down in virtual worlds. For commercial worlds, I have included the published subscriber numbers. For worlds that have a free version, I include the best "active" member number that is publicly available, not the number of accounts registered which is usually five to ten times the active members number.

Figure 1. Screenshots from four virtual worlds. Clockwise from top left: *World of Warcraft*, *Habbo Hotel*, *EVE Online*, and *Second Life*.

World of Warcraft (10M+) — A hugely successful breakout example of the genre. Has succeeded in making massively multiplayer online games (MMOGs) widely acceptable to gamers. A sword-and-sorcery style fantasy world in which players complete quests and work together to beat difficult group dungeons. (Blizzard Entertainment 2004) Other similar worlds: *Everquest*, *Age of Conan*, *Lineage*, *Runescape*

EVE Online (236k) — A space-based game world in which players both complete missions a well as fight for control of an immense galaxy. Unlike most game worlds, all players inhabit the same copy of the world. *EVE* is notable for its player run economies and rich opportunities for player collaboration and competition. (CCP 2003)

Habbo Hotel (~10M) — A primarily social game where visitors can decorate their rooms, play games, and socialize in a wide variety of different kinds of rooms. *Habbo Hotel* is primarily aimed at young teenagers. (Sulake n.d.) Other similar worlds: *Club Penguin*, *WebKinz*

Second Life (~1M) — A flexible, user-designed world where avatars can design their own clothes, accessories, vehicles, and buildings. Has a rich economy with a currency that can be converted to US Dollars. Supports a huge range of different kinds of activities including games, advocacy, education, and socializing. (Linden Lab n.d.) Other similar worlds: *There*, *ActiveWorlds*, *Lively*, *Croquet*

Although there is no single definitive typology of virtual worlds (though there are many examples, e.g. (Koster 2007)), there are a few general categories that are important to properly describe the kind of worlds that this thesis is concerned with.

The two major axes on which virtual worlds can be organized (as proposed by Bartle (2003, pp.54-61) are agency (which Bartle calls 'change') and persistence. Agency is a broad term that is the set of things that someone can do in a world. Agency can be thought of as the interface that you have onto the world. For example, the agency of players in a chess game is limited. When it's their turn they can move their own pieces in certain prescribed ways. Moving pieces is the agency players have in the chess game. In virtual worlds, agency becomes a bit more elaborate and includes movement, avatar customization, communication, object creation, etc. Different worlds have different sets of actions that an avatar can do, and I describe them as having different kinds of agency.

Persistence is the ability of the world to remember events that change something about the world. For example, if you create an object in a persistent virtual world you can expect that the object will be there when you return. This is in contrast to worlds where changes aren't saved for very long. Multiplayer first person shooter games are a good example of this—you interact with a rich three-dimensional world and might change it by dropping weapons, causing explosions that change the appearance of part of it, or by destroying certain objects in the environment. None of those changes will remain in that world the next time you play, though. It will be wiped clean and you'll have a fresh copy of the original space.

Certainly, these axes are not perfectly distinct (worlds with limited agency often have low persistence as well), but they serve as good organizing principles. For the most part, modern virtual worlds have high levels of agency but relatively low levels of persistence. In *World of Warcraft* for instance, players can kill monsters in the world, but the monsters will always reappear a few minutes later. There are virtually no actions players can take that modify any aspect of the world apart from killing computer controlled characters. Rich agency exists almost entirely in the relationships between players and the organizations they form. Worlds like this have proven to be commercial successes because they are more resistant to disruptive behavior aimed at degrading other players' experiences, but they also rule out many of the interesting opportunities that virtual spaces offer over physical spaces. Building the kinds of spaces that this thesis advocates for requires substantially more elaborate vocabularies of interaction between avatars and the spaces they inhabit.

The best modern example of a world that offers that kind of rich agency and persistence is *Second Life*, a world developed by Linden Lab. *Second Life* is a free application that connects to a single monolithic "Grid" of *Second Life* servers that provide a mostly continuous (flat) virtual space in which avatars can own land and items, build clothing, buildings, or vehicles, and embed behavioral scripts in their creations. The world also provides an economic system with its own currency system (the Linden Dollar, L$), which is exchangeable at a fixed rate for US Dollars on a currency exchange that Linden Lab manages. The community that has arisen around *Second Life* is extraordinarily diverse and rich, but an in depth discussion of its dynamics is beyond the scope of this thesis. There are a number of books that describe the history and culture of *Second Life*, which provide a good introduction to that topic, however. (Ludlow & Wallace 2007; Au 2008) For my purposes, *Second Life* is critical as an example of a world in which avatars have a considerable amount of control over the design of environments, and so *Second Life* has been instrumental in developing an intuition for how virtual spaces influence the behavior of people in them. It has also been useful as a platform for exploring the design space of algorithmic architecture. For much of this thesis, I will turn to *Second Life* as a source of inspiration, as well as to draw comparisons between the general model for virtual architecture that I explore in this thesis and the model that *Second Life* embodies.

2.3 REPRESENTATION AND FUNCTION

Specific features of both physical spaces and virtual spaces can be thought of as serving symbolic and functional purposes. As virtual spaces were first being conceived it was not obvious that they would draw their symbolism heavily from

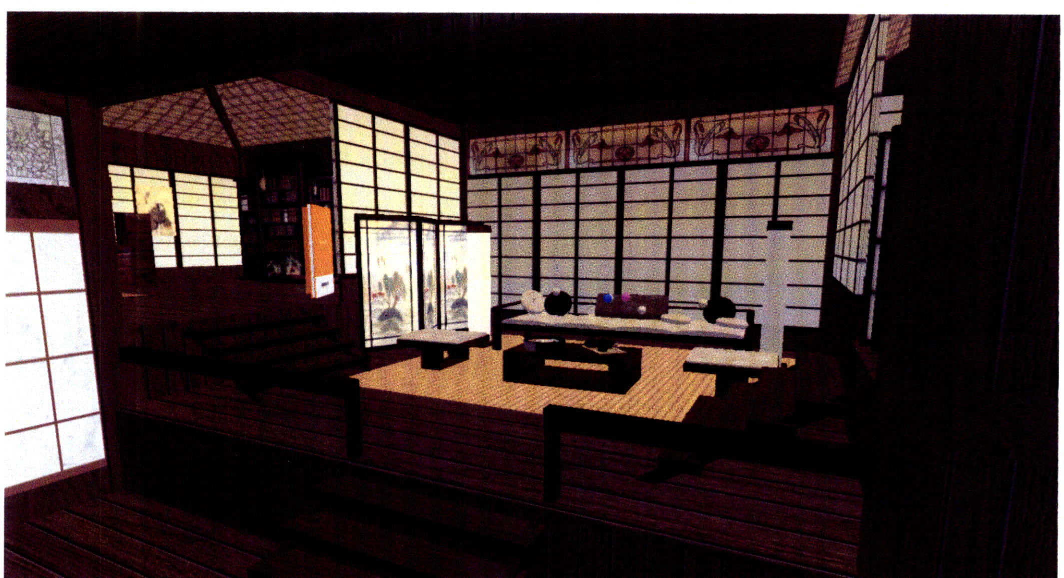

Figure 2. A *Second Life* house decorated in a generic Asian style.

Figure 3. A physical world cathedral and its virtual word equivalent. Cathedral photo courtesy of flickr user glynnis.

physical spaces (Novak 1991), a visitor to modern virtual worlds would be struck by how familiar its design elements are. In the free-form world *Second Life*, for instance, there are countless recreations of both specific architectural landmarks as well as buildings that ape familiar architectural styles. Furthermore, those buildings are filled with rooms furnished in a way that would not stand out in the least from their real world analogs. Why is it that, free of the natural laws of the physical world, so much of virtual world design is concerned with recreating familiar physical spaces?

This focus on familiar representations serves a number of important social roles. First, it functions much like the identity signals do in physical fashions. (Judith Donath, in press) Although choosing and furnishing a virtual house is substantially less costly than its physical analog, it is still a strong demonstration of taste that helps visitors to virtual spaces understand something about the person who assembled them, much like a personal homepage or profile page might on the Web. And though the price of virtual items may be substantially less than the physical artifact it mimics, virtual economies usually have some sense of relative value that allow these items to also function as signals of wealth.

The second important social role is in building spaces that contextualize behavior. Visitors to virtual worlds are forced to reform their notions of socially acceptable behavior in virtual spaces. It is substantially easier to make meaning from a virtual space built to look like something familiar than something abstract. In this way, avatars in virtual spaces can reasonably expect that spaces that look like virtual museums, dance clubs, meeting rooms or houses should be used for virtual analogs of what one might do in their offline equivalent. This argument is analogous to Norman's, with respect to the design of interactions with physical objects (Norman 1988). He describes how physical objects use metaphors to demonstrate affordances. Metaphors imply a conceptual model that makes it easier for people to make deductions about what how their interactions with the system will affect it. In a very similar way, literal representations in virtual architecture serve as behavioral

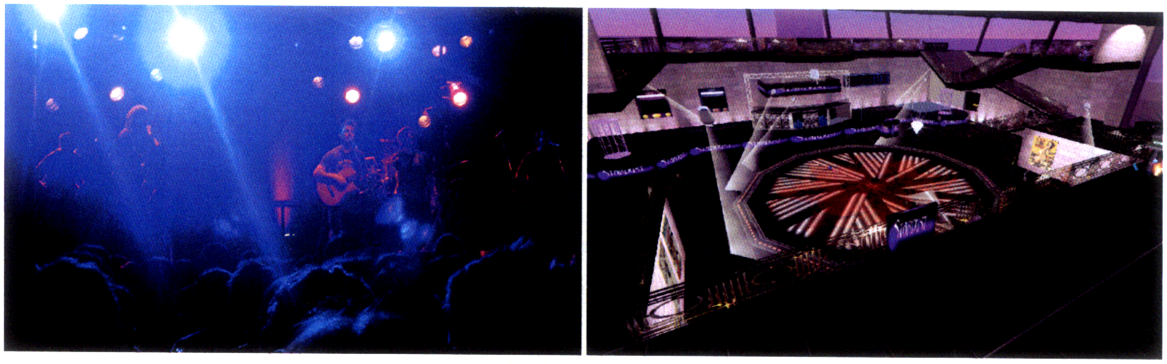

Figure 4. A real life club and its virtual world equivalent.

affordances. They use architectural metaphors to imply what the social model of the space is.

Although literal representational techniques serve effectively as identity signals and behavioral affordances, this thesis will argue that we can build spaces that not just look different and imply that different behaviors are expected but spaces that actually have different functional affordances that make certain activities more or less effective in a particular space. Functional affordances are those that are not simply based on what the space looks like, but what aspects of the world that are algorithmic and reactive in some way. This approach is akin to that in *Beyond Being There*; we should treat virtual space as a new medium that has its own strengths and weaknesses instead of trying to create the experience of "being there." This distinction is best understood through analogy to how symbolism and function interplay in two kinds of physical spaces: cathedrals and nightclubs.

The form of a classical cathedral is rich with religious symbolism that informs the overall structure of the building, detailed adornments, lighting, and scale. It also has certain functional affordances; the space is designed such that a speaker at the podium can be easily seen and heard by the people in the pews. This also means that the whole congregation will easily hear any noises from the pews. This encourages parishioners to be quiet, and re-enforces the power dynamics inherent to the church; visitors are not there to interact with each other.

Nightclubs use acoustics and lighting to create a very different kind of space. Although the form of clubs varies widely, the functional aspects of clubs are often quite similar. Loud music makes it hard to hear people far away, which both forces people to be close together to talk and makes it hard to be overheard. In this environment, intimate conversations are easily had. Low lighting makes it difficult to see people, hear them, and identify them. It creates a situation in which people must fill in information about each other because the environment makes that information hard to get. Darkness and candlelight in a cathedral would have a different effect -

the functional and cultural/symbolic meanings are interwoven. The nightclub is known to be about hedonism and escape; the cathedral, for the believer, about spiritual, solemn, and perhaps frightening/awe-inspiring experience.

Lighting and acoustics are two aspects of what I call "functional" aspects of space. They operate mostly independently of how a space looks and both respond to people's actions in the space as well as mold those actions. These two examples demonstrate how the functional side of spaces has a big impact on what kind of activities make sense in them. You would not, for instance, try to hold a business meeting in a nightclub or hold small group discussions in a cathedral. Yet virtual spaces very rarely have this kind of adaptability to their designed purposes. You could, in a world like *Second Life*[2] hold a business meeting in a virtual night club with no particular ill effects. It would be a strange juxtaposition, but the location would be only a visual distraction, not a major impediment to having a conversation. The heart of this thesis is to explore how we can bring this kind of rich design vocabulary to virtual worlds and imagining both what are the functional features of virtual space and what kind of worlds we might build with a functional vocabulary in virtual architecture.

This process starts by doing a close inspection of what the properties of virtual space are that might form the basis of a functional architectural vocabulary. Key to this is appreciating the algorithmic nature of virtual worlds. A designer in a virtual world is almost paralyzingly unrestricted in what properties of a space they could control, and organizing potential options into categories forms a useful basis for future designs.

2.4 PROPERTIES OF VIRTUAL SPACE

The properties of virtual space fall into two major categories. Those properties that represent a decrease in the cost of changing properties relative to their physical counterparts and other properties which are almost completely impractical in physical spaces.

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[2] Although *Second Life* is a convenient and particularly effective world to make this point, Chapter 3 details a wide range of other virtual worlds that are similarly afflicted, as well as some non-world environments that are not.

2.4.1 Incremental Properties

A virtual room can easily change its size or shape, the number and orientation of its chairs, its color, and even its proximity to other spaces in the world. This is possible to a limited extent in physical buildings, but virtual worlds expand the design space substantially by making radical changes relatively simple. (Au 2006) Ways of making this kind of reconfiguration accessible in physical space have long had a certain allure for architects and designers, (e.g., (Cook & Chalk 1999; Negroponte 1973)) but virtual spaces take this kind of reorganization to a level that physical spaces will likely never reach.

There is a similar pattern in using building surfaces as output devices—there is quite a bit of interest in augmenting physical spaces in this way, but no physical display or screen has the range of possibilities that virtual spaces can. Because surfaces in a virtual space are programmatically controllable, any surface can become a sort of screen.

A similar argument can be made about sensing behavior in virtual spaces. Although the set of things you can sense is not substantially different from what you might sense in a physical space, sensing can be a built in property of a world with high accuracy. The world can simply make available its internal state to programmers, taking the place of dealing with the challenges of sensing.

Physical spaces have a limited sense of memory and only accumulate certain things: people frequently walking along certain paths, certain destructive activities, modifications people have explicitly made to the structure or appearance of the space. In contrast, virtual spaces can remember in great detail everything that has ever happened in the space. It could store, for instance, everyone who has visited the space, what said or where people were when they said it. I am not advocating for virtual spaces as perfect surveillance tools, but capturing some aspects of history (and clearly representing that history, so visitors understand what is being recorded and how it's being used) can be a powerful design technique that is not very accessible in physical spaces.

Materials in virtual spaces should be understood differently than their physical counterparts. Outside of game worlds in which there is artificially enforced scarcity, virtual materials are free and non-distinct. Material textured to look like marble is not inherently more expensive than material textured to look like a laminate countertop. Consequently items in virtual worlds have economic models more like software; the incremental costs of distribution are nearly zero, and so the creation costs are predominantly an upfront investment in time. High complexity designs are always more expensive than low complexity designs. Zero material cost also means that spaces can easily create new objects on the fly to change some aspect of the space.

2.4.2 Transformative Properties

What really sets virtual worlds apart is their ability to dictate the agency someone has in a virtual world, the interface with which they access those abilities, and how they are represented in the world.

2.4.2.1 Agency

Different worlds give people different abilities in the world. Virtual worlds don't allow for everything that the physical world does. For example, virtual worlds built for playing sports would enable avatars in that world to do physical tasks that they probably couldn't actually do themselves in a physical stadium. As a result, virtual worlds focus on different categories of agency. There are virtual worlds for building things, socializing, having sex, playing different kinds of games, holding meetings, etc. All of these worlds give avatars different agency that is appropriate for the tasks that world is for. Typically, though, these differences in agency are on the world level. It is rare that different parts of the world will over substantially different agency to avatars. A world is either for meetings or shooting people—not separated into areas where avatars have abilities appropriate for shooting and areas where their abilities are appropriate for holding meetings. A big part of what virtual spaces could be doing more effectively is giving designers more control over player agency in spaces so that players need not change the world they're using to have appropriate agency for different tasks. For instance, designers should have control over how quickly avatars can move, whether there's voice communication or chat, or both; whether avatars can drag and drop URLs or files into the space; whether objects in a space can be moved by avatars or not. There's a large set of possible combinations here that have a profound impact on the social experience of a place. Having this kind of control is unique to virtual spaces, but this design space is largely unexplored in modern virtual worlds.

2.4.2.2 Representation

Virtual worlds have substantial control over how avatars are represented. This control takes two forms: control that users have over their own representation, and control that the world has over their representation. The designers of a world make some basic choices about what the representational vocabulary will be. Avatars can be rendered as humanoid, abstract, realistic, cartoonish, or perhaps not even given bodies at all. Within that vocabulary, avatars typically have substantial control over what they look like. How someone chooses to be portrayed serves as a signal of their taste and identity. In an analog to information entropy (Shannon 2001) the size of the representational vocabulary has a big impact on how representations are understood, too. In worlds with only a handful of basic avatars, how someone chooses to be represented isn't particularly meaningful. In a largely free-form structure like *Second Life*, the rich vocabulary makes someone's decisions much more meaningful because few people will occupy that particular point in the representation space.[3]

Representations need not just be subject to the control of the avatar's user. Representations can be subject to algorithmic control of some sort. In some models, this could involve some level of automation of certain avatar actions like smiling, managing eye contact, or other body language. (Vilhjálmsson & Cassell 1998) Like spaces, representations can also aggregate information about someone's behavior over time. In *Puzzle Pirates* (Three Rings 2003), for instance, players can only get peg-legs or eye patches as a result of being on a ship sunk in a certain kind of inter-player conflict. Similarly, avatars might age to show how long they've been in the game, or change to represent something about the role that they have historically focused on in the world. Representations can also change over a shorter period of time to represent information like how talkative someone has been, which other avatars they've been talking to, or what tasks they've volunteered to do.

2.5 MEANING MAKING IN VIRTUAL SPACES

Harrison and Dourish (1996) proposed a set of distinctive "aspects of the 'real world', which can be exploited as part of a spatial model for collaboration." This model is distinct from the model discussed above, in that it focuses on what's similar, not on what's different. They argue that these similarities (relational orientation, proximity and action, partitioning, presence and awareness) between the physical world and spatial interfaces give "critical cues which allow us to organize our behavior appropriately." This is very much in line with our earlier analysis—the representational and functional aspects of virtual space are critical in the meaning-making process and inform our behavior in a virtual space. Dourish and Harrison go on to argue that this model is too simple, and that it is our socially constructed understanding of a space that transforms the space into a place in which people's interactions have a meaningful context.

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[3] In *Second Life*, making a major change to your avatar's representation represents a major shift from being a novice user of the system. Players that use one of the stock avatars (or some trivial modification of the stock avatar) are widely derided and viewed with general suspicion.

Although Dourish and Harrison don't directly address the question of how people understand space and place in their first paper, Dourish's expands on their work in 2006 (Dourish 2006), and discusses in some depth how meaning is made through practice, drawing on the work of Michael de Certeau. In his view, "spatialities ... are experienced and produced from within rather than defined and imposed from without. They are the products of lived experience and embodied action." (Dourish 2006) The spatialities he identifies (from the perspective of new technical spatialities) are, for instance, mobile telephony, transportation systems, systems that modulate visual or physical access, and Internet accessibility. These are all aspects of space that are similar to the models of virtual space that I propose in Section 2.4. For instance, changing an avatar's ability to communicate with other non-local avatars is the virtual equivalent of mobile telephony; a person's experience of a virtual space without such a feature is like that of being in a room with no mobile phone signal. As a result, the practice of people in both those spaces constructs a certain meaning: this is a space in which people should be focused on the space itself, and not on remote conversations. Analogous arguments can be made for the other types of spatiality in the virtual domain.

This argument is analogous to Lakoff and Johnson's (1980) in *Metaphors We Live By*. The metaphors of spatiality provide a critical foundation to our language and understanding of spaces. Virtual worlds' spatiality ties in with metaphors they identify like "high status is up; low status is down." This in turn influences people's understandings of virtual spaces. Even in the absence of

It is precisely these features that modern virtual worlds overlook, and this critically inhibits the process of making meaning of spaces through practice. It is my hope that with a richer model of virtual space that takes advantage of some of its native characteristics more place-like experiences can be had in virtual worlds.

Chapter 3
RELATED WORK

3.1 INTRODUCTION

Virtual spaces have long attracted the interest of academics, writers, architects, and game designers. My work draws from all of these fields to some extent, and so to provide some background to my approach, I will discuss a wide range of related past work. This work falls into four broad categories. I start by giving a brief history of virtual game worlds which have been the genesis of most other types of virtual worlds, and are still the most widely used virtual spaces by far. As game worlds started to become popular, they also became a popular subject of science fiction literature. I will discuss a few of the most influential ideas to come from literature, how their models of virtual space differ and how those models have influenced the design of virtual worlds we use today. Finally, I will draw connections to academic work in virtual worlds, and show how my work relates and extends previous work, as well as discuss relationships between current work in both games and literature.

From an historical perspective, virtual worlds as a field of academic interest have grown out of their initial creation as game worlds. A complete history of virtual worlds is beyond the scope of this thesis (for one good example, see (Bartle 2003, pp.1-17))

I start with introducing how virtual architecture has been used in game spaces, both single-player and multiplayer. These examples have been both instructive to me in developing my understanding of the properties of virtual space, as well influential in the design of existing virtual world platforms. Video games are a subset of virtual worlds in general, but have used a number of common techniques to make their virtual spaces more than just mood-setting backdrops for gameplay.

3.2 GAMES AND ARCHITECTURE

One of the most common ways in which games make use of virtual architecture is to simulate actions in the game space using the familiar rules of physics. For instance, player characters in worlds like this are susceptible to gravity, can move independent of the direction they're looking. Depending on the game, players' agency will vary widely, but it is usually fundamentally spatial—what kinds of actions someone can take is a function of how far they are from someone, various features of the nearby environment and their own player-character's state (e.g. items they're carrying, remaining health or money, etc). The richness of this interplay between player abilities and the environment provides most of the game's core mechanics.

This interplay between the weapons players shoot and the environments they're in gives rise to a rich gameplay vocabulary that players quickly become adept at reading. In particular, players frequently employ different kinds of tactics depending on what kind of weapons they have on hand and what kind of space they're in. It is this sort of behavioral adaptation as a functional of environment design that I think could be harnessed for non-game oriented spaces as well.

3.2.1 Halo 3

This is approach is extremely common in modern three-dimensional video games, and is used most notably in shooters (e.g. *Half-Life* (Valve 1998), *Halo* (Bungie Studios 2001), *Gears of War* (Epic Games 2006), etc.), action-adventure games (e.g. *Mass Effect* (Bioware 2007), *Splinter Cell* (Ubisoft 2002), *Portal* (Valve 2008), etc.). Platformers like the *Super Mario Bros*. (Nintendo 1985) series also exhibit some of these same approaches.

One game in particular helps to demonstrate how this relationship can work. *Halo 3*'s (Bungie Studios 2007) multiplayer modes are quite popular and comprehensive game-play data has been made available in the form of maps that

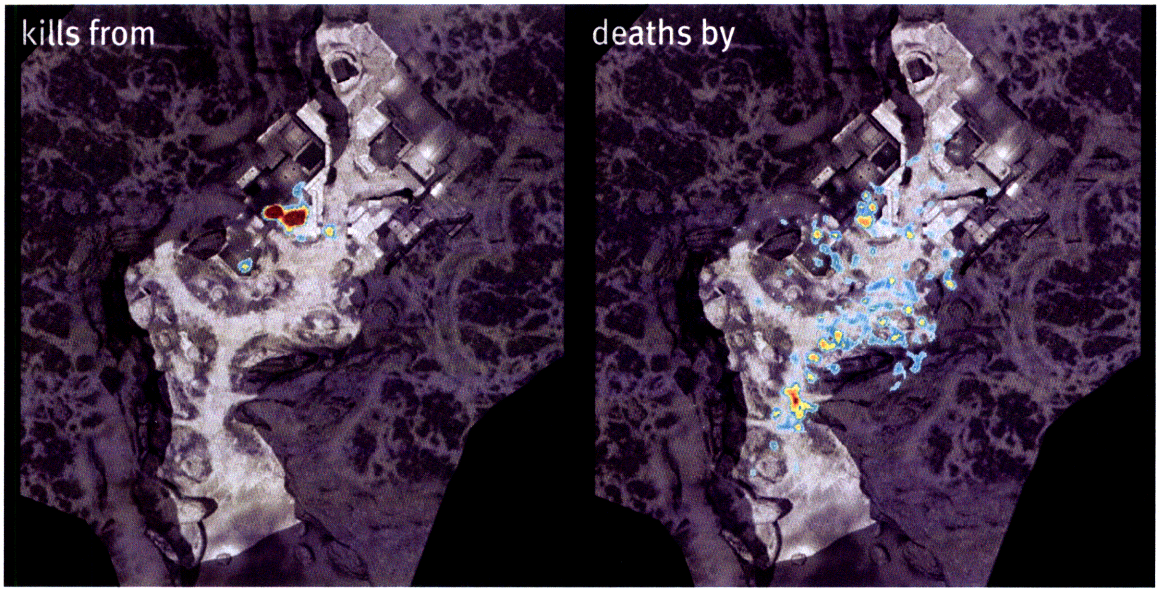

Figure 5. Comparison between where players were killed by lasers and where the lasers were shot from. Dark red is a high density of events, light blue is low density. Images courtesy of Bungie Studios' bungie.net site.

show where player characters have been killed on the map or where they were killed from. This data can be further broken down on a per-weapon basis. This lets us explore in some detail how aspects of a level's design influence which weapons and tactics are used in which parts of the map.

A few examples will help illuminate this point. One weapon—the Spartan Laser—can be found on the top of a tower on a map called "High Ground". The laser can kill any other player in one hit, but takes a few seconds to charge up. As a result, it's easiest to use at long range; at short range the target is moving too quickly to accurately track with the laser. The tower in which the laser starts is thus a prime position to use it from; it has good visibility of much of the map and is easily defendable because it only has once entrance. (Figure 5) This is borne out by the heat maps for this weapon. Almost all kills with this weapon happen from this one position. In contrast, the location of deaths show the effective sight lines from that tower. Players quickly adapt to this dynamic, and understand the tradeoffs between moving in the open (where someone in the tower with a laser is most likely to kill you) and moving in out of sight areas (where a laser-wield player is almost certainly not able to see you) are clear. The heat maps also reveal enclosed, smaller areas in which short-range weapons like shotguns and grenades are most effective or open areas where vehicles can maneuver are most effective. (Figure 6) These maps represent a window into the player's experience of these spaces, revealing the patterns that the architecture and weapon characteristics create.

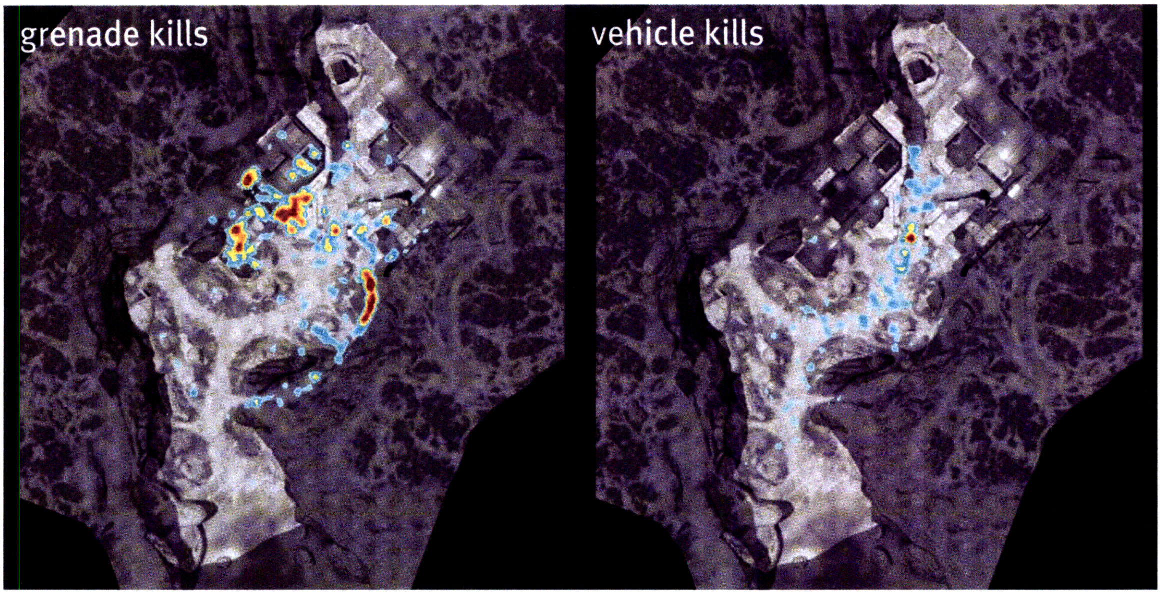

Figure 6. Comparison between where players are killed by grenades (which are effective in confined areas) versus getting killed by vehicles (which are most effective in open areas where they can maneuver). Dark red areas represent many kills, light blue areas have fewer kills.

This is one model for how the physical architecture of levels in a physics based game can influence player behavior. Although my projects aren't trying to create game experiences, they are primarily concerned with how spaces can create different affordances for interactions. Playing multiplayer *Halo 3* is a process of understanding where other players are likely to be, what weapons they might have, and the properties of the space you're currently in. Using the language introduced earlier, *Halo 3* is a system that is primarily about changing agency of players, not about functionality inherent to spaces. Depending on what weapons a player has, their interaction patterns in a space vary widely. The spaces themselves, though, don't exhibit many of the characteristics of virtual space that were discussed on the Background section. My work seeks to bring both some of this variable agency to non-game worlds.

3.2.2 World of Warcraft

Unlike the previous example, characters in *World of Wacraft* barely interact with their environments at all. Although the environments are beautifully designed, player characters interact almost entirely with other characters, computer-controlled monsters in the environment, and a handful of environmental features. In the case of player/player and player/monster interactions, players' agency is a function almost purely of the distance between the character and the ability's target. Relative elevations, walls, even the presence of other characters rarely come into play. The one effect that architecture has on the experience is a sort of narrative architecture that directs and orders the player's experience (Jenkins 2004). This is particularly true of non-combat interactions. No matter where in the world a character is, chat can be heard at the same distances, most inter-character information can be accessed with just a name. Most important chat channels are audible anywhere in the world, too, so one's particular location isn't particularly important. This devalues the meaning of space further. Characters in *World of Warcraft* don't collide with each other either, making it possible to accommodate large groups in very small spaces. This makes the size of a room largely meaningless; a big meeting could happen in a tiny store as well as in a large meeting room.

Spaces in *World of Warcraft* are very low on the persistence scale as proposed by Bartle. Killing a monster changes the world for only a few minutes; all monsters respawn eventually. Indeed, many of the most used important spaces in the world create separate copies of themselves for each group of players who wants to enter, removing any expectation of persistence beyond the few hours the players spend in that area together. There are a number of gameplay reasons why this makes sense, but it also gets in the way of most of the properties of virtual space that make it most promising for new kinds of interactions.

World of Warcraft is only one example of how virtual worlds make use of space, and the details of the design choices are different from world to world. But due to *World of Warcraft*'s success, many of its features are being viewed as a blueprint for future successful virtual worlds, including the kinds of social structures it fosters (Ducheneaut et al. 2006) and so its very limited approach to virtual architecture is likely to appear in many future game worlds.

3.3 VISIONS OF VIRTUALITY[4]

Research projects often have a hard time communicating broad visions for the impact of their research on future societies. Literature has historically been much more effective at working through the implications of particular technologies in the context of people's lives. This is particularly true with respect to virtual worlds, where imagination has long outstripped our technical ability to create such spaces. In this section, I describe three primary visions of virtuality—abstract, literal, and augmented—and discuss their impact on both modern virtual worlds and situate my approach within the range of their visions.

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[4] This section draws heavily from writing done with Dietmar Offenhuber and Judith Donath that was ultimately cut from (Harry, Offenhuber & Donath 2007).

In *Neuromancer*, William Gibson (1984) proposed one of the first coherent visions for cyberspace. His cyberspace was fundamentally a world of information and programs. Although the space itself was built based on spatial metaphors, representations of data and corporations were strictly abstract. As the main character infiltrates a company's storage space, he finds "an infinite blue space ranged with color coded spheres strung on a straight grid of pale blue neon. In the nonspace of the matrix, the interior of a given data construct possessed unlimited subjective dimension; a child's toy calculator, accessed through Case's Sendai, would have presented limitless gulfs of nothingness hung with a few basic commands." (Gibson 1984, p.63) Indeed, this kind of virtual environment seems to be inspired by a *Powers of Ten*-like (C. Eames & R. Eames 1977) vision of the recursive infinite detail of space, which has also appeared in work on zoomable interfaces like *Pad++* (Bederson & Hollan 1994).

The notion of Cyberspace had a strong impact on many architects, as well. Marcos Novak's transarchitecture (Novak 1991) charted out the possibilities of architecture in virtual space by acknowledging the fact that in cyberspace "all constants are variables." In a spatial medium without physical substance, time can become a central element of its architecture. Virtual spaces do not have to be static, but would be constantly transforming and reacting to its users. Buildings that can be transmitted and broadcasted would ultimately lead to a new language of architectural design. For him and many other architectural thinkers, cyberspace promised the liberation of architecture, the removal of constraints like gravity and continuity. This liberation would go beyond the realm of pure abstract geometry, by investigating the possibilities of non-Euclidean spaces.

Neal Stephenson's *Snowcrash* (2000) focused more on the social side of what he called the "metaverse". He imagined a much more literal space, with public transportation, private land, and avatars with human-like expressiveness. The metaverse as he describes is a pragmatic place with a single continuous sphere filled with "buildings, parks, signs, as well as things that do not exist in Reality, such as vast hovering overhead light shows, special neighborhoods where the rules of three-dimensional spacetime are ignored, and free-combat zones where people can go to hunt and kill each other." (Stephenson 2000, p.19) In this model, the metaverse is a very social space. People aren't expected to live in the metaverse, it's merely a place some people go to do certain types of activities they can't do anywhere else. An extreme version of this approach would include the fully immersive worlds like those in *The Matrix* (L. Wachowski & A. Wachowski 1999) and *Otherland* (Williams 1998) series. This model is also quite similar to Vernor Vinge's short story "True Names". (Vinge 1987)

Vernor Vinge's *Rainbows End* (2006) wasn't the first novel to propose virtual worlds that overlay the physical world, but it is an especially striking and coherent vision. In Vinge's vision, people have continuous access to different layers of virtuality overlaid directly onto physical spaces. People tune in and out of these layers depending on their interests. Layers can be data oriented (though usually still spatial data) and is navigated primarily by walking through the virtual projection on reality. People can look at layers that are not local to them by projecting their avatars to other places. Depending on the local infrastructure they using, they are sometimes represented as projections. People's representations move fluidly between the realistic and the fantastical. This approach is heavily inspired by the social dynamics of the Web—people discover and view layers based on their popularity with other users. Although my work was not really intended to be a 1-1 mapping onto physical spaces, it is exciting to imagine how its techniques could translate to a future in which modifying people's representations was easy in physical environments as well as virtual. This could very well make *Being There* into something entirely new. This approach is rapidly becoming feasible thanks to research in this area, for instance (Klein & Murray 2007).

Looking at the current state of shared virtual worlds, these visions have, for the most part, failed to materialize. Virtual environments today are an amalgam of the lowest common denominator of these visions. Buildings in *Second Life* are hardly the radical transarchitecture of Novak or the new abstract aesthetic of Gibson. Data rarely makes an appearance at all, and space in worlds like *Second Life* is experienced not as a formless void, but as a suburban sprawl. Gibson's vision is somewhat more evident in the structure of the Web. The discreteness of spaces, the focus on data, and the lack of avatar representations are all evident on the Web, but are rare in virtual worlds.

Instead of being like Novak or Gibson's visions, *Second Life* is a space that is intensely social, like Stephenson's vision, but it is marketed as a world in and of itself, which exists separate from your "first" life. Despite that, its architecture depends heavily on imported real world metaphors. In our view, Gibson and Novak's visions haven't yet played a big role in virtual architecture because of the legibility challenges they pose; understanding virtual architecture with familiar representational models is hard enough without trying to impose a new architectural language on users. While we hope virtual architecture will become more dynamic and less concerned with recreating spaces that look like their offline counterparts, we think the current phase of virtual architecture is a necessary compromise, at least for now.

That technology and media should have a symbiotic relationship is not surprising. In interface design alone, Shedroff and Noessel (2008) have detailed a huge number of instances in which modern technology has influenced interfaces in fiction as well as examples of fiction influencing real interface designs. In the case of *Second Life*, the connection is pretty clear. Philip Rosedale, Linden Lab's founder, is clearly aware of the history of virtual worlds in literature (Computer Power User n.d.) even if he professes to be inspired independently. (Dubner 2007) For the purposes of this thesis, I would like to use these differing visions to show that the future of virtual worlds still has quite a bit of flexibility. Although modern worlds have for the most part settled onto a *Snow Crash*-like vision, there are other alternatives that differ in their fundamental goals. As those new sorts of worlds are developed, I hope that the vision for virtual space that I propose might in some way impact the direction that virtual worlds develop in some of the same ways that science fiction literature has.

3.4 OTHER RELATED WORK

3.4.1 Second Messenger

Although the *Second Messenger* (DiMicco et al. 2007) was primarily interested in instrumenting physical spaces, it makes a compelling argument for how social sensing and its subsequent visualization can be a powerful tool for influencing the social dynamics of a space. By showing aggregate information about how much different meeting participants were talking, it balanced in the influence of different people in the room. Participants who were inclined to talk too would moderate their speaking times, while people who tended to speak less could use those new gaps to make their own points. This approach has also been demonstrated in the *Meeting Mediator* (Kim et al. 2008) project, in which the displays were moved to personal mobile devices. *Meeting Mediator* reinforces the idea that displaying certain social information modulating people's behavior. Other work that falls into this category includes *Conversation Clock* (Karahalios 2006) and *Visiphone* (Donath, Karahalios & Viégas 2000). Working in virtual environments makes experimentation with and implementation of these kinds of technologies substantially easier. While you might be able to include this kind of tool in a handful of conference rooms in a building, turning features like this on or off in a virtual space is as simple as turning the lights on or off in a conference room.

3.4.2 Social Translucence

Wendy Kellogg's work on what she calls "social translucence" (Erickson & Kellogg 2000; Kellogg et al. 2006) is also quite relevant to my approach. Much like *Second Messenger* and *Meeting Mediator*, she has built a series of social visualizations that make visible different aspects of interactions like lectures, auctions, waiting in lines, and holding meetings. These "social proxies" have many of the same properties as a virtual space like the *Agree/Disagree* spaces or spaces in **space*. They highlight certain kinds of behavioral properties by making them visual.

While I think this is a very effective (and surprisingly underused) technique, I believe this approach is only made more rich by making responsive spaces instead of proxies. Waiting in line, for instance, is an inherently spatial activity, and people could move their own avatars through the line instead of letting the proxy function only as a representation of the internal state. Although this poses some usability challenges (line waiting becomes more active, for instance), it also provides for much more social flexibility; if someone has stepped away and isn't moving themselves up in line, more active waiters can take their spot without there needing to be some sort of formal intervention. It is this dynamism that using a virtual environment can create in contrast to the primarily output-only social proxies.

3.4.3 Chat Circles Series

The Chat Circles series (Donath & Viégas 2002) has been particularly inspirational for the **space* project. I have drawn from that project its abstract visual style as a way of stripping the experience of interacting with other people down to its essence. Chat Circles suggested many of the issues that this work explores in more depth—showing movement trails behind avatars, the archival nature of spaces and changing representations of chat at a distance. *Talking in Circles* (Rodenstein & Donath 2000) extended the original design to include spatialized voice chat, a feature that is rapidly becoming expected in new virtual worlds. *Chatscape* (Lee 2001) focused on issues of representation in Chat Circles - specifically what the affordances are of a space that grants control over an avatar's representation to other people in the space. This general principle of making avatar representations in some way algorithmic is an interest I share, and is explored in some ways by the **space* work. In general, **space* is a generalized version of Chat Circles. Instead of providing one well-designed environment, it seeks to enable a wide range of different environments to better elucidate the design space in which the Chat Circles series resides.

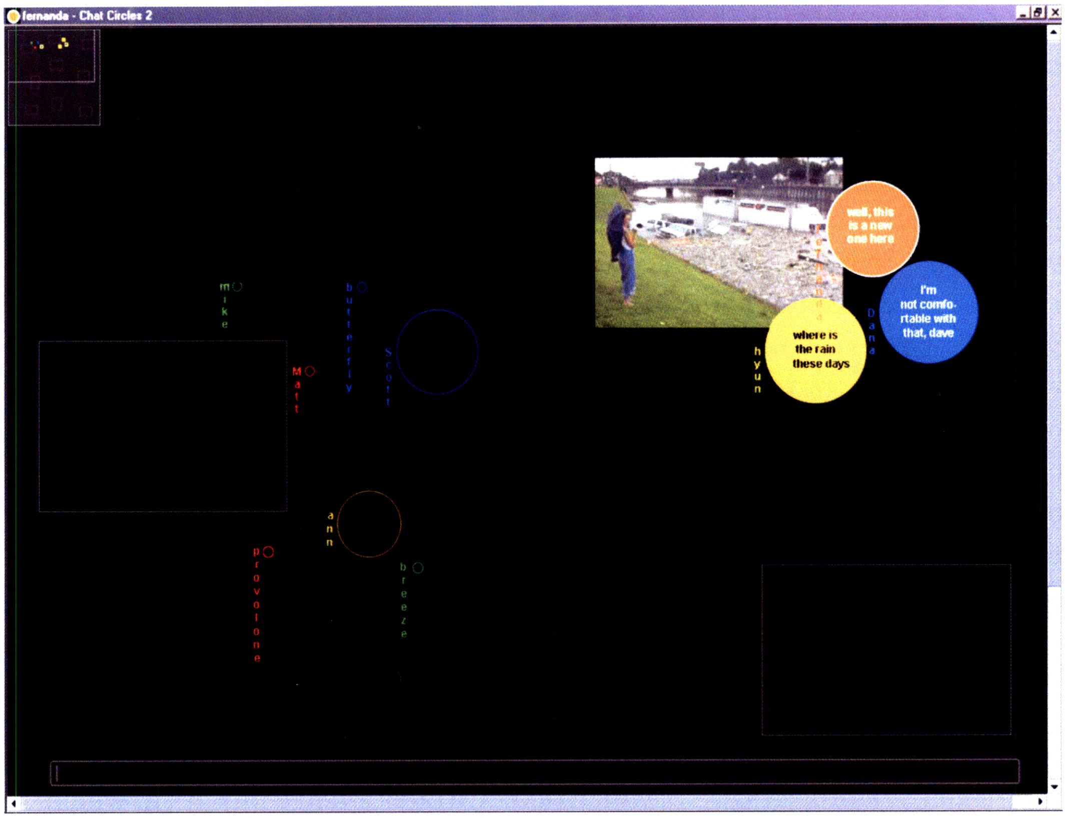

Figure 7. The ChatCircles environment with many people in it. Chat local to the client is visible, while chat farther away isn't visible. From personal copy.

3.4.4 Avatar Representations and Inter-Avatar Behavior

The Virtual Human Interaction Lab at Stanford has done a range of interesting work into transforming the representations of avatars and manipulating the social queues they send. (Bailenson & Beall 2006) Their findings make clear the range of perceptual manipulation that's possible in virtual environments. Although their work has focused on manipulating the gaze, behavior, and appearance of realistic human avatars, it suggests that other kinds of manipulations can have an impact on modulating people's perceptions about others in virtual spaces. Bailenson's approach is more than a little dystopian. (Donath 2007) By attaching different representational techniques to specific spaces, I hope to make visitors to a virtual world aware of what the implications of different representational techniques can be.

Also of note is Yee's *Unbearable Likeness of Being Digital* (Yee et al. 2007), in which the authors show that avatars in *Second Life* maintain interpersonal distances like people do in non-virtual spaces, including the expected differences between male-male and female-female dyads. This shows that even in a world that by modern standards is far from being completely immersive, people still follow familiar social conventions from face to face interactions. This poses a challenge for our attempts to move *Beyond Being There* - how much do the rules of an environment have to change before people start to adjust their behavior?

The *BodyChat* (Vilhjálmsson & Cassell 1998) project gave avatars better techniques for signaling conversational availability by using stance, gaze, and gesture changes. This approach is promising, but mapping familiar face-to-face behaviors onto avatar animations poses a number of challenges. There is substantial subtlety to the body language elements that *BodyChat* appropriates that are not represented in their avatar's behaviors. This opens the door for misunderstandings when your avatar doesn't do quite the right kind of glance you might want to do and sends the wrong signals. This is a component of the "uncanny valley" (Mori 1970)—getting close to human-like gestures can make viewers more uncomfortable than if the gestures were much more cartoony. In general, we prefer to give avatars new kinds of gestural vocabularies where users need to build up new vocabularies for interacting instead of trying to (imperfectly) recreate face-to-face vocabularies.

3.4.5 Second Life Projects

There are two *Second Life* projects of note in this space. The first is Brouchoud's *Reflexive Architecture* project (2007), which demonstrates a range of ways in which spaces can respond to people in them. For the most part, these approaches are concerned with modifying the form of a space to respond to the people inside it. For instance, a number of the pieces in his gallery move to create more space around avatars present, to create a sort of auto-expanding room. There are also a handful of examples that aggregate avatar behavior over time.

Studio Wikitecture (Shaw 2007) augments a *Second Life* space with wiki-like tools for collaborative building. Much like a text-based wiki, it is possible to browse proposed changes to a structure, make changes to a design and submit it into the tree of past designs, and vote on current design options. Although it faces a number of usability challenges largely inherent to *Second Life* itself, it is an exciting example of a kind of functional space where the properties of the spatial wiki have effectively created a new kind of multi-user asynchronous collaboration tool in *Second Life*.

3.4.6 Personal Past Work

There are also a number of my own past projects that, while not tightly linked to this work, share some similar themes. A *Second Life* project called *The Projects* (Harry & Offenhuber 2007) is a collaboration with Dietmar Offenhuber that explores how a social network might operate in a virtual world like *Second Life*. We isolate the three main roles of profile pages in a social network (social orientation, identity, and communication) and re-imagine them in an architectural context. We propose a

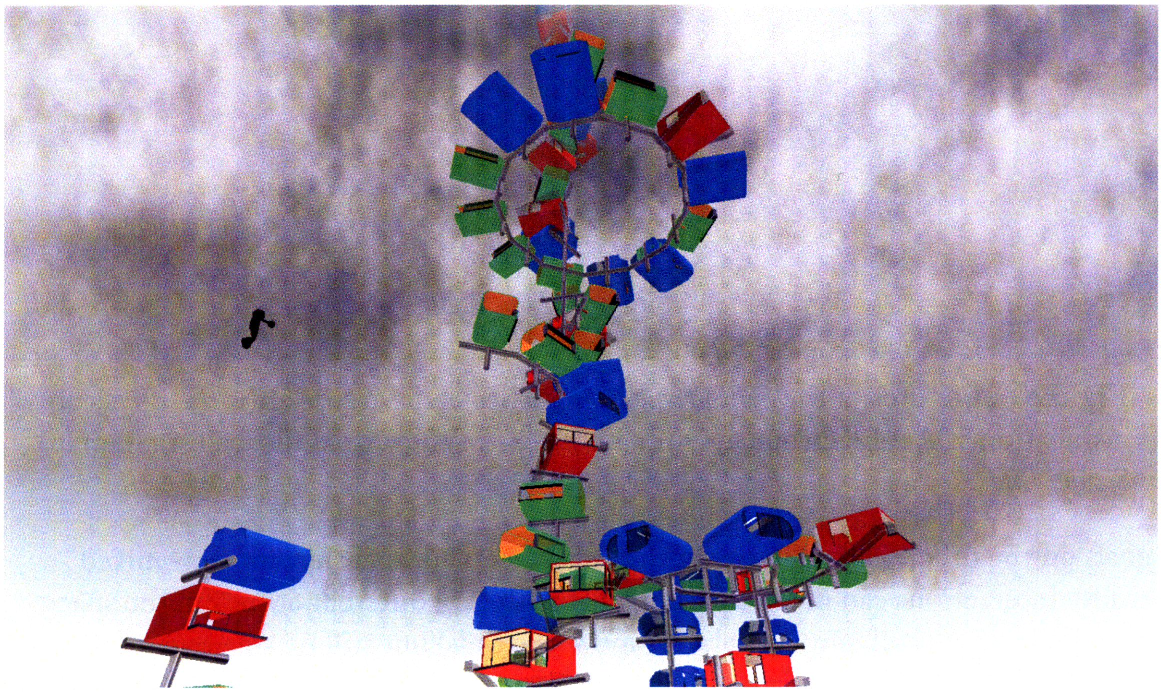

Figure 8. A tower from *The Projects*. Pods combine into an elaborate super structure following some simple organizational rules.

model where each person in a network would control the design of their "pod". Pods could link to up to four other adjacent pods, and using a set of simple rules these pod connections could give rise to elaborate architectural forms that also encoded information about the nature of the network of the people who make up the tower. This framework could then be built upon to create new kinds of playful or communicative activities that would be inherently network-centric because they could use the arrangement of the pods as the basis. In this model, we also first articulated our vision for social utilities—features of the pods that would provide amenities like popularity visualizations, identify areas of the space currently under heavy use, and displaying structural information about the network itself. In this work, we explore the possibilities of these kinds of information tracking and presentation in substantially more detail.

We've also done some projects that try to bridge virtual spaces with real spaces. One more playful example of this was the *Stiff People's League*, a collaborative project with Dietmar Offenhuber, Orkan Telhan, and Judith Donath. (Harry et al. 2008) *Stiff People's League* is a mixed reality game where teams composed of players in Second Life and a player at a physical foosball table work together to play a game of soccer. The virtual players move their avatars around the stadium and kick the ball, while the players at the foosball table can control foosball figures in the virtual stadium by moving the rods of the foosball table back and forth. Two teams compete, much like in a soccer game, to play both offense and defense and score

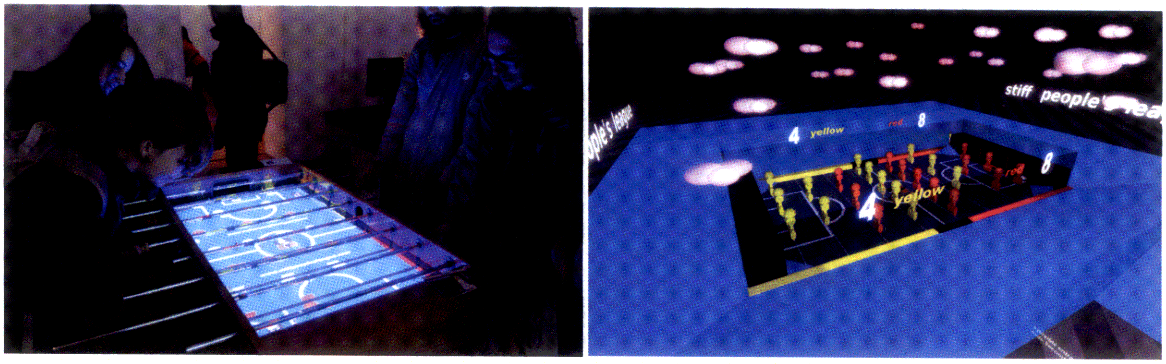

Figure 9. Pictures of the *Stiff People's League* project. On the left is the physical installation at Ars Electronica. On right, a view of the virtual foosball stadium in *Second Life*.

goals on the other team. This work is most concerned with showing how mixed reality interactions can involve participants with very different agency in the space (avatars kick the ball, physical players move the rods) but still be able to work together effectively. This approach also gives physical and virtual participants clear motivation to interact with each other, an aspect of virtual/physical interactions that is not always obvious.

Outside the domain of virtual worlds, I have developed a system for audiences (virtual and physical) to interact with presenters. *backchan.nl* is a Web based backchannel system that focuses on managing questions for presenters by allowing audience members propose and vote on other people's questions.(Harry et al. 2008) Top rated questions are projected in the presentation space so audience members, moderators, and panelists can see them. This approach provides a different kind of experience than typical backchannels like chat rooms. The projection in the room also makes purely remote participants first-class participants in the question asking process because their participation is not obviously different from that of people in the room. Future versions of this project are exploring what kinds of features of this non-virtual space that can be tuned for different applications. For instance, by changing what kind of identity information is exposed can make more or less accountable spaces, or changing the rate at which posts lose points can change the tempo of the space. This approach is similar to the algorithmic approach to virtual architecture, just with a very different visual representation. This project was a collaboration with Dan Gutierrez and Joshua Green.

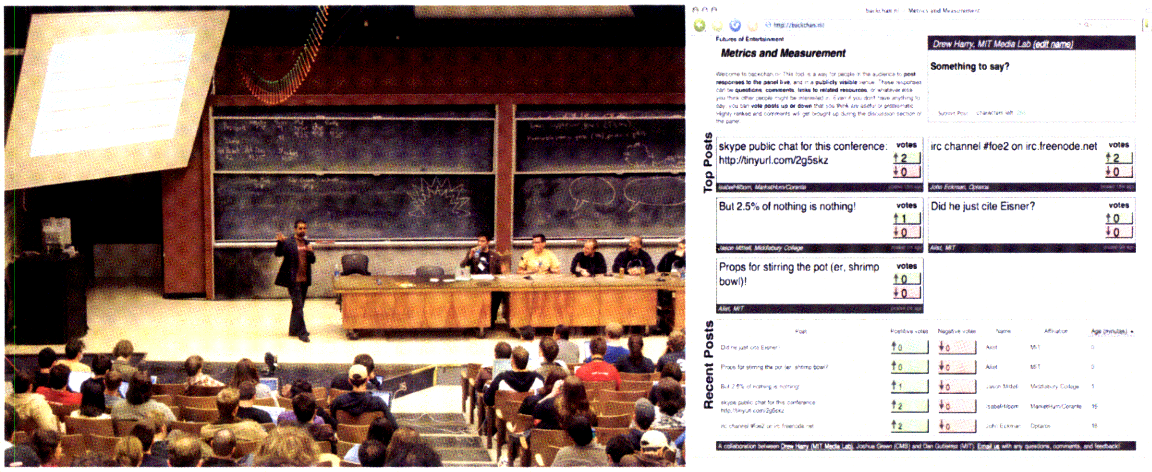

Figure 10. Left: A panel session with a projected view of the top 8 audience questions. Right: The Web interface to backchan.nl that audience members use.

3.4.7 Domain Specific Virtual Environments

There have been quite a few domain-specific virtual environments designed by researchers and artists to create particular experiences they were interested in studying. Although few were concerned with the nature of virtual architecture itself, they were nonetheless important in developing my thinking about how virtual worlds can be used.

MASSIVE (C. Greenhalgh & S. Benford 1995) was one of the very early collaborative virtual environments. It made a number of major contributions to the technical design of future virtual worlds. I'm particularly interested in the way they supported multiple kinds of clients in a virtual space, something that is still hasn't been widely adopted despite its benefits. MASSIVE has also been used for some interesting domain-specific events like poetry performances.(Benford 2000)

MOOSE Crossing (Bruckman 1997) was designed to promote a certain kind of constructionist learning environment using more or less traditional MOO technology. Although the fundamental design of the world itself was not that dissimilar from other MOOs, it was customized to encourage kids to explore issues of self-representation, writing, and programming.

Zora (Bers 1999) helped children express their identity by giving them tools to create personal virtual spaces.

Chapter 4
INFORMATION SPACES

As a first step in exploring the potential of virtual architecture, I developed a space in *Second Life* that focuses on the social meaning that an avatar's position in a space can have and how that meaning can be augmented using some of the aggregative properties of virtual space. (Harry & Donath 2008) This particular design is focused on meeting situations. In meetings with more than a few people, it can be challenging to understand other people's feelings about an issue, reach consensus, and influence others. Even logistical tasks like staying on an agenda and distributing tasks appropriately can be difficult. Our design addresses these collaboration challenges by creating a meeting space focused on non-verbal signaling using avatar positions. This is intended to be a kind of backchannel to the core conversation, much like body language can be in a face-to-face meeting. To support this use, I built a range of social utilities—systems that make visible properties of avatars' social behavior in the space. These visualizations are all controlled by a centralized dashboard, such that the nature of the space can be controlled by the moderator, much like a meeting organizer might set up the chairs and projector in a physical meeting room depending on the kind of meeting they were having. An overview of the meeting space can be found in Figure 11.

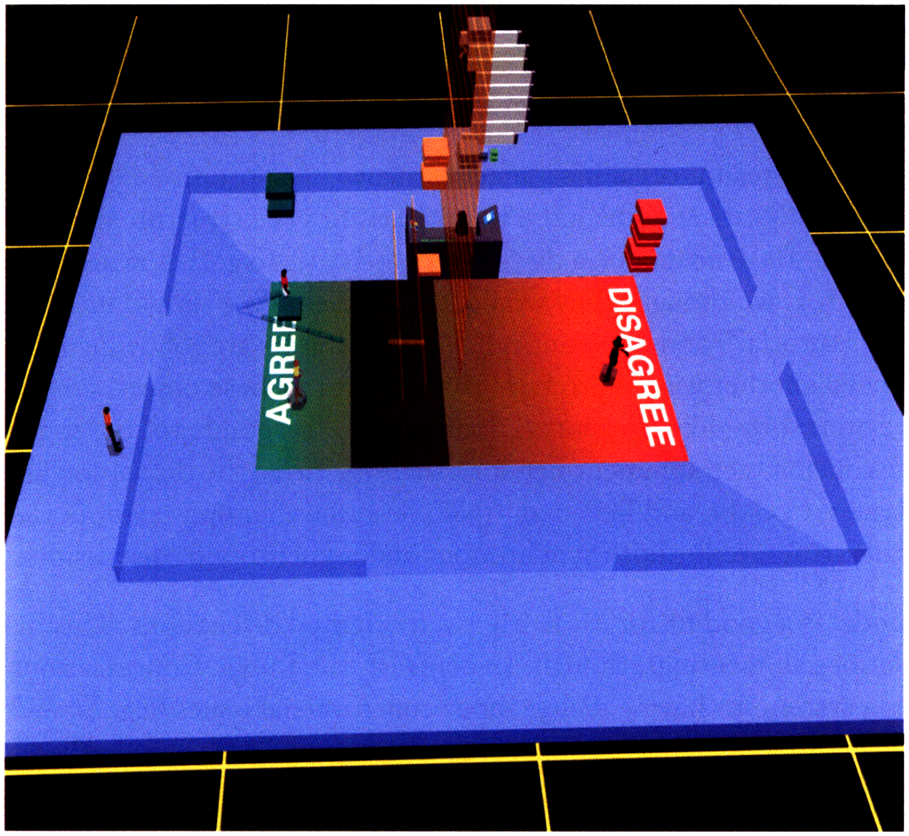

Figure 11. Overview of the Information Spaces design with all the visualization features turned on.

Beyond the space itself, I also developed a number of meeting support widgets that can augment a virtual meeting room. These widgets are not strictly architectural, but they show how different kinds of tools could create virtual spaces that are more or less appropriate for a certain kind of meeting.

4.1 MEETING STRUCTURES

Any system designed to support interaction makes a number of implicit assumptions about the nature of the social process it's trying to support. This is true across design domains. For instance, calendaring systems often assume that the important aspects of someone's work life can be captured in meetings. Meetings have a time, a place, and other meeting participants. Certainly, this describes some kinds of work life, but plenty of other jobs don't fit with that metaphorical structure. Imagine a car repair shop; a system to support that sort of work environment would necessarily be concerned with specific tasks that need to be done and which people in the shop were going to do them. A meeting organization system would not be as appropriate for managing that environment. Of course, over time systems influence people's behavior in such a way that it makes it hard to distinguish between the implicit assumptions about how people would use the system and how their behavior has adjusted to best make use of the systems they have available.

Various structures for organizing meetings have been proposed. One interesting structure is IBIS (Rittel & Kunz n.d.), which classifies the structure of arguments in design meetings. In their model, a discussion has Issues (e.g. "Users aren't using this feature as much as we thought they would"), Positions ("We should include the feature in our tutorial") and Arguments ("Not many users are following the tutorial either, we need another way to promote this feature.") These objects are linked by different relationships, like "supports", "objects-to", "responds-to" or "specializes". This creates an abstract argument network that organizes the discussion around concrete issues. Conklin and Begeman (1988) describe a computer-supported system that uses this structure for both synchronous and asynchronous discussions.

This model is a good fit for explicitly issue-oriented discussions. This by no means describes all meetings, though. In contrast, the Public Conversations Project (2003) uses a system for having dialog about controversial issues (e.g. Israel/Palestine, reproductive rights, etc.) that focuses on the context and structure of the meeting. These meetings are intentionally not about reaching consensus, but instead about building understanding, which makes an argument-based structure like IBIS inappropriate.

Part of what's exciting about working in virtual worlds is that the basic rules of a space don't preclude lots of different kinds of interfaces being built within it. The system I propose in this chapter is a simple model (neither IBIS or the PCP models) that is appropriate for only certain kinds of meetings. I imagine it as being one of eventually a set of spaces designed to work for specific situations. Just as a company might choose to use IBIS for some of its meetings, a meeting moderator in a virtual world can choose to use this space or some other virtual space for their meeting depending on whether or not their needs and the structure of their interactions are a good fit for the space.

4.2 SPACE DESIGN

4.2.1 Layout

Our space is divided into four major zones. The main area is like a traditional sports field with end zones labeled "agree" and "disagree". It provides a space for people to position their avatars on a continuum to show their attitudes about the issue under discussion. The fluid self-arrangement of people within this space based on their

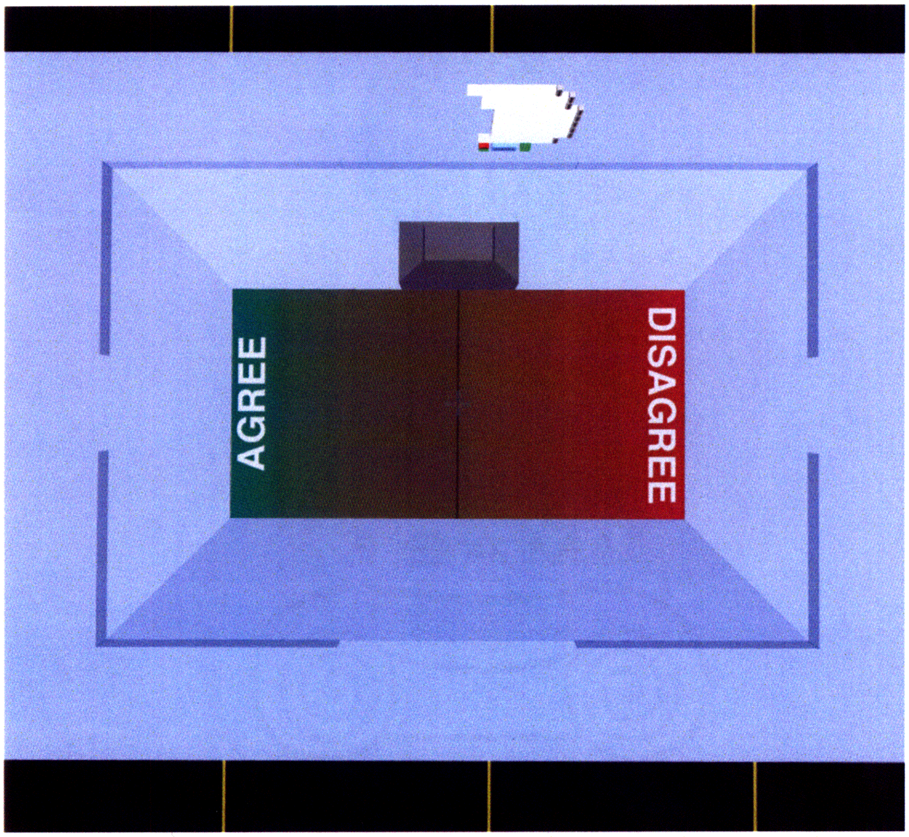

Figure 12. Top-down view of the meeting room, showing the major areas: the agree-disagree field in the middle, the sloping area for participants who don't want to be on the field, the podium with the dashboard, and an outer area for observers.

opinions provides a literal basis for seeing where someone is coming from and the status of the group's attempt to reach consensus. A single-axis continuum is used so that multiple people can easily be at the same continuum position without displacing each other.

Of course, not everyone always wants to reveal their opinion about the issue at hand. Surrounding the main agree/disagree field is an area for people to stand who want to participate in the discussion without putting their avatar on the continuum. Still further from the field is an observation area for people who want to be present, but not participating. Finally, there is a platform for the moderator with controls to manage properties about the space itself. This layout is shown in Figure 12. For the sake of simplicity, most examples in this chapter will focus on the Agree/Disagree continuum, but the implications of other floor types (for instance a process oriented Keep Talking/Move On field) will be discussed later. This spatial approach is a powerful organizational metaphor because it both relies on our knowledge of the meanings of position relative to other people in physical spaces (Yee et al. 2007) and

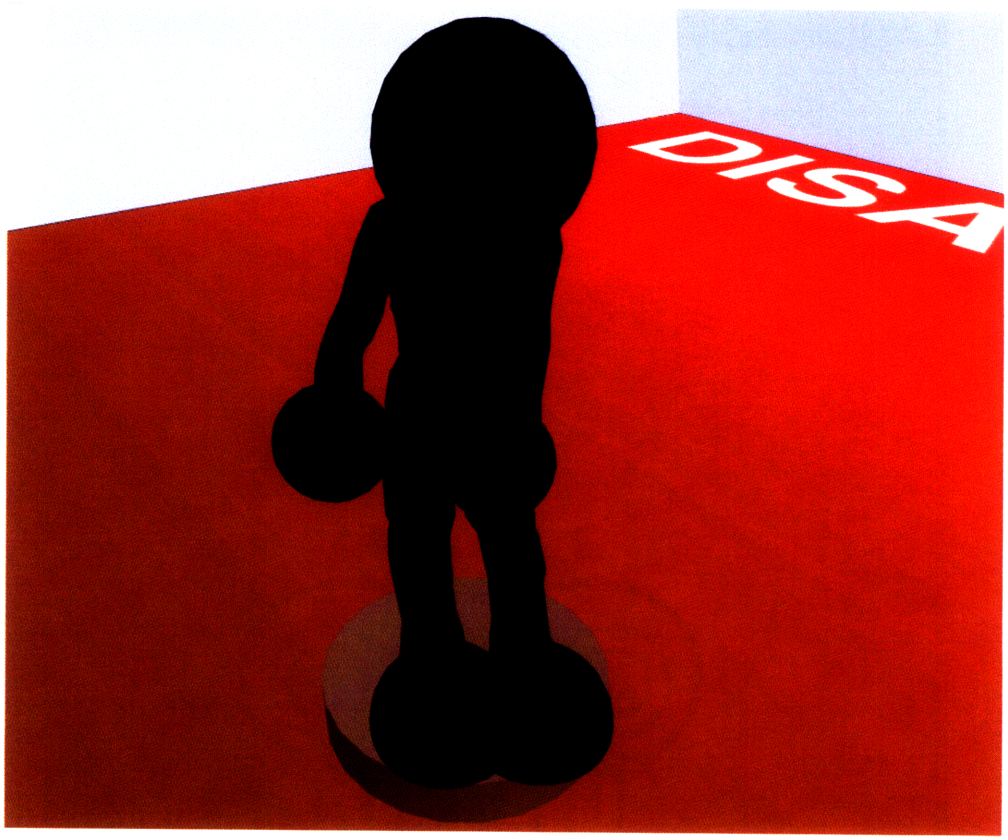

Figure 13. An avatar with a dwell indicator growing slowly at its feet.

the metaphors inherent to interactions in a spatial environment. (Lakoff & Johnson 1980)

4.2.2 Position History

Because the space is divided into socially meaningful regions, the most important information we can visualize about someone's position is how long they've been somewhere and where they last came from. When an avatar pauses for a while, a transparent column will slowly rise out of the ground. I call these columns "dwell indicators." If they move, the column will slowly shrink and eventually disappear. In this way, avatars leave a temporary mark on the space with their presence, and other people can use this signal to better understand what their position means. Someone who has been standing on the agree side of the field for the entire discussion is quite different from someone who just arrived there; this approach distinguishes those meanings visually. A dwell indicator is shown in Figure 13

As an avatar moves around this space, their path is drawn behind them. This helps meeting participants understand how an avatar arrived at their current position. In particular, it fits well with the dwell indicators; when an avatar who has been standing somewhere for a while (as shown by the dwell indicator) moves to a

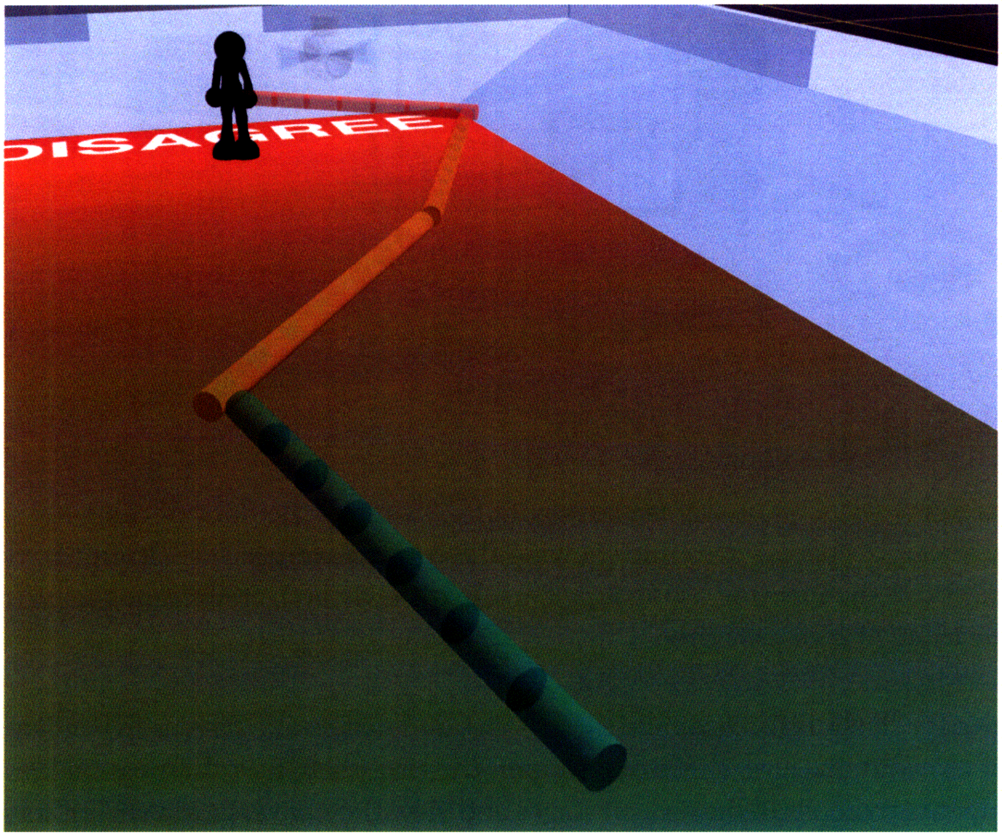

Figure 14. An avatar after moving from the agree side to the disagree side. The position history shows the avatar's path, and is colored according to the area in the space they were in.

new position, their old dwell indicator will start to shrink and a line is drawn between their old position to their new position. This connects the two dwell indicators and shows how long the avatar was in their previous position, and how recently they moved. In the case of the agree/disagree floor, this would show that someone who perhaps had long been against a particular proposal had changed their mind. This is the kind of behavior that this space seeks to visually emphasize because it's socially meaningful but is otherwise hard to convey non-verbally. A position history trace is shown in Figure 14.

4.2.3 Chat History

The space also records typed contributions in text boxes that appear above the speaker's head and then rise slowly. This creates a visualization of chat over the course of the meeting, displaying what was said, when it was said, and where in the room the avatar was when they said it. (DiMicco et al. 2007) In aggregate, it also shows that patterns of conversation of the course of the meeting. Much like the conversation visualization work discussed earlier, this allows participants to be self-reflective about the dynamics of the meeting as it occurs. By making objects appear

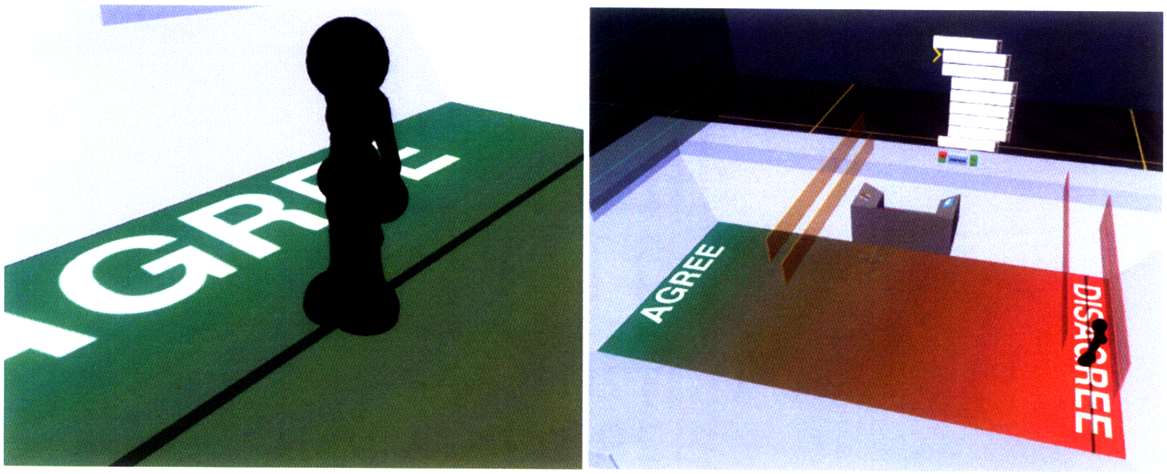

Figure 15. Displays of average voting. Left: A view of the floor of the agree/disagree space with a line showing the current average vote. Right: In the space above the meeting room, long bars float slowly up to represent the history of the average vote over time

in the space itself, it foregrounds these issues and makes imbalances in participation harder to avoid. Because the boxes contain the text itself, it is also possible for participants to zoom in on text messages and view the conversation within its spatial context—which is lost in a text-only transcript of the meeting).

4.2.4 Average

Finally, the floor of the agree/disagree field displays the current average vote (by moving side to side along the floor), as well as its deviation (by growing wider or thinner). Like chat messages, a representation of the group's collective view also floats up into the sky. These bars provide more context about the overall feeling of the avatars in the space over time, showing aggregate views of avatar movement. Furthermore, the history of the average position separates historical chat messages based on which side of the average the message came from. This helps contextualize the chat messages as well. For instance, it is easy to tell if a talkative participant was way out of line relative to the group consensus.

4.3 DISCUSSION TOOLS

During the process of developing the Agree/Disagree space, it became clear that there were a number of other common events in meetings that could be easily supported with applications. From an application design perspective, the main benefit of working in a virtual world is that it's easy to export information into shared conceptual space of the meeting room. This is a common practice in face-to-face meetings in the form of slideshows, keeping live agendas on a projected screen. It's particularly prevalent in group design practice, in which a fluid and grounded conversation about ideas is valuable. (Dwyer & Suthers 2005) It's easy to facilitate this process by creating objects in the virtual world that hold information. The kinds of information that are easily represented in *Second Life* and the challenges of working without any familiar UI widgets or metaphors limit the overall efficacy of these applications, but they are interesting first steps in building specific objects that offer functionality that can further customize the meeting room experience. Unlike in physical rooms, which are largely limited by the number of projectors available to augment the space with information, virtual spaces have many more opportunities to customize the experience.

4.3.1 Todo

Often, meetings involve some sort of distribution of tasks. This process is usually an elaborate (and sometimes unspoken) negotiation between who has time to do a task, is interested in getting it done, and the skills necessary to complete it. This application addresses availability. When a task is going to be assigned, the meeting moderator can press a button on meeting dashboard and a small pyramid will appear. (Figure 16) Text can be stored in the pyramid by typing '/todo ' followed by the text of the task. Anyone can then click on the task to claim it. Claimed tasks spin slowly above the head of the claimant. As an avatar with claimed tasks moves around, the tasks follow above their head. Tasks also have buttons on them, allowing the owner to release them (so they can be claimed by someone else) or delete them outright. The vision for this particular application is that tasks would also export from

The task objects serve as visual reminders of who in the group has already accepted tasks and who hasn't. Much like visualizing chat can encourage participation from people who are participating below average, this can serve a similar role. Task objects also operate metaphorically - by staying above an avatars head, they rely on the metaphor of tasks "hanging over us." (Lakoff & Johnson 1980) This kind of allusion doesn't work nearly as well face to face. Although you could hand out note cards with tasks on them, it would not have the same metaphorical resonance as the virtual approach does.

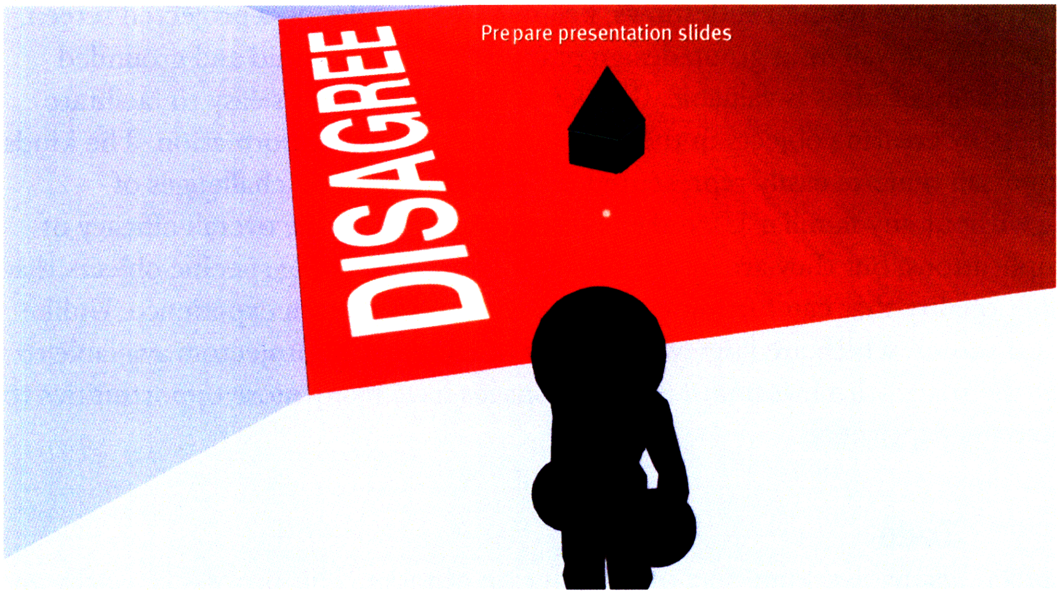

Figure 16. A todo pyramid floating above an avatar's head. Buttons below the pyramid provide a mechanism for deleting the todo or releasing it so someone else can claim it.

4.3.2 Agenda/Voting

Having a representation of the agenda in a meeting space can be a helpful way to both remind people of the what the current status of the meeting is. (Figure 17) This tool takes a note card object in *Second Life* and represents it as a hierarchical listing in the meeting room. The moderator can move a pointer between agenda items to indicate which one is currently under discussion. The system also has a voting mode, in which agenda items also act as buttons that accumulate votes. By default, the voting system operates using an approval voting in which a single avatar can vote for as many options as they want, but cannot vote for a single option more than once. As votes accumulate, the color of the item changes to quickly show which items are the most popular. In the spirit of configurable spaces, there are a number of ways the voting system can be reconfigured. Votes can either accumulate secretly until the end of the vote, or be shown as they are received. Voting can be approval or traditional first-past-the-post. Ballots can either be public or private. Depending on the kind of vote being held, different configurations would be appropriate. Although this doesn't offer nearly the flexibility of a system like *Selectricity* (Hill et al. 2006), embedding the voting in the virtual space serves as a visual reminder to past votes.

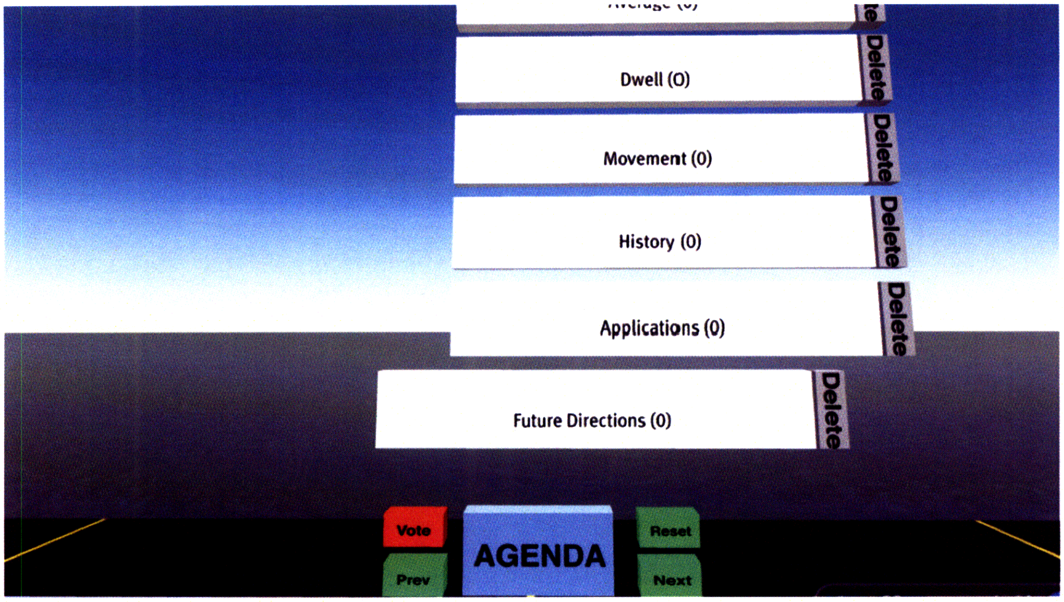

Figure 17. The agenda system, with buttons for manipulating all items as well as deleting individual items. The text for the agenda is pulled from note cards dropped on the agenda object.

4.4 DASHBOARD

The dashboard is the heart of the space (Figure 18), and contains a range of controls that customize the social experience of being in the space. Each of the social utilities described above can be turned on or off from the dashboard. The texture of the floor itself can also be changed from Agree/Disagree to an other design. The applications are also sometimes connected to the dashboard. The podium that contains the dashboard is also elevated from the floor itself, which reinforces using spatial metaphors the relative roles of the participants—the avatar in that position is understood to have more control over the space.

In a virtual space where avatars can easily act at a distance, the dashboard stands out as an anomaly; only avatars standing within the gray podium (see Figure 12) can push buttons on the podium. This ensures clear attribution to changes in the state of the meeting space. There will never be any question who turned off chat archiving—it had to be the person standing in the podium. From our experiences in physical spaces, we are used to people needing to be proximate to, for instance, light switches to change the lighting in a room. Although this breaks many of the expectations of *Second Life* users, I believe that enforcing avatar presence near the buttons is an important social cue that helps the legibility of roles and abilities in the space.

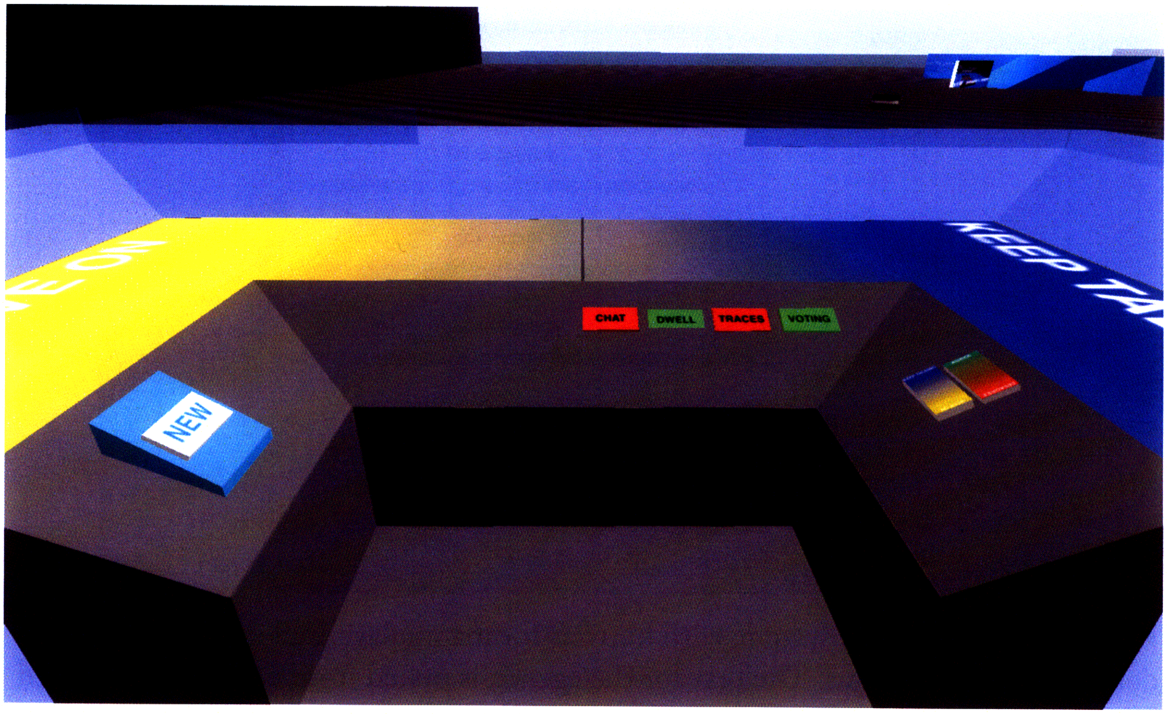

Figure 18. The dashboard that controls features of the space. Left: A button for making new todo objects. Center: Toggle switches for different visualization features. Right: Buttons for changing the floor design.

4.5 OTHER FLOOR DESIGNS

The Agree/Disagree floor that has been at the heart of the discussion in this chapter is only one potential floor design. Although it makes for a good thought experiment, its actual utility is limited. Few meetings are sufficiently organized for this approach to be effective. Even with a strong moderator who makes clear exactly what issue avatar's positions are agreeing or disagreeing with it can at times be ambiguous. There are a number of other options for floor designs that are more generally useful.

The first is a Keep Talking/Move On floor. This floor addresses the need for meeting participants to be able to express when they think the group as a whole should change to a new discussion topic. This is a generic issue, and is one that can be particularly hard to resolve in medium-sized groups. Participants might not want to speak up and say that they want to move on, but if they had a non-verbal way to express their desire to move on (and gauge others' reactions) meetings might spend less time on topics that they didn't need to.

Although these are the only two floor designs that are currently implemented, there is potential in other kinds of floors. Floors with a few multiple choice options make it easy to hold straw polls. A calendar display could be used to show preferred dates for an event. Floors could be used for setting up speaking queues, as well, dividing the audience between those who are waiting to say something, those who are speaking, and those who don't have anything to say. Multi-variate floors are also possible, although there isn't a nice way to let multiple avatars stand at the same point in the space in the same way that you can in single variable floors like Agree/Disagree.

4.6 EVALUATION

We have conducted evaluations of this approach. We worked with two existing discussion groups in *Second Life* to arrange meetings inside an early prototype design. The first group had 7 participants and the second group had 12 participants. Each group was given a list of controversial topics and asked to vote on which one they were most interested in discussing. After choosing a specific topic, they were given an editorial on that topic and then asked to move their avatar to represent whether they agreed or disagreed with the author's argument and to hold a discussion about their opinions on the topic. After the discussion, feedback about the meeting space was collected informally through both individual conversations with participants and group comments.

Participants were, on the whole, very excited about the potential of the design space. Many of them focused on the social implications of this arrangement, thinking out loud about how they would respond to, e.g., their boss moving to "agree". They also appreciated the way the space aggregates history, because they were often pulled away from *Second Life* briefly and lost track of what was going on.

In these tests, though, participants rarely moved their avatars around the space to take advantage of the many visualization features. This was primarily due to the modality of the *Second Life* interface. When we were ran these studies, Second Life did not support voice chat (it has since been added), and avatar movement is controlled by the keyboard. Switching between movement mode and typing mode is a little bit confusing. This makes it hard for avatars to both move and talk at the same time.

The other major theme from these experiences was that even relatively sophisticated *Second Life* users make infrequent use of the elaborate camera controls. As designers, we assumed that all users would be comfortable detaching the camera from their own avatar and inspecting objects in the environment—the conversation archive, in particular. This was not the case with our test groups. Many reported having forgotten about the above-their-heads information because they didn't normally change their camera view. They also reported that their avatar movement was often used to change their camera view, and so making that movement socially significant was sometimes problematic. Instead of visualizing their feelings about the topic, sometimes the space ended up visualizing their attempts to get a better view of the space without using the advanced camera controls.

As with all domains, applications that challenge users' ideas about what's possible can be hard to understand. In the case of *Second Life*, this is compounded by user interface issues. This leaves us with a number of possible explanations for users' excitement about the ideas behind *Information Spaces* but general lack of engagement with specific features. I think the most probable is that because this project reflects both a shift in how to interact with spaces in *Second Life* as well as forces users to use the interface in ways they might not be familiar, it takes a longer term study than we were able to conduct. Perhaps with a user group that was even more familiar with *Second Life* and could spend more time acclimating to the environment we could better address aspects of the design in more detail.

4.7 ANALYSIS

I propose that there are quite a few different ways in which this design influences the behavior of avatars. As in any meeting situation, the space itself is only part of the picture, and so while all these influences have not necessarily been observed experimentally, it is worth thinking through what the range of possible impacts could be.

4.7.1 Equalized Participation

One theme common to many of the features of Information Spaces is an emphasis on encouraging more equal participation by showing relative participation levels of participants. Over-talkative meeting participants are reminded over their activity, and people participating less can find space to get their say. This can work on a group level, too. It may be clear by the current average vote in the room that the consensus is squarely on one side, but a vocal minority is out-talking a quiet majority. By color-coding chat messages based on where in the spectrum they come from, the for/against balance can be equalized.

4.7.2 Open Communication

There is an inherent bias in this approach towards meetings in which participants are trying to find better ways to non-verbally express their attitudes. The whole space is focused on making these signals more legible and visible. For participants who might not be comfortable speaking up, these other channels might be a better fit. If there is not genuine interest or cultural support for this kind of communication, it may be that making these signals more visible is in fact a reason for a participant to be even less open about their feelings.

4.7.3 Conformity

If there is not group interest in equal participation, it may be that this kind of space would reinforce hierarchies instead of subverting them. While in a face-to-face meeting, substantial effort might be spent trying to figure out what an important decision maker feels about an issue, in this environment they may just move right to that position and everyone else could follow them there, obviating any real discussion of the issues. It may be that if this is really how meetings work, then quickly acknowledging that everyone wants to follow the boss might not be a bad outcome.

4.7.4 Obstinacy

By making visible someone's constant attitude about something, meeting participants might be discouraged from moving because dwelling somewhere for a while becomes seen as a status symbol. I suspect that in this situation, the dwell indicator is only making visible pre-existing attitudes about changing ones opinion. In a meeting environment where opinion changes are valued, the bias could just as well be the opposite; staying somewhere too long looks like inactivity and disconnection because the group expectation is that participants will be actively representing and changing their opinion.

4.8 LIMITATIONS OF SECOND LIFE

Although *Second Life* proved to be a valuable prototyping platform, it had a number of fundamental limitations that made it an imperfect tool for the goals of this thesis. There are a number of fundamental assumptions in the *Second Life*'s architecture that make creating the kinds of new kinds of functional spaces difficult.

4.8.1 Avatar Representation

The biggest issue is the representation of avatars. Avatars are a special kind of object in *Second Life*, and scripts have very limited ways of interacting with them. Appearance in particular is largely immutable, unless you can convince someone to wear a special object that is larger than their avatar and so functions more or less as an avatar shell. I did some experiments with work in this direction, but was ultimately dissuaded (Harry 2007b). There are also some properties of the world that are immutable; it's impossible to reliably hide an avatar's name, chat messages always propagate the same distance, avatars can always "throw" their camera long distances, you can always get info on another avatar, etc.

4.8.2 Text & Images

Another major class of issues with work in *Second Life* has to do with rendering text and images. Although static textures are very easy to use, textures that change in a non-periodic way are basically impossible. As a result, drawing in either two or three dimensions requires creating primitives on the fly to act as lines and curves. Although workable, this is an extremely tedious process, and it can quickly run into the limits on the number of primitives on a parcel of land. Another implication of this is that displaying text is challenging. There are some nice text rendering libraries (Taggart et al. 2006) that use the faces of a prim to hold single mono-spaced letters, but these techniques give you little control over rendering and style. They also don't scale for anything beyond trivially short blocks of text.

4.8.3 User Interface

One of the persistent challenges with working and studying *Second Life* is *Second Life*'s relatively inaccessible user interface. The biggest issues I've observed are related to navigating the environment, managing the camera, and interacting with objects in the environment. *Second Life* draws its interface style from 3D games, which tends to make it inaccessible to people who haven't spent much time in those environments. As a result, tasks like moving to a specific point in the environment can be very challenging, particularly if the target is not initially visible. Flying adds another layer to users' frustration. Flying avatars move substantially faster than walking avatars, which means it's much harder to get to a specific point in space. I have tried hard to avoid these issues with my particular designs, but they stand in the way of other potential work in *Second Life* that would like to make more interesting use of the 3D space.

4.8.4 Camera

By default, the *Second Life* camera follows behind a user's avatar, pointed slightly towards the ground. The camera model is capable of much more than just looking at your own avatar, though—the camera can used to zoom in on far-away objects, rotate around them, follow other avatars or objects while they move, and so on. These abilities are not broadly understood, particularly among new users. Even among users who know it's possible, the interface for doing so involves relatively erudite keyboard modifiers that are familiar to users of solid modeling software, but not average users. As a result, designs that rely on users being fluent with their cameras (e.g. the rising chat archive feature of Information Spaces) rapidly become unusable when as far as many users are aware nothing above their character's head can be seen unless they move very far away from it.

4.8.5 Agency

Finally, the interaction vocabulary with objects in the environment is quite limited. Avatars can only chat with, touch, or sit on objects. More complicated staples of screen based UI like double clicking, right clicking, click and drag, or drag and drop are not natively supported in *Second Life*. As a result, most complex tools use command-line-like text-based interactions. There are also button-based interfaces, but there are not reliable widget designs that users can become used to using. Three-dimensional UIs are still very much in their infancy and are quite a ways away from any kind of comprehensive document like Apple's Human Interface Guidelines (Apple Computer 2007) that could promote consistency in UI design. Furthermore, the expectations on the part of avatars about what kinds of behavior an interface can be tracking are not clear. While demonstrating various aspects of Information Spaces, people were always surprised when interaction options were spatially dependent; location was not something they expected to influence applications in the environment.

4.8.6 Analysis

These limitations are in no way an indictment of *Second Life* as a general environment. Linden Lab have had to make a number of decisions about what kind of access programmers should have to tools that change the appearance of avatars. They tended towards systems that made it difficult to change avatar appearance or agency programmatically. Ultimately, this is probably a better user experience and makes it more challenging for malicious developers to antagonize other residents. Other issues, like doing arbitrary drawing, are more problematic technically than socially. *Second Life*'s texture systems weren't made for arbitrary pixel level updates, and doing any kind of true 3D drawing in *Second Life* is likely years away. These limits motivated the development of our own platform (discussed in the next chapter) where we can experiment with algorithmic architecture in a way that is not limited by *Second Life*'s historic design decisions.

Chapter 5

*SPACE

5.1 INTRODUCTION

Based on our experiences developing the *Information Spaces* project (and other related projects) in *Second Life*, it was clear that the *Second Life* platform made it hard to experiment with aspects of virtual space that we were most interested in: changing agency, representing accumulated behavioral information, changing avatar representations, etc. To better understand the nature of architecture in virtual spaces, we thought it would be most useful to build a new kind of virtual world that would act as a kind of playground for algorithmic architecture. By building a new system from the ground up, it would be easier to devolve control over the kinds of virtual features from fundamental properties of the world itself to be more finely controlled by designers of individual spaces in the world. Thus instead of having to make world-level decisions about, for instance, how quickly avatars move and what they look like, we could instead have a world in which different parts of the world had different properties. In this model, the world contains different zones, and each zone has different algorithmic properties. Zones can be overlapped to combine different properties, as well. Each of the zones is discussed in some depth in Section 5.5.

Building a virtual world from scratch is a daunting task, so I made a number of decisions to simplify the problem while still addressing my core interests. I chose to focus on building a two-dimensional world instead of a three-dimensional world for a number of reasons. Two-dimensional spaces are easier to navigate than their three-dimensional counterparts—navigation can be easily achieved by clicking on a destination instead of "driving" an avatar around. Camera management is substantially less challenging in a two dimensional environment. Creating content in two dimensions is easier, too—vector graphics and images are easily created, while in a three-dimensional space elaborate models and textures are required. Many of the graphics issues I describe in *Second Life* are challenging in any three-dimensional environment, but are largely trivial in two dimensions. These aspects make working in two dimensions both easier and more effective than trying to build a three-dimensional space from scratch. From a representational perspective, I draw on the abstract aesthetic of the *Chat Circles* series (J. Donath & F. B. Viégas 2002), and have created a space that evokes *Flatland* (Abbott 1899) more than traditional notions of the Metaverse. The further implications of working in two dimensions instead of three are discussed in more depth in Section 5.3, including why the dimensionality of this particular application does not limit the scope of my findings.

5.2 TECHNOLOGY

Although this thesis is not primarily interested in the technologies that make virtual worlds possible, it is important to briefly dwell on the overall technical architecture of **space* and how my design has drawn heavily on the technical work of other research groups. The two biggest components of **space* are *Project Darkstar* and *jVoiceBridge*. Both are research projects from Sun Labs, and made this project possible in a very fundamental way. *Project Darkstar* (Sun Microsystems 2007a) is a Java library that handles many aspects of creating a persistent online world. *Darkstar* has both server and client components. On the server side, *Darkstar* provides a structure for maintaining a persistent representation of the world. This model is quite abstract—you need only to indicate which kinds of objects should be persisted on the server, and *Darkstar* manages update tracking and streaming the data to disk. This abstracted notion of managed objects proved to be quite helpful. Since *Darkstar* is managing the server-side data, it can also gracefully deal with shutdowns and restarts, without losing any of the world state. *Darkstar* also provides nice abstractions of client and server communications, on which I rely extensively. Many of my architectural decisions, particularly those having to do with the messaging system, were drawn from the Darkstar-related *Project Wonderland* (Sun Microsystems 2007b) code.

To handle voice communication, I used the *jVoiceBridge* library, an open source library version of the *Meeting Central* project (Sun Microsystems 2008; Yankelovich et al. 2004). *jVoiceBridge* provides both server and client components. On the client side, *jVoiceBridge* has a voice-over-IP softphone application that connects to a server-side *jVoiceBridge* audio server. The softphone transmits sound data to the server, which then transmits the audio to other connected clients. *jVoiceBridge* is particularly well suited for this application because it has a built in model for spatializing audio; users' positions in the audio space can be specified in three dimensions, and the audio they receive other clients will be adjusted appropriately. For instance, speakers who are far away from each other will only hear faintly hear each other, while nearby speakers will hear each other at full volume. Similarly, left/right balance is handled such that as someone moves through the audio space people to their left will be heard primarily from their left speaker. The model is rich enough that complex spatialization strategies can be used in which certain speakers can project their voice farther than others, the exact audio attenuation function can be specified as a function of distance, and so on. This library accomplishes in a high quality and abstracted way much of the challenging technical work of Roy Rodenstein's thesis (2000).

The last major component I rely on is the open source *Slick* library. (Glass et al. 2006) It uses OpenGL to provide high performance graphics, but while abstracting away much of OpenGL's complexity by only providing two-dimensional drawing. It also provides a number of useful abstractions related to shapes, gradients, geometry, and other graphics related functionality.

5.3 DIMENSIONALITY AND SPATIALITY

> One question we are frequently asked is why use 3D for a collaboration environment? While it might be possible to build a 2D tool with functionality similar to MPK20, the spatial layout of the 3D world coupled with the immersive audio provides strong cognitive cues that enhance collaboration. For example, the juxtaposition of avatars in the world coupled with the volume and location of the voices allows people to intuit who they can talk to at any given time. The 3D space provides a natural way to organize multiple, simultaneous conversations. Likewise, the arrangement of the objects within the space provides conversational context. If other avatars are gathering near the entrance to a virtual conference room, it is a good guess that they are about to attend a meeting in that space. It is then natural to talk to those people about the content or timing of the meeting, just as you would if attending a physical meeting. In terms of data sharing, looking at

> objects together is a natural activity. With the 3D spatial cues, each person can get an immediate sense of what the other collaborators can and cannot see. (Sun Labs 2008)

The role of dimensionality in virtual worlds is subtle. Like the authors of *MPK20*, I am often asked about the tradeoffs between working in two dimensions versus three. To answer this question, I think it's important to tease out the difference between dimensionality and spatiality.

The dimensionality of a world is an aspect both of its display and its abstract data representation. Objects in a three-dimensional world have a position in three-dimensional space, a solid volume, and an orientation in three rotational axes. In an intuitive sense, a three-dimensional virtual world looks a lot like the three-dimensional physical world we are used to. The programmatic representation of the world need not be bound to its visual representation, however. It is possible to build a three-dimensional representation of a fundamentally two-dimensional world. The *MASSIVE* system demonstrates this nicely; they had both a three-dimensional visual client and a text based two-dimensional client. Both clients could almost completely represent the world state. As a world, *MASSIVE* had no vertical dimension, so its three-dimensional representation was simply a skin on a two dimensional world. What's important, though, is drawing a distinction between the dimensionality of the world itself and the dimensionality of its visual representation—they need not necessarily be the same thing.

The perspective on a world is an important related aspect of the world that is related to its dimensionality. Three-dimensional worlds have two major perspective options: first person and third person. In a first person perspective, the user views the world as if the camera was placed where the eyes of the avatar would be. If they see their own body at all, it is usually only their hands or feet. In this mode, the user literally inhabits the body of avatar and becomes that character in a significant way. In a third person perspective, the user sees their character from a camera that is usually behind them looking down. This provides a better sense of the world around their character, but can sacrifice some immersion by showing the avatar animating itself or looking different than a user's own vision of them. (Kietzmann 2007) The choice of perspective is primarily one of immersion: first person views are more immersive than third person views. In two-dimensional worlds, third person views are essentially the only option. A first-person two-dimensional view would be *Flatland* (Abbott 1899), with all of the challenges of navigation and interaction explored in that book.

Spatiality is harder to precisely describe because almost without exception virtual worlds are all spatial in some way or another. MUDs offer perhaps the best starting point as one of the least spatial examples of a virtual world. In a MUD, players occupy discrete rooms. Each room can contain many players and objects, and is connected to other rooms through a series of nominally spatial relationships. For instance, from a given room, you might direct your character to move north which would move your character into the room that the system thinks is north of the room you were in. Although this model is spatial in the sense that you can be closer or farther from people, avatars in early MUDs had little agency or perception of events anywhere but their current room. In a given room, there is no functional spatiality; all players and objects occupy a sort of indistinct space where they could hear and interact with each other, but have no finer position than the room itself. As a result, there was no context for using the kinds of spatial language that make spatiality so useful. A player couldn't describe an object as being "the thing on your right."

Furthermore, the connections between rooms themselves were not reliably spatial in any particular way. Although they were ostensibly arranged in cardinal directions, there is no enforcement of "normal" spatiality. A series of rooms could easily fold back on itself such that moving north a few times would return you to the room you started in. Different routes out of a single room might all go to the same room. Paths might even behave differently in different directions; moving north from one room to another, and then south to try to get back again might not necessarily take you back to where you started. In this way, even an ostensibly spatial metaphor breaks down and fails to convey the contextual and perceptual benefits of true spatiality. In contrast, a world where objects and avatars have distinct discrete locations immediately confers these benefits. Avatars can indicate group membership by avatar proximity, can have a shared visual reference point, and so can communicate about objects behind or to the right of other avatars.[5]

Returning to the quote about MPK20 that introduced this section, I argue that they are conflating notions of dimensionality with spatiality. All of the beneficial features that are ascribed to a "3D world" are more properly ascribed to a world with rich spatiality. A two-dimensional virtual conference room can have an entrance where avatars congregate just as easily as a three-dimensional world. Two-dimensional worlds confer the same benefits regarding shared gaze, too. An avatar in a two dimensional world can infer another avatar's view on that world in the same way they might in a three-dimensional world. These are all properties of a world's spatiality and not its dimensionality. Although the work I describe in this chapter is

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[5] Spatiality as a feature is not limited to world-like experiences, either. The spatiality (in particular, its absence in recent versions) of files in the Macintosh operating system's "Finder" application has inspired intense emotions among commentators. (Siracusa 2003, p.2)

two dimensional, I have maintained spatiality wherever possible. This maintains many of the benefits in the introductory quote while avoiding the many challenges of working in three dimensions. Translating this design approach into three dimensions is certainly possible, although maintaining spatiality in three dimensions requires a certain vigilance. *Second Life* is an instructive example here. Avatars in *Second Life* freely move their cameras with no external representation of its current location. As a result, an avatar's position in the space has little to do with their current view, and so spatial language isn't necessarily that useful.[6] Chapter 4 demonstrates how three-dimensional spaces can be used with this same approach, and similar analogs could be built for essentially all the zones and ideas presented here.

While I believe that worlds that are fundamentally two-dimensional are not inherently less spatial than their three-dimensional counterparts, there is something to be said for the representational language (as opposed to the functional or algorithmic language) of three-dimensional spaces. As discussed in Section 2.3, three-dimensional spaces tend to offer more legible spaces because they use a representational language that is familiar. Meeting rooms represented in three dimensions (or even some sort of isometric view) may be more obviously meeting rooms than the very abstract vector-graphics style rooms I show in this chapter. For my purposes, though, I think the dimensionality is not particularly important for demonstrating the design space of algorithmic architecture. What is critically important is its spatiality, and I have maintained that aspect of the world, even without a third dimension.

5.4 DESIGN

The design of **space* is very much a response to design choices made in other virtual world platforms. In this section, I describe some general world-level design decisions I made in **space* and discuss how they fit in the context of virtual worlds. I pay particular attention to the social environment that arises from particular design decisions. While each of these areas could be a thesis of its own, my goal here is to paint a broad picture about what's possible in virtual spaces and where the generally interesting areas of future work are.

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[6] This is magnified by *Second Life*'s bizarre ability to render sound based on the location of the camera, not the avatar, such that you can be talking to someone's avatar who can't hear you because their camera is far away. The reverse is also true—someone might be listening to your conversation but their avatar's body can be nowhere in sight.

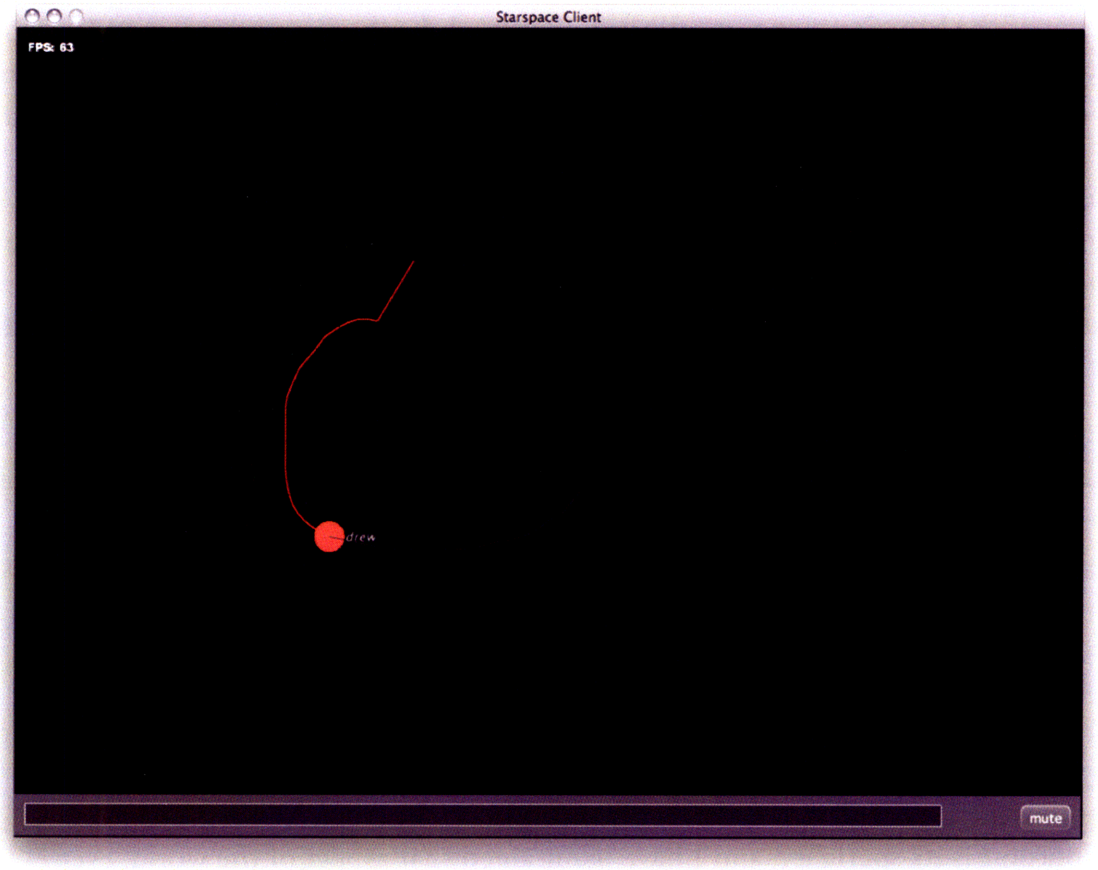

Figure 19. An avatar moving through an empty space. The rest of the planned path is shown in gray; the past path is shown red.

5.4.1 Movement

Movement in **space* is a simple click to set destination system. Avatars will always follow the straight-line path from their current location to their destination. Destinations can be queued up by clicking to add subsequent targets or by clicking and dragging to set a precise path for the avatar to follow. Running into some sort of impassable obstacle (either a wall or another avatar) will cause movement to stop and all targets to be cleared. Double-clicking a point causes all targets to be cleared and that point to be added as the new movement target. Avatars move at a constant speed unless they're in a zone that modifies their movement parameters in some way. Avatar's future paths are shown only on the client controlling that avatar, not to other clients. This general movement model means that **space* also mimics *Chat Circles*' click and drag movement strategy; clicking and dragging on the avatar appears to drag the avatar around for slow mouse movements. If the mouse is moving faster than the avatar's movement speed, the avatar will follow the drag path at top speed until it reaches the end of the dragged path. Path-finding in a world like **space* would be relatively easy, but to maintain the sense that users have complete control over their avatar's movement through the space, no attempts to avoid collisions with world objects is made. If an avatar tries to move through another avatar or a wall, they will bump into them.

The simplicity of click-to-move-to-target movement interfaces is attractive, but often hard to manage in three-dimensional worlds like *Second Life*. Instead, most three-dimensional worlds rely primarily on a game-like interface involving the arrow keys or so-called "wasd" key set. This approach moves the avatar forward as long as the user is holding the "forward" key down. The downside to this approach is that managing movement completely occupies the keyboard, even though managing movements through the space is not a particularly involved activity. In contrast, the **space* approach allows users to quickly describe a complete movement path and then let that path execute. Using the mouse for this leaves the keyboard free, making moving and talking a viable activity. The click-and-drag system also allows for much more gestural movement than a keyboard movement system does. An avatar can easily circle around another avatar frantically or curve slowly towards someone. An avatar shaking back and forth quickly could be analogous to shaking your head. As shown in the *Cheiro* project (Lam 2006), mouse gestures can have emotive aspects to them and by mapping those directly onto the movement of avatars in the space, they can transparently show those emotions in a much more direct way than direct keyboard manipulation could.

The movement system in **space* is always continuous. There is no way to "teleport" from one point to another point in the world in a discontinuous way. This has a profound impact on the meaning of spatiality. Being able to teleport from point to point breaks down distances between spaces such that every point in the world is effectively equidistant from every other point. The Web is structured like this; all URLs directly address a "place" on the Web and getting there is an essentially instantaneous process. Movement costs can have important benefits, though. Presence in a particular part of the world then represents a cost on the part of people present—they have invested the time to get to this particular part of the world. These costs can be understood by analogy to board games. Games like chess have meaning precisely because there are limits and costs to how pieces can move around the board. Removing those costs would remove the game meaning of moving the pieces. In a similar way, making it possible for avatars to teleport around the world would be to devalue the meaning inherent to spending time slowly navigating a space.[7]

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[7] *Second Life* has an interesting approach to this issue. Early in *Second Life*'s history, avatars could only teleport to "telehubs", a sort of virtual subway stop. This model was later abolished and point-to-point teleportation was nominally instated, (see

5.4.2 Avatar Representations

Perhaps the most remarkable aspect of virtual worlds is the ability to change how avatars are represented in the world. The importance of this is clear through analogy to physical worlds. How we present ourselves to other people both in terms of our own bodies as well as through fashion encodes all kinds of signals about taste, wealth, and culture. (Donath, In Press) In that domain, we are well trained to interpret even the most subtle nuances of personal presentation. Analogously, profile pages on the Web have evolved as a new way to communicate important information about who we are and how we are socially situated in a larger context. Representations in virtual worlds have a similar potential power. (This is also discussed in Section 2.4.2.2)

The base avatar representation in **space* is very simple and *Chat Circles* inspired. Avatars are rendered as different color circles, with names shown just to the side of each avatar. Unlike in *Chat Circles*, chat is shown to the side of the avatar, not inside it. Although the goal was for users to be able to draw their own avatars, the current system doesn't incorporate that particular feature. The algorithmic representation features in **space* are discussed in the Growing Avatars section. There are a large variety of other possibilities for algorithmic avatar representations. Although these are not implemented in **space*, hopefully they can serve as inspiration and a basis for thinking about what's possible:

Social network avatars. An avatars appearance can adapt to show the relationships they have with other avatars in the world. As avatars spend more time near each other, lines are drawn between them to show their connection. Thus as avatars move around the space, their past conversation partners remain visible and patterns of interaction can emerge.

Color changing avatars. Avatars could have a starting color and as they spent time near other avatars their color starts to change to match the color of the avatars they're near.

Task assignment. As in the *Information Spaces* project, avatar representations could expand to show specific tasks that avatar has promised to do.

(Reynolds 2006) for the ramifications of that change) there are still are quite a few limits to teleportation. Landowners can specify a "landing pad" to which any avatar that tries to teleport into the parcel is directed. This acts as a sort of local, user controlled telehub that creates a similar sense of spatiality within certain zones. Teleportation is also disallowed within a simulator, which prevents avatars from easily flitting about without moving.

Shape changing avatars. Avatars could aggregate the position of other avatars around them. This concept is described in more detail in (Harry 2007a)

Publicly controlled avatars. As described in *ChatScape* project, avatar representations can be made a function of other people's attitudes about that person. (Lee 2001)

5.4.3 Camera

Many of the benefits of having a spatial environment for interaction depend on some knowledge of what other people's view on that space is. We take this for granted in the physical world, because we understand that other people view the world through their eyes. As social creatures we are naturally very interested in what other people can see and what they can't, and we avidly track the gaze of other people around us. We use knowledge of what other people can and can't see to inform our behavior and language. We are particularly interested in whether other people are looking at us, or whether they know that we're looking at them, and the social signals that develop from this dynamic can encode a wide range of meaning from aggression, conversational availability, boredom, or flirtatiousness.

In virtual domains, gaze becomes a complicated concept. Most games have some notion of a camera through which someone experiences a world. In some cases that camera is bound in some way to an avatar in the world. For example, in *World of Warcraft* the camera is always focused on a player's avatar in the world. The camera can be zoomed in or out and rotated around the avatar, but is always pointed at the avatar. Zooming all the way in changes to a first person view, which is not focused on the avatar, still creates a view of the world that is from that avatar's position. In contrast, *Second Life* lets people move their camera almost limitlessly far away from their avatar, including through walls. Having this kind of control is obviously tempting—part of the promise of virtual worlds is that one need not be bound by the limits of the physical world. In practice, though, some of these limits are quite important because they form the foundation of our understanding of what is and is not visible to other people in the world. That ability, in turn, is an important basis for making effective use of spatiality. If you have no idea where someone's camera is while you're talking to them, you lose some of the supposed environmental context of the conversation. In practice, this isn't quite as bad as it sounds—conversations typically assume that people have their camera near their avatar most of the time and for the most part, this allows for acceptable shared visual context. It is more troubling for privacy reasons. There is no guarantee that some far away avatar is not watching you with an invisible camera.

In a world represented in two dimensions, these issues are somewhat simpler to deal with. In **space* I made a number of decisions to emphasize a sense of shared

Figure 22. Comparison of a zoomed out view of the space (due to avatar movement, left) and the standard zoomed in view (right).

visual context. To a first approximation, an avatar's view of **space* follows their avatar. Rather than constantly move an avatar's view of the space such that the avatar is always in the middle of the screen, the view stays stationary until an avatar moves near the edge of the screen. Any further movement towards the edge the avatar is near slides the avatar's view of the space in that direction. Over the course of long movements, the avatar will appear to move towards the center of the screen, centering the user's view of the space. During viewport movement, the view of the space also zooms out significantly, to give a better view of the broader context. At this zoom level, interacting (or even reading chat messages) can be challenging, which reinforces the notion that this zoomed out view is for long distance moving, not for interacting. Zooming poses a similar reciprocity problem as the invisible camera in *Second Life*—it's possible for one person to see another while still being outside the view of the person they're looking at. Ultimately, though, I think this tradeoff is acceptable. Unlike in *Second Life*, it would be very hard to stay unseen for long - all it takes is for the person being watched to start moving themselves and they could see the same distance as anyone else.

5.4.4 Audio and Chat Distances

In the physical world, it is natural that louder sounds propagate farther than quiet sounds, but that below a certain sound threshold speech can't be heard. Spatialized voice in virtual worlds tries to mimic this behavior by attenuating the volume of someone's speech by the distance between them and the audio's recipient. In this way, nearby avatars will sound louder while far away avatars will be almost completely silent.[8] From a technical perspective, this process can also become substantially more complicated. Avatars could have both speaking ranges and hearing range. A lighting analogy is apt here—an actor on stage can be seen clearly by everyone in the theatre but the stage lighting makes it very hard for them to see anyone in the audience. This kind of asymmetry is possible in voice in virtual worlds. A virtual microphone could be built that broadcasts someone's voice such that everyone nearby can hear it, but cuts down on their ability to any conversations in the audience. Although this type of model is exciting (it might be interesting to give avatars audio points that they could allocate to listening or hearing such that they could play different kinds of roles), it is beyond the scope of this particular project to get too deep into experimenting with different ways of representing that model to users.

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[8] It should be said, though, that in practice the spatialization features are often eschewed. In *Second Life*, voice conversations tend to convert quickly to full-volume conference call style conversations that don't change in volume as the participants move around the world. Games like *World Of Warcraft* or *EVE Online* that offer voice chat in game tend not to spatialize it at all in favor of conference call style interactions. In situations where you have a fixed audience and are moving around the world trying to accomplish something, it seems that players want to not worry about their relative positions. I suspect this has more to do with the nature of the activities going on and not on a fundamental disinterest in spatializing voice. If the goal was to support multiple simultaneous conversations with fluid groupings, a conference call-like system is obviously not appropriate, but scenarios like that are quite rare in game worlds. In essentially all the worlds I have experience with, switching to voice chat is perceived as a sort of escalation of intimacy and so it is rarely used in the scenarios where audiences are unknown and spatialization might be most useful.

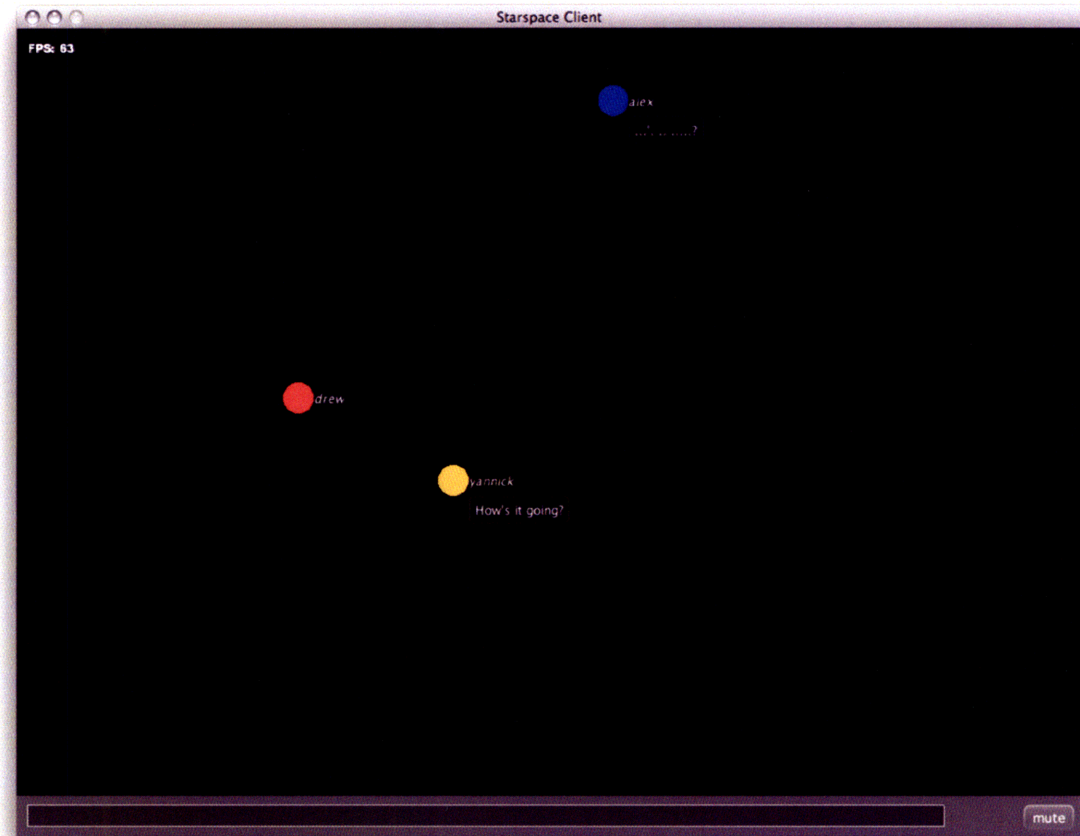

Figure 24. Chat attenuation is a function of avatar distance. This picture is from the point of view of the red avatar. From his position, Yannick's chat is legible, but Alex's is not.

In **space* we aim instead for a simpler model in which all avatars have the same hearing distance, although speaking distances can be changed by zones. The current speaking range for any avatar can be seen by mousing over that avatar and changes to that range are animated. This ensures that users can tell when there is a significant change in the abilities of other users. The distance shown is the so-called "zero volume distance"—the point at which no audio can be heard from the avatar. Text chat is also attenuated at a distance. When inside the zero volume distance, chat is rendered normally. Outside it, chat messages are processed such that they are illegible, but they are still rendered in a way that shows that people are chatting, even if you can't see what the actual contents of their chat are.

5.4.5 Walls

One of the major functions of architecture—both virtual and real—is to organize the movements of people. Walls are closely related to notions of access, control, and privacy. In a very primitive way, walls define the edges of spaces. Shapes and sizes of

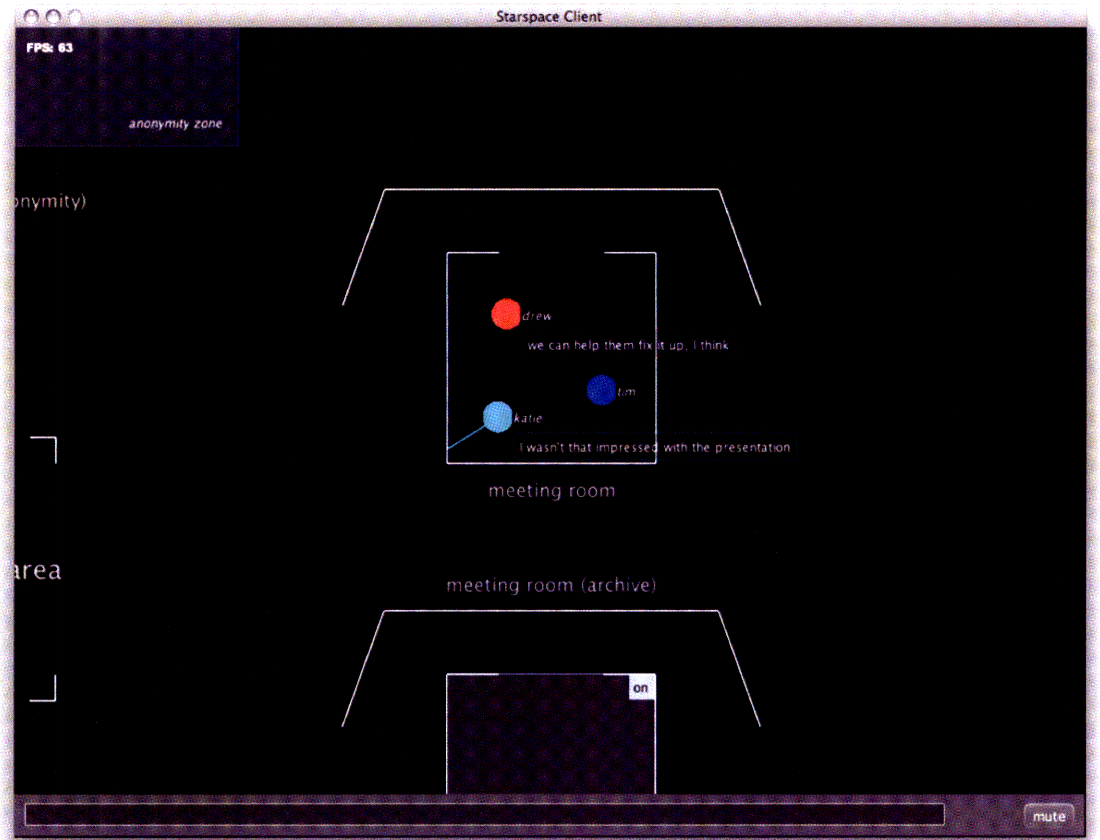

Figure 25. A private chat room. An avatar outside this space wouldn't see any representation of the group's chat.

spaces define our understanding of the function of a space. For instance, long and thin spaces tend to function as corridors while large open spaces are understood as rooms. Indeed, many of the ways in which walls are used in physical spaces have an analog in virtual space. Certainly there are some new challenges (for instance understanding how spaces without collision are designed differently than those that have collision), but much of the design vocabulary described in, for instance, (Palladio 1965) is relevant here as well.

In **space*, walls also organize communication. Chat and audio cannot travel through walls, so walls guarantee a certain control over the audience of your communication. This is analogous to how walls in physical spaces organize communication, but is rarely evident in virtual worlds. In *Second Life*, for instance, chat travels a fixed distance regardless of walls. As a result, most private conversations are quickly routed to the instant messaging system, which does guarantee that you won't be overheard. For the sake of simplicity, **space* looks for walls on the straight-line path between any two avatars, and if a wall intersects that path they can't hear each other. Using this mechanic, different kinds of communication spaces can be built. Spaces can be built that are essentially private conversation rooms. Walls can also be used to afford both group discussion and private discussion at the same time by using podium zones (described in Section 5.5.6). The converse is also true—spaces without walls are naturally suited for freewheeling public discussion.

5.5 ZONES

The primary spatial vocabulary in **space* is its zones. In this section, I describe some of the main zones I designed and the roles they play in the virtual space. Zones can be easily combined and overlaid to create hybrid spaces that have the features of multiple zones, but for the purposes of best understanding their properties and effects, I will address them one at a time.

5.5.1 Anonymity

Controlling what information about the identity of an avatar's controller is made available to other avatars is a critical to creating different kinds of spaces. Changing a space to be anonymous is akin to turning the lights off in a room. In a virtual world, though, we need not necessarily remove all visual information to remove identity cues; it is possible for an anonymity zone to change just how someone's identity is represented. Anonymity need not be binary, either. Anonymity is only one end of a continuum of options for controlling how identity is represented in the virtual space. Avatars might, instead of showing names or custom avatar designs, show only their controller's discipline (e.g. marketing, engineering, or manufacturing), giving people some limited information on other avatar's roles in the conversation without exposing their identity. Identity information can also be scoped spatially. Metaphorically, this would be turning the lights down but not entirely off—you can still get close to an avatar and discover more about who they are. In the virtual space, names and identifying information like avatar color or shape could be made visible only to avatars who are close together. Closer to anonymity, there are distinctions between connecting messages to a specific avatar (but not providing any information about who that avatar represents) and hiding the number of anonymous avatars in the space and having all messages appear as coming from the anonymous zone without any identification.

Maintaining true anonymity can be quite challenging. Once in an anonymous zone, anonymity is easily maintained, but the transitions between anonymous spaces and non-anonymous spaces are problematic. If a user says something in an anonymous zone and leaves subsequently leaves the zone, it could be easy to connect that person's identity to their chat messages. Similarly, if positions of avatars are shown it's easy to track an avatar of known identity who goes into an anonymous space and subsequently speaks. Perhaps the most reliable anonymization technique is to show all messages coming from an anonymous zone as disconnected from any particular avatar, and reveal nothing about the total population of avatars in an anonymous zone or anything about them. Avatars should probably enter the space in an anonymous zone and have to opt to become non-anonymous.

Anonymity can be useful in conversations in a number of different ways. It is most important in situations where there might be ramifications to expressing some idea if that idea can be linked to someone's identity outside the virtual world. The canonical example for this is speaking up to someone in a position of power; an employee might be afraid to express their disapproval of an idea from a high ranking manager if there was a fear of retribution, but they might be willing to express their idea anonymously and conversations that might have otherwise been difficult would become easier. *True Names* (Vinge 1987) took this idea to an extreme, demonstrating the power that knowing someone's identity outside of a virtual world can have inside the world. Even in situations where there are not explicit costs to saying something, anonymity might still be useful. There can be unacknowledged biases in, for instance, brainstorming processes that could be avoided by anonymizing participants' contributions.

The specific implementation of anonymity in **space* is relatively naïve. In anonymous zones, avatars are shown without their names, colors, or custom shapes. Although this suffers from the issues outlined above, it does provide enough anonymity that if someone is really worried about it they just have to make sure to move into the space when no one is around and stay there. This sort of lightweight anonymity might be effective for situations like brainstorming in which the participants are known and anonymity is simply used to balance group biases. It is precisely this sort of technique that makes *Beyond Being There* experiences possible—this would not be possible in a physical space.

5.5.2 Movement

Zones in **space* can change movement dynamics in two ways. A zone can increase an avatar's base speed, making the avatar move faster or slower in any direction. Zones can also specify a movement vector that is imparted to any avatar in that zone. As a basic vocabulary, this allows us to create many different kinds of spaces. A few ideas:

Road systems. Because there is no teleportation in **space*, getting around large spaces can be slow. Roads that speed up an avatar when moving in certain common directions can be quite useful. A fancy road system might move faster in the middle of the road than the edges to make leaving a road

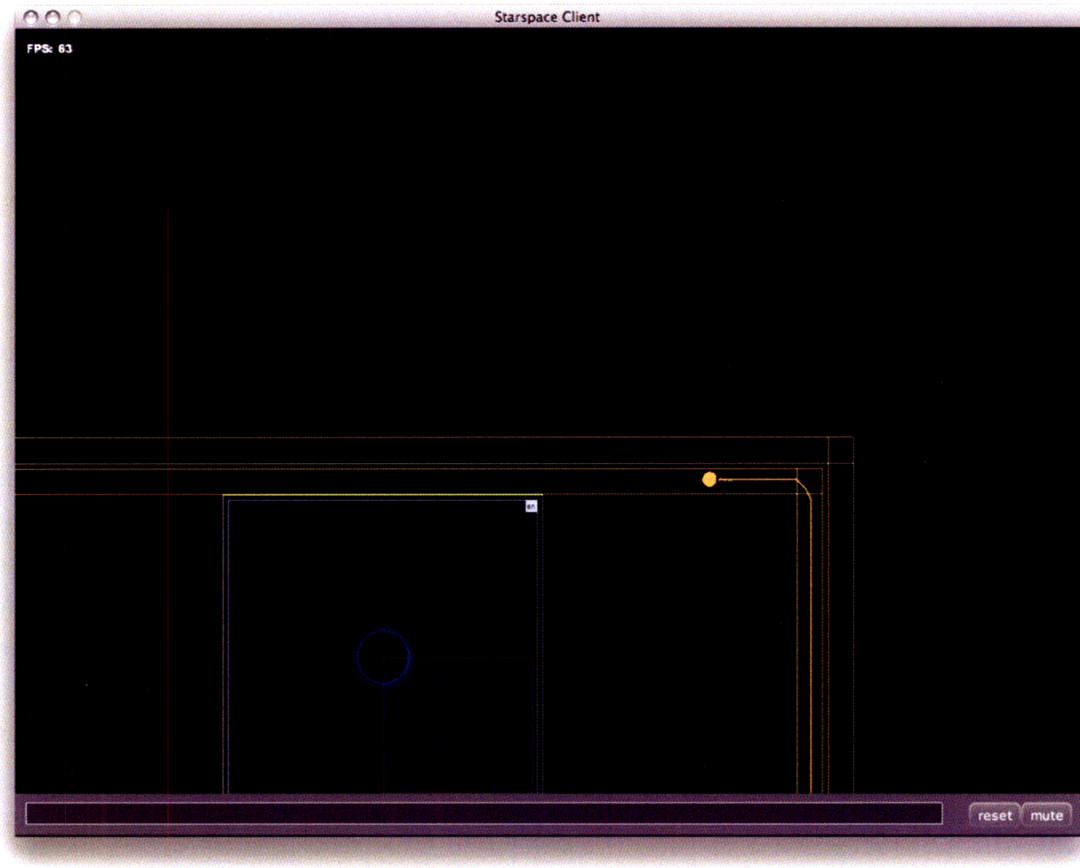

Figure 26. An avatar moving very quickly on one of the two ring-roads around the space. The inner road pushes avatars counter-clockwise, while the outer road moves clockwise.

precisely more effective. Roads should probably not have collision turned on so that avatars trying to cross a road perpendicularly don't interrupt the flow.

One way doors. If the movement vector is larger than an avatar's absolute speed, avatars will only be able to pass through going in one direction. If the movement vector is just slightly less than avatar's speed, they will still be able to move through it, but very slow. This helps create clear costs in movement time to being in different parts of a space.

Enforcing involvement. In a space where it's important that everyone stay actively involved and not be switching to other applications, a slight movement vector could be applied towards the back of a room such that unless users actively give their avatar move orders to stay in position, they will drift towards the back of the room. The reverse is also interesting—a space might try to push everyone towards the center to discourage side conversations but still allow them to happen as long as people away from

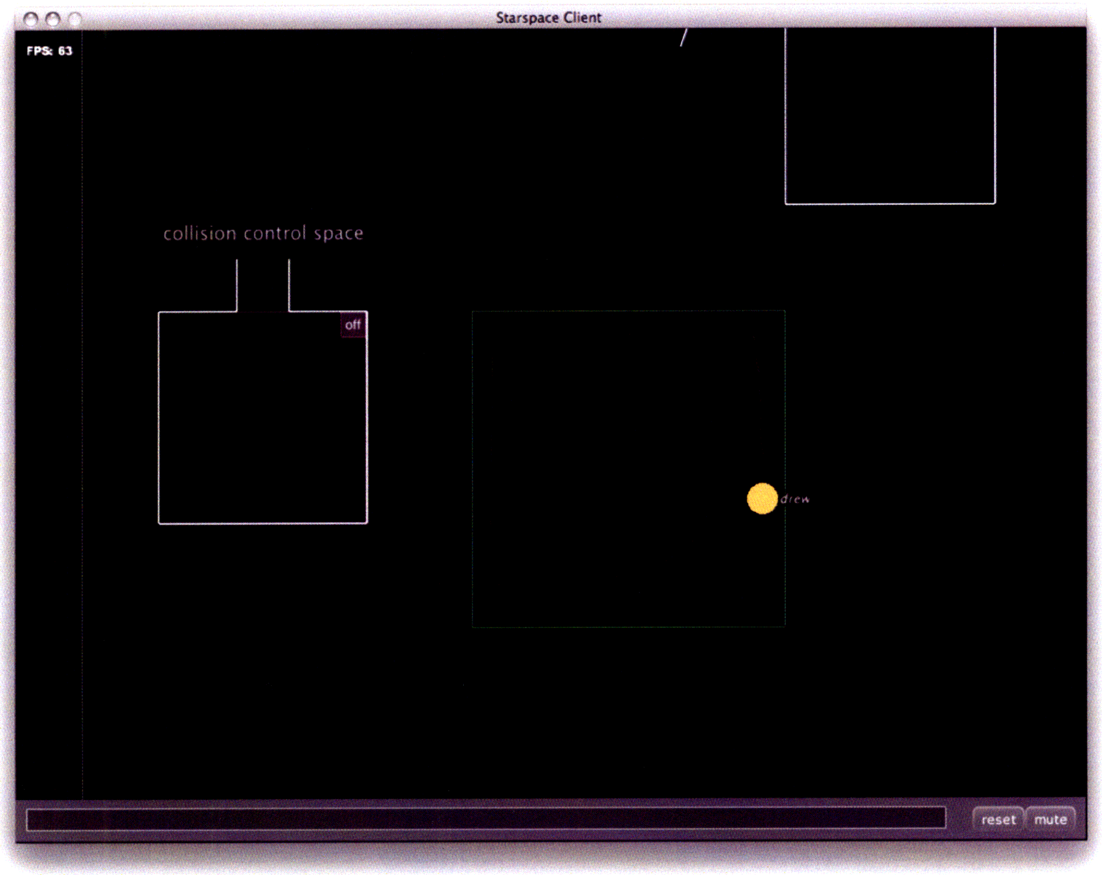

Figure 27. A movement history space. Old movement paths are shown faintly and they fade slowly away over time.

the center of the room make an effort to fight the movement vector and stay where they are.

5.5.3 Movement History

One of the few ways that physical spaces aggregate information about their histories is through the movement of people within them. Common paths get worn into the environment over time. These worn paths also function as signals of age—new spaces don't have them while old spaces do. Virtual environments, by contrast, seem to never age on their own. It's usually impossible to tell if another avatar has visited a virtual space since you were last there because nothing persists about movement though a space. Adding a way for spaces to aggregate avatars' presence and movement provides a way for us to better understand what's happened in spaces while we were gone.

Movement history aggregation also plays a role in helping us understand spaces. Much like social navigation sites on the Web like *Digg* (Digg, Inc. 2004) tell us

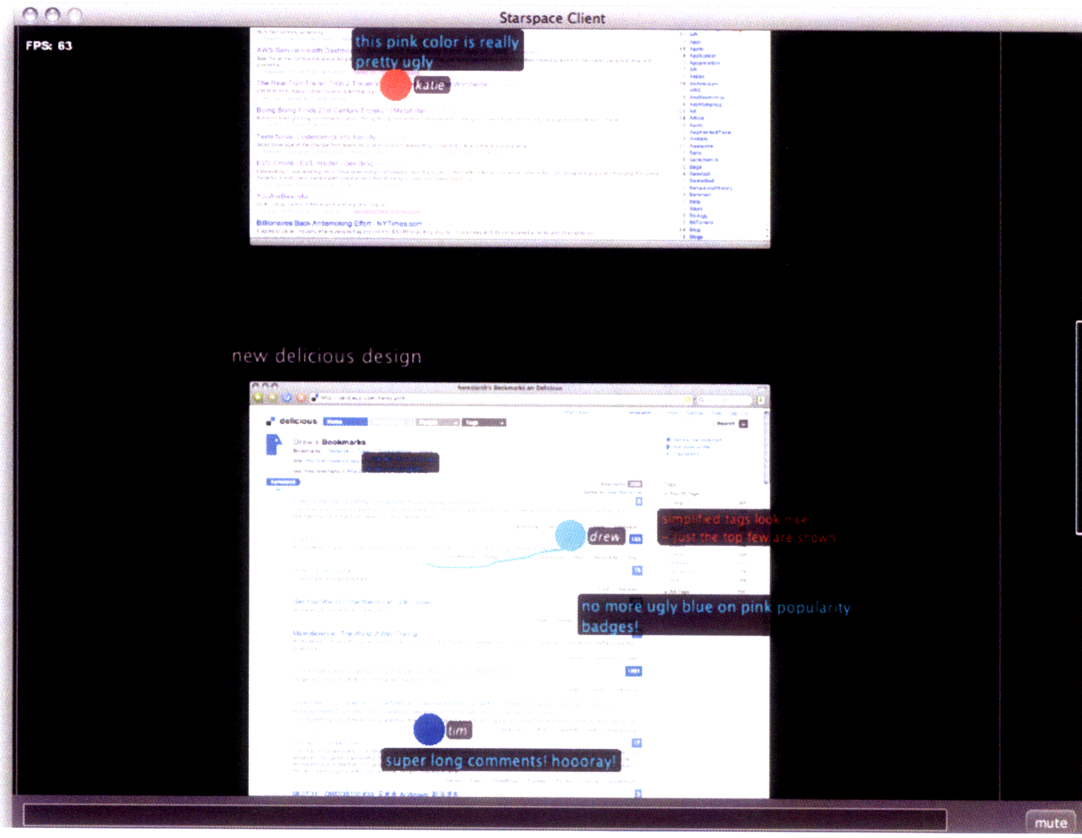

Figure 28. Avatars discussing design changes between two versions of a website. These comments persist in the space. When no avatar is near a comment it shrinks. When an avatar is nearby it grows to reveal its contents.

which sites are currently popular, movement histories help us understand which parts of a virtual world have attracted interest recently. Depending on the time scale that movement history is aggregated on, this kind of navigation can draw on very recent movement ("where might I go to find someone who's still there"), activity this week ("what places in the world are popular recently"), or activity over the whole life of the world ("what are the main routes in the world and what are the most popular areas ever"). Having flexibility on the aggregation time-scale opens up many more opportunities for social navigation than are available in physical spaces. This functionality is available in **space* in the form of Movement History Zones that aggregate people's movements through them, although the current version doesn't have flexibility about the timescales over which it aggregates movement.

5.5.4 Chat History

As discussed in the Background chapter, virtual spaces can aggregate kinds of behavior with great specificity that are harder to sense and display in physical spaces.

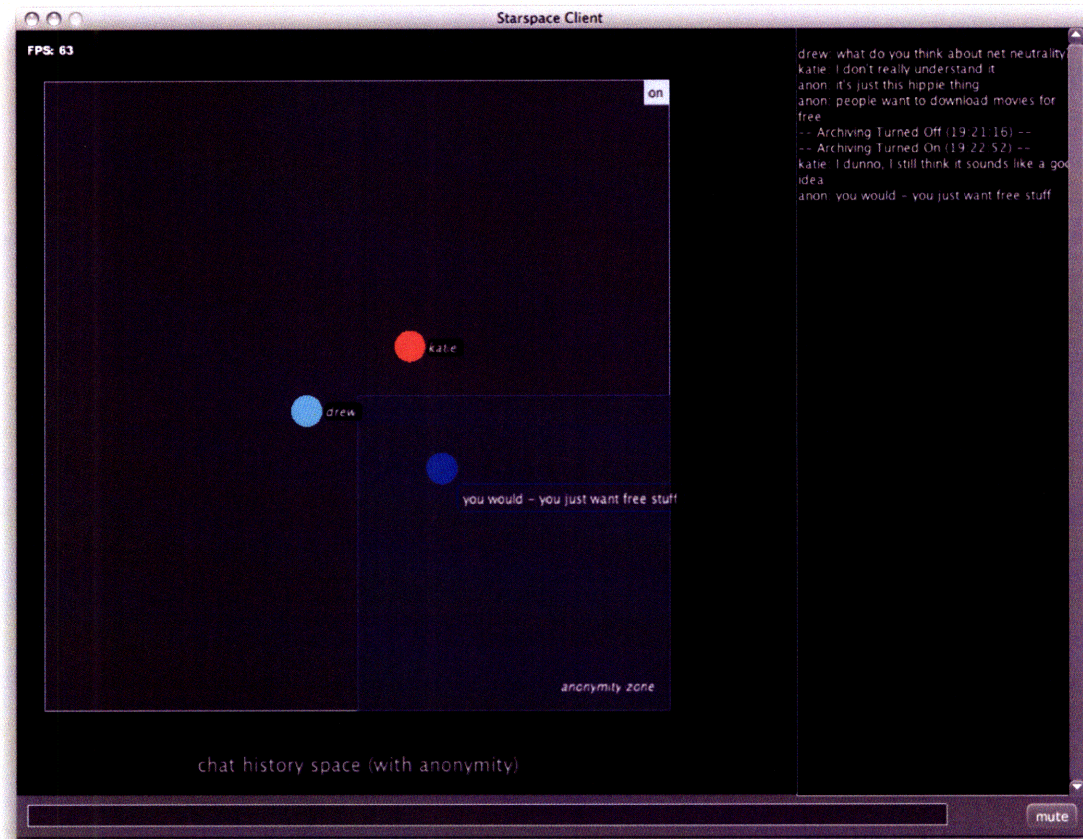

Figure 29. Avatars holding a discussion with chat logging. A chat history is provided in the pane on the right. Comments from avatars in the anonymity zone (bottom right) are anonymized in the zone's chat record, too. Logging can be turned on and off with the button in the upper right hand corner.

One particularly practical technique is recording chat messages and making them available in some way to avatars.

There are two different ways that this is implemented in **space*. The first is a very impressionistic chat history zone in which chat messages are rendered as part of the background of the space. When an avatar is near the location of the chat message, it grows larger. When they are far away it shrinks to almost nothing. This provides a sort of spatial chat history that is brows through avatar movement. The problem with this approach is that it sacrifices temporality in its display. Although you can see where messages were said (and infer who said them by their color), you can't tell when they were said. In a scenario in which there was not supposed to be dialog, but chat messages are intended to be (for instance) questions for a presenter, this approach might work out. It could also work as an asynchronous spatial commenting system. If this type of zone was layered on top of an image, avatars could attach comments to particular part of the image, taking advantage of the spatiality of the space to scope their messages. This creates an interaction that looks more like the Web where participants need not be co-temporal and co-located to hold a conversations.

The other mode of chat history aggregation is more familiar. It sacrifices the spatiality of chat but preserves the ordering in time. When an avatar enters this sort of chat zone, a scrollable chat pane appears on the right side of the interface. This view aggregates all chat that has ever occurred in this space. Avatars in the space can scroll through the chat history to see past messages. New chat messages from avatars inside the zone are appended to the bottom of the chat log.

By binding chat archives to certain parts of the world, we can build a number of interesting kinds of spaces. We can have one of these zones within another, too. For example, a zone that's just for questions to a presenter, that is within a larger chat history zone. This provides two different archives—one that contains all chat and one that contains just questions for the presenter. We can also imagine other structures where persistent chat spaces like this are used to conduct asynchronous discussions about some artifact in the virtual space.

This approach is in contrast to the *Chat Circles* work on building personal archives. In that model, chat archives were a personal experience. If an avatar wasn't in range of a chat message then it isn't saved as part of their local experience. Although this is a fascinating model, it requires co-presence for recording. One of the major benefits of virtual space is that it can become its own record of what happened in the space for people who weren't at the original event. A hybrid model might make the most sense, in which an experiential log of chat messages that were seen in the space is constructed locally for each client, but that avatars can still visit virtual spaces that their own aggregative properties.

5.5.5 Growing Avatars

The potential for zones that change an avatar's representation is vast and there was only time to implement one particular technique. The zone in **space* most concerned with avatar representation is one that maps an avatar's chatting volume with the size of their avatar. The more chat messages from an avatar, the larger the avatar. This is not just true for messages spoken inside the zone, but aggregates all chat history anywhere in the space. In this way, the zone acts as a sort of lens; when an avatar moves into the space it reveals a different view of their behavior from the normal style. This particular mapping is a simple one, but even just using avatar size, there are other kinds of behaviors that could be mapped to size, like movement—sedentary avatars get larger while mobile avatars are small.

5.5.6 Speaking Distances

The Podium Zone increases the speaking distance of avatars within it. As discussed earlier, this speaking distance effects both audio messages as well as chat messages. The zone is rendered in a way that attempts to evoke a raised platform from which someone can speak. While this particular design is meant for a presentation setup, it might sometimes make sense for certain spaces to have much larger speaking ranges than the default. Although spatialization is nice, some scenarios would be better if everyone can always hear everyone else. This is easily achieved by using a zone like this in combination with whatever zones are necessary to appropriately configure a space.

5.5.7 Collision Control

The specifics of inter-avatar movement dynamics play an important role in the social feeling of a space. The most basic issue is collision—can avatars in a space run into

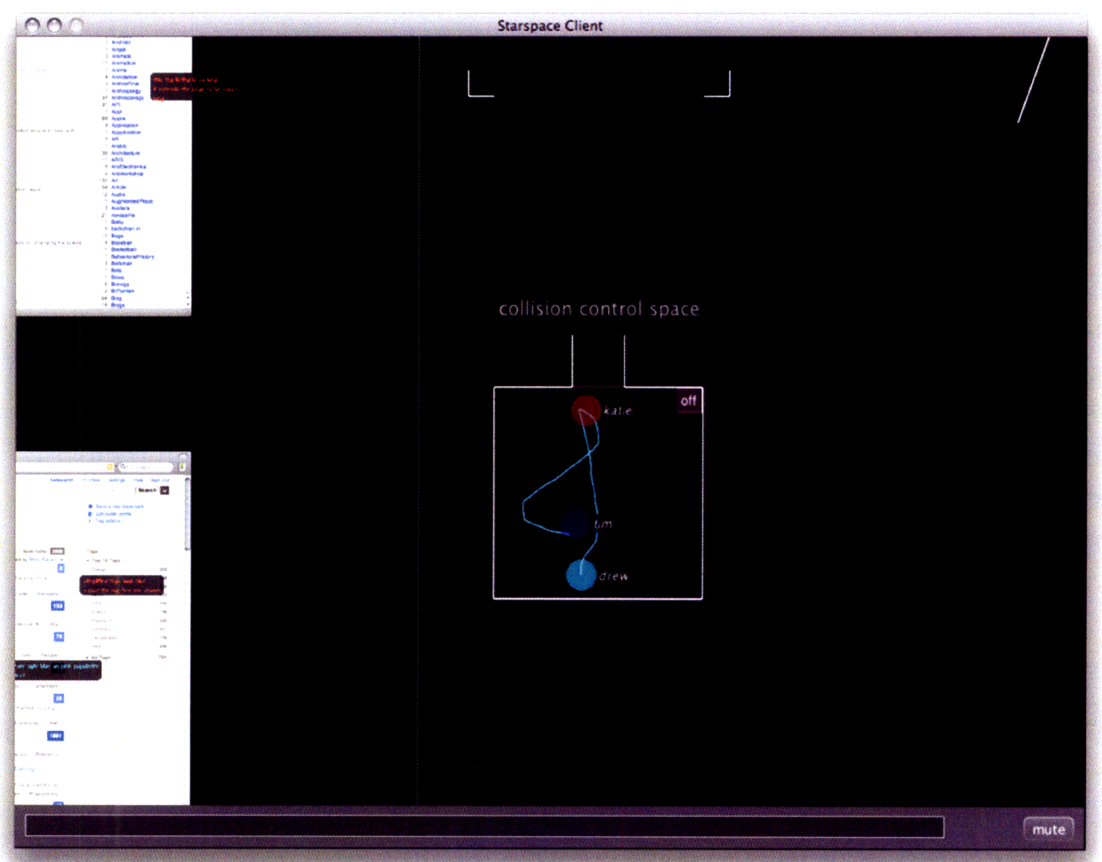

Figure 30. Avatars in a space with collision turned off. Their bodies are shown with transparency and they can move easily through each other. Collision can be turned on by clicking the button in the upper right hand corner of the zone.

each other or not, and what happens when they do? Enforcing collisions between avatars reinforces a sense of personal space, especially if colliding brings one or both avatars to a stop. In spaces with collision turned on, avatars tend to try to avoid running into other people because it feels analogous to running into someone in the physical world.

Collision can also be a way of exhibiting a sort of spatial power over other people. In games where collision is turned on, players can, for instance, block all the entrances to a space and prevent other people from getting in. Often, when there is collision there can also be mechanics for pushing other avatars around the space, too. This makes possible a whole range of antagonistic behaviors (Zinexgs 2008), which are traditionally bemoaned by players. This kind of expression of spatial power is not entirely dissimilar from non-violent protest techniques used to great effect in a wide range of political movements in the physical world. Even mundane activities like standing in line make less sense if avatars can move freely through each other. Thus taking away the ability for avatars to collide is a very significant design choice. Without collision, avatars become formless ghosts who lose a major physical method of interacting with other avatars.[9]

A space without collision also has a number of implications for design. If avatars don't collide, much less space is necessary for avatars to move around each other or even just to stand still. Avatars can be packed tightly together without collision without adversely effecting anyone's experiences too badly. As a result, turning collision off in densely populated spaces (as described in *Snow Crash*) can in some situations be helpful. In a more fundamental way, this also forms the basis for space-appropriate behaviors. The lack of collision sets up a space where new norms for inter-avatar behavior are possible. While in a space with collision the "being there" like behaviors of a system like *Body Chat* makes sense, removing collision removes many of the reasons why we move around other people the way we do and makes *Beyond Being There* interactions possible.

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[9] *World of Warcraft* is the most high profile example of a world without collision. It is almost certainly intended as a way of avoiding precisely the spatial power issues I describe here. It is a sort strategic design decision similar to Napoleon's desire to make the boulevards of Paris to make it harder for citizens to stand up against the army. As a result, players can have little impact on each other outside of the built in combat system, which is tightly prescribed. This makes for an ultimately safer experience for everyone, but sacrifices much of the richness that can make virtual worlds exciting places to be.

In **space*, spaces can choose to either make avatars "solid" (i.e., collidable) or not. The option can also be made a switch in the space such that avatars can hit a button and it changes whether or not avatars in that zone are solid or not. Avatars that are not subject to collision are rendered transparently. By default, all spaces have collision turned on.

5.6 SCENARIO

Meetings naturally move between a wide range of different situations, and the spaces that support them naturally change too. In this scenario, I discuss a hypothetical meeting situation with a few different stages and the virtual spaces that might support them.

This is a planning meeting for a large organization, and the meeting participants come from all around the company and have different kinds of expertise and knowledge. The goal of the meeting is to develop and propose new product ideas for the company. The meeting starts with a presentation of the structure of the process. The audience is in a space that doesn't have collision, so it can easily accommodate many people. It's also relatively small, so private conversations are hard—everyone can hear everyone else. This helps keep people from getting sidetracked. After the process is explained, there is time for questions. People with questions can move their avatar into a question queue (which has collision turned on, per Section 5.5.7) and their questions can be addressed one at a time. Latecomers to the meeting can tell where it's happening because the paths that led to the meeting area left by the large group of people that recently traveled to the meeting area.

After the process is explained to the audience they split up into their groups to develop different ideas. Each group has its own area such that they can each have a discussion and be well out of the hearing range of other groups. The zones have highways between them so meeting organizers can quickly move among them to answer any questions participants might have. Each group has a number of tools at their disposal. One group in particular chooses to start with the brainstorming space to generate ideas. The brainstorming space has a combination of different chat history zones; one that saves discussions about ideas over time, and one that arranges chat messages based on where they were said (Section 5.5.4). Over the course of the discussion, when someone has a new idea, they can leave it in the spatial history zone, so that everyone can see it. This makes the space operate a bit like a bulletin board. After ideas have been generated, participants can arrange themselves near the ideas they're most excited about. This makes it easy to decide which ideas to pursue and develop. This entire process happens inside an anonymity zone (Section 5.5.1), so participants don't make assumptions about the people they're working with and defer to the status or authority of others during the brainstorming process.

After settling on a single idea to develop, they start to develop visual materials to communicate their idea back to the larger group. A member of their group uploads a series of images that explain their idea. These images are embedded in the world. After all the groups are done coming up with their ideas, they visit the presentation areas of each group in turn. While a group presents their idea, other people can use a dedicated comment area to leave messages for the group to review later. This area has low chat range, so these comments aren't visible to anyone else and so don't distract the presentation of the idea. The group presenting can review these comments afterwards because they persist in the space. These messages create a tangible record of what happened at the meeting.

Chapter 6

CONCLUSION

My overriding goal in this thesis is to propose new ways of thinking about the design of virtual spaces. Although much attention has been paid to the graphical and networking capabilities of virtual worlds, I argue that the design language of virtual space is just as important to creating effective virtual world experiences that will enrich people's lives. In particular, I have focused on how virtual spaces can have procedural or algorithmic characteristics that can influence the functional experience of being in a virtual space. In this thesis, I have used two projects to demonstrate the ways in which this process can happen. In the first project— *Information Spaces*—I used *Second Life* to build meeting rooms that used avatars' positions in the space as social signals that could facilitate discussions. In the second project—**space*—to more broadly demonstrate a wide range of possible techniques for describing virtual spaces. In both projects I analyzed the design space to help guide others faced with the challenge of designing their own virtual world or future virtual world architects faced with the challenges of working in a largely undefined design space.

I close this thesis with a short-term road map for research extensions to this work, as well as a longer-term vision for what role virtual worlds have to play in the future.

6.1 FUTURE WORK

This has been a relatively high level exploration of the design space, and the detailed questions of how specific design parameters influence people's behavior in a virtual space remain unanswered. For example, I suggest a number of ways in which avatar appearances could be algorithmically controlled – studying the resulting behavioral changes would provide a better understanding of how virtual spaces can have a substantial impact on group dynamics. A similar process could be used to study how collision effects avatar interactions or how movement histories in a space influence navigation. We might also explore different models for audio spatialization that more effectively support different sorts of social situations.

There are also some notable design areas that could be explored much more. Tools for users to design their own avatars were ultimately omitted. There are a number of interesting design decisions to explore in this space. Most interesting to me is the potential for users to animate their avatar's appearance in a kind of gestural body language. Avatar collision is also under-explored; what happens if avatars that collide stick to each other and exert force on each other? How might avatars kiss, hug, or hold hands?

Because this thesis attempts to flesh out a design space, a logical next step is to build tools that make it easy for end users to rapidly design and build virtual environments with these characteristics. Because **space* is a two-dimensional environment such tools would be akin to familiar drawing tools, making the experience much more accessible to a broader audience. Such a tool would help us better iterate through possible designs and understand how designers of virtual spaces understand the general spatial vocabulary we have outlined here.

There is also substantial applications work to be done in the design of specific virtual spaces for specific tasks. How could we use these tools to build spaces for large group presentations? How should a space grow or shrink to accommodate different group sizes? Can we build more playful spaces that support story telling or something akin to a virtual dance performance? Could we build a virtual office for maintaining a sense of remote presence among employees? How might a brainstorming space work? These are just a few of the potential application domains that this work informs and that the **space* platform could help explore.

6.2 VISION

Driven in large part by literary visions like *Snow Crash* and *Neuromancer*, virtual worlds are often described as the future of interaction on the Internet. A good example of this particular vision can be found in *Technology Review*'s "Second Earth" article. They argue that:

> "the Metaverse that's really on the way, some experts believe, will resemble Stephenson's vision, but with many alterations. It will look like the real earth, and it will support even more users than the Snow Crash cyberworld, functioning as the agora, laboratory, and gateway for almost every type of information-based pursuit. It will be accessible both in its immersive, virtual-reality form and through peepholes like the screen of your cell phone as you make your way through the real world. And like the Web today, it will become "the standard way in which we think of life online," to quote from the Metaverse Roadmap" (Roush 2008)

Although this approach is grand, I don't think it accurately describes a probable future for virtual worlds. Communication tools rarely obsolete their predecessors. Instead, they tend to evolve into finer and finer niches as new options come along. Physical mail still exists—and likely will continue to exist for quite a while. Rather than being the dominant form of communication that it once was, it has evolved into a medium that acts as a strong social signal because of the costs in time and money to send physical mail. A similar process is happening with email. Although email remains perhaps the dominant form of mediated communication, there are more and more options for certain historical uses of email that may well replace it in some domains. Instant messaging, for example, takes the place of short, time-critical email messages in some situations. Large discussions tend to be more effective on forums. File exchange and discussion often makes more sense in dedicated Web applications.

I believe this process points to a likely similar path for virtual worlds. There are some applications where having a synchronous, spatial, embodied experience can be quite effective. To meet these needs, many people may occasionally use a virtual world client. But in many domains, I believe virtual worlds will remain too awkward to replace experiences that are currently common on the Web. The Web does a wonderful job manipulating two-dimensional information that is not fundamentally spatial. Browsing a virtual bookstore does not (and I doubt will ever) compare favorably with using a Web-based store like *Amazon.com*. The metaphorical flexibility of the Web makes it effective for this sort of activity, while the spatiality of virtual worlds makes them less effective. As a result, activities that fit with virtual worlds' strengths may well migrate to new virtual world platforms, but virtual worlds are highly unlikely to become the dominant form of online interaction in the foreseeable future. Nonetheless, for problem domains that are a good fit with virtual worlds' strengths I believe they will prove to be highly relevant and more effective than existing alternative technologies.

Chapter 7

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