IMMERSION, INTERACTION, AND COLLABORATION IN ARCHITECTURAL DESIGN USING GAMING ENGINES

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Abstract. This paper investigates the role of gaming engines in the architectural design process through the introduction of features such as immersion, interaction and collaboration. While traditional 3D modelling and visualization systems such as 3D Studio MAX and form?Z offer increasingly convincing visual simulations, gaming engines are approaching the visual realism of such systems and are offering additional interactive features that are usually available only in more expensive immersive virtual reality systems. Additionally, the capability to have multiple individuals inhabit and navigate the space offers unique opportunities for collaboration as well as the investigation of human behaviour. Participants with internet access can be invited to access a shared virtual environment. Collaboration among users can be further enhanced by combining immersive navigation with peer-to-peer instant messaging and/or adding a voice channel. This paper analyzes these issues through research summary and the creation and user testing of a prototype based on a publicly available gaming engine. Through a series of assignments within an academic course, students in the school of architecture were asked to iteratively use and test this prototype for the collaborative exploration of designed environments. Students made their environments available for others to navigate in real-time and offer comments. A final design review was conducted in which critics were asked to enter the designed environment, explore it at will and interact with the student as well as others present in the same virtual space. This paper will illustrate some of the student projects and describe the immersive, interactive and collaborative features embedded in them, it will offer an analysis of the advantages and limitations of the applied prototype, and it will indicate the requirements for future work.

1. Introduction

David Hockney, in his book, “Secret Knowledge – Rediscovering the Lost Techniques of the Old Masters,” asserts that Renaissance artists began to depict their world with photographic accurately by using lenses and simple cameras to project their subjects on two-dimensional planes: *“Alberti’s story of Brunelleschi and the “discovery” or “invention” of perspective is well known…. It happened in Florence in 1420-30. Today, it is the window through which the world is seen, with television, film, and still cameras. The Chinese did not have a system like it. Indeed, it is said they rejected the idea of the vanishing point in the eleventh century, because it meant the viewer was not there, indeed, had no movement, therefore was not alive.”* (Hockney, page 286).

To reject the vanishing point is perhaps a rejection of stasis, passivity, or both. Contemporary culture, which includes those who grew up with movies and television, has been striving to interact with projected imagery in various ways. An animated children’s series of the 1950s, *Winky-Dink and You*, encouraged children to draw, with crayons, images on their television screens to which the show’s characters would appear to respond and interact. In 1971, when Nolan Bushnell designed *Computer Space*, acknowledged to be the first coin-operated arcade video game, interactive video and computer games became part of the world’s culture. The following year, Bushnell and Ted Dabney started Atari and released their first product – *Pong* – and the first generation of video gamers was created.

Video games have piqued the interest of a new generation weaned on electronic media, which includes budding architects and designers. In much the same way that we are engaged by motion pictures with their elaborate (albeit sometimes contrived) sets, evocative lighting, sound design, and simulated motion through space, video games are garnering mainstream attention (the video gaming industry enjoyed $10 billion in sales in 2002). Although movies are generally scripted and not interrogative, when seen in a theater, they can become an immersive experience. Modern video gaming provides a similar immersive experience, allowing those who use their imaginations to transport themselves to faraway places and unknown, never before seen worlds and environments. The video games differ from the movies, however, in that they are interactive and interrogative, allowing the participant a level of control over his or her presence in the simulated environment.

2. Background

Can video game technology be used directly and effectively in the architectural design studio? Since 1995 we sought to answer the question at the New Jersey School of Architecture by employing publicly available game engines as spatial design tools. Our first experimentation was with id Software's *Doom II* engine. Since then we have successively tested game engines created by id Software, including *Quake I, Quake II,* and, most recently, *Quake III*.

At the time, there was growing interest in using digital technology as a means of cross-germinating the design process. A 1996 paper presented at ACADIA ("Reconstructions, Remakes and Sequels: Architecture and Motion Pictures") discussed the integration of motion pictures as a suitable subject for study in an architectural design studio:

"Students increase their awareness of the significance of architectural detail on human activity, perception of space and scale, and impact of color…. Issues sometimes taken for granted become significant elements in the design.

"The study of motion pictures and the creation of animations acclimate students to the idea of understanding buildings and spaces serially. The expanding use of electronic media in the design process allows students and architects to design with time-dependent phenomena and animation. With computers, designers can more easily evaluate their own proposals in a manner that is consistent with the visual experience that people have come to expect from movies. Designing and presenting serially also gets students comfortable with the idea of sharing their ideas with others (clients, regulatory agencies, etc.) in an engaging manner that removes a layer of abstraction for non-architects. With judicious viewpoint placement, animation puts both the designer and viewer "in the action" or, in this instance, in the space." (Goldman 1996)

Students would later be allowed their choice of exposition for a subsequent digital design studio, fielding projects submitted in the form of animations, VRML worlds, and game environments. Research continued into the feasibility and effectiveness of these different methods. In specific regard to the observations of the use of gaming engines, the perceived impact, both positive and negative, that this approach had on the development and presentation of conceptual spatial ideas will be explained.

3. Early Research

In an effort to better understand the usefulness and limitations of gaming engines in Architecture, practical experimentation was undertaken. In all, four game engines were examined *(Doom II, Quake I, Quake II, and Quake III)* for their capacity to represent both existing spaces and conceptual spatial designs. Specific aspects of potential application to architectural modelling and presentation are outlined and summarized.

3.1 *DOOM II*

Doom II was released in 1994 by id Software as a first-person perspective shooter that offered four degrees of visual freedom (no ability to look up and down). In 1995, to test whether the game engine was compatible with the depiction of traditional space, the creation of a game environment was undertaken in which accessible sections of the interiors of two connected buildings then part of the New Jersey School of Architecture were modelled. The spaces were chosen specifically for easy access, which facilitated continuous measurement for accurate documentation. Close proximity also allowed an ongoing comparison of spatial qualities between the actual space and the space depicted in the game environment. Interested students were enlisted as volunteers for this documentational phase.

Once level-editing software was successfully installed (not an easy task), the modelling phase was surprisingly straightforward, but at the same time very limiting. *Doom II* is actually a two-dimensional engine that simulates 3D by vertically projecting 2D texture information. Photographed images of local textures were cropped, resized to a maximum 128x128 pixels, and resampled into the 8-bit *Doom II* palette. This procrustean manipulation obviously stressed the original image a great deal and necessitated several cycles of judicious doctoring and field testing before the mapped surfaces rendered satisfactorily.

Because the *Doom II* engine uses a simplified lighting model and it is not a polygon-based engine, the time required to compile editable maps to game files was very short (<5 minutes on a dual processor 90 Mhz Pentium). This was useful in that it facilitated the refinement process by offering almost immediate feedback. In comparison to still-image rendering time requirements of the day, the *Doom II* engine offered more experientially gratifying results, despite overall deficiencies in visual richness.

Figure 1. Screen Captures Illustrating *Doom II* Environment

Despite the formidable obstacles, the virtual place that was created with the *Doom II* engine captured some hitherto unreachable aspect of spatial representation. Many students who were invited to 'play' the level for extended periods reported fleeting moments of confusion and panic while walking the actual physical space, unsure if an experience in the virtual world could be expected in the physical world. This could perhaps be attributable to an interaction of space, function, and mnemonics.

3.2 *QUAKE I*

Quake I, backed by a true three-dimensional polygon-based game engine offering six degrees of visual freedom, was released in 1997 by id Software. At the time, *Quake I* created an abundance of excitement in the gaming community for its radical new graphics engine and its polygon based characters, but discernible shortcomings in its relevance to architectural depiction caused reservations about its potential usefulness. Experience with *Doom II* level editing provided evaluative sensitivity to the potential for gameplay versus the potential for Architecture. Screen resolution was poor, the palette was limited to 256 colors, and glaringly absent was a function to simulate swinging doors. This diminished the possibility of gleaning any value from large scale testing. Nevertheless, two intrepid student who had had involvement in the *Doom II* project decided, in 1997, to make use of the *Quake I* engine in exploratory study of architectural design and graphics. Fortunate to have had open-minded instructional guidance, the students produced projects that were innovative in their representational scope, if somewhat inconclusive in architectural value.

3.3 *QUAKE II*

In 1998 id Software released a sequel to *Quake I* with *Quake II*. The *Quake II* engine offered major improvements which included 3D graphic hardware support through the OpenGL API, better screen resolution, and more sophisticated actor behavior. Interest in testing the feasibility of this more mature game environment in an architecturally relevant project was abetted by access to the conceptual design process of a New York City residence. The designer of the project agreed to consult on the game environment development while concurrently creating still renderings of her design in *3D Studio 4* from Kinetix. Since the design had reached a developmental plateau before game modelling commenced, the work would involve only the transcribing of a conceptual design data and would not be used for design development until after presentation to the client.

The transcribing of the residence into a digital format would present formidable challenges for any 3D modelling package. Within the residence was a mezzanine creating a double-height space over the main living area. The centralizing design element was an open riser stair crafted of diamond-plate steel in a housed stringer with cable railings above. Most floors were exposed concrete. There was extensive use of glass on the front façade to give views of the city and grey-smoked glass panel partitions were used throughout the interior to express ambiguity of spatial confinement and to offer views of the stair from otherwise enclosed spaces. Among other challenging elements were a fifth-floor terrace and a kitchen ceiling expressed in sheet copper and configured as triangular in plan and curved in section. Overall, the heavy use of transparency would ultimately manifest itself in the contrast between visual and physical accessibility with particular regard to circulatory paths and rich materiality. This and the urban siting, with its attendant sights and sounds, made the project a good fit for the perceived capabilities of the *Quake II* engine.

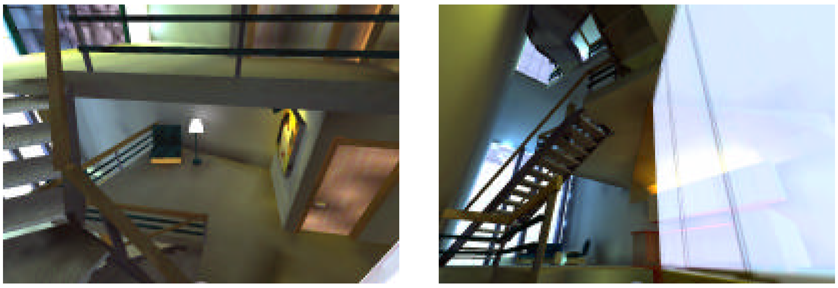

Figure 2. Screen Captures Illustrating *Quake II* Environment

To reinforce the idea that the building was sited in a busy urban environment, 'objective' sounds were integrated into the spatial experience. On the street level, the participant would hear a city soundtrack, replete with the sounds of crowd chatter, footsteps, passing automobiles, and the occasional honking horn. Upon entering the building, the sound would attenuate as the participant gained distance from the street. The street sounds could still be faintly heard if the participant moved close to the windows of the front façade, but would become less discernible as one moved to the upper floors. On the fifth floor terrace, the street sounds were barely audible, now replaced by the sound of light wind and occasional bird chirps.

The clients of the project, a real estate developer and a banker, were presented with the final results as a supplement to a traditional design proposal. The designer opened with a presentation of traditional plans, sections and elevations before moving to her rendered images, then demonstrated the game environment. Both clients demonstrated enthusiasm for the game presentation, stating that it had clarified many personally important issues, particularly in regard to material choices, spatial adjacencies, and visual accessibility. None of these issues were obscured in the traditional presentation; on the contrary, the designer had conveyed these ideas quite lucidly.

In conclusion, the game model had acted to substantiate the same information that was given via traditional methods, which included both orthographic line drawings and detailed high-resolution renderings. It is not known how the clients would have reacted to the game presentation alone. Although the scope of these findings is limited, it is probably safe to conclude that most laypeople will find value in interactive virtual presentations because of the diminished abstraction and the experiential nature of the depiction. Feasibility, however, is a yet unresolved question which must be subject to cost/value analysis.

The documentation of the Manhattan dwelling was extremely useful with regards to the clear, accessible representation of a complex conceptual design solution. Complemented by traditional tools, the game walk-through added an experiential dimension to the presentation and gave the clients valued confidence in the elapsed process, the current results, and the potential of continued design development.

Another documented experience with the *Quake II* engine is offered by Richens and Trinder, who used it advantageously in the design development of the new Computer Laboratory at the University of Cambridge.

4. Coursework

An elective course using gaming engines was developed and first offered at the New Jersey School of Architecture in spring 2002, when the gaming engines and ancillary editing tools were judged to have reached an acceptable level of graphics capability and technical maturity. The purpose of the course was to introduce design students to the power of the game engines within an architectural context. While the structure of the course was based on the digital design studio paradigm, the additional capabilities of the game engine were used to exploit the potential for participant immersion, spatial interaction, and multi-user design collaboration.

The graphics engine chosen for use in the course was a version of the *Quake I* engine heavily modified by Valve Software for use in the game *Half-Life*. The original engine was modified to remove irrelevant gaming-specific features. Through a series of assignments within an academic course, students in the school of architecture were asked to iteratively use and test this prototype for the collaborative exploration of a designed environment. Starting with theoretical readings in virtual reality, the students were asked to design and create spatial environments using the 3D graphical editor *QuArK* (a freeware game level editor not to be confused with *QuarkXPress*). Students made their environments available for others to navigate in real-time and offer comments. Design reviews were conducted in which critics were asked to enter the designed environments, explore at will and interact with the student as well as others present in the same virtual spaces.

Three major projects were required to complete the course. The first, an art gallery design proposal, accustomed the students to the interface and forced them to concentrate on circulation, lighting, and custom texture libraries. In the second project, students used the scripting functions of the game application to explode a construction detail within a virtual space for abstract analysis. This also required careful consideration of how an exploding detail event should be announced to, and triggered by, those navigating a virtual space. The final project was to express the cumulative knowledge of the semester in a programmed design challenge, the relocation and redesign of the Great Falls Cultural Center in Paterson, New Jersey.

Figure 3. Screen Capture Illustrating Advanced Lighting and Texture Mapping

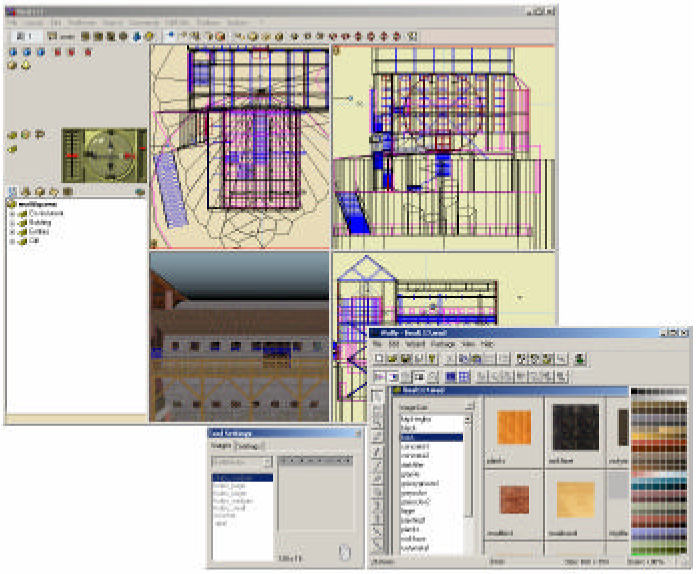

Figure 4. Screen Shot of the 3D World and Material Editors

Figure 5. Screen Capture Illustrating Other Avatars.

5. Observations

The following is a summary of current gaming technology features, observed during research outlined by the mentioned projects. They are intended to be specific to potential usefulness in architectural applications. Listings have been broadly categorized in terms of perceived advantages and limitations, despite the understanding that a polar distinction is inappropriate in many cases.

5.1 ADVANTAGES

5.1.1 Fully Interrogative

Like the well known animated architectural walk-through, the game interface represents space from the visual vantage point of one moving through an environment on foot. Unlike most animated walk-throughs, however, the direction, the speed, and the sequence of movement is not forcefully prescribed or scripted. This effectively eliminates the passive nature of the animated walk-through and allows participants the complete and thorough interrogation of the rendered spaces.

Creating virtual spaces that are fully interrogative allows, for example, the discovery and possible subsequent enhancement of underutilized parts of buildings. This has potential usefulness in the design of museums, shopping plazas, and other public spaces. By observing the directional tendencies of participants, as well as their propensity to linger or aggregate in particular spaces, architects can tailor designs changes responsively to the more efficient use of all spatial resources.

5.1.2 Tactile Solidity

Solids in game environments assert their solidity. This may seem elementary, but the impact that this feature has on the experience of a virtual space cannot be overstated. Through collision-detection, gaming engines allow for proper navigation through spaces bounded by solid elements such as walls as well as realistic navigation of staircases and ramps. Unlike traditional animations where the viewer can go through walls and fly through spaces, a gaming engine can be configured to disallow unrealistic navigation. Many game engines allow the spatial designer to account for friction and slippage of specific materials under foot to help reinforce the sense of an interactive presence. This accounting for the behavior of materials alludes to Tobin's exposition on the value of constraint-based three-dimensional modelling.

5.1.3 Integrated Audio

The nature of sound and its relationship to visual space is another important part of game environments. Sounds can be triggered by specific events in the virtual game world, complementing the visual stimuli. For example, the impact sound of the footsteps of the viewer or other characters corresponds to the material that is being treaded upon. Appropriate sound can issue forth from moving water or air. Doors can squeak or slam, mechanical systems can hum, crowds can roar– often with controllable levels of volume, reverberation, and attenuation. The widespread use of digital stereophonic sound, 360-degree panning, and dopler shifting in many games helps reinforce the nature of space by allowing noise sources to express their locations relative to a player.

Game environments also provide rich opportunities to test and use nonobjective sound. Nonobjective sounds may be used alone or as a supplement to reality-based, or objective sounds. They can be used as audile enhancements to spatial experiences in attempts to create and nurture specific emotional dispositions in participants. While the technique is rarely used in architecture (Helmut Jahn's United Airlines Terminal at O'Hare Airport is a notable exception), it is used heavily in the film industry. In similar ways it can be used in game environments to underscore, for example, grand entries, spatial contrasts, anticipatory movement, etc. How successfully non-objective sound works in virtual architectural depictions is largely dependent on the skill of the spatial 'director' and how well he or she is in tune with the social and physiological makeup of the audience. There are also serious ethical issues to consider as the use of nonobjective sound may be considered by some to be abjectly superfluous and emotionally underhanded.

5.1.4 Multiple Simultaneous Users

Most computer games are designed to be networkable, or multi-user. To the spatial designer, this means that designed game environments can be simultaneously experienced by multiple participants (the current limit is 64 connections on some higher-end games). This is, of course, a boon to the possibilities within the collaborative component of architectural design. Colleagues, clients, and consultants can all meet together within a space, virtually, regardless of whether the individuals are in the same room or across the globe. In fact, the immersive nature of the game interface seems to enrich the collective comprehension and appreciation of a space even when participants in a critical evaluation are shoulder to shoulder, insofar as each critic becomes an active inhabitant. For more distant collaborations, most games feature an intercommunications function that takes place within the game interface using internet chat-like typed dialogue or voice channels.

As a spatial designer invites other users into a virtual world during design development, their input is likely to affect the design process more forcefully than traditional collaborations. Spaces designed for public use, for example, can be experienced by other design professionals acting as surrogate users. Opinions about perceived successes and failures in the design can be clearly communicated because the game interface allows the articulation of the total spatial *experience*, rather than a perception of the cumulative effect of spatial elements. The tendency for some designers to embrace design solutions because of some personal or idiosyncratic ideal will likely be diminished within the facilitated consensual framework. In many ways this reinforces the paradigm of the studio peer critique; nonetheless the potential impact on individual creativity should be duly considered.

5.1.5 Inclusion of Avatars

A functionally and philosophically significant feature experienced while engaging in multi-user game environments is the presence of moving human-like characters. Considering that most architecture is designed for human use, representing spaces without the human presence for which they were intended may be something of a deception. In order to properly represent an architectural space meant for humans, designers must accept that humans are design entities that impact space as powerfully as walls and columns.

Understandably, humans are not walls or columns– they sit, they stand, they move from place to place, they change their clothing, they interact, and they express free will. Perhaps the very complexity of this 'design element' accounts for its omission from most architectural depictions.

Networked implementations allowing multi-participant interactions provide an enriched simulation of the human/spatial dynamic. Multiplayer entities in games are dynamic, purposed characters that can be very much the avatar of their embodied user. Participants can choose how their virtual character appears to other players by choosing from libraries or by creating custom models; this can help afford immediate visual recognition of participants in virtual space. To varying degrees game characters can gesture or otherwise interact with other participants.

5.1.6 Simulation of Movement

Game environments are predicated on the fact that things move. Whether it is the movement of ourselves through space or the movement of other characters, the dynamic relationship of occupants to spatial boundaries helps us to understand the ergonomic characteristics of a space. Movement also introduces a valuable temporal quality to spatial depictions, demonstrating the time it would take to move across a single space or among multiple spaces in particular regard to obstacles to free movement, line-of-sight versus available path of movement, and separation of visual and tactile accessibility. This feature can simulate wait times for elevators, predict delivery times for goods, and test effectiveness of locations for emergency means of egress. The movement of inanimate object through space also helps to gauge the changing characteristic of a space, e.g., a closed door containing space versus an opened door admitting space.

5.1.7 Simulation of Site

Since game environments are interrogative, bitmapped views of the surrounding site must be dynamically adaptable to the viewer's constantly changing position. To address this, environments modelled for games with views of the surrounding world use panoramic texture-mapping to simulate distant views. This technique is somewhat difficult to accomplish without proper photographic equipment and obviously does not allow participants to interact with the objects pictured on the panorama bitmaps.

5.1.8 Interaction with Objects

The competition to enrich gameplay has led to some innovative strides in the gaming industry with regard to player interaction with inanimate objects set in the virtual world. In early games, most inanimate objects in space did not respond to user interaction. Because most inanimate scene objects (walls, furniture, appliances) were part of a precomputed visible set of polygons in the binary space partition data tree, performance goals dictated that they remain static. Eventually, doors and windows began to open and shut, lights responded to switches, and elevators could be operated. Each successive version of these games brings some new level of interactivity with scene objects. At this writing, there are movable objects (e.g., furnishings), breakable objects (e.g., glass panes), and operable objects (e.g., video monitors, soda machines). While there are clearly shortcomings in the physical behavior and visual quality of affected objects, these will only improve with time. What may be potentially more useful to spatial designers is Woodbury's idea of 'designerly virtual reality' in regard to inanimate objects. In such a world, even 'non-movable' entities would be modifiable during the spatial experience. For example, walls could be moved or reconfigured, ceiling heights could be adjusted, openings could be shifted or resized, etc.

5.2 LIMITATIONS

5.2.1 Comprehensiveness

Giving outsiders an interrogative 'run of the place' is essentially relegating control over what is viewed and how it is viewed, an important aspect of traditional architectural presentation. As such, neglect and omission become glaringly obvious. 'Minor' spaces and details may receive as much scrutiny as major ones. As abstraction diminishes so will the benefits of its economy. Details will invite more details.

Comprehensiveness can of course be considered an advantage. Differing approaches to design development will find differing value in a representational paradigm that demands completeness. Nevertheless, this technology will likely force a reevaluation of the acceptable balance between abstraction and reality.

5.2.2 Complexity

Game environment creation software currently lacks turnkey functionality and professional polish. Setup can be frustrating and lines of support are informal at best. There are still very few industry standards or conventions regarding features and user interface. Geometric data exchange between game applications and industry-standard CAD and modelling software is spotty at best. Familiarity with traditional CAD and modelling software is often more a hindrance than a help.

However, developers of high-end modelling software are beginning to take notice of the needs of gaming content creators. Polygon-friendly data exchange formats are beginning to appear in high-end modelling software that allow the exchange of geometry with game level-editing tools. In fact, Discreet's *3DS Max* is heavily used to create game content, such as landscape elements, vehicles, and furniture. Character Studio has become an indispensable tool for designing avatars and the parameters of their behaviour.

5.2.3 Geometry Limitations

One of the most difficult aspects of working within the current state of game modelling is geometry limitations. Objects in any possible scene must be rendered in real time. Binary space partition data trees can be used to construct a predetermination of the visibility and draw-order of objects from any given viewpoint, but the dynamic depiction of the world must occur instantaneously. Most game environments necessarily avoid excessive geometric detail opting instead for textural detail, with mixed results.

On the positive side are the continuing advances in graphics hardware and software Application Programming Interfaces (APIs), i.e., OpenGL and DirectX. Furthermore, manufacturers of consumer level GPUs (graphics processing units) are responding to the gaming industry's appetite for rich, complex graphics with powerful and sophisticated hardware solutions that optimally handle off-loaded graphics operations that were previously accomplished through software and CPU, i.e., lighting, shading, shadows, mapping, fog, antialiasing, etc. Game designers are in turn leveraging this newfound computational potency to create more detailed and expressive virtual environments.

5.2.4 Lack of Standardization

As with any fledging technology, there can be expected to be many similar but competing products. As the push to create better game engines ensues, the advances are certainly an overall benefit but the volatility of the industry is frustrating to those using game-editing software. While there is some level of compatibility of game geometry files among game engines, the finer points of the virtual depictions (textures, behaviors, sounds) do not translate very well among the various game content creation packages.

5.3 SUMMARY

While many of the features of gaming technology were designed for the needs of interactive entertainment rather than for the needs of architecture, there is clearly potential for usefulness within the profession. It should be noted that many of digital tools now widely used by architects were conceived for other disciplines (in fact, advertising literature for Discreet's *3D Studio Max* and Adobe *Photoshop* make very little mention of a usefulness to architects). Nevertheless, any tool that demonstrates utility should be examined. Wide adoption, if it occurs, it will most certainly be followed by the discovery and development of a more specific tool set.

6. Recommendations

- Spatial designers should explore the advances in gaming technology as a means of furthering their own goals. The tools have reached a level of maturity that allows their use in informal design development and, with the proper modifications, formal presentation. Rather than let this valuable graphic tool continue to fledge only within the gaming community, the spatial design profession should extract the architecturally relevant components of the technology to develop and nurture a specific tool set.
- Architects should seek to develop new abstractions for use in the virtual world that will supplement the information availed by increasingly accurate depictions of reality. Using the experience and knowledge gained through the use of traditional conventions, architects can complement the weaknesses of the emerging game systems by judiciously borrowing from established tools.
- Slavish attention to the details of reality should be pursued carefully. The cost of this in both computational resources and man-hours must be justified by project goal requirements. Rather, synergies with more traditional methods of depiction should be established and standardized.
- Educators should exploit the game engines both for the analytical and representational values as well for the apparent affinity for this informational interface displayed by a new generation of students.

7. Conclusion

The technological advances in computing during the last 15 years are precipitating a fundamental reevaluation of the tools that define Architecture as a profession. The maturation of graphic engines which use binary space partition tree data structures is clearly a watershed in the present digital graphics revolution. Like cinema before it, this technology will inexorably insert itself into public consciousness.

Much of the scholarly discourse on the nature of Architecture and Virtual Reality submitted over the past three decades opines that the technology needs further development before issuance of formal conclusions. This technology threshold has been recently breached from outside of the Architecture profession. The computer gaming industry has developed tools that allow architects access to mature and useful technology that applies directly and germanely to their spatial, pedagogical, and physiological sensibilities. The trajectory that these tools will take as they continue to advance into the realm of public acceptance should be directed by those who best understand the nature of space, both real and virtual.

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