NOT JUST ANOTHER PRETTY FACE:
Images and Arguments in an Anthropology Web Site

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Abstract:

We are developing a web site with photorealistic animations and virtual reality walk throughs of architecture and artifacts at an archaeological site in El Salvador. The goal of the site is to support research and teaching about household anthropology in sixthcentury Meso-America. To counter the false sense of realism and truth these experiences often convey we have developed Image Arguments, a scheme for integrating with images the arguments and data that they are based on. We provide this contextual information using a server side database and client side Java applets, enabling viewers to examine the assumptions and the data behind the images.

1. Introduction

Computer generated imagery has provided useful and fascinating reconstructions ancient sites for archaeology and anthropology. However, the richness of information, the levels of discussion, the complexity of understanding and the ambiguity of decisions behind renderings are lost when images are viewed as isolated singular objects. In constructing an anthropology web site for teaching and learning [http://wallstreet.colorado.edu/cheren/cheren html] about village life at Ceren, El Salvador 1400 years ago, we are developing interactive computer-based imagery that: links images directly to the information used to generate them. Seeing images in this context, viewers can formulate informed opinions about a rendering, perhaps developing
their own arguments. A rendering is no longer viewed merely as a pretty picture; instead it serves as a visible argument.

1.1 MODELING CEREN

In Fall 1995 we were invited to construct computer models for the archaeological site of Ceren, a pre-Columbian village in El Salvador buried in ash over 1400 years ago (Sheets 1992). Discovered in 1978 by Payson D. Sheets and in excavation since, Ceren is a fascinating site. Due to the sudden nature of a volcanic eruption villagers fled from ancient Ceren leaving everything as it had been used in daily life. Volcanic ash deposited on Ceren has prevented the decay of almost all objects. Thus Ceren offers exciting potential to modern anthropology by providing a glimpse of everyday Meso-American life.

Computer modeling offers an interesting view of the site and environment as it once appeared. Ceren's impeccable preservation and the large number of household artifacts found there promised rich, colorful and visually informative computer images. The project was especially interesting because it brought together students and faculty members with diverse skills and backgrounds: undergraduate architecture students versed in computer graphics and three dimensional modeling, and anthropology students studying household living patterns at the village of Ceren. Ground-penetrating radar suggests that Ceren had twenty-five household groups (Conyers 1995). We began production of computer models for one of the household clusters in excavation by Payson Sheets and his team.

The richness of Ceren, the vast quantity of information available and the abundance of artifacts makes Ceren a difficult site to understand without graphical representation. Computer models created for Ceren provided new views of the site and artifacts. Except for a few artist's sketches, the images we produced were the first real visualization anthropologists had of the site in its built form, the way it might have existed. Research at Ceren had previously consisted of analyzing numbers, charts and simple twodimensional sketches and the computer renderings led to several new observations that were not apparent in the raw numerical data (Lewin and Gross 1996).

Our original goal was to graphically describe the site, creating full three dimensional computer models and renderings for all excavated households. Whether the computer renderings would go beyond the function of display was initially unclear. We believed computer images of Ceren as it looked 1400 years ago would be informative and we did not doubt that computer modeling would provide a highly flexible and effective way to construct images, capable of displaying multiple views, variation in lighting effects, materiality and environmental effects. We did not, however, understand the complexity of creating highly accurate architectural computer images from the archaeology site data, nor did we reckon on the potential for the images we made to evoke powerful viewer response and insight into village life at Ceren 1400 years ago.
1.2 THE ILLUSION OF REALITY

Computer renderings carry an illusion of reality. Miller's article "the Good the Bad, and the Down Right Misleading: Archaeological Adoption of Computer Visualization" (Miller and Richards 1994), and Kiernan's "Lies, Damned Lies and Slick Graphics" (Kiernan 1994) both emphasize that the apparent realism of computer generated images implies a degree of certainty that is not necessarily true. A photorealistic rendering evokes awe and wonder and can seduce the viewer to believe an image without question. While realistic computer imagery can be used to effectively display an architectural model of a no-longer-existing building, images also foster the illusion that the building once existed as it has been displayed. For example, models of Palladio's villas as they were originally designed suggest a reality that in some instances never existed (Mitchell 1992, p. 170) [http://andrea.gsd.harvard.edu/workshop/].

Interestingly, the renderings we made of Ceren did not create the illusion of existence for researchers familiar with the site. Although they were delighted to obtain realistic looking visualizations of their field data (they previously had relied solely on artist's interpretations), they treated the images we made with a degree of skepticism questioning their interpretations of data. Each image we produced is the result of a multistep decision process. Anthropologists worked closely with the modelers, resolving inconsistencies and making hypotheses about physical form that could not be resolved directly from the site data. Because creating each computer image required close examination and interpretation of site data, the process of rendering often entailed lengthy argument.

As we made the images, debates began about their content. For example, in one structure (# 11) the placement of artifacts was unclear from the archaeological evidence. To make the model, an opinion had to be formed and decisions taken regarding where artifacts might have been located in the original household. Often, after seeing an image, a researcher would disagree with the artifact placement it showed and request a new image with different artifact placements. The computer generated imagery of Ceren is not fixed; rather we continually produce images to explore new ideas that arise as the anthropologists examine and question the existing views.

However, as Kiernan argues (Kiernan 1994), our computer images play a different role for 'outside' viewers who are unfamiliar with the Ceren site. Without access to the site data and not having participated in the debate behind the renderings, outside viewers tend to be misled and see images as final and unquestionable views. To overcome this implicit acceptance our approach makes available along with the rendering the information and process behind its generation. By allowing outside viewers to see the process engaged by the Ceren research team we extend the function of computer generated images beyond mere display, and enable them to play a more integrated role in the underlying intellectual argument.
We are using Apple's QuickTime Virtual Reality (VR), the programming language Java, and database server software called Tango with a back end File Maker Pro database to construct a web site structured around what we call 'Image Arguments'. An Image Argument allows a viewer to browse a rendering, triggering information displays that explain the components of the viewed structure and relevant issues, and to delve more deeply into the raw data and associated text about what the image represents. Thus an image is never viewed as a single isolated unit; rather, each image is seen in context of the information from which it was created.

The rest of the paper is organized as follows. We begin with an introduction to the use of computer images in archaeology. We then discuss false reliability in computer imagery and why this was not a problem for members of the Ceren research team. We introduce Image Arguments as a way to make visible to uninformed viewers the data and their interpretation that led to an image. We describe the methods and techniques we use to implement Image Arguments. Finally we conclude with a summary and discussion and outline the directions we are pursuing in the next phases of the project.

2. Computer Imagery in Archaeology

Computer graphics can be powerful and informative tools in archaeological research where physical models and artist's renderings have traditionally been the only visual aid available. The use of computer imagery in archaeology has grown increasingly popular as a way to display a site as it may have appeared in real life. Such imagery is the closest we can get to apprehending-through primary visual experience-structures that no longer exist. A number of recent projects have produced compelling views of various archaeological sites.

For example, a reconstruction of the temple precinct of the Roman town of Bath (UK) (Wallis et al. 1990) revealed information that could only be made apparent through such a visual experience. When the computer model was examined from several standpoints it became clear that views from one entrance of the precinct towards the temple were more impressive in contrast with views from the top of the steps of the temple towards the entrance (Reilly 1992). Such renderings provided the opportunity to see a site from the perspective of a user and make inferences that might not have been possible using other representations.

Other models such as the 1995 Lancaster University Archaeological Unit [http://www.lancs.ac.uk/users/archaeo/unjt/luau.html] reconstruction of Furness Abbey (deLooze and Wood 1990) and the 1989 model of Langcliffe Lime Kiln (Wood and Chapman 1992) provided a means to check reconstruction ideas, simulate structural systems and communicate results through images.
Brian Hayden and colleagues at Simon Fraser University constructed computer models of pithouse dwellings excavated at the Keatley Creek site in British Columbia, Canada, (Peterson et al. 1995). Their renderings show the distribution of found artifacts through real time interactive animation, and allow a user to view artifact placement with respect to surface slope and daylighting in three dimensions. This enabled them to "more readily identify potential relationships between artifact data distribution and the pithouse structure" (p. 54).

Other projects include experiments with visualization technology such as the medieval church of St. Giovanni in Sardinia (Nuero 1989), the Acropolis (Eiteljorg 1988) and reconstructions of the city of Messina prior to the 1908 earthquake (de Cola 1990).

Computer modeling is especially valuable for sites and structures that no longer exist and therefore cannot be seen. Computer modeling efforts in anthropology and archaeology are essentially an attempt to compile and present ideas about a once-built form; computer models are being built for many major archaeological sites. In short, modeling has become a popular and useful tool in archaeology and anthropology.

3. The Reliability of Computer Imagery

No doubt renderings can be useful, but there remains a question about their reliability. Unlike a hand drawn sketch, whose intrinsic graphic character reveals clearly that it is a subjective interpretation, computer images are treacherously seductive in their appearance of completion and correctness. Rendered images cannot display uncertainty, ambiguity and fuzziness, yet these characteristics are all prevalent in archaeology data (Miller and Richards 1994). Computer images suggest certainty, but in most cases they are at best theoretical interpretations of what may have been.

This danger of computer generated images is not limited to archaeology, but is problematic in other realms of computer visualization as well. Kiernan, (Kiernan 1994), noted that computer forecast air pollution images had an extraordinary influence over policy makers whereas dry tables of numbers and charts were relatively ignored. Commenting, Miller points out, "Worryingly, there is little, if any, quality control for computer graphics which are not subject to the same intense peer review as scientific papers" (Miller and Richards 1994). Seeing is believing: images tend to sway viewers more easily than numeric data or textual information.

The computer images we made of Ceren appear to display a complete and refined reality and they leave a viewer with the sensation of looking at photographs of the site as it once appeared. It is difficult to question the accuracy of these images. For example, looking at figures 1 and 2 an uninformed viewer is more likely to be awed than skeptical.
Although each figure represents a subjective view of Ceren, questions of ambiguity or the possibility of debate are not apparent.

*Figure 1.* Renderings of the insides of Structure 1 and 7. Vertical placements of elevated artifacts, although determinate in these images, are actually the result of inference and superposition.

*Figure 2.* The inside of Structure 12 as we modeled it. Information found in excavation indicates a large painted mural on one exposed wall. The graphic content of this mural had not been fully determined, so it was not included in our renderings.
In many instances, renderings (either static views taken from the model, or walk-through animations) are the only experience that outside viewers are provided of the computer model, hiding the complex process of making the model and evaluating the site data. The image creation process is never revealed. For example, an award winning animation of the baroque Frauenkirche of Dresden destroyed in World War II [http://www.ibm.com/sfasp/mason.html] (Collins et al. 1994) seems more designed to evoke awe and wonder than to inform a viewer about the building (Reilly 1993). Although the animation contains a great deal of information and does provide a view of how the structure once appeared, it blurs the line between animation for research and entertainment. Regrettably, the process of research and discovery experienced by researchers who produced the animation is largely lost in the final product.

A photorealistic image is based on a large amount of descriptive information about a site, and though this information is displayed visually in the final graphic presentation, it cannot be retrieved. Grant, in modeling the old city of Glasgow using his ISSUE program (Interactive Software System for the Urban Environment) (Grant 1993), describes the frustration of working with the computer model's inability to respond to queries. Although the models and renderings he made successfully display spatial forms, they were inherently unable to respond to simple questions about their underlying data. According to Grant, due to a basic lack in the model's intelligence "answers remained locked inside the data structure" (p 558).

In summary, computer images are a dangerous medium. They hide uncertainty and ambiguity. They argue implicitly for the information that created them by displaying and describing a point of view. Yet viewers cannot examine this hidden information and therefore cannot truly understand the context an image represents.

4. Images as arguments in modeling Ceren

Perhaps predictably, anthropologists who were involved in the modeling process were not fooled by the apparent reliability of the images. Members of the Ceren research team did not treat the images as unquestionable facts. Rather, the images acted as catalysts for research and argument. The production of computer graphics for Ceren was a highly developed process requiring a sequence of specific decisions. Each image portrayed, collected, discussed, and evaluated information from the Ceren dig site logs and archives. Often an image served as an argument in support of a researcher's hypothesis.

For example, renderings for Structure 6 suggested an argument for new findings at Ceren. The adobe walls for Structure 6 were being rebuilt at the time of eruption with only the structural wood posts left standing. In collecting information from the
archaeological evidence and participating in the production of the image (figure 3), anthropologists observed an interesting fact. Although the structure contained a diverse collection of artifacts, most were of a larger size than the artifacts found in many other structures. Why? Several views suggested a theory: Without the adobe walls it would have been easy for a passing person to reach smaller artifacts through spaces between the wood posts. Larger artifacts, however, that would not fit easily through the spaces would be more difficult to steal. Perhaps smaller artifacts had been removed from the structure for safe keeping. Although this inference might have been made directly from the excavation data, in fact the renderings produced for Structure 6 acted as a catalyst for this discussion. The images became-in a sense-arguments for this idea.

Figure 3. Interior renderings of Structure 6 showing the exposed posts and artifact distribution suggested a theory explaining why this structure contained mostly larger artifacts.

A second example involves the placement of artifacts in Structure II. Figure 4 shows a plan drawing of Structure II and relevant excavation information. Descriptions of a higher shelf were available in published articles about the structure (Sheets and McKee
1989) but the shelf had never before been drawn. Due to the lack of data its placement in the original dwelling was unclear. We made renderings for Structure 11 that display an elevated shelf (see figure 5). These renderings were produced collaboratively with (then Ph.D. student) Scott Simmons. Simmons had to study the site data to infer a placement for the shelf (Simmons 1996). Thus the rendering reflects Scott Simmons's opinions about the placement of artifacts in Structure 11, and it is possible, even likely, that another expert could come to a different conclusion.

Figure 4. Plan sketch of Structure 11 showing artifact distribution.

Figure 5. The height of the shelf in Structure 11 is based on the informed conjecture of Scott Simmons.
Renderings were often debated, sometimes provoking changes in the model and requiring the production of new renderings. Often an image did not satisfy the anthropologists' perceptions of the site and led to changes based on their arguments. For example, Figure 6 shows two views for two models of Structure 12 that were made in a sequence, as the images were changed and reevaluated. Each image describes a different interpretation of the data regarding roof structures. The two views of a hip roof structure in the top row, and the two views of a shed roof structure below are both plausible interpretations of site data. It was later determined, due to evidence of support pole deposits, that a shed roof was most likely.

![Figure 6. Alternate roofing schemes for Structure 12.](image)

Computer images of Ceren, when viewed by researchers familiar with the site, serve in two ways in arguments about the interpretation of previously collected excavation information. First, each image is the result of an argument, a position that represents a set of hypotheses about how to interpret the archaeological record. Second, the image is a representation that aids certain inferences, enabling one to see things that might otherwise be difficult to understand.
5. Image Arguments

The difference between Ceren researchers and outside viewers is their knowledge of information about the Ceren site and the ability to formulate an opinion about the image. We are attempting to reduce this difference by using Web technology to develop a database of issues associated with the production of each image and to make these issues available to a broad audience of students and professional anthropologists. By linking the image with the information behind it, we aim to make the process of argumentation employed by the Ceren research team available to outside viewers.

Our system uses Apple's QuickTime VR tool kit to enable a Web user to view a fully interactive 360 degree rendering of all the currently excavated Ceren structures. Moving around the structure, the viewer can query areas of interest by clicking on an object or by typing a search command into a frame below.

Figure 7 shows an example of a QuickTime VR panel with a corresponding dialog box displaying the raw excavation data as the user examines specific objects. Excavation data about each object is stored in a server-side database, called up from the client side by CGI (Common Gateway Interface) requests and delivered to the user. The top left image is a QuickTime VR of the interior of Structure 12, with a triggered hot spot (the bottom center of the image, concentric circles). Directly to the right is a dialog box describing the object, a grinding stone, or 'metate', triggered by the QuickTime VR. Descriptions include basic dimensional data, as well as excavation comments. Below is a text area displaying general excavation remarks for Structure 12. Two applets are also displayed. The rightmost includes excavation comments describing other objects with important relationships to the metate. The applet window (bottom right) displays slides and text about continued use of the metate today.

Although it may be informative for an outside user to view the excavation data in a rendering as seen above, this will not necessarily leave the user with a complete understanding. Ceren researchers have a more general view of issues at Ceren and often formulate their ideas around these issues to motivate research about specific data. For example, there is anthropological evidence that Household Two has a higher status of wealth than Household One. Theories about this difference can be formulated and judged by studying images and detailed site information. An outside viewer trained in anthropology may frame a new issue by becoming familiar with the data, but issues provided by the Ceren anthropologists can also guide less experienced students in exploring the site.

Each structure at Ceren triggers a series of issues. When the user browses a Quick Time VR scene of Structure 12 the lower dialog box displays issues (phrased as questions) that are relevant to the structure (figure 8). The opening graphic for Structure 12 displays a rendering of the outside of Structure 12. To its right is a text area displaying pertinent
excavation information found in Structure 12. Areas of text are linked to their subjects. Below, a 'hint' about the structure is displayed providing the user with guidance if necessary. A menu applet (bottom left), and an image display window (bottom right) are shown.

Figure 7. QuickTime VR image and related excavation records. Hot spots in the QuickTime VR image link to field specimen data and excavation notes.
Figure 8. Outside view of Structure 12 link, to the interior Quick lime VR shown in figure 9. The dialog below the rendering displays a more general issue for structure 12.
Further exploration reveals more specific issues. As the user browses the Quick Time VR of the interior of Structure 12 (figure 9), a new issue is displayed. The previous site issue remains visible for the viewer to refer to. To the right of the QuickTime VR is a more general listing of the artifacts in Structure 12. Each artifact is linked to its specific information. The user can search for an artifact by clicking on this list, or by clicking on the artifact within the QuickTime VR.

![Figure 9. Internal Quick Time VR of Structure 12. As the user browses the QuickTime VR scene, relevant issues are displayed.](image)

In summary, Image Arguments extend the capacity of images to convey needed context and they create more dynamic and information rich renderings. Viewers are no longer isolated from the process of image generation and they can participate in the questions, issues, and types of data required to understand the site. Viewers not only can see the image, but they can begin to explore the layers of information used in anthropology research. The result is a tool that provides a greater potential for understanding both a computer rendering and its context.
6. Implementation of Image Arguments

Constructing an Image Argument requires organizing both the graphic and the data set in a dynamic, aesthetic, and integrated fashion. The image acts as a gateway to the data as well as to the overall organizing argument. The data set is created by re-tracing the steps made in generating the image, including the data collection, arguments and discourse that occurred as part this process. We kept detailed records of the information and events in constructing each rendering. The record for each image includes raw data, charts, measurements, sketches, excavation text, excavation images, published text, references to journal articles, conversations, notes, corrections, and a history of changes. Because we needed this information to complete the models and renderings, compiling the rendering record was a relatively simple additional step.

After constructing a set of still rendering images from our initial models, we chose to use a more dynamic form of imagery and began producing QuickTime Virtual Reality (QuickTime VR), 360 degree images. QuickTime VR (Apple Computer 1992-1995) offers a degree of detail not yet available in other systems, as well as the ability to manage extremely large and complex models. We explored using Virtual Reality Modeling Language (VRML) based on Open Inventor (Wernecke 1994), but found that it was difficult to obtain real time performance with high graphical detail of the models we need for Ceren, which typically contain more than twenty thousand polygons. The drawback with QuickTime VR is that the representation of the modeled objects is lost in the final rendering, which is simply a color pixel map representation. VRML overcomes this limitation, and as it becomes faster we expect future implementations to use this technology.

The QuickTime VR solution has enabled us to rapidly deliver interesting images over the web. Users can browse different portions of each structure and select and inquire about artifacts that interest them. Because QuickTime VR uses image format files, areas of ambiguity can be shaded and changed through time within the animation to highlight problems or questions. QuickTime VR also makes it easy to specify hot spots in a rendering with URL links.

Figure 10 shows a block diagram of the Image Argument system, as well as the relationships between the image and its information. This system architecture provides a great deal of flexibility. We can quickly change the issues and information in the back end database and text searches are easy. Text stored in the server side database about Ceren, raw data, and images can be searched and viewed in conjunction with the computer rendering. For our server side data base we chose a combination of two commercial products: Tango (EveryWare 1997) and FileMaker Pro (Claris 1984-1985). Information from Ceren was compiled in a FileMaker Pro database and made viewable on the web through Tango calls. Tango provides a link between a server-side CGI and a database, fielding database requests from Web clients and dynamically delivering this.
information. Quick Time VR's hot spots trigger requests to the Ceren data base that Tango serves.

Figure 10. Graphical representation of the Image Argument system.

The client side uses Java applets (Sun 1996) to control the placement and viewing of the images and information and to guide the user throughout the Web site. Pop-up applets provide menu bars that enable users to navigate the Web site using a single consistent user-interface. We are developing additional user dialogs including internal maps that allow a user to log parts of the web site already visited and information viewed as well as a means to annotate and discuss areas of interest with other users.

7. Discussion and Future Work

7.1 SUMMARY

Computer renderings can be valuable visual aids to describe built form, but alone they have clear limitations in both their reliability and their function as research tools. Renderings create an illusion of existence; yet they reflect only a small portion of much larger bodies of knowledge that lie behind them.

Although animations and other computer graphics technologies have created exciting imagery, typically images are viewed separately from the information that led to their creation. In constructing computer models, renderings, and interactive animations for anthropologists studying Ceren's images served as arguments about a large and complex
body of information. However, this richness of information, the discussion and the complexity of arguments about Ceren are lost when images are considered as solitary isolated objects. Although the Ceren anthropologists can connect images with the information behind their creation, outside viewers cannot.

We have described Image Arguments, an approach to extending the function of computer generated renderings to provide more informative tools for exploring-in this case-an anthropology/archaeology data set. The creation of Image Arguments, dynamic images, linked to the information used to construct them as well as new issues they raise can extend the function of computer imagery. Computer renderings viewed in conjunction with the rich data set behind them become not only more informative, but also more impressive. They no longer stand alone as a single portrait, but instead, like the cover of a book, provide an entrance into a larger story. They no longer ignore the context from which they have emerged.

7.2 USE IN INSTRUCTION

We have slated the Image Argument system for use in an undergraduate level anthropology course in the academic year 1997/98, and we expect that this will enable us to observe the effectiveness of our system. We aim to challenge students to become anthropologists, exploring the Ceren site and the arguments that have been made about it, to answer questions posed by the instructor. Students will be asked to explore the Ceren data set to answer anthropology questions, such as

It was a surprise to us to find that household #1 had more than 70 ceramic vessels. Do you know of any households, in your experience, with that many containers? What are the range of uses to which ceramic vessels can be put?

Questions like this require a student first to browse the Ceren data (in this case, to determine if there are any other households that contain more than 70 ceramic vessels), but then to look also at the interpretations and arguments of anthropologists who have written about the site, in this example, to find the range of uses to which the vessels can be put. Of course, some uses are a matter of common sense and do not require exploring the texts further. But other uses are particular to Meso-American agricultural life, and it will require looking through the sources of the site to discover them. We believe that this process, which requires students to do more work than if they merely looked up the answers in their textbook, will engage them more seriously, even at an introductory level, in the questions of anthropology.

7.3 APPLICATION TO ARCHITECTURE

The Ceren modeling project fortuitously offered us the opportunity to engage in a fascinating set of questions and to develop a set of tools and techniques that we plan to
apply in our home domain of architectural design. Many of the same issues arise with respect to computer generated images of buildings. We have intentionally developed Image Arguments as a ‘shell-infil’ system in which the anthropology/archaeology content is distinct from the technology used to provide the links between interactive animations and back end data and arguments. Architectural computer renderings in this format can provide interesting tools for education, helping students understand the decisions and development behind a building's design.

7.4 FUTURE WORK

We have argued that any computer generated image reflects a combination of data, opinions, and arguments from which it was constructed. Our Image Argument system aims to link an image with the data and the arguments behind it. In our current system, the arguments serve essentially as explanations, but the user cannot explore the consequences of other resolutions of the arguments behind the images. "How, for example, would Structure 11 appear if ...?" We envision a more fully interactive system that makes accessible to the end user the process of producing a rendered model from the data, a process that now requires the assistance of skilled computer graphics modelers. That way, users could argue about how to interpret the site data and generate images themselves, interactively, to serve their arguments. An obstacle is the interface to the modeling programs; even simple editing requires the user to be an expert operator. A speech or text interface to the models combined with a pointer into a three-dimensional rendering would enable a user to edit by simply saying, for example, "move the shelf up a foot. Place the ceramic vessel --Field Specimen 415 -- on the shelf."

7.5 CONCLUSION

Computer renderings can extend their potential to communicate. Images no longer need to act as stand alone displays, but can themselves become innovative tools to display and describe vast quantities of information. By itself computer imagery is little more than entertaining, but combined with information, it becomes exceedingly more successful as a communication tool. As Vicki Goldberg remarks in an article The Power of Photography, "bearing witness is what photographs do best" (Goldberg 1991). In this spirit, computer imagery should bear witness not only to its subject, but to the process that creates it.

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