Spacing Out: Web 3D and the Reconstruction of Archaeological Sites

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Abstract

The emergence of high-speed processors with 3D graphics acceleration and the accessibility of high-speed internet connections have propelled web 3D from a frustrating to a viable internet technology. Without a doubt, the addition of spatial dimension to customary 2D web graphics can be visually gripping. But greater potential for the technology lies beyond its ability to command attention. Web 3D presents students and scholars alike with a new tool for visualizing and understanding ancient sites. Fundamentally, 3D digital reconstruction allows architecture, sculpture, and other remains to be considered in their respective contexts as a whole, rather than as individual items divorced from their intended settings. At the same time, digital reconstruction can incorporate a distinction between the "real" and the "hypothetical" just as found in other types of modern restoration work.

The Perseus Project is currently preparing 3D models of various archaeological sites. These will be linked to other related materials already in its digital library: maps; plans; photographs; QTVR walkthroughs; site, architecture, and object catalogs; and literary and historical documents. In part, the models are intended as databases of geographic and architectural information in their own right. They are also intended to serve as the underpinning for a contextual presentation of architectural and freestanding sculptures. This paper surveys Perseus' work on the Apollo sanctuary at Delphi. It addresses both the process of digital modeling and the method used to integrate the model with Perseus' existing tools and databases.

Keywords: CAD, QTVR, VRML, archaeological reconstruction, data contextualization, data integration, digital library, digital model, QuickTime, virtual reality, web 3D.

1. Introduction

This paper addresses the internet, three-dimensional graphics, and archaeology. Specifically, it addresses the Perseus Project's inaugural efforts to produce 3D models of archaeological sites for dissemination through its digital library. The paper begins with a broad review of web 3D. Discussion touches upon the barriers to the use of web 3D, the reasons for its resurgence, and the promises for its future. Next follows a description of the Perseus Project's foray into a

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[*] This paper was presented at *Ancient Studies -- New Technology: The World Wide Web and Scholarly Research, Communication, and Publication in Ancient, Byzantine, and Medieval Studies*, Salve Regina University, Newport, RI, 8-10 December 2000 (http://www.roman-emperors.org/wwwconf.htm). The lecture text provided here has been reformatted, February 2003, to make it stylistically suitable for written distribution. Diction has been formalized. Parenthetical information, footnoted in the lecture to accommodate time constraints, has been re-integrated with the text. Figure 3 and Figure 4 have been augmented with images of link-triggered windows. And URLs for products mentioned in the text have been added to the References section.

range of 3D formats. A prototype for the delivery of those formats is presented using one of Perseus' works-in-progress as an example.

2. Web 3D

"Web 3D" refers to the use of 3-dimensional vector-based graphics, viewed in real-time, over the internet, with a client-side renderer. This is similar to the standard internet experience in which a client-side browser renders 2-dimensional pixel-based graphics. In fact, many renderers for 3D graphics are designed as plug-ins to existing internet browsers [15]. Examples include Cortona [10], Cosmo Player [5], and WorldView [5]. Other renderers, such as OneSpace [4, 9] and SolidView [13], are designed as stand-alone Java applications that allow real-time shared access to 3D CAD models. Unfortunately web 3D continues to be a concept ahead of its time, this despite being a recognized need from as early as 1994.

The tools for authoring 3D content are well-developed, but the technology for delivering that content is not as robust. There are three weaknesses to web 3D's enabling technology:

- Bandwidth,
- Client-side graphics acceleration, and
- Client-side processor power.

Insufficient bandwidth, graphics acceleration, and processor power are an impediment to the transferal and rendering of complex geometry and textures. This impediment limits the attainable detail. As a consequence, web 3D has not established itself as a practical solution for applications in which this detail is either desirable or necessary. Furthermore, two additional factors are cited occasionally as impediments to the popularization of web 3D:

- Plug-ins, and
- Content.

Despite the technological obstacles, or rather because of them, numerous formats for producing and distributing 3D content have emerged. Each of these formats requires its own viewer plug-in. And this diversity results in an inconsistent web experience for individuals who are unwilling to spend the time or to sacrifice the storage needed to download a different plug-in for every site visited. Then again there is little incentive to do so, since current 3D content frequently does not extend beyond a superficial level to exploit the practical aspects of the medium [11].

Regular improvements give reason to be optimistic about web 3D. Advancements in technology are lowering the hurdles set by bandwidth, graphics acceleration, and processor power. Broad band internet connections have entered the mainstream. Graphics cards have become standard components [12]. And "supercomputing" processors are turning up in offices and homes alike. Plug-ins, too, pose less of a hindrance now than before. The improved experience is due in part to the predominance of a few graphics formats across the internet, Flash for example [7], and to the number of browsers which provide built-in support for those formats. And there are even Java-based 3D viewers, such as Shout3D [6], which run without any plug-ins at all on browsers equipped with a Java Virtual Machine.

All of these technological developments are coincident with a retooling of the Virtual Reality Modeling Language, or VRML, the open standard that emerged in the mid-1990's but never achieved widespread acceptance. The product of this revision, X3D, is approaching finalization. One strength of the revised standard is its tight integration of VRML and XML [14]. Another strength is its flexible design which employs a small core browser and a system of integratable components. The combination of improved enabling technology and a more efficient 3D standard is priming web 3D for significant growth.

Nonetheless, high-polygon immersive environments are still not feasible. This might change with technology which is in development at the Mitsubishi Electric Research Laboratory in Cambridge and the Swiss Federal Institute of Technology in Zurich [8]. Using point samples known as surface elements or "surfels," the new approach ultimately dispenses with polygons. Objects are modeled using traditional polygonal techniques and then converted into surface elements. The conversion effectively preprocesses the model and thus accelerates client-side imaging.

Content appears to be the facet of web 3D that is most in need of attention. The purpose and the value of 3D content needs more consideration, and this focus needs to be reflected in the content's quality and interactivity [11].

3. Perseus, 3D models, and contextualization

Perseus' digital library already contains a wealth of archaeological data. By producing 3D models of archaeological sites, the Perseus Project is also producing a tool for accessing that data. But beyond providing an intuitive interface, the new content also conveys important contextual information about the Perseus data.

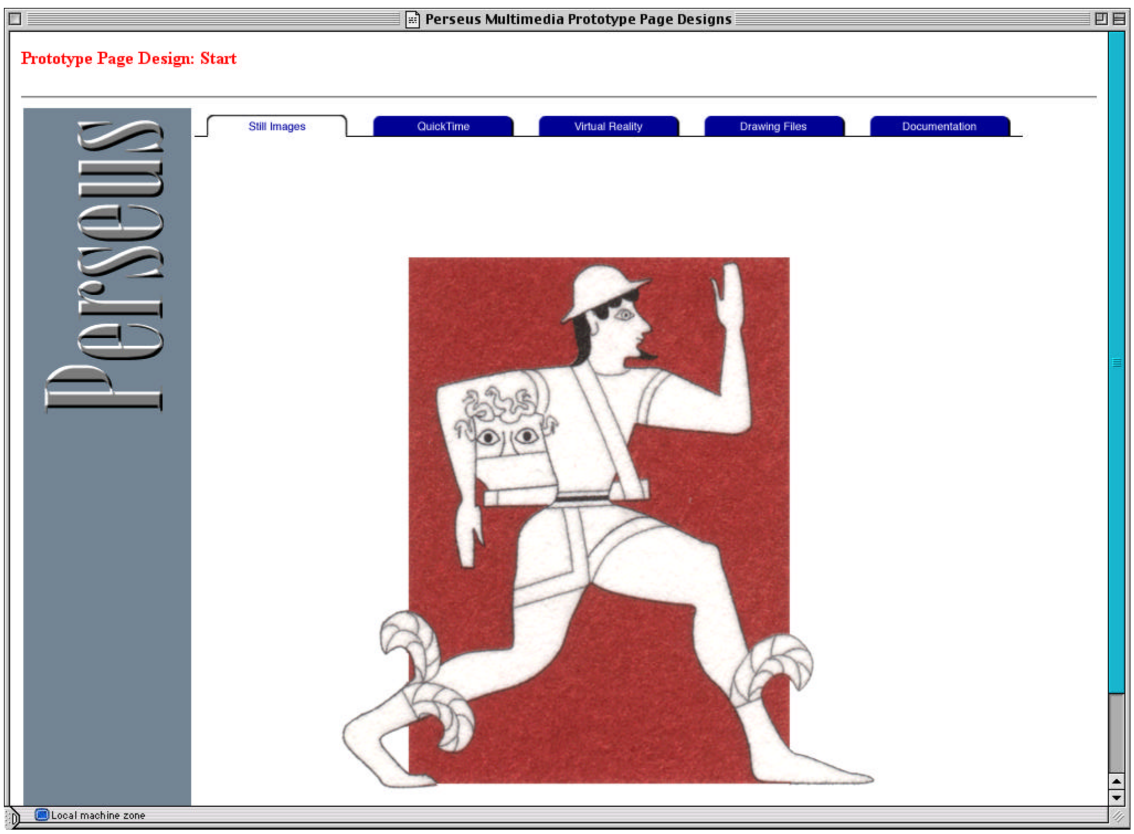

Figure 1. A tabbed interface provides quick access to five different categories of content.

As indicated by the tabs of the page prototype illustrated in Figure 1, the Perseus Project will offer its 3D content in four categories:

- •Still Images,
- •QuickTime,

•Virtual Reality, and
•Drawing files.

These categories represent steps in a converse relationship between level of detail and client-side system demand. The tabs allow individuals to select the categories suited to the capabilities of their internet and hardware configuration. The tabs also allow individuals to cycle quickly through the different formats of the same model without having to perform a separate search for each format.

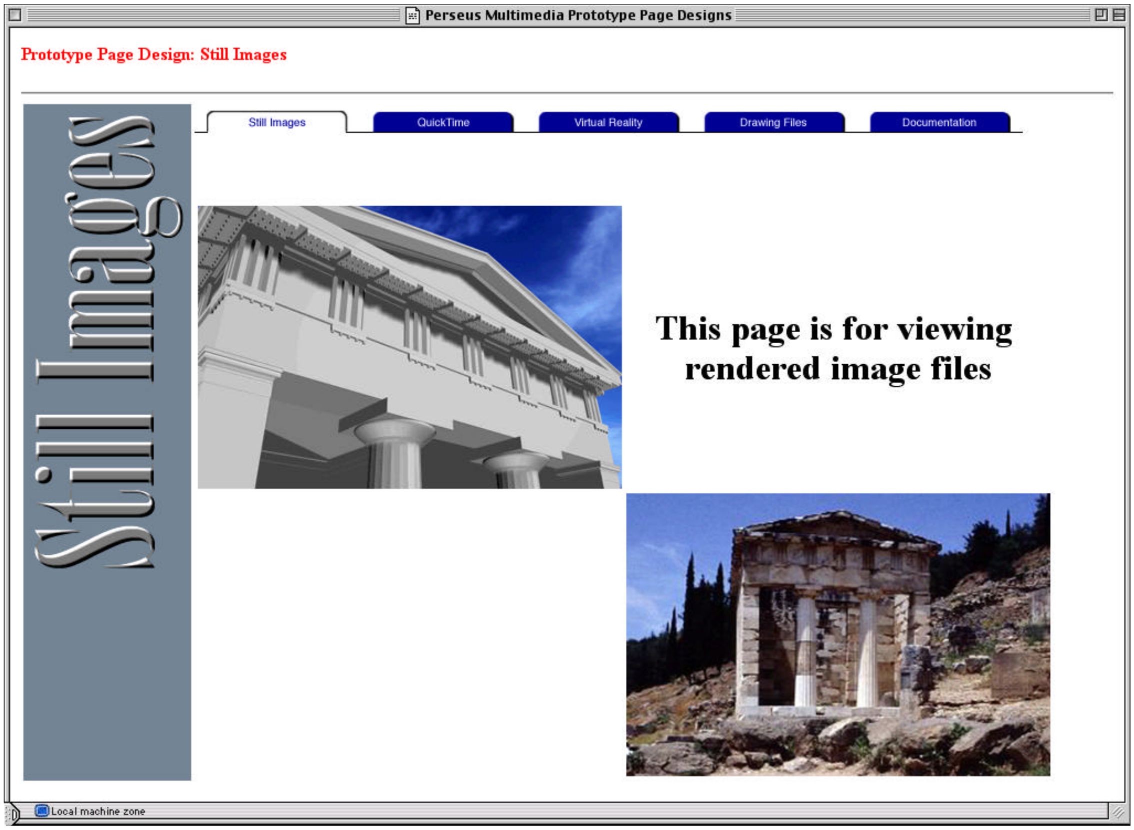

Figure 2. The Still Images category. This page presents the highest quality images of Perseus' 3D content. They are not interactive, but can be viewed by any browser capable of rendering a standard HTML page. Above left, a rendered image from an unfinished model of the Athenian Treasury at Delphi. Below right, a photograph of the actual building.

Of the four categories, still images are able to provide the greatest detail with the least demand on the client-side system. For example, the left image in Figure 2 has been rendered from an unfinished model of the Athenian Treasury in the sanctuary of Apollo at Delphi. A photograph of the actual building is included on the right for comparison. The bandwidth, acceleration, processor, and plug-in requirements for this category are exactly those of standard internet browsing. Thus the still images allow for the widest possible audience. Individuals will be able to access the stills both through the traditional Perseus search methods and through this tabbed interface, which will be directly available from the Tools link of the Perseus navigation bar. There will be an option on the tabbed page to view the images as list items, as thumbnails (using the Perseus Image Browser), or as a combination of the two views. While all of the images used to produce the QuickTime content will be available, the stills themselves will not have QuickTime's immersive aspects.

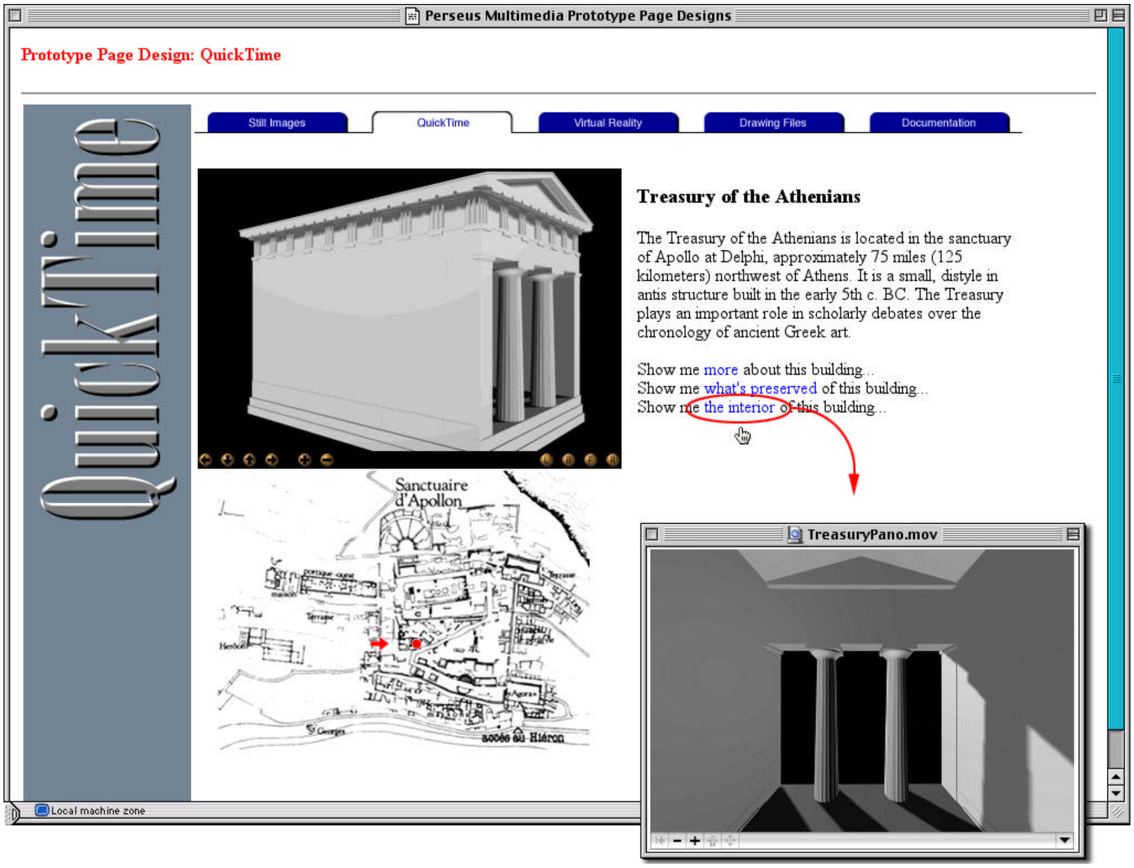

Figure 3. The QuickTime category. This page presents images which have a lower resolution than still images, but which are highly interactive. The image of the Athenian Treasury at top left is an object VR that may be turned in a full circle, as well as tilted up and down. The directional arrow on the map rotates to indicate the viewing position. The pop-up window at bottom right displays a panorama VR of the building's interior. Networks of object VR and panorama VR are efficient simulations of immersive environments.

The second category, QuickTime, permits a limited virtual reality or "VR" experience with only modest demands on the client-side computer. QuickTime files can only be viewed if the appropriate browser plug-in is present. As noted previously, this might deter some individuals without the plug-in from accessing the content. However, QuickTime is a widely used and distributed format. According to statistics on Apple Computer's website, more than 100 million copies of QuickTime have been distributed worldwide [1]. QuickTime's immersive quality comes at a minor cost to image quality. But QuickTime VR achieves good client-side detail and playback by laying the burden of imaging on the production system (Perseus currently authors its QuickTime content on a 400 MHz Apple Macintosh G4 with 320 MB of physical RAM). The VR is basically a series of pre-rendered still images which have been combined into a cylindrical or spherical environment. QuickTime supports object type VR in which an environment is viewed "externally" from multiple points. QuickTime also supports panorama type VR in which an environment is viewed "internally" from a single pivot point.

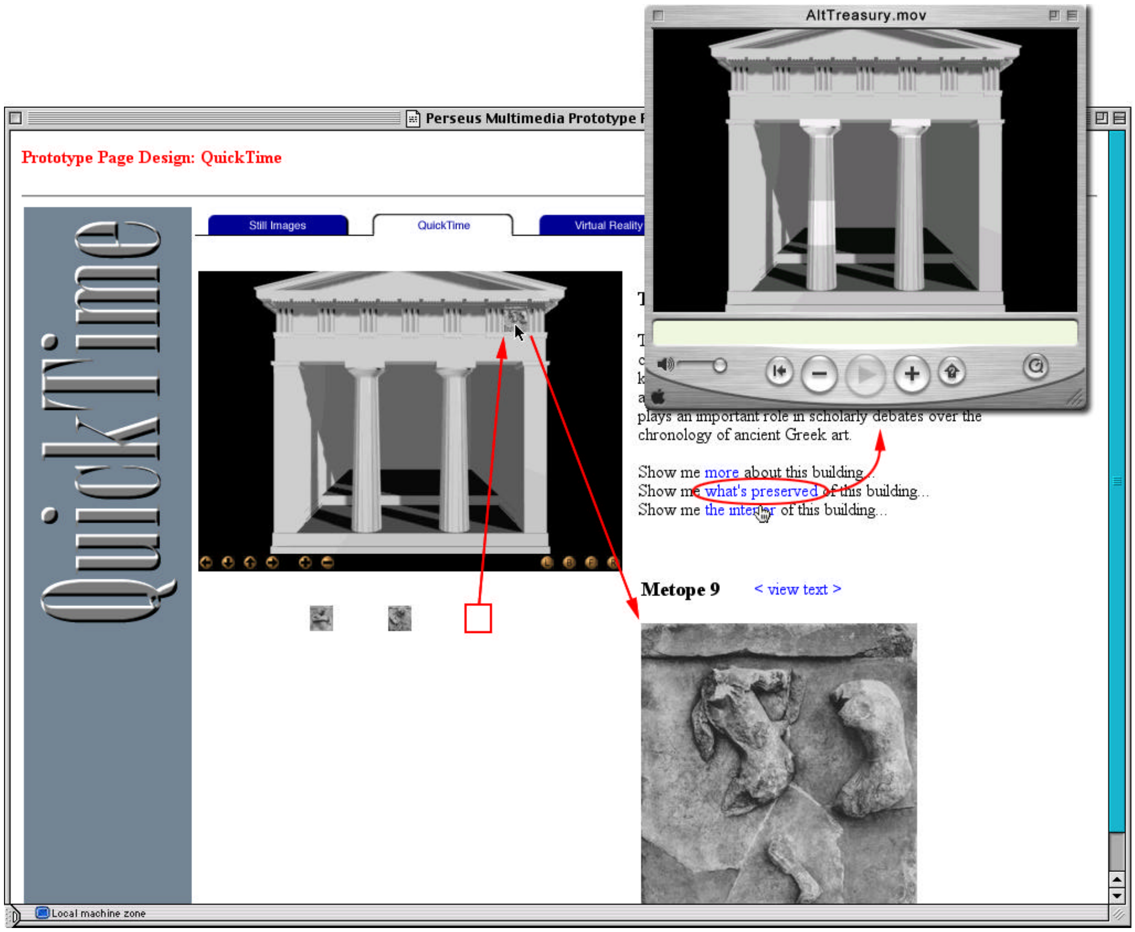

Figure 4. This figure illustrates several interactive features of QuickTime: 1) turning the Athenian Treasury to a frontal view dismisses the site map and introduces thumbnails of the building's metopes, 2) mousing over each thumbnail calls up a larger image at bottom right, and 3) the thumbnail metopes can be dragged into place on the treasury. In this illustration, one metope has been positioned between the two rightmost triglyphs. The pop-up window at top right displays an alternate (mouse down) view state of the treasury in which surviving pieces of the columns are redisplayed in white.

QuickTime's interactivity is not limited to its VR navigation controls. It can contain hyperlinks to web pages. It can respond to mouse actions and other events. It can read and store variables generated by user actions. And it can send that data to a CGI script running on a web server. By capitalizing on QuickTime's interactivity, the Perseus Project is transforming this 3D format from a simple end into a graphical interface for accessing other materials in its digital library. The treasury object in Figure 3 has six buttons on the bottom left for navigation (to rotate left, down, up, and right; to zoom in and out). There are also four buttons on the bottom right for preset views (Left, Back, Front, and Right). Clicking on the "F" button for the principal facade dismisses the map and introduces thumbnails of the building's metopes as illustrated in Figure 4. Moving the cursor over a thumbnail displays a larger image, which includes a link to information about the metope. The thumbnail metope itself can be dragged and positioned between the triglyphs of the building. The images used in this prototype are too small to be practical. But in a larger version the idea is to permit the rearrangement of sculptural pieces and to allow the modified view to be printed or saved to a file — a useful tool where the original arrangements are uncertain or the published arrangements are not accepted. In this way, individuals can test and illustrate their own sculptural theories.

Yet another significant feature of QuickTime is its allowance for an alternate view state. In a modified example of the treasury object, clicking down on the mouse displays a different view of the building in which surviving pieces of the columns are colored white and restored pieces of the columns are colored gray as illustrated in Figure 4. The alternate view state can also be used to display inscriptions cut into the building. And these inscriptions can then be hyperlinked to commentary in the Perseus digital library. However, to produce an alternate view state, its images must be appended to the main sequence of images. Adding an alternate view state thus places additional demands on the computer creating the object VR. In some instances the overall resolution must be degraded to allow the object VR and its alternate view state to be created. Consequently, there are two reasons why it might be better to produce a separate object VR for the alternate view. First, there is no need to sacrifice image quality. And second, the alternate movie can easily be called from a link in the primary movie.

A network of linked QuickTime objects and panoramas is an effective way to simulate an immersive environment. Individuals can pass through an ancient site, move around restored objects, and even enter reconstructed buildings. Nonetheless, the QuickTime environments are really VR "bubbles" that restrict freedom of movement to predetermined viewing points. This characteristic has a pedantic advantage. But it is also a barrier to individuals who wish to look at unanticipated details.

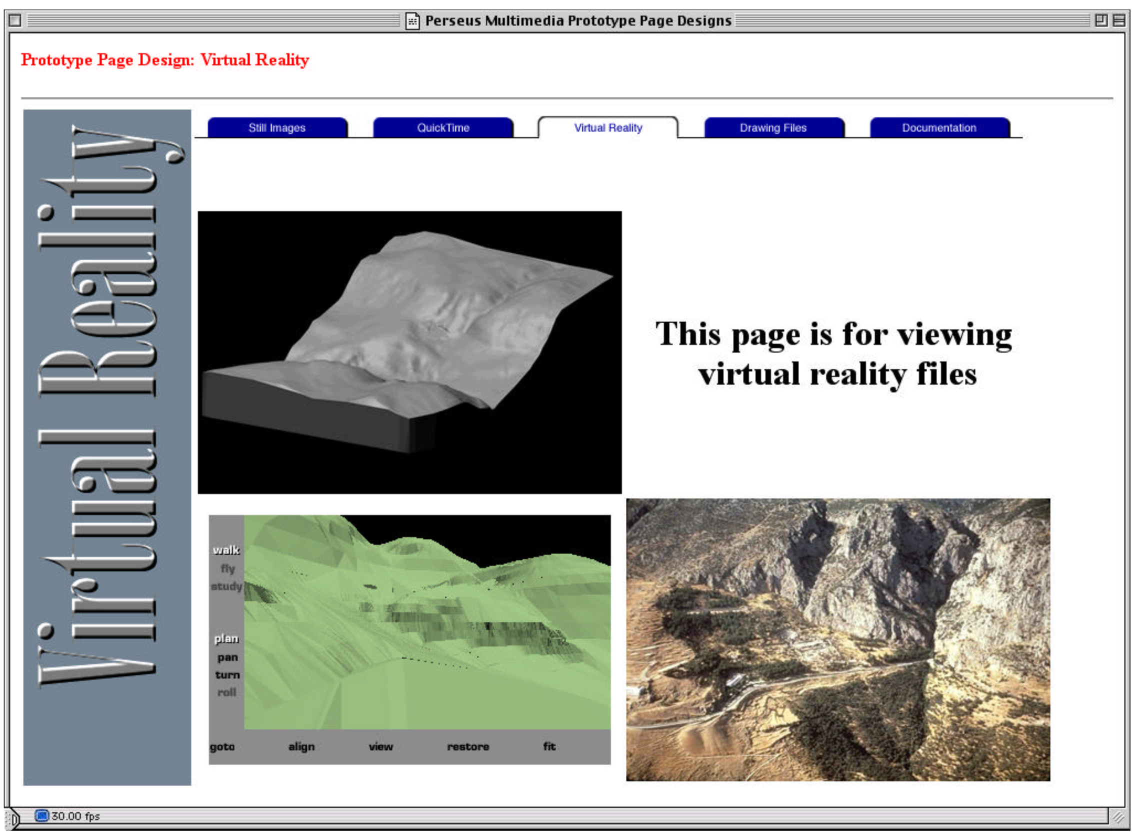

Figure 5. The Virtual Reality category. This page offers images which have the lowest quality, but which have the highest interactivity. These are true 3D

environments and allow unhindered movement within the scene. Above left, a rendered image from an unfinished model of the terrain around Delphi. Below left, the view while immersed in a VRML environment of the model; note the coarse graphic quality. Below right, an aerial photograph of Delphi from about the same angle as the image of the terrain model.

The third category, Virtual Reality, removes the barrier to free movement. VR environments like those authored in VRML allow individuals to explore wherever and inspect whatever they choose. However this freedom places significant demands on the resources of the client-side system. Consequently, the detail of the VR environment must be progressively degraded as less and less powerful computers are targeted for playback. One software manufacturer recommends that a VR environment should contain less than 10,000 polygons [2]. As a matter of comparison, the model of the Athenian Treasury used in previous examples contains 160,000 polygons (and is too complex to display on a 330 MHz Apple PowerBook G3 with 64 MB of physical RAM). The top left image in Figure 5 has been rendered from a 23,000 polygon terrain model of the Pleistos River valley, the basin which cradles the Apollo sanctuary at Delphi; an aerial photograph of the site, taken from about the same angle, is included on the right for comparison. Immersion in the terrain model adequately illustrates the problem of geometric detail despite that the model makes rudimentary use of VRML and does not take advantage of possible optimization techniques. The terrain is intelligible but exhibits the coarseness which VR models must have to run from the hard drive of a mid-range system, let alone across the internet. A trick from the game development community can restore some details; still images rendered from a complex model are applied to a simplified version so that it might convey the missing geometry. However the effect is purely illusory and any attempt to look beneath “projecting” geometry will fail because it has been transformed into a flat picture. As I discussed previously, the limitation on geometric detail is imposed by the current state of technology. Advances in the near future will improve the level of detail that can be attained in VR environments.

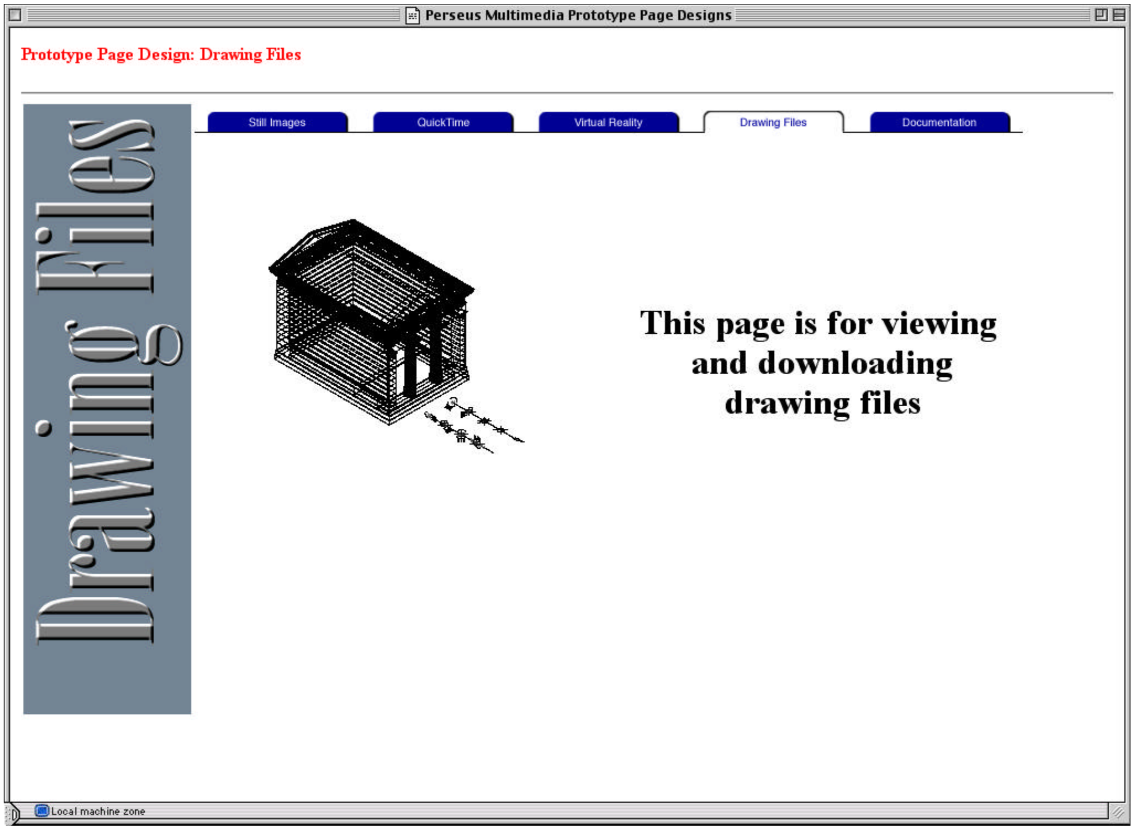

Figure 6. The Drawing Files category. With the right tools, individuals may look at and manipulate copies of the source files. Individuals may also download copies of the drawing files to be opened on a client-side drafting program. The download feature offers the greatest scholarly value.

The fourth category, the drawing file, is the most significant from a research perspective. Image, QuickTime, and most Virtual Reality files are shadows of a drawing file. They are aids to visualization, and their value to scholars is limited since they cannot be mined for data. In contrast, drawing files are databases (of size, shape, location, orientation, etc.) and can be mined for various object properties such as volume, surface area, and mass. Individuals can access this data with several tools designed for viewing, measuring, marking-up, and printing drawing files online. Examples include SolidView [13], Volo View [3], and WHIP! [3] software. However, a drawing file needs to be open in a client-side drafting program to be fully exploited. Therefore, the drawing files will be downloadable from the Perseus website as indicated in Figure 6. Once in hand and with the appropriate software, the models can be sectioned, modified, and rendered. Scholars working with the models will only be limited by the capabilities of their drafting program.

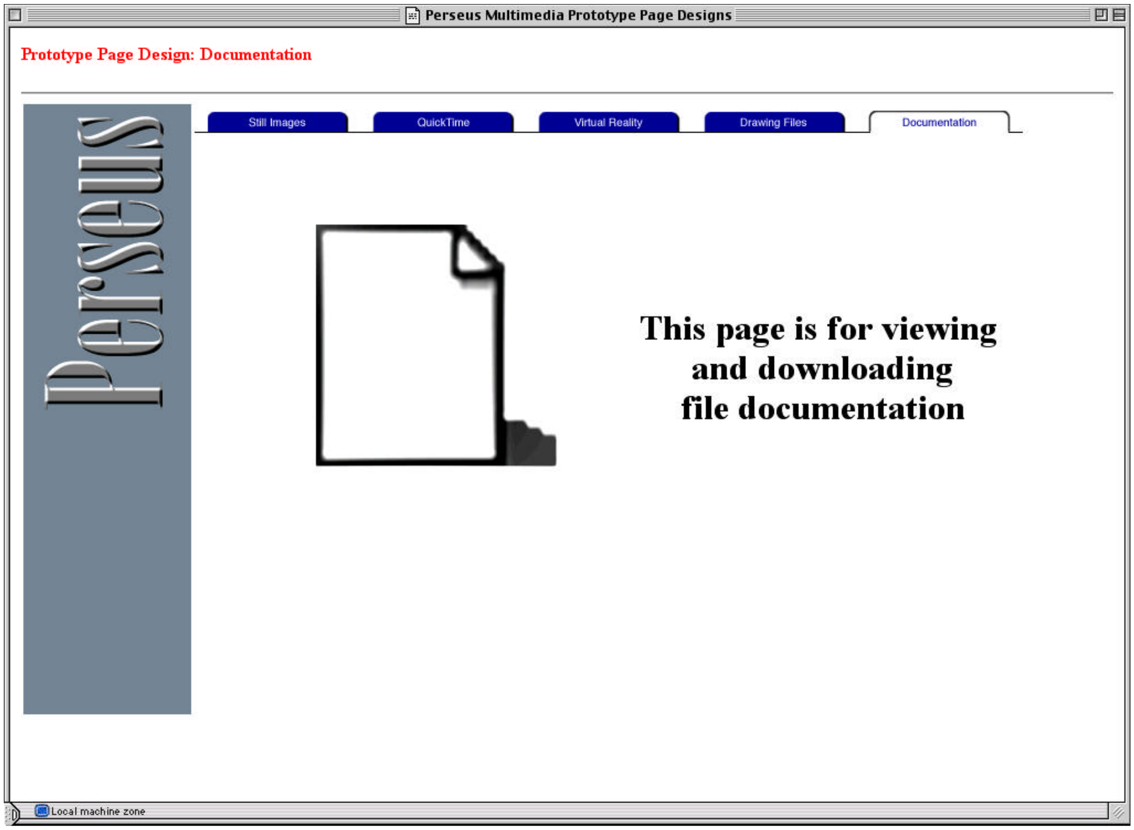

Figure 7. The Documentation category. Full documentation of the sources and processes used in the creation of each model will be made available.

Of course, access only creates the potential for academic value. Ultimately, a model's value is determined by the quality of the information on which the model is based. The adage "garbage in, garbage out" is entirely appropriate to the situation. Inevitably, the creation of a model requires multiple sources. There needs to be a record of these sources and the parts modeled after them. There also needs to be a record of the parts modeled purely on educated guesswork. Like other scholarship, missing or improper documentation throws the academic validity of an entire model into doubt. In contrast, proper documentation can preserve a model's overall integrity even if an element is known to be incorrect. Documentation which appropriately details the sources and processes used to create a model will support each of the Perseus drawing files as indicated in Figure 7.

4. Conclusions

The true geometry and freedom of movement which characterize web 3D make it an enticing choice for reconstructing ancient sites. Mainstream technology has advanced to the point where it can handle the basic requirements of real-time 3D graphics. However, current systems are generally underpowered for the type of detailed environments that most archaeologists would find beneficial. Continuing advancements in technology and the finalization of X3D are certain to help alleviate the existing limitations.

The Perseus Project is now producing 3D content which it hopes will be both compelling and practical. While recognizing the potential of web 3D, the Perseus Project is not focusing on it alone. Instead, the Perseus Project is also providing still images, QuickTime VR objects and panoramas, and even native drawing files. By doing so, the Perseus Project is exploiting the strengths that each category holds for 3D material. It is also allowing the widest possible access to its content. And lastly, it is maximizing the content's academic value.

5. Acknowledgments

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