International Scientific Journal
Architecture and Engineering
http://architecture.scientific-journal.com

The Emergence of Architectural Animation

What Architectural Animation Brought to the Fore and Pushed to the Background

Maha Zeini Al-Saati, David Botta, and Robert Woodbury
School of Interactive Arts and Technology
Simon Fraser University
BC, Canada
malsaati@sfu.ca, dbotta@sfu.ca, rw@sfu.ca

Abstract— **We present the emergence of architectural animation from the point of view of Marshall McLuhan's *media effects*—what is suppressed, enhanced, and revived, and what takes on different meaning.**

Keywords-Architectural animation, Marshall McLuhan, Tetrad of Media Effects.

I. Introduction

By the late 1980s, 3D computer graphics facilitated the emergence architectural animation. Soon, architectural CAD tools included modules for 3D modeling and rendering (using lights, colors, textures, and camera positions to make images). Animation tools could import standard architectural file formats. Prior animation techniques were ostensibly not applicable to architectural animation, and therefore the kinds of things that they are good at portraying were suppressed. Furthermore, 3D computer graphics reduced architects' reliance on some techniques, such as pen-and-paper perspectives. On the other hand, 3D animation supports the common interest of architects to convey the experience of architectural space. Similarly, the advantages of CAD support certain ways of thinking and teaching. But questions arise, like the cinematic portrayal of space is not in itself the experience of space, so would the ignored techniques and suppressed qualities help cinematic spatial experience to match the richness of real experience of architectural space? To help answer this question, we looked at the emergence of architectural animation from the perspective of Marshal McLuhan's media effects [1]. We looked at what is suppressed, enhanced, and revived, and what takes on different meaning.

II. The Tetrad of Media Effects

Most of the techniques of animation have remained current. But 3D computer graphics, in the context of portraying architecture, pushed other techniques to the background, and enhanced the ability to portray the experience of architectural space. Therefore, Marshall McLuhan's [1] figure/ground gestalt taxonomy for thinking about the effects of media (enhances, obsolesces, retrieves, reverses) seems pertinent to the study of architectural animation. To illustrate, 3D computer graphics in the context of architecture:

Enhancement: Speeds up the production of realistic images, and eases broadcast of the images. The digital modeling component of 3D computer graphics speeds up the design process by enabling drawings to be easily revised.

Obsolescence: Suppresses technical pen-and-paper perspectives, sequential sketches, architectural scale models, architectural endoscopy, stop-motion animation, and the humanized touch.

Retrieval: sculpting, chalk-boarding, connecting-the-dots, theatrical staging, and narrative space once again relevant.

Reversal: Difficult to learn 3D animation and CAD interfaces together with rapidly evolving technology in a technophile culture flips the designer from being one who is in control to one who is controlled by the technology. Convincing realism becomes a vehicle for telling lies [1].

The following fills out these points.

III. Enhances

A. *Thinking and Design Process*

In the 1980s, graphical user interfaces (GUI) began to supplant command line interfaces. The GUIs' structure tended to influence designers' thinking, and thereby limited the way they designed. Early architectural CAD software was limited to rigid forms, and embedded traditional templates such as columns, doors, windows, etc. These restraints produced rectangular rigid forms resembling modernist mass-housing projects of the 20th century. It was not until the late 1990s that several architectural firms switched to using 3D animation packages, such as Alias, that were originally designed for graphics, film and game industries. These packages allowed easy creation of fluid, smooth, complex forms. By 2000, the curvaceous 3D computer graphics forms popularized in games and film became evident in architecture. Buildings became free-flowing, smooth, complex, dynamic, and unpredictable. No longer were spaces predicated on specific functions or form, nor divided or separated by boundaries. These spaces all flowed into one, melting into one another with no distinct boundaries, reflecting the aesthetics of "total continuity" [2].

Architectural animations were often for presentation in the final stages of the design. However, research is still on-going about using it as a design tool in the early concept stages, such as to record the thinking process and design intent. Although CAD and animation enhances the way designers shape form, there is still a question on whether it can replace sketching in the early concept thinking process. In architectural education, sketching is considered a foundation skill that must be taught and mastered in the early stages [3]. Sketching remains an essential and popular practice in exploring or conveying ideas in the early design concept stages, due to its simplicity, immediacy, and ease. It is considered an extension of the designer's hand, a skill often associated with creativity and talent. Sketching is also cheap, requiring no more than paper and a pen [4]. Unlike CAD software, the abstract nature of sketching does not require thinking about details, or constraining thoughts to the laws of physics or the variables of the 3D space [5]. Some have also argued that the introduction of computers has turned design into a systematic and repetitive task [6], flipping it from a natural process to a purely sequential mechanical practice [7].

B. Variable Form

Computers represent visual, temporal, spatial, interactive, and structural phenomena as a set of variables with changing values. Each object has a long list of variables such as geometric dimensions, position, orientation, color, reflectivity, transparency and other properties with values that can be changed and animated in the scene. Manovich calls this the variable form, because each object continually changes with continuous visual rewriting, erasing, and gradual superimposition [2]. CAD software has made it possible to produce 3D models and animations faster than traditional methods. It enabled easy editing, modifying, saving, storing, and retrieving of information. Unlike traditional architectural practice, which tended to be linear, computerized animations allow the designer to easily backtrack throughout the whole design process [8]. CAD software is precise, enables work with real scale, work with separate components through switching off layers, and using distinguishing colors [6].

C. Communcating Information

Architectural animations are useful for communicating information about space. For instance, they can be used to simulate natural phenomena like the movement of natural light and wind shear [8]. Architectural animations are also useful for simulating the spatial experience [9]. If the correct cinematic effects are used, viewers can be engaged both psychologically and emotionally [10]. Architectural animation can also visualize the life cycle and design intentions of a project, starting from the initial concept design to the final construction stages. It can also be used to simulate the construction and assembly process, to provide a detailed coordination of the construction tasks [11]. Some time-based (4D) CAD tools will show an animation sequence of the construction process, while enabling the user to turn off certain layers, chose certain colors or transparency levels for certain elements to understand the process better [12].

D. Realism

There are various modes of visualization, including: photorealism, accuracy, abstraction, and expressiveness [13]. Early 3D computer graphics had a synthetic rubbery, plastic look, which made them unappealing for general audiences [3], though Toy Story (1995) demonstrates that great artists can utilize such limitations. Models for lighting and materials have since advanced to great sophistication. With the introduction of After Effects, and other cinematic effects software, in 1993, filmmaking went beyond spectacular effects such as simulated fire, and included subtle, *invisible* effects that do not call attention to themselves, such as substituting an actor's face. The aim here was to achieve photorealism, even if it meant mimicking properties of original physical media, such as the lens flare, or the depth-of-field in traditional cameras. These effects were superimposed, amplified and made programmable in 3D software [2]. Since then, a major trend in computerized animation was toward achieving realism through the use of lighting, shadows, textures, and other material properties. There have been ethical questions of non-photographical art (such as painting, animation) imitating photorealistic qualities of mediums (such as photography and film), as some have considered this imitation of reality fraudulent. On the other hand, expressionism has been adopted by several mediums. In cinema, film noir films examples such as The Cabinet of Dr Caligari (1919) are known for their expressionist, exaggerated sets, lights and sounds, marking a clear departure from reality. This style evokes certain emotions and responses from the audience. However, the question of realism vs. expressionism in computerized animation remains related to the function of animation. For example, if the animation is for educational/scientific purposes, it will make sense to visualize its proportions realistically, although distinct unrealistic colors may be used for clarification. Animations for entertainment may choose the naturalistic or expressive approach, depending on the desired style and purpose of the animation [13]. It must be taken into consideration that rendering may also affect the viewers' judgments. For example, a seductive impression of a design might not match reality, and thereby lead to disappointment [6]. Conversely, a building design can be caricaturized or *cartoonized* to exaggerate particular features and leave a memorable impression [14].

IV. OBSOLESCES

A. Traditional Animation

Animation is the art of displaying a sequence of images (frames) at a rapid speed to create the illusion of movement [10]. The practice of animation can be traced as early as the 1800's [15]. It has been mostly associated with the entertainment industry, and its early forms include silhouette cut-out puppetry, stop-motion photography, and the most popular form of the 20th century: cel-animations [16]. On the other hand, the use of animation in architectural practice is relatively new, having been introduced to the architectural practice with the advancement of 3D CAD animation software in the 1990s [17]. There are no records of traditional cel-animations being used in mainstream architectural practice prior to the introduction of 3D computerized animation. Although computerized architectural animations are sometimes used to explain technical information, they are usually used to depict the experience of space. 3D animation draws many concepts from 2D animation; therefore, it will be useful to gain an understanding of traditional cel-animation. In fact, elaborate cel-animations in the entertainment industry, such as Disney's cartoons, have given great importance to the creation of spaces in their backgrounds [18]. In cel-animation, foreground figures are painted on transparent celluloid sheets (called cels), and layered over an opaque background. Often different artists would handle different characters on respective layers, entailing that the production be carefully planned, including that inking and coloring in the outlines could be postponed and delegated to colorists [18].

Key-frames: These are the major frames which depict the character at its peak initial and final positions between movements. These are drawn by the senior artist.

In-betweening: In this time-consuming process, transitional in-between frames are drawn, to give the appearance that the initial image (key-frame) is smoothly transformed into the final image (key-frame). To achieve a smooth movement, a typical animation would usually display 24 frames per second for film, and 30 frames per second for NTSC video. Using less than 10-15 frames per second produces jerky character movements [10]. These in-between frames are drawn by assistant artists.

Pencil testing (line testing): Here pencil drawings are photocopied on transparent cels. These cels are then filmed in synch with the audio in order to test the quality of the animation. Mistakes are corrected, and details are added, to be tested again, until perfected.

Traditional inking: In this time-consuming process, the rough pencil outlines of the finalized drawings are cleaned up and inked on transparent cels.

Traditional painting (Opaquing): In this time-consuming process, the finalized cels are colored by hand. Special attention has to be paid for the grading of colors, as front cels usually appear darker than those in the back, due to the transparency of the cels.

Filming: in this final step, the background and foreground character layers are brought together and filmed. Sound is also added in this phase [16].

With the introduction of computer and digital scanner technology, many of the previous time-consuming processes in traditional animation have been changed. It is important to make a distinction between two categories of computer intervention in the traditional animation practice: computer-assisted 2D animations, and computer-generated 2D animations [16]. Computer-assisted animation is a process in which computers are used to perform time-consuming tasks of 2D animation, such as traditional inking and painting (opaquing) [16]. This step has been replaced by digital inking and painting. Instead of inking them on transparent cels, the cleaned up sketches are entered into the computer via a digitizing camera (nowadays replaced with a scanner). The grey edges are removed and the basic outlines are smoothed by means of *anti-aliasing*. Opaquing in the early days, as those seen in the Hanna Barbara cartoons, offered very limited colors. With digitized cels, computers eased the looping of repeat sequences, such as a man walking [16]. Computers increased the possibilities by enabling control over each layer (cel), to add effects such as transparency or blur [2].

Computer-generated 2D animations mathematically generate the in-between frames [16]. Early research by Computer Graphics Lab in the NY Institute of Technology produced a program called TWEEN, but it was not adopted for commercial use because it lacked the fluidity and smoothness of traditional sketches [19]. Throughout the 1980's, several 2D animation software packages, such as Aegis Animator ST, have offered some very basic tweening and morphing effects [20]. Morphing uses *vector* drawing, which is like connect-the-dots; dots are moved, added, or deleted, and the connecting lines are automatically redrawn. In 1991, Autodesk launched Animator Pro, a 2D cel-animation program that offered a smooth tweening function [21], which became popular throughout the 1990's [17]. *Macromedia Flash* introduced in 1996, enabled artists to keep libraries of reusable, replicable parts, including moving parts, with a focus on vector-based 2D drawing. Vector-based art is independent of size (is stretchable), and thereby light weight and handy for delivery over the internet [22].

B. Technical Pen-and-Paper Perspectives

Prior to the introduction of computerized animations, the architectural practice relied on static mediums to present design ideas, such as freehand sketches, technical 2D drawings of elevations and plans, 3D drawings such as perspective, isometric and axonometric drawings, and architectural scale models [6]. The most common technique of presentation was traditional perspective, which was produced in a lengthy-process involving a perspective grid and vanishing points. This process would later be radically changed with the introduction of Computer-Aided Design (CAD) into mainstream architectural practice [23]. The first 3D CAD graphical systems were developed by NASA for space research in the 1970s. Shortly after, the use of these CAD systems has extended to other disciplines such as the medical, manufacturing, educational, and structural engineering industries [3]. Disney's milestone film TRON (1982) was the first in the film industry to use 3D computer graphics, employing *WaveFront* animation software [3]. But in general, the use of CAD systems in the 1980s was still limited to major companies, due to the limitations of the technologies of that time, the expensive hardware, as well as the required programming and mathematical knowledge to produce graphics [20]. These barriers put CAD systems far from the reach of smaller public businesses [3], including architectural offices. Although personal computers, such as Apple and Atari, were rising, they were not yet equipped to handle 3D graphics [16]. One of the earliest personal CAD systems was the *NorthStar* Advantage PC, which had built-in graphics that enabled wireframe 3D modeling. The system was also able to calculate the angle of the sun, wind sheer and icing effects [16]. Another early CAD system was Paul Lutus' *Apple World* program. Lotus, a former NASA designer, developed a program with a graphical user interface (GUI), enabling users to select shapes using a joystick or a graphics tablet, without having to calculate coordinates. The system also offered the ability to change the view, featuring the beginnings of animation in personal computers [24].

By 1993, an invisible revolution occurred along with the rapid technological and cultural change. Personal computers became relatively inexpensive, came with faster processing speeds, increased memory, and were capable of running graphical software for design, animation, video editing, special effects, and vector-based illustration [2]. In 1993, Autodesk launched 3D Studio V.3, which had the ability to animate 3D models. Around the same period, Silicon Graphics Inc. developed Open Graphics Library, a standard specification for defining 2D and 3D graphics support, independent of computer language or platform. 3D graphics tools proliferated: Alias, *Lightwave 3D v.5*, Autodesk Walk-through 1.1, and 3D Studio MAX. In 1995, Disney's Toy Story (1995) was the first full-featured animated film to completely use 3D graphics [17]. 1996 brought predictions of CAD making the traditional architectural mediums obsolete [6]. By the end of 1999, 3D CAD software packages became standard tools in the architectural practice. Computer graphics and animation software that were originally designed to be used by professionals were now available for freelance graphic designers and small production and animation studios. Software manufacturers started making these different software packages compatible with one another, enabling designers to use different packages while working on the same project. This combined previously separate mediums such as 2D graphics, photography, animation, 3D computer animation, video, causing these multi-media to blend in, influence one another and form what Manovich calls hybrid media [2]. With the introduction of CAD into the mainstream architectural practice, designers switched from the manual grid paradigm to 3D modeling paradigm, to produce perspectives and animations. The new paradigm made designers produce perspectives by first modeling objects, specifying a camera position and viewpoint angle, and then taking a perspective shot from the desired angle. To produce computerized animations, the designer would have to specify the camera movement path, specify key changes in the camera angle and position, and then let the computer produce each frame, render it, and then stitch all the frames together in the finalized animation file.

The current animation pipeline follows three main phases: creative development, production, and post production.

- Creative development: sketch storyboards are scanned to the computer, and then mixed with the sound effects to produce story reels. This is a testing phase to discover the faults in the drawings and make changes. 3D models, sometimes made of clay, are also constructed to understand characters to portray them correctly
- The production phase. The art department animates the models. This step includes simulating the laws of physics, while exaggerating some movements for special effects. Later on, detailed work is done on colors, lighting, shadows, textures, reflections, transparency and camera movement. Render-farms (banks of computers, often subcontracted) are equipped with hardware that can handle compute-intensive rendering.
- In post-production, the rendered sequences are matched with pre-recorded sound, and finalized corrections and edits are performed [18].

C. Sequential sketches

Sketching is one of the fastest and most direct ways to convey ideas [6]. Since a single sketch or perspective alone cannot depict movement, a common traditional architectural practice that aimed to depict the experience of walking through space is sequential sketching. To depict movement through space, a series of sketches are produced, each sketch offering a different viewpoint of the space [25]. This process is similar to Gordon Cullen's concept of the serial vision which indicated that movement through space makes architectural spaces come alive. By concealing spatial elements behind visual barriers, then revealing them gradually as one moves through space, a sense of curiosity, anticipation and discovery is created, and the space is serially revealed. Each angle from which the building is viewed reveals a different impression and distinct feel [26]. To produce sequential sketches, angles and viewpoints must be well-selected to capture the essence of the space and its changing geometry. These free-hand sketches are not usually detailed, as their aim is to give an impression of the space, rather than an accurate technical representation [25]. The concept of revealing the spatial experience through movement is brought to life through computerized architectural animations.

D. Architectural physical models

Architectural scale models (also referred to as physical or tangible models), are miniature construction of space in a reduced scale and detailing [6]. These models are constructed from cardboard, wooden blocks, polystyrene, foam, foam boards or other materials in an expensive, time-consuming process [27]. Scale models are used for two main purposes: demonstration and investigation. When used for demonstration, a model communicates ideas, concept and information about the building. It can also be effective in presenting ideas to lay-audience, who may not understand architectural 2D drawings. When used for investigation, the scale model is used to conduct a study for testing a hypothesis or analyzing the conditions of the environment such as daylight illumination, thermal conduction, structural bending, acoustics, and airflow. This approach is done to obtain information, rather than present it. Scale models have several disadvantages, for instance, seeing all of the building at once, instead of selected portions or details, overwhelms the viewer. It is also harder to study the interior spatial relationships, due to its small scale, but it is better for understanding the big picture. 3D CAD has reduced the popularity of scale models. In CAD modeling, animations and walkthroughs are easier to produce and are extremely useful for understanding interior spaces. However, one thing that these computerized animations have not been able to replace is the tangible appeal of the scale model to the human senses, as computerized 3D animations are limited to the flat screen. In that sense, scale models are sometimes still used for exhibiting major projects for public audience [28]. Instead of becoming obsolete with the arrival of the new technology, scale modeling has been forced to reinvent itself with the emergence of 3D printing, a new technology that constructs prototypes from 3D CAD models, using layers of polymer [29].

E. Architectural Endescopy

Due to their small scale, scale models' interiors are hard to see or access. A periscope lens (also known as a snorkel lens or inverted periscope) has been used to view the interior spaces of the scale model. Since an actual camera body cannot fit to film these interior views, endoscope tubes were used. These tubes were connected to a photographic or video camera to capture sequential shots, or smooth fly-through of the interior space [30]. These photographs or videos are then played as an analog video on a large screen, offering a better spatial understanding of the space [27].

F. Stop-motion Photgraphy

Stop-motion photography is a technique in which a physical object is slightly moved or manipulated in front of a still camera, which takes one shot per move. The photographs are later compiled as frames, and then played at a speed that will simulate movement [16]. This technique has not been commonly used in the architectural practice, due to the time and effort it takes to construct scale models and then construct the stop-motion animation. However, there have been designers and hobbyists who have used this technique with cut-out models, such as in SYAA's paper movie [31] and Rob Carter's stop-motion film Metropolis [32]. This technique is mostly used to show how space is constructed externally, rather than how it is experienced internally. It is worth noting that the stop-motion technique has been used in the entertainment film industry to construct imaginary spaces with a certain aesthetic appeal. This technique is evident in most of Tim Burton's works such as *Vincent* (1982), *Beetlejuice* (1988), *The Nightmare Before Christmas* (1993), and *Corpse Bride* (2005) [33].

G. Human Touch

In the early days of design software, some attitudes towards the new technology were that it was just another tool [8]. Others raised questions about replacing the natural humanized/personalized art with the mechanical, computerized one. Traditional artists have considered the computer art as demeaning to true art, an insult to the human touch to art [16]. The natural immediacy of the hand on paper has been replaced by the mouse and keyboard, severing the human skill and dislocating it into the mechanical [34]. This relationship between the human and the computer was called the ghost in the machine [8]. The skilled hand had to adapt to the new way of designing, that which deals with computerized adjustments and symbolic manipulations that mathematically highly-perfected generated geometry [34]. The growing trend towards accuracy and photorealism grew with the increasingly sophisticated rendering, lighting, and texturing effect, which were finally able to mask the geometric computerized look to make the 3D animation more realistic [34]. Because of nostalgia for hand-sketched art, several animation tools emerged which offered sketchy rendering effects of computerized effects [35]. In the early 1990's, Disney was also famous for retaining its traditional 2D cel-animation look [3]. For example, Beauty and the Beast (1991) used computer-generated geometry to generate the ballroom scene, but rendered it so that it appears to look as if it was hand drawn and painted [36].

V. RETREIVES

A. Sculpting, chalk-boarding and connecting-the-dots

Creating a CAD 3D model can be likened to sculpting with clay, where pieces are added, then manipulated, all in a simulated 3D space that can be turned around and moved back and forth. At a more detailed level, the surfaces are usually represented by meshes and edges. These are vector-based, which is much like connect-the-dot puzzles [24], as explained previously on the subject of tweening. CAD enables a chalkboard-like approach to design, in that designs are easily modified and erased, which are qualities that drive chalkboard animation, as seen in Emile Cohl's *Phantasmagorie* (1908) [15]. The important points in a geometrical shape are specified before the shape can be generated. Later, the points can be moved around, and the shape changes.

B. Theatrical Stage: Narrative space

Virtual space in animation is like theatre [13]. It is a stage of continuous transformation and metamorphosis [2]. This imaginary world is a metaphor of the Euclidian space, although it may depart from the physical world's rules of physics. Sets and props can be situated anywhere within this world [18] to establish a feeling or presence, scale [6] and character, resembling a theatrical stage. Such virtual spaces revive a sense of 18th century American novels, which revolve around the exploration of space [37]. This revival reinforces the importance of space as a narrative element [3]. In the animation tradition, the emphasis on space is not a new concept. For instance, we find the technique of multi-layering used in the early cel-animated cartoons such as Snow White and the Seven Dwarfs (1937). To achieve depth in a scene that seems to dolly into a space, different elements of the 2D background are placed on various layers (depth perception via overlapping edges) and moved at different speeds to simulate deep perspective [16].

VI. REVERSES

A. Resource Overload: The controller becomes the controlled

Computer animations can push computers to their limitation in demand for memory, storage space, and capabilities. They also require much time, effort and expense to produce. The demand for faster, more powerful machines never ceases [3]. There are instances when hardware or software fails the designer by running out of memory, slowing down, or crashing. In these cases, the controller (the computer user) becomes the controlled. The software hence "trains" the user to overcome this problem by frequently saving backup files, using shortcuts to achieve tasks faster, finding methods to retrieve damaged files due to a computer crash, or sub-consciously developing a way of getting around a certain move that seems to cause the software to crash.

B. Knowledge and Training Curve

In the 1970's and 1980's, generating graphics and animations required knowledge of programming and mathematics. The spread of GUI animation software in the 1990s caused a separation between artist and tool. Most graphics designers and animators were no longer required to program, but became dependant on what capability the tools had to offer. Although this made animating easier and more accessible to non-programmers, it imposed limitations and constraints on the designer. The more sophisticated these software packages became, the more design capabilities they had to offer, but the more complex and harder to master they became [3]. To overcome this problem, animation tools like Maya enable users to get rid of all the options, leaving only the workspace and the necessary basic options. Maya also offers MEL, a scripting language that enables users to create and use even more functions [5]. When animation software started becoming more popular, there was a concern about competition from insincere practitioners who could be anyone with an animation software package [3]. However, a software package does not come with knowledge, talent, or creativity, which is needed to create meaningful results [2]. An animator who only knows how to use a tool is like a draftsman doing tedious labor work. Therefore, animators are required to perfect other forms of technical knowledge, such as traditional animation principles, the crafts of art, sketching, storytelling, character design, and communication [3].

C. Deceptive Visuals and the Suppression of the Other Senses

The visual is prevalent in popular culture today, increasingly privileging the sense of sight, and sometimes including the auditory sense, but often neglecting the rest of the senses: the sense of touch (tactile), smell (olfactory) and taste (gustatory). This bias is certainly stressed in architectural practice and education. Pallasmaa [38] argues that this visual bias is the reason why architectural concepts look good on paper drawings or the screen, but sometimes become disappointing in reality or "in-the-flesh". It is because our experience of the world, including architectural spaces, is multi-sensory. By engaging our five senses, we enhance our understanding of the space, and strengthen our sense of belonging and integration in this spatial experience [38]. 3D graphics and animations may also sugar-coat reality by producing computerized visuals that are too clean and sterile, and thus seem unrealistic. The use of cinematic techniques in the production of animations depends on highly constructed and sometimes unrealistic experiences to play on the emotions of the viewers. The cinematic language stresses visual storytelling, rather than the spoken word [39]. Virtual worlds can also abandon the laws of physics, making the physically impossible, possible [10]. The auditory sense is the second privileged sense in the creation of architectural animations, perhaps only added as an aesthetic feature, rather than an essential feature for experiencing space. New sound technologies can be used to enhance the auditory experience of architectural animations, such as *holophonics* [40], binaural recording, and 3D audio techniques. These sound technologies record and reproduce realistic spatial recordings that give the effect of real listening [41]. The use of such technologies in architectural animations may enhance the spatial experience, and reverse visual spaces into acoustic spaces [7].

D. Interactivity

There are also attempts to flip architectural animation into an interactive experience, rather than being a completely authored one. For instance, the authors of the Architectural Cinematographer system claim that the future of architectural animations is the interactive walk-through, which allow a free exploration of the model [42]. However, interactivity does not come without a price. The ability to control the walk-through robs it of the guided experience in order to achieve the desired effect [42]. Animation may also flip into artificially intelligent VR environments that support the design process while the designers are immersed in the spaces that they are creating [6] [43].

ACKNOWLEDGMENT

The author would like to thank Dammam University in Saudi Arabia for providing financial support to the first author's research.

REFERENCES

[1] M. McLuhan and E. McLuhan, Laws of media: The new science, Toronto: University of Toronto Press, 1988.

[2] L. Manovich, "Understanding Hybid Media", in Animated Painting. In San Diego, 2007.

[3] C. McCracken, "Issues in computer graphics education". In International Conference on Computer Graphics and Interactive Technique. ACM SIGGRAPH 2006 Educators program, 2006.

[4] A. T. Purcell and J. S. Gero, "Drawings and the design process: A review of protocol studies in design and other disciplines and related research in cognitive psychology", vol.19, issue. 4, 1999.

[5] A. Beesley, "Animation – A study and comparison of concepts and software issues". Bachelors in Communication Technology Thesis. Eastern Michigan University, 2004.

[6] J. Breen, "Learning from the (in) visible city". In eCAADe, 1996.

[7] M. McLuhan, & B. Powers, The global village : Transformations in world life and media in the 21st century, NY: Oxford University Press, 1989.

[8] R. Flanagan, "Fantasy, reality & animation, factors in design. in constructing the digital space". SIGRADI, 2000.

[9] J. Bermudez, "Designing architectural experiences: Using computers to construct temporal 3d narratives". In ACADIA. Seattle, WA, 1995, pp. 139-149.

[10] D. Dowhal, "A seven-dimensional approach to graphics". In ACM SIGDOC Asterisk Journal of Computer Documentation". ACM, vol.21, 1997, pp. 26-37.

[11] K. McKinney, J. Kim, M. Fischer, and C. Howard, "Interactive 4D CAD", vol. 135, issue. 11, 1996, pp.383-389.

[12] M. Clayton, R. Warden and T. Parker, "Virtual construction of architecture using 3D CAD and simulation". Automation in Construction, vol.11 , issue.2 , 2002, pp.227-235.

[13] P. Power, "Animated expressions: Expressive style in 3d computer graphic narrative animation," vol.4, issue.2, 2009, pp.107-129.

[14] G. Rice, E. Akleman, O. O. Ozener, and A. Naz, "Caricaturing buildings for effective visualization". In ECAADE, 2004.

[15] J. Mosley, "Animation history timeline," available at http://joshuamosley.com/UPenn/courses/Ani/AnimationHistory.html, 2010.

[16] D. Fox and M. Waite, "Computer animation primer," New York: McGraw-Hill, Inc, 1984.

[17] M. Bazdoc, “Marian Bozdoc's history of CAD,” available at http://mbinfo.mbdesign.net/CAD-History.htm, 2003.

[18] M. Henne, H. Hickel, E. Johnson, and S. Konishi, “The making of toy story”. In Proceedings of COMPCON ‘96. 41st IEEE International Computer Conference, 1996.

[19] D. Sturman, “The state of computer animation”. ACM SIGGRAPH Computer Graphics, vol. 32, issue.1, 1998, pp.57-61.

[20] J. Bell, “Drawing, animation and computer-aided design software”. Start, issue.1, 1986, p.28.

[21] H. Wang, “An approach to computer-aided styling”, vol.16, issue.1, 1999.

[22] R. Waldron, “The flash history: How it all began”. Flash Magazine, 2000.

[23] cadazz.com, “CAD software history CAD CAM computer aided design,” available at http://www.cadazz.com/cad-software-history.htm, 2004.

[24] R. De Marrais, “You ain't seen nothin' yet!”, Computer Graphics, 1982.

[25] B. Edwards, “Chapter 9: Sequential sketches”. In Understanding architecture through drawing. London ; New York: E & FN Spon, 1994, pp. 62-69.

[26] G. Cullen, The concise townscape, New York: Architectural Press, 1995.

[27] L. Alley, “Three-dimensional models: How effective?”, Journal of Architectural Education, vol. 15, issue.4, 1961, pp.19-24.

[28] absoluteastronomy.com, “Architectural model,” available at http://www.absoluteastronomy.com/topics/Architectural_model, 2010.

[29] M. T. Chang, “Rapid prototyping in architecture,” available at http://www.articlesbase.com/hardware-articles/rapid-prototyping-in-architecture-507693.html, 2008.

[30] S. Mealing, The art and science of computer animation, UK: Intellect Books School of Art and Design, 1992.

[31] SYAA, “SYAA's paper movie”, Romania: SC SOARE & YOKINA ARHITECTI ASOCIATI SRL (SYAA), available at: http://www.youtube.com/watch?v=xGbNAXtovFY, 2008.

[32] R. Carter, “Metropolis,” available at: http://vimeo.com/4360666, 2008.

[33] R. Chambers, “Tim Burton’s advancement of dark Gothic art”, unpublished thesis, 2007.

[34] S. Shannon, “The line and the pixel”. Computer Animations, vol. 30, issue.5, 1997, pp.434-447.

[35] A. Lake, C. Marshall, M. Harris, and M. Blackstein, “Stylized rendering techniques for scalable real-time 3D animation”. In Proceedings of the 1st international symposium on Non-photorealistic animation and rendering. SIGGRAPH: ACM Special Interest Group on Computer Graphics and Interactive Techniques. ACM, 2000, pp. 13-20.

[36] J. Tracy, “An inside look at the original”, In Digital Media FX Magazine, available at http://www.digitalmediafx.com/Beauty/Features/originalbeauty.html, 2001

[37] H. Jenkins, “Game design as narrative architecture,” in First Person: New Media as Story, Performance, and Game. Mass.: MIT Press, 2003.

[38] J. Pallasmaa, The eyes of the skin: Architecture and the senses, Wiley-Academy Press, 2005.

[39] J. Van Sijll, Cinematic storytelling: The 100 most powerful film conventions every filmmaker must know, Studio City, CA: Michael Wiese Productions, 2005.

[40] H. Zuccarelli, The world of holophonics, available at http://www.acousticintegrity.com/acousticintegrity/Holophonics.html, 2009.

[41] R. Gilkey and T. Anderson, Binaural and spatial hearing in real and virtual environments, Mahwah, N.J.: Lawrence Erlbaum Associates, 1997.

[42] C. Calderon, K. Nyman and N. Worley, “Architectural cinematographer (AC): Creating architectural experiences in 3D real-time environments”, vol.4, issue.4, 2006.

[43] D. Bouchlaghem, H. Shang, J. Whyte, and A. Ganah, “Visualisation in architecture, engineering and construction (AEC)”. In Automation in Construction 14. International Conference for Construction Information Technology, vol. 14, 2004, pp. 185-295.