A New Communication Model for Architecture
Using Video and 3D Computer Animated Graphics

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ABSTRACT
The University of Arkansas School of Architecture has produced a half-hour television program describing Richard Meier's Athenaeum in New Harmony, Indiana. The program uses an analysis technique developed by Dr. Geoffrey Baker, RIBA. The treatment for the material is a combination of on-site video and computer generated 3D animated graphics. An instrument was developed to evaluate the video and its 3D graphics. Based on analysis of the test data several conclusions are apparent. Students believe the video to be very helpful in understanding this building. This video appears to be paced too quickly for understanding in one viewing. Repetitive viewings of the video are helpful in understanding the content. Some students are able to understand principles presented visually better than those presented verbally, but best learning happens when information is reinforced visually and verbally.

INTRODUCTION
For several years, the University of Arkansas School of Architecture has recognized the need for public television programming in the field of architecture and environmental design. It has produced a series of television programs and video tapes that describe important issues confronting society like energy efficient design or historic/cultural issues that help people understand who they are by knowing from whence they come. These programs have been used in architecture classrooms and have been broadcast nationally, regionally and locally. Through this work we have developed the skills necessary to produce network quality programming.

Our experience with communicating design issues has led us to our current project. We have developed a new communication model for describing architectural ideas and issues. This model (called cinematic treatment) is based on the analysis of the design and form of buildings and a description using computer generated graphic animation mixed with on-site video. For this project we are using the analytical technique developed by the British architect and analyst Geoffrey Baker but we are also working with Francis D. Ching on another project. Our first video using this new treatment uses an important building, the Athenaeum, designed by architect Richard Meier.

The first goal was to place a computer animation work-station in house
and to train a cadre of faculty and students to use it. This was accomplished using software/firmware from Cubicomp Corporation that is MS DOS based.

Second, we produced a half-hour video using the new communication model. The video is complete and the program is ready for distribution from our Center for Design Media and Environmental Research.

Finally, we have studied the effectiveness (using a quantitative measurement tool) of the use of video and computer animation for describing complicated design and spatial concepts.

BACKGROUND

Architectural design is a difficult subject to teach because the process of design is a complex mixture of intuitive decision making and critical judgement. It also challenges the way we look at our environment. We can describe buildings in a variety of ways - its particular historical and cultural context, its unique geographical context, its structural system, its meaning, the particular bias of the designer, and a whole variety of other ways.

Analysis has become an important teaching vehicle in our school. It is a significant thread of continuity throughout our program because we believe it has such a direct link with design itself. There are several approaches to analysis but we are currently using one developed by Geoffrey Baker, RIBA, from Brighton Polytechnic Institute, presently at Tulane University School of Architecture. In this method, the final product of the design process (the building) is dissected in order to reveal its design organization. A good analysis of a building will explain a building fully and cause the viewer to address all those issues which concerned the designer. In some respects, it is the reverse of design - a sort of "reverse engineering."

This analytical methodology seeks to discover those primary organizational factors which operate in a building, and in so doing to reveal the preoccupations of the designer. As I mentioned, this is done by a process of dissection which charts the existence of such factors as volumetric disposition (including the kind of geometrical system used), the circulation pattern (in many cases directly linked to the volumetric disposition), the location of key axes, both within the building and in the immediate proximity, and the structural system. The relevance to the general organization of the materials used, environmental considerations (sun control, prevention of heat loss, etc), and the arrangement of services may also be taken into account if they were important issues for the designer. These factors are analyzed with reference to the purpose which the building intends to serve, and to the kind of symbolic imagery which the building seeks to express. The analysis can also take account of cultural context, especially technological and economic factors.
An important feature of this analytical methodology is the way the building is considered in relation to the site. Important site forces, such as the presence of a river or other topographical factors, are charted and the building's axes are related to other axes in the vicinity. The analysis relates these site forces, (which include orientation, views and access) to those organizational forces identified within the building. Essentially, the analysis seeks to discover how the building is conceived in relation to its function and to its site. The task is to reveal, as far as possible, those intuitive processes which have guided the designer. As in literary or musical analysis, major themes are sought within the work then examined to discover whether or not they are carried through consistently. A systematic and ordered analysis of a building can explain a work of architecture more fully than a typical art historical critique.

As an educational process, we, at the University of Arkansas, have found this analytical method invaluable because it enables architectural design to be examined in an ordered and systematic manner. Unlike the design process itself, which is a complex and often confused intuitive act so that a designer will not always know exactly how he has reached a design decision, design analysis does enable a charting of the conclusion reached by a designer in so far as these are expressed in the final work. This study of the resultant building enables a clear understanding of the designer's own input in the built work. All the design decisions have been carried through to a point which expresses the architect's philosophy, in terms of site relationship, arrangement of the parts, materials used and so on.

So far, this analytical approach has been used only in print format and in illustrated slide lectures. My experience in teaching architecture is students are often surprised when visiting a building site they have studied beforehand. They often discover the actual size or situation is very different than they imagined. This revelation is especially true if students have studied traditional texts. Plans, sections, elevation, and axonometrics are conventionally the sources of information when a building is discussed, with words used as the main vehicle of communication. Again, our experience has convinced us that this approach to communication has deficiencies. Usually, wordy explanations leave the reader with too many images to conjure up. Descriptions make too many demands and often fail to discuss three-dimensional articulation altogether.

In lectures, slides of the buildings combined with a graphic analysis such as found in Dr. Baker's book Le Corbusier: Analysis of Form are used to describe the buildings. But this is really a crude version of what we believed could be achieved using video and computerized graphics. We believe video is better than slides because it can show a building in its setting more effectively. Video enables the viewer to move through buildings experiencing spaces and volumes. As John M. Culkin summarizes in his book Films Deliver, "Film gets through because it's an emotional and sensuous medium that interacts with
students...Film delivers experience and not just copybook maxims."

This is echoed by Philip Oltman of the Educational Testing Service, whose monograph, "Cognitive Assessment and the Media," was published in 1963 by the college Board. Oltman concludes: "Any given medium, be it print, radio, or television, is not simply an envelope in which to send a message; it is itself a major part of that message. Changing the medium does not leave the enclosed message unchanged...Like language, (media) are different windows on the world - each with its own optical properties. Each medium's peculiar refractions are due to the properties of its symbol system."

By the use of multi media and sharing from conditions more or less ubiquitous, you have established certain relationships which have admired my attention. This is architecture. In Graphs one seems unhindered.

The motto Schuam brings together some of the design principles that were emerging in architecture work. These principles formed the basis of his later work and in his computer he refers to them as ‘Graph Analytic’.

Print Analysis by Dr. Geoffrey Baker, RIBA

We believe video, with the addition of computerized animated graphics and electronic image processing, can expand the possibility for information content leading to deep understanding. The on-site video material substantiate the actual conditions and give the viewer a sense of completeness about the place, its ambiance, and its relational nature with other buildings and its site context. Computerized graphics, including 3D solid modeling, animation, and image processing, can be used to illustrate the analysis. Since the images are then capable of being electronically manipulated, they can illustrate things not otherwise capable of being shown. They can be metamorphosed one into another, they can be rotated and tilted to reveal their true form and the perspectival effects of parallax phenomenon. Axes can be inserted and additional graphic information can be layered as necessary for richer comprehension. Through animated synthetic graphics, the observer can actually move in and through the diagram. The combination of these two powerful techniques, on-site video and computer graphics can act synergistically, thereby altering dramatically the amount of information capable of being transferred to the student.
THE PROJECT

The use of Geoffrey Baker's analytical method to describe a building and this technique of using on-site video combined with computer generated graphics is the foundation of our current work - the development of a new communication model for describing architecture. This "treatment," as it is called in the motion picture business, seems, on the one hand, obvious, but the results are, we believe, uncommonly powerful.

The US Department of Education's Fund for the Improvement of Post Secondary Education (FIPSE) is interested in computers in higher education and so they funded our proposal to illustrate the effectiveness of this new communication model.

Although our preliminary submittal to FIPSE proposed to purchase the computer animation rather than generate it in house, it became obvious during the proposal writing stage that for about the same amount of money required to purchase the animation, we could purchase the in-house capability. This made infinitely more sense since it would guarantee life to the project beyond the demonstration phase and the original FIPSE grant. The technology of 3D computer animated graphics has progressed over the last few years to the point where it is reasonably easy to use and to afford. Only a few years ago, 3D animation was reserved for the research labs of major universities, corporations and giant television networks. It was awkward to use with clumsy data entry techniques and was very expensive. When we began, we investigated using MOVIE BU with our IBM mainframe only to realize the complications involved were untenable. Not only is modeling extremely complicated using batch entry format and not at all interactive, but the cost of mainframe operation at departmental rates was unaffordable, let alone attainable.

The expense of 3D animation has changed. Software for low-end platforms based on MS-DOS have excellent rendering capability and they are more affordable. Animation stations utilizing micro-computers such as the IBM-AT or the Compaq 386 actually compete head-to-head with systems based on mini-computers such as Silicon Graphics or Apollo computers. Virtually all of the software features of the mini based systems are resident or emulated on the micro based systems, albeit slower.

After investigation of several animation systems based on PC platforms, we committed to CUBICOMP in part because of their generous participation in the project. CUBICOMP is a very capable 3D animation station. We operated the system on an IBM-AT running at 3MHz. Our system includes an external 16 bit frame buffer (actually two complete frames) with a video board with analogue RGB video output. The most recent upgrade system offered by CUBICOMP is a 3 slot inboard system that contains two 24 bit frame buffers (one acting as image capture board), video board, and VTR animation controller. Analogue RGB is directed to a 19 inch high-res monitor with menu and text instructions output to the IBM monochrome monitor. We also have a Sony 13 inch
fine pitch monitor for NTSC display of images and for checking animation. Finally, animation is recorded frame-by-frame to a Sony BVUB500 after the analogue RGB is encoded to NTSC by an encoder. Complete systems like this are available turnkey from CUBICOMP and comparable manufacturers for 60-80 thousand dollars.

However, having operated a 3D animation station for more than a year reveals that the price of the system is deceiving. Training for artists and operators is expensive and time consuming. Complicated 3D models are not easily created even though software systems use interactive modeling techniques. Two faculty and two students received initial training from the manufacturer in Hayward, California. The two students are the principal operator/artists and they have both received advanced training from CUBICOMP in Dallas and Atlanta as well.

Most micro-based systems are slow, where animation is measured in seconds, not minutes. With our system eight seconds of animation is a long animation sequence. Rendering time varies depending on the model to be animated (the number of polygons it contains and the general complexity of the model) but our experience is that 3-4 minutes rendering time for each frame (there are 30 per second of animation) is actually short. We produced several important models for our project that required more than an hour to render each frame. This makes an animation sequence of any useful length virtually out of the question. Render accelerators are available. CUBICOMP markets one that increases rendering speed from 10-20 times over the IBM-AT 8MHz for just under $20,000.

The building we are using for the demonstration project is Richard Meier's Athenium. We were looking for a building that was complicated enough to deserve the kind of analysis we intended and also one that follows in the tradition of the Swiss early modernist Le Corbusier because of Geoffrey Baker's previous book Corbusier: Analysis of Form.
The Athenaeum, a tourist information building which is the frontispiece for the historic town of New Harmony, Indiana is such a building. Geoffrey Baker proceeded to analyze the building using his typical sketches and diagrams. As you can see from the illustrations, Professor Baker is partial to the axonometric and virtually all of the diagrams are illustrated in 3D. This would also help later in designing the illustrations for the video. The marginal notes he made formed the basis for the script narrative.

On-site video production was accomplished in one week in July, 1987. Here is as good a time as any to emphasize the team aspect of film making. Our field production team consisted of three videographers, one sound engineer, and three grips. For interior and exterior tracking shots, we used a rubber wheeled dolly extensively but did not lay track. We did rent a Steadicam camera stabilizing system for walking dolly shots. This equipment allows the videographer to walk with the camera without producing the normal but annoying bouncy or shaky results. It accomplishes this with a patented system of counterweights and springs so the camera "floats" as the operator walks.

Typical Storyboards

After the final script was completed, we recorded the narration track. Geoffrey Baker narrates the video and appears live in the video several times as well. After the narration was recorded, the storyboards for the animation could be produced.
Animation is so expensive in terms of time and effort, complete storyboarding is essential. As mentioned before, with animation time measured in seconds, the luxury of "doing a few minutes of animation to see how it looks so you can choose the right one" is completely out of the question. Like special effects in a production movie, every second of animation and effects is accounted for with extensive storyboarding. After the visual effects are drawn along with notes about colors, movement path, and timing, the computer models are built.

Remember, we are not talking about "designing" a building using a computer, we are only "illustrating" a video to describe a building already built using animation. Several things effected the modeling for our project.

CUBICOMP uses integer based math and therefore intersecting planes and co-planer polygons can confuse the hidden line removal algorithm and produce unpredictable results. This problem meant that the models had to be built to "look" right, but not necessarily to actually "be correct." For instance, a fundamental aspect of the analysis is the idea Meier used of intersecting a regular orthogonal grid with a slightly shifted axes. This is modeled with a plane slicing through a transparent box. On-screen, this is exactly what is looks like but in reality, the plane slices nothing. There is a plane with two transparent "boxes" on either side.

![Diagrammatic Wireframes](image)

One of the most time consuming aspects of rendering is hidden line removal. In order to help the computer deal with this process, except for extremely simple models, we would kill off all polygons that would never be seen on-screen. Again, this emphasizes the requirement for accurate story-boards.

The actual animation and image processing took place over a period of 10 months beginning fall 1987. Part of CUBICOMP's software package is a re-distributed version of AT&T's True Image Processing (TIPS) by Island Graphics. We used the image grab feature of this program extensively, digitizing one frame of on-site video then either animating diagrams over it or just painting a feature to emphasize or
draw attention. In fact, during the project, we came to realize that often, 2D animation can be just as powerful as full 3D and the cost of doing 2D image manipulation is significantly less than the cost of creating the 3D model.

Editing the final video was accomplished in a 3/4" editing suite operated by the University's Instructional Media Division. Luckily, the editor was, in fact, the principal videographer so he had good knowledge of the project.

The final version of the video lasts one half hour. It is not designed for public television and makes no apology for the immediate assumption that the viewer already has a working vocabulary of architectural concepts and issues.

EVALUATION PROCESS

We prepared a quantitative instrument to measure student learning of the design concepts discussed in the video. We took the original video tape with full motion and animation. We then prepared a duplicate version of this tape with still images lifted from the final edited version. It was identical except there was no motion and animation. We isolated one single variable, movement. We prepared a paper and pencil test to measure learning to the level of comprehension on Benjamin Bloom's taxonomy of educational objectives. The two instructional materials were used with four groups. They were all tested. Then statistical analysis was performed using the Statistical Analysis System (SAS) program. The results were somewhat predictable but also surprising.

The first group was a group of 50 architecture students. They screened the normal video and without discussion, answered the 18 content questions on the instrument.

The second group was another group of 19 architecture students who also had taken the first test. This group screened the video one week after the initial test, then retook the test.

The third group was 120+ students of mixed majors who watched the video program without any movement and then took the test.

The fourth group was 120+ students of mixed majors who watched the video program with movement and then took the test.

As expected, architecture students performed best on the instrument with an overall score of 74%. Next were engineering students with an overall score of 70%. Finally, business and arts and sciences students scored 63%. Since the video described complicated spatial ideas using a building, these observations are not surprising.

Hypothesis #1: Concerning pacing of the video: Students who screens the video with movement will understand the building better (and
therefore will perform better on the instrument) than students who screen the video without movement.

Both test groups 3 and 4 believed the video to be helpful in understanding the building, group 4 who watched the video with movement were more confident in the video's effectiveness (91% vs 80%). However, the actual level of learning in both test groups 3 and 4 is about the same (61% vs 59%). In fact, group 3 who watched the video as a series of still images fared slightly better than those who watched the moving video.

This confirms the criticism that the video is paced too fast. From the beginning, we were driven to produce a video which could be used in the classroom. My experience in using films and videos in teaching is that 30 minutes is ideal because it gives time to introduce the video and place it in the context of the course and then leaving some time at the end to answer questions and have a short discussion. One criticism of the video I have made myself and have received from peers is the video moves too quickly and the constant camera movement is distracting. Time is required in order to understand a complex image. I interpret this analysis to confirm this criticism. However, it may be that the students screening the moving video learned different aspects about the building than those students screening the still video - for instance, the feeling of the spaces or perhaps a more complete understanding of the movement sequence. As John Culkin mentioned before, films deliver experiences and not just didactic content (copybook maxims).

Hypothesis #2: Concerning architecture students and the way they gather information: Architects will perform better on questions whose answers are revealed visually in the video rather than verbally.

Three types of content questions were included in the instrument; questions whose answers were revealed visually, those whose answers were revealed verbally, and questions whose answers were reinforced by both the video and audio track. Not surprisingly, the architecture students did much better on those questions revealed visually (84%) rather than verbally (70%). They did no better on questions revealed in both the audio and video track (84%).

Hypothesis #3: Concerning non-architecture students and the way they gather information: Students who screen the video with movement will perform better on those questions presented visually than those questions presented verbally.

Both group 3 (those screening the still video) and group 4 (those screening the moving video) answered about the same on those questions presented visually and verbally. However, both groups did significantly better on those questions presented in both ways - visually and verbally. Below is a chart of the results in percentile scores.
<table>
<thead>
<tr>
<th>Method of Presentation</th>
<th>Architects</th>
<th>Still Group</th>
<th>Movement Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visually</td>
<td>84%</td>
<td>59%</td>
<td>44%</td>
</tr>
<tr>
<td>Verbally</td>
<td>70%</td>
<td>56%</td>
<td>47%</td>
</tr>
<tr>
<td>Both Ways</td>
<td>84%</td>
<td>71%</td>
<td>61%</td>
</tr>
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The significant finding is not between scores within the group but between the groups. It is interesting that the groups other than the architects did better on questions presented both visually and verbally. More importantly, group A (movement group) performed poorer overall. Notice, however, the relative percentile score is about constant.

Hypothesis #4: Concerning re-viewing the video: Students who screen the video a second time will understand the building better.

Group 2 screened the video once with group 1 and then reviewed the video one week later and re-took the test. No contact regarding the video was made during the interim.

It is apparent that the second viewing of the video is helpful. The overall percentile score increased from 70% to 74%. However, remember, there was no contact or discussion about the building in the interim. I believe more significant gains in learning can be made if the material is reviewed in seminar format after screening it in video format.

FINDINGS

Students who screen the video believe it to be very helpful to explaining the Athenaeum. However, we did not test this method of teaching (video media) against, say, print media so no direct comparison is available.

There is a benefit in repetitive screenings of the video.

There appears to be a problem with the pacing of this video in so far as its movement is able to increase learning.

Architecture students performed better on questions presented visually rather than verbally. Also significant, these students did not do better on information presented both visually and verbally.

For the non-architecture student, information presented only visually and only verbally was understood about equally but information presented both visually and verbally was understood significantly better.

Overall performance on the test instrument decreased with the addition of movement in this video.

CONCLUSIONS

This project has served its original purpose of developing a
communication model or treatment that describes architecture using an
analysis technique developed by Dr. Geoffrey Baker, RIBA, and
television video that combines on-site video with computer animated 3D
graphics. It has also served to lead us to develop evaluation
techniques for testing its effectiveness. Preliminary observations of
evaluation of this video will help us in refinement of future videos
so that teaching using this media is effective and efficient.

ATHENEUM Interiors