# Conceptualizing Complexity Using Interactive Digital Movies to Understand the Relationship between Structural and Construction Systems

LAURA CAMPBELL AND NILS GORE[1]
Mississippi State University

## WHY USE DIGITAL TECHNOLOGY TO BRING TOGETHER THE LESSONS OF TWO TECHNOLOGY COURSES?

In schools of architecture, the information taught in structures classes is often separated from the information taught in materials and methods classes. This might make sense if one looks at structural knowledge as merely an understanding of mathematical formulas, or a structural system as a complete component which doesn't necessarily relate to the rest of the building. It might make sense if one looks at construction as an assembly of parts to create a facade, or an enclosure system as merely a way to keep water out of a building. But this separation of information fails to engage students in understanding how buildings are made, and fails to appreciate the degrees of interdependence between building systems. A joint case-study project at our school, undertaken by students in both Structures and Assemblages classes, seeks to explore the relationship between "how a thing is made" and "how a thing looks."

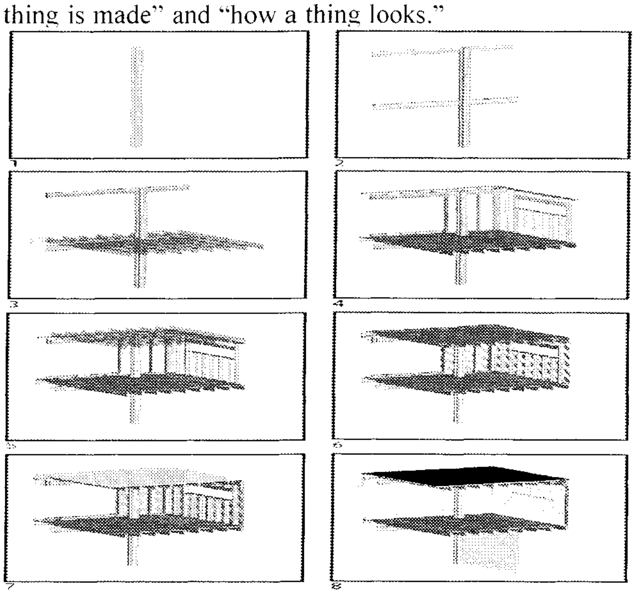


Fig. 1. Breuer. Wolfson House. These screen shots from a QTVR movie demonstrate the systematic construction sequence. The model can be rotated 360û to view the sequence.

This project uses a relatively well-known tool-interactive QuickTime(tm)VR (QTVR) movies-to study notable buildings in a new way.

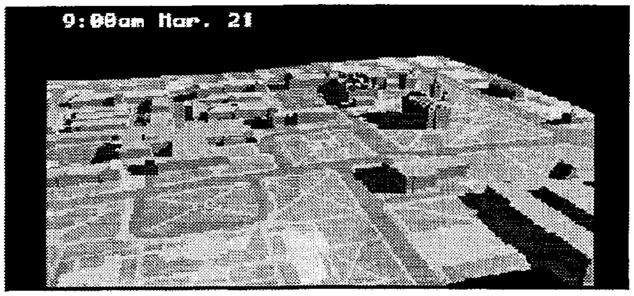
The QTVR movie can show more than one level of information-in this case, multiple views and construction over time. In a fundamental way, creating these models forces students to understand and conceptualize the building process as a logical construct of systems. But more importantly, it shows them how the construction of a building involves the interaction of these systems over time.

The computer becomes a powerful tool. By introducing the element of time, the digital movie allows students to understand a process-the "how a thing is made" part of the relationship between "how a thing is made" and "how a thing looks."

## WHY QTVR MOVIES?

Traditional drawings, models and movies show only one level of information: a perspective drawing gives one view of a building, a basswood model shows construction at a certain level of completeness, a movie runs in sequence.

The QuickTime(tm) VR object format takes the traditional one-dimensional movie format and creates a two-dimensional array of images.[3] The vertical and horizontal movements of the mouse control any two kinds of information. The most obvious kinds of information are different views of a model-horizontal mouse movement causing an object to spin horizontally and vertical mouse movement causing an object to spin vertically. Thus one can view a model from any point. But other kinds of information can be incorporated into the movies as well. The Digital Research and Imaging Lab (DRIL) at Mississippi State University has created movies which allow viewers to move around a university campus, changing the time of day to see the effects of shadows.

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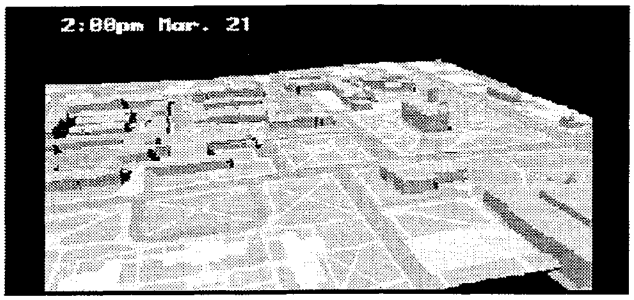


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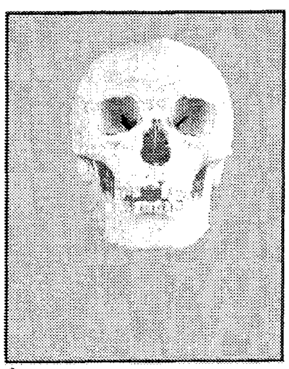
Fig. 2. Auburn University Campus. This QTVR movie allows the user to rotate around a vertical axis with horizontal mouse movement, and change the time of day with vertical movement. (Courtesy DRIL, Mississippi State University)

Walk-through models have been built which allow a user to look right and left as they move through a building. In work done for the Smithsonian Institution, DRIL created movies which allow a user to compare primate skulls.



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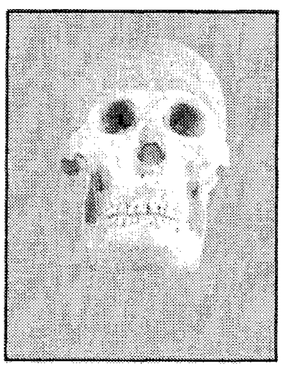

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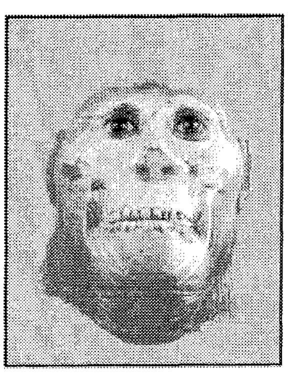

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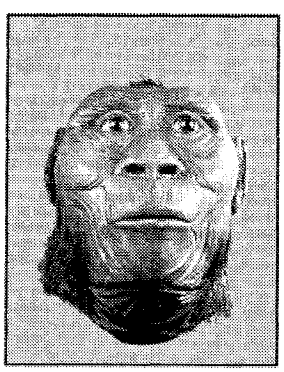

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Fig. 3. This QTVR movie allows the user to compare two skulls from different periods in primate evolution using the eye sockets as the common element, and then superimposes a representation of what the earlier primate may have looked like. Transparency greatly enhances the effect. (Courtesy DRIL, Mississippi State University)

The possibilities in this matrix or array of images is virtually limitless. Our project uses QTVR movies to show multiple views of a construction sequence occurring over time.

## BACKGROUND

It may be useful to provide some background to help the reader understand how this case study project developed over the past 4 years and how it may be of value in their own work. Consider the following quotation (an important theme in our criticism of the work):

> "What all of these works demonstrate in different ways is a mastery over the means of production, and an ability to break down the construction of a building into its constituent parts, and to use this articulation as a stratagem bestowing an appropriate character on the work in hand."[4]

Since 1996, the beginning Structures class and the Assemblages class at our school have collaborated on a project which looks at notable buildings to understand the degree to which their construction determines their character. A team project for third-year undergraduates (simultaneously enrolled in both courses) requires students to model a portion of a building.

The pedagogical intentions for this project are as follows:

- To understand the relationship between structure and the rest of the building's construction;
- To understand how the architect's intentions are implied through construction;
- To gain appreciation of historical construction techniques;
- To improve a student's model-building skills;
- To gain appreciation for the relative strengths/weaknesses of the different media;
- To gain an appreciation of how these technologies can be employed in one's own design process.

The idea of the case-study is simple: students study existing building designs by looking at photographs and drawings. They analyze how the structure and enclosure of a building work as a system, how these systems interact, and how they affect the appearance of the building. They then build models showing the interaction of these systems. Models were chosen because they emulate a construction process; they have a physical presence (wood) or allow one to get inside for a perspectival look around (digital). The case study allows the student to understand how a particular building might represent the construction of a particular place and time; how the structure and construction systems have withstood the test of time; and can compare construction from different historical epochs.

With few exceptions, all of the buildings analyzed were selected from Edward Ford's Details of Modern Architecture, (Volumes 1&2) (MIT Press, 1990 & 1998). In these books, Ford investigates the primary tenets of modern architecture. These include economy of material, structural expression, and standardization. Ford makes a very useful comparison of modernism's preference for monolithic construction, and the practical realities of layered (structure and skin) construction. His drawings give students detailed construction information which allows them to build accurate, thorough models.

In the first years we (1996/97), this project required students to craft 1/2"=1'-0" scale basswood models, along with a comparative formZ5 model.

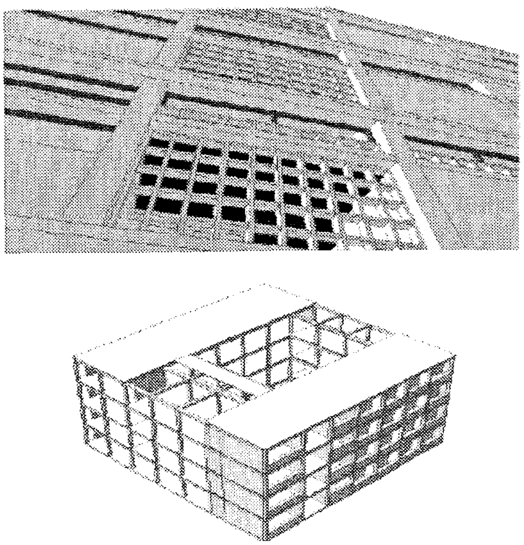

Fig. 4. Terragni, Casa Del Fascio. These were the sorts of forms models produced in the early years of the project. (1996)

The physical models consisted of a 16"x16"x16" sectional "cube" of a portion of the building, and were required to represent an exterior wall condition. Emphasis was placed on the representation of the ideas exemplified in the construction, as described in Frampton's quote above, and on craftsmanship and durability of the physical model.

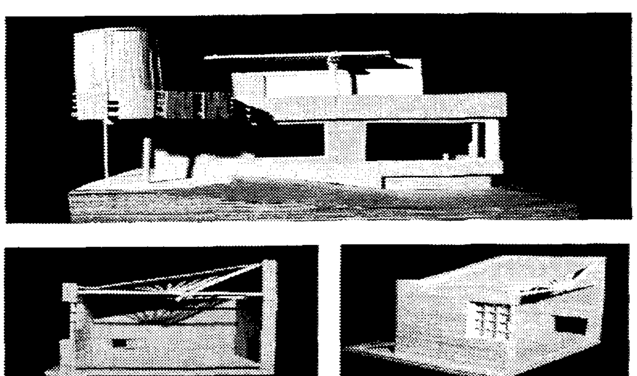

Fig. 5. Aalto, Villa Mairea; Saynatsalo Town Hall. These are the sorts of basswood models built in the early years of the project.

When making the digital model, students were asked to employ the strengths of the digital medium, using multiple views to show a sequence of construction.

## RECENT WORK

This fall, the project engaged students in the production of interactive digital movies. By using two levels of information, in this case rotation and time, students achieve a more sophisticated level of understanding. Though students had produced formZ models before, the use of QTVR for the final movie forced students to pay close attention to the process of constructing their models. When building their models, they took great care in how layers and objects were named and used and how they corresponded to actual construction systems.

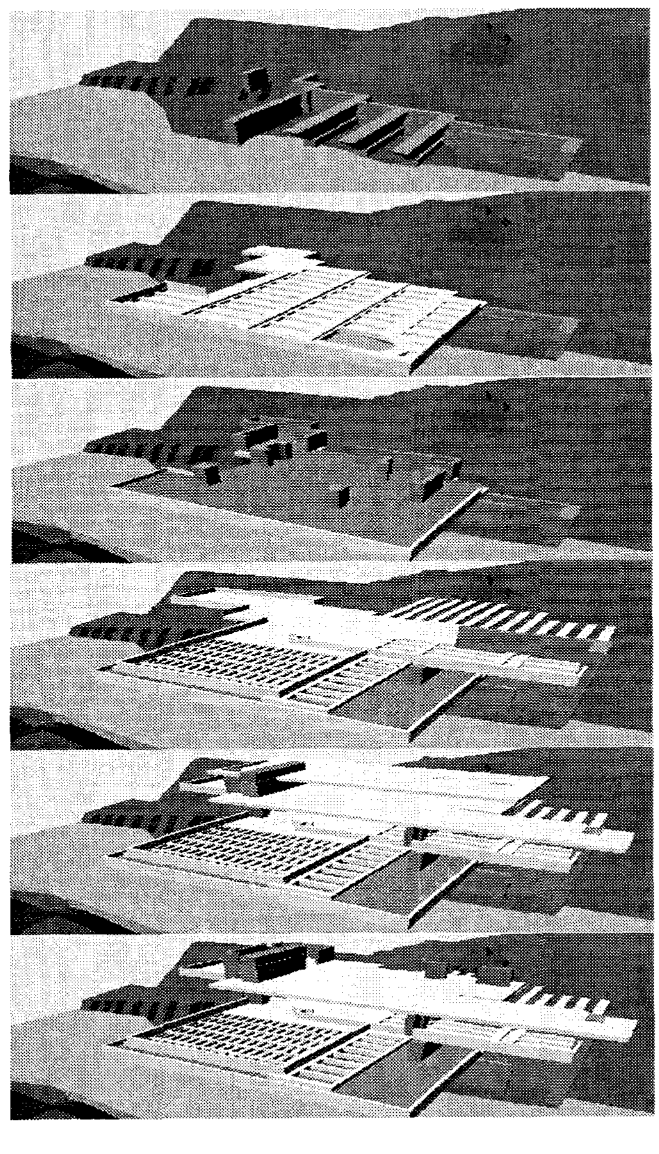

Fig. 6. Wright, Falling Water. This is a 1996 example of how the formZ model was used to simulate the construction process in a series of slides. QTVR introduces interactivity to the experience.

Except for the absence of gravity and the ability for twoto occupy one space digitally, making a computer model is virtually identical to making a physical model. In each case, one models pieces and places them into an assembly. The difference comes from the fact that the computer allows information to be embedded in model making. Specifically, the use of layers allows students to build a model which understands and elaborates a construction process. Students develop layering systems for the structural assembly (i.e. foundation, superstructure, substructures), the wall assembly (i.e. framing, sheathing, waterproofing, insulation, finishes) and the roof assembly (i.e. purlins, decking, insulation, roofing, flashing). They learn two things from using a systematic layering strategy. The first is an "Oh, I get it" understanding that buildings are built in a logical order, that there is a rationale to their making. The second is the ability to use layering information to turn a formZ model into an interactive digital model which allows a user to move a mouse to see a construction sequence occur over time.

To make the QTVR movie, students first build the basic model, carefully placing different parts of the construction on different layers. Then they run a series of formZ movies, each showing views of the building at different levels of construction. So Movie1 is made with all layers turned off except for, say, foundation steel. Each movie starts at a particular position and rotates about the vertical axis. Movie2 has the next layer turned on (foundation concrete). Movie3 has the foundation concrete and the next layer (steel columns). Using the transparency capabilities of the program enhances the illusion and understanding when things become buried inside of other materials (as in the case of reinforcing steel). The process of turning successive layers on and running the next movie continues until the student ends up with 15 to 20 movies, each of which shows the next successive construction system installed. They then use Apple's(tm) QTVR Authoring Studio to stitch the individual movies together into an interactive QTVR movie. (See figure 1).

This interactive movie project had multiple payoffs. Most important, many students came to understand the logic of a construction sequence, gaining an in-depth knowledge of process and system and tectonic of their particular building. In creating these movies, using rigorous layering systems, they gained the ability to conceptually take apart construction systems, understand them as components, made of pieces, which relate to a larger whole. In their research on the buildings they understand how this particular building conforms (or not) to "orthodox" construction systems. The ability to rotate around an assembly gives them a more sophisticated understanding of the assembly as a constructed thing (as opposed to the abstraction inherent in an orthographic representation). The QTVR movies, rather than becoming ends in themselves, become the means to enable and enhance learning. Of course, the finished artifacts are also useful teaching tools for future technology courses. Students access them on a web site and can use a mouse to see construction processes of a variety of buildings.

## WHAT NEXT?

Criticism should always follow each phase of a project as we look for ways to better achieve pedagogical intents. What went wrong? What could be improved?

First: the size of the models. To understand a structural system (but not necessarily an enclosure system), students generally need to model an entire building. At the same time, file size needs to be kept small enough to limit frustration-in this case movies were generally 200 x 300 pixels. But modeling a greater portion of the building and making small movies means a viewer sees less detail in the final model. This was unfortunate, because students modeled a great deal of detail, and detail clarifies the relationship of the different construction systems. It takes some experience to understand the relationship between file size, level of detail, compression algorithms and the finished product. Deployment of these models in the Web environment would be desirable for teaching purposes, but requires a compact file size.

In the next iteration of the project, we will ask students to make two interactive movies. The first will show views around the entire structural system of a building and will allow a viewer to zoom in on a detail. This allows students to better understand the complexities of a structural system (resistance to lateral loads, load transferring, structural details). The second will take a portion of the building and focus on showing the construction sequence in depth. This will give students a better understanding of how the structure and assembly of the building relate to each other and will better reveal the fine grain of their investigation.

Second: the amount of time given to the project. In the next iteration of this project, we will give students more up-front time to study and analyze their building and place it in a historic context. This would allow a more sophisticated "big-picture" understanding of how each building and its construction fit into the history of building, the practices and limits of available technologies, and the innovative capacities of the architect.

Finally, it is important to begin to think about how QTVR technology could be used in other studios to enhance learning. One could imagine an urban history project that would investigate how a city changes over time. Or a facade and interior study showing shutters and windows at different positions of open and closed. The movement of the sun and its relationship to porches and overhangs could be studied. In each case students use a tool which models and conceptualizes the complexities of our built world, giving them the ability to study and focus on the design issues they control.

## NOTES

[1]Grateful acknowledgement is made to Charles Calvo of the MSU Digital Research and Imaging Lab. who assisted us with the QTVR technology and permitted our students to use the lab.

[2]For more on QuickTime(tm) VR. see the Apple web-site at http://www.apple.com/quicktime/authoring/interactive.html

[3]This section on QTVR is indebted to Calvo. et.al." The Digital Darwins Project: 3-D Resources for Interactive Natural Science via the Internet." (Archives & Museum Informatics. 1997) p. 337-346.

[4]Kenneth Frampton. Studies in Tectonic Culture (MIT Press. 1995) p. 386.

[5]FormZ is a 3D modeling software package manufactured by auto•des•sys.