The Presentation of Spatial Design using Autonomous Characters in Virtual Environments

A Thesis

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By

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ABSTRACT

This research is an exploration of virtual environments as it relates to presenting spatial design, specifically focusing on the use of autonomous behavior in virtual characters for simulation purposes. The characters in motion gives the viewer of this environment an understanding of circulation routes, traffic density and space usage (function) among other aspects. Since the characters can ‘think’ by themselves through the programmed artificial intelligence, the resulting simulation may be unexpected. Flaws or miscalculations in the design may be highlighted due to the chaos that arises from the virtual crowd.

To conduct the research, two virtual environments were produced and examined. These were modified through an iterative process based on analysis and review by groups of peers, academics, as well as designers in the field. My documentation includes the necessary steps taken prior to production, an analysis of the environments, as well as possible future directions. The existing uses of this technology were also analyzed and compared.
Similar to the impact on the design field by the introduction of perspective drawings, the use of virtual environments has the potential of creating a new method of designing, one where design is conceived and experimented on a computer, as opposed to orthographic drawings and perspective vignettes. This is due to the ability of real-time spatial manipulation which allows one to see the direct effect of any proposed change upon the characters in the simulation. One could experience the environment through these autonomous beings, giving us a dimension of sight we could never see otherwise. The functionality of designed space could now be ‘discovered’ by the virtual characters, thus enabling the most ambiguous forms to take on roles we may not have conceived ourselves.
Dedicated to my two daughters.
ACKNOWLEDGMENTS

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My gratitude to my siblings and family members, most of all to my wife, who patiently attended to my needs in very difficult times.
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DEFINITION OF TERMS

The term simulation is repeated throughout the paper. It is used here to describe an imitation of a scenario. The reproduction of events in a setting using alternate means would be considered a simulation. A computer simulation then is the imitation of a real-world scenario using digital props and virtual characters.

Autonomous character here is defined as a character entirely computer driven. These characters are programmed such that certain general parameters are specified. For example, solid objects are never to be intersected with. Also programmed is the response to certain events. For example, a character may turn around and walk in a different direction if its path is blocked.
CHAPTER 1

INTRODUCTION

1.1 Limits of Existing Modes of Presentation

There are some inherent disadvantages in the traditional methods of presenting spatial design. The use of multiple sets of information, like orthographic drawings and physical models, require the viewer to correlate various bits of information and mentally reconstruct a space (Ching, 1998). Aspects of circulation and function then need to be imagined by the viewer. This, clearly, can be an issue especially when the viewer is not trained in the field of spatial design and visualization (Arnheim, 1977). Even for experienced designers, the means of representing a space is static while spatial design is dynamic (Gargus, 1994).

1.2 Advantage of Virtual Environments

The use of virtual environments for presentation purposes can allow for a dynamic model that incorporates visually articulated layers of information that work in conjunction with each other. The unrestricted time, space, and
dimension that virtual environments can offer allows for one to experience the space relatively closer to how we would do so in our daily life. The presentation can be enhanced with the use of virtual characters that could help ‘narrate’ the design. Viewing a character walking through a space immediately gives us an understanding of the scale, function, circulation routes, and traffic density. By applying a level of autonomous behavior to these characters, we can produce possible scenarios of a space that we may not have thought up ourselves, potentially sparking new ideas for the viewer. Besides a communication tool, the virtual environment could essentially serve as a test bed to make informed decisions.

The following is a list of the advantages of virtual environments along with some examples of their use. Defining these possibilities served as a precursor to the development process of this project.

1. Interaction Capability
   a. Responds to user input
      Ex. Using mouse control, one can highlight areas and get more information like an enlarged view
   b. Allows for intuitive movement
      i. Of the user through the environment
      ii. Of the elements in the environment
2. Use of Layers
   a. Layers of Data Can be viewed at once
      Ex. Circulation routes, Usage of space, and traffic density can be seen simultaneously
   b. Layers can be turned on/off
   c. Opacity of Layers can be increased/decreased

3. Ability to Change Parameters in the Environment
   a. Conditions can be changed to see the effect in real-time
      Ex. Adjusting the time of day to see the effect of light in the space

4. Alternate Viewing capability
   Ex. Wireframe view, shaded view, a combination of various rendering methods.

5. Unconstrained Point of View
   a. Users look at what they choose to
   b. Contrary to linear animations where information is presented only from one angle as the designer prescribes.

6. Unconstrained Time
   a. Viewers can view static & time-based information simultaneously

7. Ability to Visually Articulate
   a. Displaying the same information by a different means
      Ex. Displaying a massing model to communicate the building form
b. Displaying the same information separately at the same time
   Ex. Displaying the plan and perspective view adjacently

1.3 Advantage of Characters

It is my assumption that viewing characters using and circulating through a given space immediately gives us:

• a sense of scale
• displays the entry and exit into the room
• displays traffic pattern, density
• shows a function of the space
• distinguishes service/served spaced

and if made autonomous, the character could potentially:

• show flaws/problems in the design
• show advantages in the design

Besides this, a virtual character that wanders a spatial design, without any parameters specified regarding that particular design before hand, could allow for spatial design to be tested. The test in this case would be specifically on the efficiency of circulation.
1.4 Adverse Factors when dealing with Virtual Environments

The production of virtual environments and computer simulation in this research requires a wide assortment of skills including programming knowledge. The ability to skillfully program the various elements in the environment can greatly reduce production time. I needed to develop computer programming skills in order to carry out this research.

Another factor to overcome is the computer processor power. Many computers cannot handle larger virtual environments like the one produced at the end of this study. Although this may not be an issue in the future, the processor capability is limited and therefore, the designer must take that into consideration when building virtual environments.

1.5 Phase of Design Process

The phase of a proposed space in the design process is an important issue to consider before building the virtual environment. The stage will determine where emphasis will need to be directed towards.

If a simulation can be made while the spatial design project is still in its early phases, a good design can be presented and analyzed in front of the decision makers. It is essential for this analysis to take place in the early phase of the project. It is here that the designer and client must come to an understanding of
the relationship of the project components, scale, as well as the overall appearance and form (Ching, 2005). The virtual environment projects produced in this study contain designs in the schematic phase.

1.6 Research Methodology

To explore the possibilities of autonomous characters in virtual environments for presenting spatial design, a few virtual environments were built from ground up, keeping in mind the design considerations that would concern a spatial designer. There were three stages in this exploration:

First, the path-finding capability of the characters needed to be produced. The background research and trialing took place in this stage. Defining what role the character will serve, what information should be provided to this character and their behavior to one another were all concerns that were addressed. After a series of experiments, a path-finding system was found and implemented. This stage resulted in a firm understanding of one of the most fundamental aspect of this research: autonomous behavior.

The second step was to apply the path-finding capability in a real world scenario. Virtual office workers were spawned in an office park. They were to head to one or more locations of a nearby café and utilize the space accordingly. To better track the movement, every character emitted a particle trail that would
disappear over time (Figure 1.1). The resulting visualization clearly depicts the circulation routes and traffic density.

The last part of the process was an advancement of a specific aspect of the virtual environment. Even while seeing people in motion, utilizing a space, we must speculate their experience. In this stage, we are able to fixate ourselves onto any character in the virtual environment (Figure 1.2). This is basically experiencing the space in the shoes and through the eyes of the characters in the environment.

Issues of the virtual model, camera, materiality, and interface were dealt at every stage. Self analysis, review by peers, and analysis of other works like computer games, were critical in developing the later iterations.
Figure 1.1  Characters with their Particle Trails

Figure 1.2  Virtual Environment from the Character’s perspective
CHAPTER 2

BACKGROUND AND STATE OF THE ART

2.1 Literary Works

Various literature and applications were reviewed to build and understanding of the capacity and limitations of spatial representation, virtual environments and computer simulation. The following reviews helped direct the decision making process of the virtual environments constructed in this research.

2.1.1 Presentation Challenges

Edward Tufte highlights the problem of “flatlands” in his book, Envisioning Information. Flatlands are the 2-D representation of 3-D data (Tufte, 1990). Tufte argues that a flat view of space is unnatural since we experience the world in three dimensions. Such representations then, inhibit spatial understanding. Other, less flat modes of visualization, like perspective drawing, cannot serve alone in conveying spatial data. Tufte quotes Paul Klee who states, “One cannot discuss a whole entity or an image that is broken into parts, when that entity or image has at the same time multiple dimensions (with
one means of representation)" (Tufte, 1990). Tufte provides a few solutions to the flatlands issue in information display.

The information presented should be broken down into layers that correspond to each other. Tufte argues that layering and separating data “gives hierarchy and organizes complexity”. Furthermore, the macro and micro levels of reading should be included to allow for a broad overview, observation of detail, and the ability to compare parts to whole; all simultaneously. Lastly, Tufte states that details clarify data. The need to add details in presentation reflects the complexity and intricacy of the world (Tufte, 1990).

Virtual environments can accommodate Tufte’s theories relatively easier than through a paper medium. Space does not have to be viewed in a flat manner; or even on a flat screen (through the use of stereoscopic or head-mount display). Also, unlike a paper with one surface of information, virtual environments may contain any number of layers, infinite cross-sections, because of its ability to construct 3-dimensionally and be observed as a time based experience. This can provide the viewer with the perception of a 3-D dynamic environment unlike traditional static methods.

Virtual environments are only a few steps from becoming common to the field, something that has already taken place with the Building Information Model (BIM). BIM is essentially a comprehensive virtual model built up of layers
of information from across the construction disciplines. See Figure 2.1. Most importantly, the BIM is fully 3-dimensional and is put in digital form early in the design development phase (Gonchar, 2007). The addition of attached (or baked) textures, animated characters, and their programmed artificial intelligence would allow for a simulation similar to the one produced in this study.

In short, the argument of involving much detail and multiple layers is already taking place with BIM. The addition of autonomous characters provides another layer of valuable information.

Figure 2.1  **The Building Information Model** (Building the Future, http://www.aecbytes.com/buildingthefuture/2007/BIM_Awards_Part1.html)
2.1.2 A Background Study on Graphical Practices in Spatial Design

Tom Porter discusses the background information of various presentation modes of spatial design in his book, *The Architect’s Eye*. The advantages and shortcomings of physical models as well as 2-dimensional drawing formats are expressed. The apparent shift towards computer technology and its ramifications are also covered.

With the discovery of perspective drawing, designers were able to depict space on a flat surface at a more accurate level than before. This allowed for conceptual design to be represented in their proposed setting and occupied by people and artifacts. Such a drawing method helped Renaissance designers find “ideal geometrical unity”, a trait that is carried out in their architectural styles (*Porter, 1997*).

However, perspective drawing had a major downside:

“Brunelleschi’s (Italian architect of the Renaissance period) perspective was a contradiction to the very nature of visual perception as it caused the viewer to freeze in time and space.” (*Porter, 1997*)

Perspective, in essence, is a single state in time. As useful as such an image may be, space and the movement through it require the factor of time in order to be fully understood. Despite this apparent disadvantage, the accessibility of the print
medium encouraged the growth of drawing until it became the common mode of spatial delineation (Porter, 1997).

In regards to physical models, Porter states:

“By working directly in space, albeit in a small scale, concepts are formed and reshaped as a result of their exploration in three dimensions; a process in which options are open in design routes – options that may not appear available to the designer trapped within the confines of paper.”

Architect Eero Saarinen’s explanation of his own work is mentioned by Porter. Saarinen states that, similar to Michelangelo, he would model his design in clay first before pursuing drawings on paper. The architect argues that the form of his TWA terminal design “could not have been achieved on paper alone”. We understand from this that scale models assist in the design development process. In addition, models become necessary for those who don’t understand drawings. Porter reiterates Sir Christopher Wren who comments:

“A good and careful large model’ should be constructed for the encouragement and satisfaction of the benefactors who comprehend not designs and drafts on paper” (Porter, 1997).

Besides the downside of the obvious time and material cost, physical models can convey ‘miniaturom’; a skewed sense of the design due to the differences between the scale of the model and human. Another downside of scale
models is the absence of people (Porter, 1997). The only way this could have been achieved before was if the model was the actual size.

Physical one to one scale mockups of architectural elements have been used in the past. For example, Michelangelo created a mock up cornice out of wood and it had hoisted in place so that he and his clients could assess its suitability before construction took place. Sir Christopher Wren did the same for his sculptures on St. Paul’s Cathedral. In both cases, the designer and client are able to examine the visual effect, the scale, and the people’s reaction or behavior towards the proposed work (Porter, 1997). Although very costly, this examination provides an informed decision.

Using virtual reality for the same purposes, according to Porter, can reduce the cost factors of money, space, and time. Furthermore, computer generated virtual reality systems provide a platform to “explore an un-built environment” as well as “function as convincing and engaging presentation devices”. Virtual reality, as porter discusses, can be used for more than conceptualization of new form. Antiquated buildings that have been damaged or lost over time can be reconstructed (Porter, 1997).

“Being portable, the computer model can be referred to at the monthly monitoring meetings. It is also used in dealings with the local council, community representatives and, of course, for marketing to potential
private-sector investors. ...the ability to visualize a building in advance is a necessary and real part of the creative process of architecture. Individual building designs are examined and studied in the virtual space of their settings and appropriate modifications made. Urban design issues such as massing, circulation, views and disabled access, are also checked according to the findings of walkthroughs and flythroughs.” (Porter, 1997)

It is important to note that virtual environments can serve only as a supplement to the presentation of space, as opposed to an alternative. To cite an analogy, floor plans continue to be used despite the application of newer presentation forms, like the BIM mentioned in the last section. This is because orthographic sectional drawings, like floor plans, accentuate the relationships of design elements including form and function (Ching, 1998). Although virtual environments may provide us a different dimension of visualization, other means of presentation are necessary since, as discussed before, an entity containing multiple dimensions cannot be explained with only one means of representation (Tufte, 1990).

As the use of computers has become commonplace, its impact on the design field is having a similar effect as the proliferation of the print medium. In other words, the process of designing space has clearly transformed due to computer technology. Further details and examples will be discussed in the assessment section.
2.1.3 The Use of Computers in Spatial Design

Nicholas Negroponte theorized the use of computers as an integral part of the architect’s design process. He argues that humans are incapable of handling large and complex problems while considering the small details. For example, while designing a city, the planners must overlook the state of each urbanite as an individual, according to Negroponte. In this regard, computers can potentially handle large complex issues while keeping account of the smallest details. Maxis’ SimCity is an appropriate working example. On the other hand, humans are good at handling problems the size of buildings. Because the disparity between the building form and the humans’ interaction with the designed space (the overall and the details) is not so great (Negroponte, 1970).

The disadvantage with computers Negroponte points to is the application and depiction of accuracy. In the conceptual stage of the design process, freehand sketches are used to convey ideas instead of hard lined drawings using a ruler. The former does not require all decisions to be made. For example, while freehand sketching the conceptual form, the exact dimensions of the walls do not have to be taken into consideration. The same cannot be said about drawings produced in AutoCAD®, where every input is an exact measurement. In short, designing by sketching on paper allows us to ignore accuracy and concentrate on other aspects of the design, like form (Negroponte, 1970).
In addition, a sketch on paper looks like a design in the conceptual stage. This is due to the irregularity of the lines and the messiness of the paper. In contrast, a sketch depicted on a computer is composed of straight lines that meet exactly at defined points. The accuracy invokes a sense of completion when in fact many decisions may have not yet been considered (Negroponte, 1970). In this regard, Autodesk (a drafting/modeling software developer) recently produced a plug-in to their product, Autodesk Impression, which allows for drawings to be viewed as a sketch (Autodesk, http://www.autodesk.com).

Besides these disadvantages of computers, Negroponte discusses two benefits computer simulation can offer designers:

1. To understand how a particular behavior works. One can compare their understanding of a particular event, vertical circulation for example, to what actually happens in the computer simulation.


This research is essentially an implementation of the latter point.

Negroponte states:
“When simulation techniques improve and are a part of architecture machines, physical structures can be tested with in environments that acknowledge their presence. In other words, when a change is contemplated for some neighborhood, it can be tested by observing its effects over time, but in fast time, unreal time. ... Direct interplay between events and effects, desire and result can be observed and can be enveloped in simulation procedures.” (Negroponte, 1970)

2.2 Application of Virtual Environments

The following are two examples of contemporary uses of Virtual environment in the field of spatial design. Provided at the end of this section are two examples of works used for other purposes.

2.2.1 “Khufu Revealed”, a Dassault Systemes Production

French architect Jean-Pierre Houdin pursued a theory on the construction of the Khufu Pyramid of Egypt. He believed that the previous theories, some involving lever-type machines or large ramps, were impossible. With the help of Dassault Systemes, a firm specializing in virtual simulation, Houdin was able to analyze and confirm a more revolutionary theory: that the pyramids were built from within (Malherbe, 2008).
The theory Houdin brought could only be tested if the event of construction was recreated. He believed that the pyramid was built partly by an external ramp and the rest using an internal spiral ramp. The team found it was necessary to check that the labor and material according to the theory was coherent with that of the pyramid’s construction. Using numerous calculations, they sought to test the structural and physical reliability of the construction process within the time constraints the original builders had. A series of computer simulations allowed for other questions regarding the construction to be answered, thus improving and supporting the proposed theory (Malherbe, 2008).

For this simulation to take place, the Dassault team first created a digital geometric model of the pyramid. This allowed for the visualization of the structure that until recently would have been impossible. The digital model allowed for viewing the model in any direction, producing cross-sections, and observing the corridors and rooms transparently. The developers used this to get a better understanding of the nature of the construction; information that also helped in building evidence for the internal ramp theory (Malherbe, 2008).

Dassault Systemes then applied the laws of physics to each element of the geometric model. Gravity was simulated and the density and elasticity was applied to the stone and other materials. Mechanical systems of the time, like sleds, were added. The simulation accounts for the difference between an object
sliding across another surface and the same object rolled over wooden beams (Malherbe, 2008).

With the digital model, inclusive of the pyramid and mechanical systems, conforming to the laws of physics, the developers were able to put Houdin’s hypothesis in virtual action. In the end, the simulation showed that the internal ramp theory was plausible within the constricted time span. Dassault normally uses such technology to help manufacturer’s minimize production time. In this case, it helped in resolving a theory that could not be resolved in any other such way. However, the use of the digital model was not restricted to analysis purposes. It was then used to explain the entire construction process theory to others (Malherbe, 2008).

The Dassault team used the virtual environment as a means of conveying information and as a teaching medium. The viewer of this environment can move around the site at will and see the process of construction through all its stages in real-time as hypothesized, and confirmed, by Jean-Pierre Houdin (Malherbe, 2008). (Figure 2.2)
Figure 2.2  The Virtual Simulation of the Construction Process (Malherbe, 2008)

An interesting point is that of the developers’ insight in the entire process. They reach a level of appreciation of the original designer (of the pyramid) that no one else might achieve. Recreating the environment, albeit digitally, is the closest to reconstructing the original pyramid since, in this case, the construction process, factors of material, physics, and time were accounted for.

2.2.2 “A Virtual Environment for Conceptual Design in Architecture”

A team of two computer scientists and an architect at the University of Minnesota created an immersive virtual environment application for the development of conceptual design in architecture. The goal was to create a work area where a designer can: create & manipulate geometry, design within, around or beside the space, and evaluate the design process and result all in real time.
Working in multiple scales was key to the development of this “Design Station”, as it is referred to (Anderson et. al., 2003). See Figure 2.3.

The developers of this research project argue that computer aided design applications are difficult to use for concept development because of problems with the computer screen (the monitor). They state:

“...the limited viewing angle and resolution of a typical work station screen tends to objectify the space being designed, leading to a tendency to concentrate on external form rather than inhabitable space; the design of
the space can be negatively influenced by the shape of the screen and by its strong horizontal and vertical edges...” (Anderson et. al., 2003)

During the early stages of the project, the team researched the typical architects’ needs, their work areas, and the overall design process. The team determined that the use of images & videos, sketches of possible design solutions, and a visual record of the design process were essential to the architect’s work area. The availability of these three elements was made possible for the Design Station. Much emphasis was put on using images and videos because, according to the research team, they served as a reference and information pool for use in the immersive virtual environment. They can also be used to represent geometrical form, material, and flat surfaces (like a façade). Images and videos can be used to show people and their activity in the space (Anderson et. al., 2003).

One of the conclusions the research team formed was that changing scales of objects in the virtual environment created understanding of parts to whole. The example brought forth was the relationship between an entry way of a building to the building itself and eventually to the surrounding site (Anderson et. al., 2003). Seeing multiple scales simultaneously also assisted in building this understanding.
2.2.3 Other works

An actual functioning real-time simulation had been started in 1946. The Massachusetts Institute of Technology’s Servo Mechanisms Lab developed Project Whirlwind, a computer system used to simulate “air traffic control, industrial process control and aircraft simulation” (Eames, 1990).

Another work is ‘Infinite City’. This is an interactive virtual reality installation created by Jean-Marc Gauthier, Miro Kirov and James Tunick. ‘Infinite City’ is a user controlled city-like environment (Gauthier, 2005). The artists create more of a mood than an understanding of the space. This is a good example of portraying virtual space in a way that is of no use to the understanding of form, function, and circulation. (Figure 2.4)
2.3 Virtual Environments and Computer Simulation in Games

The graphical practices and the simulating of characters and environments in games provide insight into possible applications in other fields. The following are three games that were analyzed. The intention was to review games of different genres, each that utilize the virtual environment and the characters in separate ways. Topics of interest towards this research were highlighted and are elaborated below.

2.3.1 Age of Empires II

Age of Empires II is a real-time strategy game involving empire building and conquest. Each player is pitted against several other CPU or human controlled teams. The teams develop economic and military resources to overcome the other players. (Age of Empires 2 : Age of Kings, http://www.microsoft.com/games/age2/)

The game takes place on a computer generated map. This map is randomly seeded to include terrain features like water and vegetation of varying proportions. The player may construct buildings, move units, and perform almost all other actions upon the map.

For a game that is 3-dimensional in nature, the camera’s fixed isometric view is very reliable for game play. Units can be located even when behind
obstacles or with in buildings with techniques such as silhouetting (Figure 2.5) and flags (Figure 2.6). Even so, the isometric view fully informs us on the spatial layout. This may not be the case if the environment contained stacked elements, like a multi story structure.

Figure 2.5 **Silhouetting Characters** (Age of Empires 2: Age of Kings, http://www.microsoft.com/games/age2/)
Since the map is too large to be viewed in one viewing, the camera can be moved in all cardinal directions. A smaller schematic map that shows the entire world is provided on the side; a trait similar to many other games. The schematic map in relation to the isometric is comparable to a human utilizing a map for navigation. Both cases highlight our deficiency in relating parts to whole by memory.

In Age of Empires II the user can produce and control numerous units, each that carries out specific tasks. Besides their soldier or civilian duties, the units serve other purposes in the virtual environment. A city in the game with the birds flying and windmills turning still looks empty, (like a ghost town), with the absence of characters to animate the space. On the other hand, the city looks real
and believable once the villagers mend the farms, the trade carts pass through the market, the soldiers are on patrol, and other such actions take place.

Another advantage of seeing these characters in movement is the direction of certain places on the map. Normally, the areas of the map not occupied by one’s units are shrouded by fog. It may take some time to find the enemy cities and camps. However, when seeing a caravan or army contingent headed in a particular direction, we quickly understand two bits of information: the approximate direction of the origin and destination. Approximate because the path of travel on the map may not be a straight line. For the purpose of the game, this information is of great value, especially when we know which character is travelling. The character indicates the probable origin and destination type. For example, a caravan wouldn’t head in the direction of battle.

In regard to the character artificial intelligence, the game developers produced an astonishing system. The computer controlled players need some type of decision making ability for the game to function appropriately. Because the situation on the map changes, the units, CPU controlled or otherwise must change as well. In essence, predetermined behavior or paths of travel are not possible for this game.

After analysis, the CPU controlled units are found to identify dangerous zones on the map. With in some time, the CPU team will work to subdue such a
zone until it is no longer a threat. For example, an enemy guard tower that may hamper another team’s access to a mine will be destroyed until it is no longer a threat. This is unlike the ‘lemming effect’ where many units may be sacrificed until a possible solution is found. In this game’s case, the computer finds a solution and expends the team’s resources to maintain such a solution until another is found. Such a problem-solving method can be used to identify dangerous or inappropriate zones in spatial design and then resolve the issue.

The city building capability of the computer is also of interest. We find that the cities generated follow a few patterns that may change based on the landscape it is built in. The city’s plan may change after a raid or siege in anticipation of further damage of a similar nature. Such decision-making and implementation happens immediately. This phenomenon happens in countless games. However, we can use such technology for designing purposes. This will be discussed in later chapters.

2.3.2 Grand Theft Auto: San Andreas

Grand Theft Auto (GTA): San Andreas is a role-playing game developed by Rockstar games. The player controls a small-time criminal who must work his way up the ranks of the criminal underworld in the virtual cities of the game. One can follow the main story line that includes missions of all natures, or pursue
one’s own freestyle adventure. (Grant Theft Auto: San Andreas, http://www.rockstargames.com/sanandreas/)

The virtual environment consists of three cities, the rural areas in between, as well as small villages and landmarks. The cities include a range of buildings and zones including ghettos, skyscrapers, parks and golf courses. The layout of the city, its representation, and simulation make a realistic and believable arena.

All areas of the environment are accessible including the interior s of some buildings. The view is through the eyes of the main character or, if one chooses, from just behind him. This gives the human player a familiar vantage point. Like in the previous example, a mini-map assists in navigation.

The cities are populated by both virtual people and vehicles that obey traffic rules and respond to events around them. Displaying a weapon in public for example, will cause the characters in the vicinity to flee or duck down. Every character can be interacted with. Their behavior varies from aggressive to indifferent. The characters are also distinct in appearance, easily distinguishing, for example, a cop from a soldier and office worker from a Triad agent.

The virtual environment setup for GTA: San Andreas provides a theatrical experience for the human player (Figure 2.7). Unlike Age of Empires II, where we maintain an omnipresent, angel-like, view of our virtual empire, this game
situates us in the eyes and shoes of an individual in a sprawling city. The stereotypical and exaggerated forms of the characters, the ‘pimped’ cars, and other meticulous details in the landscape assist in bringing us into the setting.

Figure 2.7  A theatrical experience (Grant Theft Auto: San Andreas, http://www.rockstargames.com/sanandreas/)

In Age of Empires II, we may imagine the experience of walking through our virtual built cities but never actually walk through the space as it is unnecessary for game play purposes. The units moving are enough to understand the nature of the space. In GTA: San Andreas however, we move ourselves through the space at eye level giving us an experience that may be tough to visualize without. Picturing hundreds of characters and vehicles, their interactions with each other and the environment as well as the buildings and landscape is much easier done when the picture is created on the screen rather than in one's mind. This is in essence what Negroponte states in his book
mentioned earlier, that humans cannot process the micro and macro efficiently at the same time. In the case of GTA: San Andreas, the micro are the characters, vehicles, and the scenario they create. The macro is the encompassing environment.

The change of day and night in the game environment is advantageous in depicting the lighting configurations. One can see the events that will take place at the different hours of the day but also how the space itself looks like. Such a feature can prove useful in presenting spatial design for the same reasons. In addition, the shade and shadow enhances the depth perception of the space (Ching 1998).

Besides game play, the virtual environment of GTA: San Andreas becomes a tool for culture dissemination. One is exposed to the walking style, clothing, speech, and music of each character type. In the city, one could see the lifestyle of the stereotypical California gangster, hillbilly, and country club golfer in action. For presentation purposes, the same stereotypical characters can be used to give space personality. For example, an airport with drug dealers and over exposed women will drastically affect our perception of the space, and subsequently our design decisions.
2.3.3 The Sims

The Sims is the first of a series of life-simulation games developed by Maxis. In the course of the game, the player manages the life and lifestyle of one or more households, develops relationships between the characters, and designs the interior and exterior of their houses (The Sims™, http://thesims.ea.com/)

The virtual environment in The Sims consists of a neighborhood with each house and family accessible to the player.

The default isometric view of the space can be adjusted to include the neighborhood, a single house, or a small portion of the house (Figure 2.8, 2.9, & 2.10 respectively). The unrestricted camera view allows for many vantage points and details. The game developers allowed for the opacity of some objects to be automatically reduced so as to see behind them (Figure 2.11).

The characters, human controlled or otherwise, respond to certain needs throughout the virtual day. For example, a character, which may not have had their food in some time, will build up hunger and will make their way to the nearest food source, usually the fridge, to satisfy their need. Unsatisfied needs will cause the character to breakdown or even die. The player must manage all the needs of a household for a healthy, functioning family to prosper.
The player must also develop traits and skills into the character by having them perform actions like reading, painting, or playing chess. These skills will modify the character’s personality; an important aspect for building relationships with other characters. The characters can be made to befriend, dislike, and even marry other characters in the neighborhood. A marriage could lead to a new household, children and eventually, more needs for the characters to satisfy. In essence, the character evolves through the course of the game. This phenomena can be used to teach a computer controlled entity how to use a space, and then inform us on the possibilities of that space.

Regardless, we notice throughout the game that the characters assist in narrating the space by showing how the space is used, where the location of functions are (entertainment, food), and what the possible circulation patterns are. In this regard, The Sims can be used as a tool for spatial designers. However, there two main issues with this: the focus on the characters and the limits on the complexity of the space.

In The Sims, the focus of attention is on the characters. The clothes they wear, their facial expressions, their mood, and their behavior with other characters take away from the environment. In addition, the characters are little affected by the spatial form, natural lighting conditions, and circulation of their houses. A double heighted living room, for example, seems to make no difference
to the character. The space is not the “machine for living” rather the container of the machines (like the bed, TV, sofas etc).

All the possibilities of spatial form in the game are also simplistic and traditional. A different or newer building convention cannot be applied. It is relatively easier to convey familiar design, but it is the unusual space which a platform like The Sims cannot narrate. The ability to experiment form and light (natural) would be a useful add-on to the game.

With distinct character personalities similar to ‘The Sims’, one could witness the use of the space as it relates to different types of peoples in a virtual environment. For example, comparing the use of a library lobby by a student, an employee, and a homeless individual could provide useful information. The same is the case for observing a student in a hurry to get to their destination and a student who decides to take their time, staring at the posters on the wall. The differing personality traits enhance the realism and provide a greater set of information for the viewer.

More beneficial than incorporating personality is the inclusion of the disadvantaged. Observing the use of a staircase by a cripple or the pathway of an individual in a wheelchair is a prime example.
Besides the developing of distinct personalities, the addition of traits common to everyone can also prove useful. For example, if rain showers were simulated, the virtual people may rush to seek shelter.

Figure 2.8  **View of the Neighborhood** (The Sims™, http://thesims.ea.com/)

Figure 2.9  **View of a Single House** (The Sims™, http://thesims.ea.com/)
Figure 2.10  **View of an Individual Room** (The Sims™, http://thesims.ea.com/)

Figure 2.11  **Ability to see behind objects** (The Sims™, http://thesims.ea.com/)
CHAPTER 3

PROJECT DOCUMENTATION

3.1 Development of a Virtual Environment

3.1.1 Concept

The virtual environment was to be capable of interacting with a digital model in an intuitive format; closer to how one handles a physical model. The basic manipulations that were found useful are as follows:

1. The rotating of architectural elements (Figure 3.1)
2. The peeling away of layers of material (Figure 3.2)
3. Changing perspective from birds eye-view to an eye-level view
4. The viewing of sections (cut in real-time) (Figure 3.3)
Figure 3.1   The Rotating of Architectural Elements

Figure 3.2   The Peeling away of Layers

Figure 3.3   The Viewing of a Section
These specific functions stemmed from my inability in my undergrad years to present an architectural model in AutoCAD® to my professors and others in an efficient, smooth pattern. Even though a very-well planned and produced digital model was at hand, we could not ‘experience’ it the way we do a physical model, thus making it a challenge to present. This challenge was made further difficult when our audience had no prior experience with spatial design.

I figured that if we could experience the digital model the way we do a physical model, we would have a very powerful means of presenting. I also understood that an interactive virtual environment was potentially capable of just that.

### 3.1.2 Procedure

The most basic component of virtual environment is the digital model of the spatial design. This digital model must then be imported to software that is at least capable of programming the various elements in the scene as well as allow for the real-time rendering of the model.

#### 3.1.2.1 Virtools

3DVIA Virtools, (referred to as Virtools in this paper), is software that, among other things, allows for the development and programming of interactive environments (Dassault Systemes, http://www.3ds.com/). The creation of
geometric form, virtual characters, as well as texture maps are better completed in other programs and then imported into this software. In short, this program may be used to integrate the latter elements into one medium; much like we use images, video clips, radio buttons, etc. to produce one shockwave file in Adobe Flash®. Virtools is used throughout this study to build the virtual environments.

3.1.2.2 Texture Baking

The means of producing a single image rendering requires:

1. A digital model
2. Materials to put on the model e.g. brick texture, wood texture, a plain color etc.
3. Lights to produce shadows, highlights
4. A camera from which the model can be viewed

The shadows and highlights from the lights on to the digital model are processed in the rendering stages. This can be quite lengthy, even a few hours. In Virtools, there is no rendering stage, everything is rendered in real-time. Without shade and shadow, form is more difficult to comprehend (Ching, 1999). So the shadows had to be ‘baked’ on to the model’s texture. This is essentially pre-calculating the lighting prior to export and attaching that as a texture to the model.
With the attached (or baked) texture, the digital model of the spatial design was ready to be brought into Virtools. See Figure 3.4.

Figure 3.4  The Digital Model in Virtools

3.1.2.3 Navigation

A camera by itself in Virtools cannot be controlled except by navigation tools built in to the program. These tools would not carry through when exporting the virtual environment to a place of presenting, a website for example. This requires one to program functions into the camera so it can be controlled from the mouse and keyboard.
In this virtual environment, one of the cameras rotated around the scene from a birds-eye view. The other was set to an eye level view. The altitude of each camera could be changed by using the keyboard buttons. Besides that, all other navigation was similar to a typical RPG-style video game with the cursors keys allowing for the camera to move and the mouse movements allowing for the camera to change direction.

The cameras could be switched back and forth through keyboard input.

3.1.2.4 Miscellaneous

I found it was necessary for the user of this virtual environment to know what each component of the spatial design was. A simple code was written to allow for the component’s name to be displayed upon selection. For example, “Restaurant” would be displayed by clicking the restaurant building.

3.1.2.5 Characters

Controlling a character requires a rigged virtual character model with predefined animations to be imported into Virtools. The animations, like walking or jumping, can be triggered by keyboard, mouse, or any other input.

After producing one character in the scene, I figured it would be very useful if the character could use the space by itself, without a human controlling
it. This would lead the way for many characters to use the space simultaneously and, to an extent, realistically. Having this, we could see how the spaces are utilized, the circulation patterns, the separation of different character types and others occurrences.

### 3.1.2.5.1 Nodal Network

To allow for character movement, a network of nodes, or modules, were produced. These nodes are connected by straight lines (Figure 3.5). The nodes were placed such that a character can go from one place to another, avoiding walls and other obstacles. A script was then written which allowed the character to walk from one randomly chosen node to others.

The ability to calculate ‘random’ numbers is a built in algorithm of Virtools. The computer can output a number between user-provided ‘max’ and ‘min’ integers. The ‘max’ integer in this case is the number of possible destination nodes.
3.1.3 Findings

One major problem with this first attempt at path-finding was that the character would only walk on the pathway specified. Subsequently, two characters using the same pathway would prevent each other from moving forward. I also found out that it would be very time consuming to cover the entire floor plan with nodes and to do so intelligently.

However, it occurred to me that with minimal parameter specification, the character could use any spatial design. For example, the character could be programmed to recognize walls, stairs, other characters etc. This autonomous character could eventually be used to analyze the spatial design. i.e. to ‘check’ for ambiguities or problems in the space.
This thought led me to focus increasingly on autonomous behavior in virtual environments.

### 3.2 Autonomous behavior and Path Mapping

#### 3.2.1 Concept

Seeing a simulation further enhances our understanding of a spatial design (Negroponte, 1970). A simulation in general can remove the guess work in mental visualization. This addresses my original concern of presenting spatial design to especially those unfamiliar with the tools we use to present.

In addition, I found it inadequate to limit my research to the visualization of spatial form. Computers have an amazing ability to compute and display multiple events simultaneously. We could utilize this for ‘testing’ a spatial design for either missed opportunities or blatant problems in the design. Areas of heavy traffic or locating remote regions are an example of this.

In short, the characters with their autonomous behavior serve as a tool for presentation and analysis. This section of the research addresses the path-finding capability of these characters.
3.2.2 Procedure

The Nodal Network path-finding method poses a few issues as mentioned earlier. The following are attempts to circumvent the need for the nodal network.

3.2.2.1 The Satellite Solution

As an initial step, the character was made to walk from a position outside a room to a node, the goal, placed inside the room. There was no line of sight to the node from the character’s initial position. The spatial elements in this stage included a ground plane, a single room in the center of the plane with two entrances, and a roof to the room. (Figure 3.6)
The character, named Montana, was given two simple rules: stay on the floor surface and do not intersect solid objects. Besides this, Montana had a simple command to walk toward the node. If this command was to remain active, the character will walk directly into the wall. So this command would only activate if a line of sight existed between the character and the node. Since this line didn’t exist initially, it was necessary to either:

1. Move the character around the environment until a possible line of sight could be established
   Or
2. Allow for a secondary agent to establish a line of sight to both the character and the end goal.

The first option would require Montana to have an inefficient route. He would have to walk relatively longer distances in awkward directions to find the goal.

I would like to note here that this can be very desirable to potentially test which areas are most visited by a person and/or how long it would take for a human to find its way around a given space. Of course, this direction of study would require a much more ‘intelligent’ character to compare it to the human path-finding ability.
The second option was proceeded with and so a ‘satellite’ node was produced that would orbit the goal at a radius the same distance the character is initially from the goal. This satellite would stop orbiting once a line of sight is established between the goal and the character. Once this would take place, the character would walk from its position to the satellite and then to the goal. See Figures 3.7 to 3.10.

Figure 3.7  The position of the character relative to the goal inside a room

Figure 3.8  The orbiting of a satellite node around the goal from the characters initial position
Although the character eventually reaches the goal node inside the room, there are some obvious flaws with this method. Some issues were:

1. What happens if the satellite never establishes a line of sight? (Figure 3.11)
2. What if, even a line of sight is established, the character cannot reach the satellite?
3. Orbiting the goal node could possibly be the worst way to finding a line of sight, and thus an inefficient route.
A single satellite has the ability to lose its line of sight with the character. In the last step, one can see that the line of sight is key to this path finding method. If intermediary satellites existed, the character will have a chain of ‘lines-of-sights’. For example, a character could walk from satellite to satellite up until the goal node. The question that arises for me is: How many satellites does one need? Too few may not work, and too many could possibly be a heavy load for processing (considering a multitude of characters in later stages).

I began with three satellites as this is the minimum I need, as I found out, to locate elements over a corner. Because the last test was successful, a more complicated plan was produced. (See Figure 3.12) The intention was to increase the complexity of the plan along with the development of the artificial intelligence.
The satellite nodes were named sat1, sat2, and sat3 with sat1 being closest to the character's initial position (See Figure 3.13). The programming of each is as follows:

Figure 3.12 The Environment

Satellites

The satellite nodes were named sat1, sat2, and sat3 with sat1 being closest to the character's initial position (See Figure 3.13). The programming of each is as follows:

Figure 3.13 Satellite Positions
Sat1:
On starting, this node will continuously rotate on its own Z-axis from the character's initial position. The mechanics of this sat1, and even from the previous step, works as such: a ray is emitted from the nodes center point to the furthest intersecting point.

At this intersection point, sat2 is positioned.
If a line of sight is established with the goal, Sat1 immediately stops and a message is activated to the character to walk towards the goal.

Sat2:
Sat2 will always face the goal node whether a line of sight can be established or not. It is important to note here that end goal can be immediately located relative to any given point. I am only concerned with path-finding.
Sat2 will be positioned based on Sat1’s ray intersection. Sat2 will always emit a ray from its face towards the goal node.

If a line of sight is established with the goal, sat2 immediately stops and a message is activated to the character to walk to Sat2 and then towards the goal.
If a line of sight is not established, Sat3 is positioned at the intersection point of Sat2’s ray. See Figures 3.14 to 3.18.
Figure 3.14  The position of the character relative to the goal inside a room

Figure 3.15  The absence of a line of sight from the character to the goal node
Figure 3.16  The rotation of Sat1 and the positioning of Sat2 and Sat3

Figure 3.17  The absence of a line of sight from Sat1 to Sat3. This will cause sat 1 to reposition itself and begin the process again.
Sat3:

Sat3 will always face sat1. If a line of sight is not established with sat1, all satellites will stop. Sat1 will reposition itself to the position of Sat2 and the entire process restarts.

Every position the Sat1 positions itself in can be recorded. And the character can walk from point to point until the goal node. More specifically, the character would not walk up to the next node; rather, it will walk in the direction of that node only until it can see the following node. (Figure 3.18)
The character will walk towards a Satellite until the next Satellite is visible

In this specific scenario, the character could walk to the end goal and therefore the test was successful. But I could foresee problems in a more complicated environment. It occurred to me that this satellite setup was not necessary for every character put in the scene. Instead, this set of satellites, as well as the number of other sets, could ‘map’ all possible waypoints for every character to use.
3.2.2.2.1 Relation to Nodal Network

With an entire network of waypoints established, the character can walk from point to point until the end goal is reached—similar to the very first stage. Except in this case, the nodes or paths of travel are not specified beforehand.

3.2.3 Conclusion

Although path finding systems have been developed, the revisiting of this issue from a different standpoint could lead to new discoveries. For example, when ‘inducing’ virtual characters to a new environment, the characters can begin to wander the space without predefining floors, walls, or other parameters.

3.3 Virtual Simulation I

3.3.1 Grids in Relation to Path Finding

In addition to the placement of nodes and satellite solution just mentioned, Virtools enables the use of a grid where specified regions of the environment can be declared as an obstacle. With this, a character can be prevented from walking directly into a wall and instead will be made to move through a doorway. Moreover, Virtools has built in path finding functions which, when using the grid, including translating an entity, in this case the character, from one
point to another avoiding all walls. This can basically serve as the characters’ path finding engine. (See figure 3.20)

![Grid System Defining Place of Obstacles](image)

**Figure 3.20** A **grid system defining the placement of obstacles**

It is important to make sure that, although one character can circulate without problem, multiple characters can also wander freely. If not, a realistic simulation cannot be achieved. After a series of testing, the grid was ready for use in a mock setting.

### 3.3.2 Concept

A simulation of a simple spatial design could demonstrate what autonomous behavior in virtual environments can do relative to the intended goal. This stage is essentially utilizing the previous learned mechanics in a possible real-world scenario.
Many questions arose earlier that now needed to be answered. These include:

Is the character merely a wanderer or do they serve a specific role to take on in the environment? An apartment resident or office worker would be an example of the latter.

Are we just trying to look for circulation patterns and its related issues? Should we be concerned with space use (function) as well?

Using the grid technique mentioned earlier, the floor plan becomes predefined to the character. What is the purpose of autonomous behavior if such information is already given?

What drives the character towards his/her destination? Should motivation be a factor in this simulation?

Our intended audience is the decision-makers in the planning of space, i.e. the designer, who must be informed of his/her decisions, and the owners/clients, who should have their own understanding enhanced. With that said, the question arose: who else could benefit from this simulation?
3.3.2.1 Role of the Characters

If the character is simply a wanderer, the circulation patterns would not be typical of a given space. For example, in a school environment, it would be awkward for characters to constantly move in random directions. Using the same scenario however, it would be very useful to see what the situation is like in the corridors at given times during the day.

One drawback with assigning a role for each character is the predefining part. It was my hope to ‘dump’ this intelligent character in any environment and have it utilize the space. But this idea was withdrawn since a space is designed for a user-type. How useful is a test if the wrong user-type is being tested? So I concluded that the character will have a specific, but simple, role and/or purpose in the environment.

I didn’t know if the visualization of circulation patterns was adequate for my purposes. It is my opinion that seeing the movement of people in an environment is enough to understand much of the function and even form of a space. This simulation will either support or contradict this belief.

3.3.2.2 Pathfinding vs. Pathlearning

In regards to using the grid system, I understand that just as an environment is given for the characters to circulate through, a floor plan defining
what is solid and void would not be inappropriate. The autonomous movement is still useful in producing a near realistic simulation. As a human, one knows not to walk into a wall or another person. The addition of the grid is like giving me a map. In the end, one still need to get to a destination. This is very similar to the approach in the simulation. The other option is to have the character literally find its path. This is very difficult and unnecessary in this direction of study.

3.3.2.3 Motivation Factor

Motivation is largely dependent on the who, what, where, and when. For example, an office worker could be motivated around lunch time to walk to the closest restaurant due to hunger. In this case, I would need the office worker, the office (his origin), a restaurant (his destination), a clock to simulate actual timing, and finally, some indication of when the workers get hungry.

Using this logic, a simplified version of the same example was considered.

3.3.3 Procedure

An office park environment with a close by café was realized. If all the visible characters were hungry and no time of day is set, aspects of timing and motivation could be disregarded. So we have a flow of characters from the individual offices to the café and back. A take-out window, main counter, exterior
seating, interior seating, and bathroom, all in or around the café, are the five possible goal nodes in the environment.

The addition of a pedestrian character that walks from one end of the environment to the other also has the ability to go to the café. The pedestrian is a non-office worker; his origin and destination is not an office.

The proposed design here is the café. I am looking at the circulation to and from, within, and around the café.

3.3.3.1 Environment

A row of offices line one side of a walkway. The other side is the proposed café. See figures 3.21 to 3.23. I didn’t find it necessary to see inside the offices so the walls are left opaque and static. On the other hand, the café’s roof pops up on a button click to see how the insides are being animated. Furthermore, the café’s material stands out to indicate that it, i.e. the cafe, is the proposed addition to the environment.
Figure 3.21  Plan of Café

Figure 3.22  Site Plan
A birds-eye view and eye-level camera were put in the scene. It would be interesting to see the advantages of each.

### 3.3.3.2 Characters

The environment begins with one character, Sebastian. This character is duplicated to a randomly selected office or to one end of the walkway. See diagram. The characters’ point of origin defines their role and, consequently, final destination.

The office worker will walk from his office to the café. If he goes to the take-out window, he will (pretend) to take his food and go back to his office. If the
character goes to any other destination, he will randomly go to two or three other goal nodes and then back to his office. For example, the character walks to the service counter, then seats himself down, followed by a bathroom visit, and finally back to his office. Another example is a visit to the bathroom, go to the take-out window, and then back to the office.

The difference between the office worker and pedestrian is in their origin and final destination. For the pedestrian, the origin is one side of the walkway and the destination is the other side. Upon reaching the destination node, this character ‘leaves’ the scene (he is actually deleted).

3.3.3.2.1 Trails

Every character leaves a particle trail behind them, enabling us to understand the flow of traffic and density over time. The color of this trail is an indication of character type: office worker or pedestrian. (See Figure 3.24)
3.3.4 Conclusion

There were many aspects learned while making and observing this simulation. First, ‘using’ the space here did not require the character to display elaborate details. The character merely walking to a secluded room may be enough to infer that the location is a rest room in this case. In other words, an animation of the character sitting on the toilet seat was not necessary. The same cannot be said about the café seating, however. If the character did not sit down, it would seem odd that a character will stand next to a table idle for some time. Even so, sitting at a table while moving one’s hands, appears to suggest that a character is eating. In short, the level of detail can be relatively low. I believe
that, similar to a floor plan, it can be limited to simple furniture that helps the viewer recognize the function of a space (dining table, stools, etc.).

Second, it is very distracting when a character does run into a wall or appears to be blocked by some force. A small amount of irregularity jeopardizes the already minimal realism of movement.

More so than the characters themselves, the trails they leave behind are very useful in determining traffic density and flow. Perhaps this is one set of information that serves the designer's interests more than any other element. See Figure 3.25.

Figure 3.25  **Comparing the circulation trails**

These and other conclusions will be discussed in detail in the assessment chapters.
3.4 Virtual Simulation II

3.4.1 Concept

In the previous stage, a relatively simple design was simulated. Such a space can be mentally constructed in one’s mind rather easily from looking at its orthographic drawings. However, what could I learn from issuing a complex space into a virtual environment; a very complex design that does not follow the norms of building construction?

In my junior year of undergrad, I designed a non-traditional structure that could not be well expressed until the physical model was built. I myself did not know the ramifications of the design process I applied, so some aspects of the finished building were unexpected. Essentially, I was experimenting a concept that turned out to be a very distinct and unique space. This design was ideal for presentation via the virtual environment.

The virtual environment of this design would be the most appropriate goal considering my initial challenge stemming from my undergrad years.

The project was a design for a student union for a university of the Columbus area (Capital University). See Figures 3.26 to 3.28. The design itself was never completed. Many design considerations, such as fenestration, handicapped access, roofing systems, and materiality, were overlooked. However,
the building was function-able and all the spaces were accessible through at least one means of circulation.

Besides this design, the surrounding environment was absolutely necessary. In fact, the design stemmed from the context it was to be placed in. So, much of the surrounding needed to be produced and put in relation to the proposed construction.

Figure 3.26  **Floor Plan**
Figure 3.27  Site Plan

Figure 3.28  Image of the Environment
3.4.2 Procedure

A digital model with the baked textures was added of each of the adjacent buildings as well as the proposed structure. The addition of trees, clouds, sidewalks and other details were incorporated to enhance the realism of the environment.

3.4.2.1 Characters

The characters would serve as students of the university, approaching the student union for one or many services it provided: a café, audotorium, meeting rooms, study area, and offices. Similar to the last setup, motivation and time of day would be disregarded.

Because of the nature of the space and, subsequently, the circulation routes, navigation through the building is quite cumbersome. The grid system could be used, but a technical problem exists: a character traveling over multiple grids, with some grids are overlapping (due to the many levels shown in Figure 3.29), will cause the character to be confused. Initially the grid system was implemented throughout the space. Unfortunately, the characters would stop and spin in circles because of the overwhelming amount of calculations and seemingly opposing logics to follow.
In such a scenario, the node system works well since some paths of travel could be predetermined; thus, eliminating the confusion around the vertical circulation. Besides, there is only one way to use a stairway, it wouldn’t hurt to specify the circulation up and down the stairs. The remaining spaces, like the café, union, etc., would be circulated through using the grid.

### 3.4.2.2 Navigation

Prior to this stage, one could see the characters from the third-person and even first-person. This former gives an omnipresent perspective that shows us the characters as a group. The first-person view allows one to see from the perspective we are most familiar with. However, if one could see from the character’s view, this can give us a very informative dimension. We could essentially experience what our characters are going through, again providing us scenarios we may never have considered otherwise.
The camera in this stage will attach to the head of any character selected by the viewer. The camera moves along with the trajectory of the character whilst giving us the freedom to orient our eyes (the camera lens) towards any direction.

Along with this ability, the viewer can choose to clip the picture plane. This is basically viewing sections in real time. However, the section cut view can be produced from any angle.

In addition, the camera’s field of view (FOV) can be changed real-time. This option becomes useful especially in an interior space where a non-distorted view provides a seemingly constricted cone of vision.

3.4.3 Conclusion

The exploration of the building form in the virtual environment was a surprise even to me. The qualities of the space while moving through it could not be demonstrable from a static image. The case is strengthened with the availability of the surrounding buildings and trees.

More so than the understanding of the space, the environment produces a feeling of awe. This has been noticed through peer reviews and informal discussions with various peoples. This was not the intended goal, but an impressive presentation piece could obviously win favor in the field.
This final environment sets the stage for many more directions of study. The simulation can be improved to incorporate the changing of lighting conditions and the addition of different character types and personalities. These and other aspects will be discussed in the next chapter.
CHAPTER 4

ASSESSMENT

4.1 Using Autonomous Characters and Virtual Environments

4.1.1 Data Collection

During and after the production of the latter two environments discussed in the procedure chapter, informal discussions were held with groups of students, educators, as well as professionals in and outside the fields of design. The discussions were to serve as a means to develop ideas for subsequent iterations as well as to assist in analyzing my own work. (Discussion questions can be found in the Appendix.)

Much interest was expressed by the viewers at the interactive capability of the virtual environments, especially the moving of spatial elements (popping-up of the roof) and the camera fixation on each character.

One possible future direction of study mentioned was performance testing. Autonomous characters could be used to identify the highest probable areas of
occupancy in a city or college campus for the placement of cell phone towers or Wi-Fi hubs respectively. The characters with low coverage from a communication hub could be highlighted.

Another performance testing application conversed was for structural purposes. A series of simulations of character circulation could provide data on possible load distribution upon a floor surface.

Besides performance testing, the traffic density displayed by the characters can be used to inform our decisions in the placement of spatial elements like sidewalks in an open space. In the same consideration, the traffic patterns could show the most often visited areas of a structure or open space. Such data can prove useful to retailers and vendors in a mall for example.

The analysis aspect of the autonomous characters was found unfavorable, even useless, by some practicing architects. The argument brought forth revolved around the human’s ability to make purposeful decisions in a systematic process quite efficiently. There is no need to replace the human mind with the computer since design is successful as it stands.

However, we can understand clearly from the discussion on Age of Empires II that the computer has already become a designer. Moreover, as per Negroponte’s argument, computers have an advantage over humans in their
ability to consider the large complex issues and intricate details simultaneously.

In short, the computer can be used not just to highlight areas of concern in a design, but also modify such problems for us. This can prove useful particularly to design work that allows little room for creativity. In space planning for instance, a designer may be asked to maximize the space to fit in as many rooms of a minimum size in a specific building with adequate circulation. Another example is the planning of parking lots to maximize occupancy. Appropriately programmed, a computer can optimize space usage in accordance to building codes and user requirements. Character simulation can be then applied to analyze and validate the computer generated schemes.

Towards the end of this conversation, the introduction of CAD (computer aided drafting) programs was pointed out. Initially, CAD was met with hesitation because until then, the software was unnecessary as hand drafting served the needs of designers. Similar to the acceptance and ‘normalization’ of CAD, computer simulation may become common with further research and development of technical skills by designers.

4.1.2 Design Process Considerations

A question arose as to why this field of study should be pursued as a designer. Why not leave it to the programmers? A similar question came up in my
undergraduate years: why get involved in modeling and rendering when there are graphic designers to do the job?

One aspect learned from building the virtual environments was forcing the designer to contemplate the rest of the design. For example, a designer texturing their virtual model becomes obligated to consider materiality. Decisions need to be made that may not have been resolved. Modeling a space forces one to consider the entire form, not just the look of the form from a couple views (plan, section). Producing a virtual environment has a similar effect to the design process.

While modeling the design for the last virtual environment, the character trajectories were always considered. I developed a greater realization of the impact of human circulation within and around structural form. This is because any problem will, without doubt, produce a faulty simulation. The process of programming and other technical work also allowed me to understand the strengths, weaknesses, and potential of this direction of study.

4.1.3 Disregard of Statistics and Human Psychology Factors

The regard absence of statistics in this virtual environment simulation causes inaccuracies in the circulation patterns. To be specific, the percentage of the characters using the bathroom in the ‘Virtual Simulation I’ stage was around
20%. That percentage was not intended or even researched beforehand. So we basically have an exaggerated performance as far as how many people go where.

Another aspect that is lacking is the human psychology of using the space. Humans tend to favor certain qualities in an environment that would cause a place to be more inhabited or circulated through. Including such information is definitely a possible step in the future development of such a simulation. This has been omitted in this study for the purposes of accelerating the research. Instead, I have chosen to assume the statistics and overlook the more complex human psychology.

It seems then, that an AI controlled simulated environment could never perfectly emulate the real world due to the overwhelming number of factors that affect human behavior. It is important to state here that, in this study, we don’t need to create a perfect scenario. The simulation assists in the conceptual narrative of the space e.g. This is how people come in the building, this is the seating situation etc.

This virtual environment can still prove useful to the people who cannot create mental visualization of the space. Also, from the decision-informing standpoint, a simulation could always spark new ideas or build upon existing ones. This is because the design can be seen from a different dimension: the real-time dimension.
4.1.4 Circulation Patterns

Because one can change the amount of people using the space in the beginning of every simulation, we can come to an understanding as to an optimal user limit of the space. For example, if there are twenty duplicates of the original character, the space seems underused. On the other hand, one hundred characters seems very full, especially given the number of seating.

The simulation was found very useful not just in the café but in the space between the offices and the café. In other words, the model would be ideal to study the circulation patterns of public space. The particle trails could inform us on how to position different spatial elements in a public space. In addition, furniture layouts can be examined within spaces. To cite an example from the ‘Virtual Simulation I’, one can come to an understanding of how best to position the tables and an optimum count of chairs.

The application of this simulation for analysis can be then separated into two categories:

1. A study of the interior space – looking into furniture layout, the placement of entries/exits, optimal accommodation, placement of functions (e.g. service counter, carry-out window etc.) within a layout.
2. A study of the public space—the size of pathways and spaces, proximities of different functions, etc. in the “open” space. A public square, mall space, zoos and gardens are an example of this.

4.2 Possible Future Directions

4.2.1 Real-time Spatial Manipulation

A daunting task is to manipulate the architecture in real-time. This way we could find the exact cause and effect on the character’s circulation patterns. For example, one may conclude that a larger hallway will cause more characters to occupy a certain section of a building. This is basically Negroponte’s first proposed application of simulation: to test out how a particular behavior works (discussed earlier on Page 15). Our understanding of spatial elements and their placement can be greatly enhanced when the effect of every individual design decision can be visualized. The biggest problem with this is the creating of space in real-time. The platform, Virtools, doesn’t have the capability of manipulating 3D objects in real-time with the relative ease that modeling programs offer.

4.2.2 User-Initiated Disaster

Examining the consequences of user controlled disaster, such as a fire or hostage crisis, can be incredibly valuable. Besides considering these situations by the designer, the simulation could provide law enforcement personnel an
understanding of the environment. This may help in developing strategies to overcome such crisis, akin to the work of Project Whirlwind.

4.2.3 Wanderer vs. Role Player

In contrast to the characters serving a role in the space, a wanderer or, a character with no aim, can also be useful. A virtual character with no predefined goal or ‘map’ (such as the grid concept) can show us how a person may discover the route to a particular location.

Another benefit of a wanderer is the discovery of form. This can happen by using the virtual character's to find for themselves what the space can be used for. Programmed appropriately, the characters can potentially use a heap of what seems to be ‘junk’, giving us insight into more ambiguous forms.

Using this ability, the process of designing space may instigate a new trend: one where the form is contemplated irrespective of function. The digital characters may be ‘dumped’ into a virtual environment to utilize such form. The characters’ use of the space may inform us of the various possibilities.
4.2.4 Materiality

Understanding a space can be enhanced by manipulating the way we view it. Since we have the ability to interact with a virtual environment, it would be practical to alter the texturing of spatial form for our benefit. For example, reducing the opacity of an exterior wall allows us to see the insides.

Furthermore, Negroponte claims that a sketch serves as a better means of communicating conceptual form. This is due to the inaccuracy and messiness of the paper. A sketch shows that a scheme is still in the design stages. In this regard, a sub-project was completed dealing with sketch like depictions of space. See Figure 4.1. Although I did not come to any solid decision as to what an appropriate sketch-like shaded texture for an environment should be. I felt that the sketch-like view was a low priority so long as the form was understandable. I also don’t find the defined points of a model disturbing as Negroponte claims.

Research in this direction would be desirable if virtual environments become more commonplace.
Figure 4.1  Various sketch-like visualization of an interior space

4.25 Online Virtual Environment

The discussion thus far has included autonomous agents driven by the computer. The simulation could provide a different set of data if actual people navigate through the virtual environment. This ‘human-driven’ simulation can take place by posting the virtual environment on-line accessible to anyone with internet access. If the user information as well camera trajectories of each individual are saved, one could analyze the data for various purposes including areas of most interest as well as navigation routes.
4.3 Affect on the Design Process

4.3.1 Change in the understanding of space

We can understand that spatial design can change based on the medium of presentation provided. Tom Porter states on this topic regarding Antoni Gaudi:

“He rarely drew plans and relied almost exclusively on three-dimensional forms of visualization – a method which rather than exhibiting creativity, increased his capacity for articulating highly complex space.” (Porter, 1997)

Even the discovery of perspective drawings changed the way designers see space, subsequently, changing the way we design (Porter, 1997). In this way, a new style of building form comes into being. This is obvious from Frank Gehry’s work who could not have designed some of his buildings without the aid of a computer (Fazio et. Al., 2004). See Figure 4.2. There is a parallel between the discovery and implementation of perspective drawings and virtual environments to the field of spatial design. Virtual environments offer a different mode of visualization and allows for a change in the way we design. An example of the latter is the virtual environment for conceptual design produced mentioned earlier, where the developer was able to design while sitting inside the space (Anderson et. al., 2003). In short, the use of virtual environments could alter the form and functionality of the contemporary building.
4.4 Application to other Fields: Pre-Viz

Storyboarding is used to test ideas in the process of film-making. The producer can come to a decision on camera positions, scene composition, the organization of events, and other aspects of the film before the actual shots are taken. The next step prior to production is pre-visualization (pre-viz): “digital storyboarding with a certain degree of interactivity” (Kaufman, www.hollywoodreporter.com). Bill Ferster states:

“The process (of pre-visualization) provides a test-bed for the working out ideas in a ‘low-cost’ environment. It can also be used as a way to express those ideas less ambiguously to others.” (Ferster, www.stagetools.com/previs.htm)
Essentially, pre-visualization is for the presentation and analysis of film prior to production. Virtual environments can be used in film for the same reasons as discussed in this research. With the digital model of a scene inclusive of characters and props, the lighting, camera angles, cinematography, etc. can be changed in real-time until a viable option is determined by the producers and others decision-makers. The abstraction of the story board is reduced, thus forming a greater understanding of the filming concepts for others.
CHAPTER 5

CONCLUSION

The intention of this research was to explore the use of virtual environments and autonomous characters therein for the presentation of spatial design. The research involved literature reviews, a background study on the state of the art, as well as projects dealing with the building of virtual environments from ground up. The documentation provides an understanding of the design process, an assessment of the research project, as well as future directions of study.

The inclusion of virtual environments to the field may require us to consider elements of the design early in the design process. The change in the way we design and visualize space can alter the form and usage of space. In this regard, virtual environments are not a long way away from becoming a common component in the field.

Autonomous characters simulating a space in virtual environments can prove useful besides an observation tool with the addition of human psychology factors, statistics, character types and personality, as well as the ability to
manipulate space in real time. We may use this system to test the function of and circulation through architectural form.

This research can be useful to spatial designers who may stumble upon the same issues encountered in this work. The research project and documentation also serves as a platform from which many other directions of study can be pursued, including for those fields of study outside the field of spatial design.
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Appendix

Discussion Questions

Discussion Questions for informal discussions with colleagues, designers, and professionals in the field:

1. What do you see/understand? What captures your attention?

2. What are the people doing?

3. What do you see as an advantage of this virtual environment? Limitation?

4. Did the virtual environment clear up some of the misconceptions you had about the design originally presented?

5. What do you think this virtual environment needs?

6. Where have you seen simulation in the past? Did you find it purposeful?

7. What is the potential of artificial intelligence in the field of spatial design?

8. What do you see as the potential of virtual worlds and simulation in the field?