

Visualizing and Investigating Architectural Space Using Spherical Panoramic Imaging

WASSIM JABI

State University of New York at Buffalo

Abstract

This paper reports on the use of immersive spherical imaging techniques to document, visualize and investigate architectural space. This technology can be used in the classrooms and design studios to augment traditional instructional and design investigation tools. As opposed to cylindrical imaging found in the popular QuickTime VR format, spherical imaging provides a 360-degree view in all directions – horizontally and vertically. The ability to capture and display a full sphere can be crucial for many interior architectural spaces. Spherical panoramas can originate from real, synthetic or hybrid source images. In addition to the ability to embed links to web pages or other panoramas, a unique feature of this technology allows the viewer to navigate through a scene as well as pause at any point and view the space in all directions. In addition, the technology allows the user to sketch over the scene in an intelligent manner such that the sketched artifacts rotate correctly when the target view shifts. The software also integrates with collaborative tools to allow synchronous viewing of shared panoramas over the Internet. These features allow for a truly immersive and interactive experience of the space that can be quite useful in a design studio setting. Finally, this paper describes ongoing efforts to integrate this technology with an interactive web-based, database-driven virtual slide tray system for the storage, sorting, and display of multimedia content.

Introduction

Le Corbusier, in his analysis of objects in nature and the Parthenon in particular, wrote: “It is because *we see clearly* that we can read, learn and feel their harmony.”¹ Much of our ability to understand a work of architecture depends on our perception of the spatial qualities of the depicted space. Short of actually inhabiting it, we rely on representations and projections of the space to help us understand its qualities, proportions and relationships. These projections have been for the most part analytic static representations that attempt to reveal, abstract, edit, or – in some cases – even distort the properties of the actual space.² While these representations have an important role to play in dissecting the space and exploring some of its hidden qualities, they often fail to convey its experiential qualities. Photography, to a certain extent, helps us visualize the space, but remains, for the most part limited to the chosen frame that excludes whatever is beyond it. Furthermore, photography cannot help us when the space has not been built yet.

The advent of synthetic imaging using computer-based tools has greatly enhanced our ability to predict the implications of our design decisions (Mitchell and McCullough, 1995). Using photo-realistic renderings, we can accurately model the behavior of materials and their response to light. Using navigable three-dimensional computer-

generated environments, we can walk through spaces and investigate them from various viewpoints. However, short of access to an extremely fast computer, navigable virtual worlds have to be rendered at a lower quality to allow the user to navigate them in real-time speeds.

To augment the visualization tools that are currently available to architecture students, the author obtained a research grant to purchase software and hardware to capture, edit, and display spherical panoramic images of real and synthetic worlds. This particular technology (iMove, Inc.) was selected after carefully studying its capabilities and comparing it to other similar, but less versatile solutions (Apple Computer, Inc.).³ Panoramic imaging is uniquely appropriate for architects. Below is a list of example uses with a brief description. Once faculty and students learn and implement this technology, other more innovative uses are surely to emerge:

1. **Site and Design Documentation:** For many years, architects have relied on manual stitching of panoramic photographs to document a project site. Panoramic software automatically and seamlessly stitches the photographs to produce a smooth, continuous, and immersive panorama.
2. **Design Exploration:** Using this technology students can examine the sequence of spaces to better appreciate the three-dimensionality of the building in question. This is a fundamental visual skill that we try to embed in our first year incoming students. This software will help the student visualize more realistically a project site or building especially if that site is remote and inaccessible.
3. **Artifact Documentation and Remote Desk Reviews:** Architecture at the beginning levels is usually about making. Making models, for example, is not simply a representational tool, but an analytic one. With this technology, students can document, analyze, and add annotations to their models. This can become an essential tool to discuss the design with a geographically distant reviewer over the Internet.
4. **Research into linked virtual communities and spaces:** Perhaps one of the more interesting possible uses of panoramic imaging software is its ability to create a linked multi-nodal set of panoramas. Using this capability, students can experiment with creating linked virtual communities and start to investigate the architectural language most suitable for virtual space.

This paper describes what spherical panoramic imaging is, the process of creating spherical panoramas and some of the advanced features of this technology. In addition, the author has developed a web-based virtual slide tray system that allows the user to search, interactively sort, and display digital images. This system is being extended to include spherical panoramas. It is expected the two technologies will be useful in the design studio as well as in courses that heavily depend on visual media (e.g History of Architecture courses).

Spherical Panoramic Imaging

The software, the iMove Spherical Photo Solution, allows the user to look in every possible direction from a single point of view. The shifting of the target view is smooth

and seamless such that the result is an interactive and immersive 360-degree image projected onto a virtual sphere with the viewer positioned at its center (figure 1).



Fig. 1. A conceptual diagram of the projection of spherical panoramic images.

The images are spherically distorted (figure 2) and seamed together (figure 3). The steps include capturing several images using a specialized tripod head (Kaidan, Inc.) and transferring or digitizing the images.⁴ The optics of spherical distortion is not a new discovery. Rather, distortion techniques such as anamorphosis were developed during the baroque period. Anamorphosis transformed depicted objects so that they would recover their correct proportions when viewed from a particular vantage point or projected on a cylindrical or conical surface. Perhaps the most famous example of anamorphic distortion is *The Ambassadors* painting by Hans Holbein (1533) where an anamorphic skull is hidden in the image as a symbol of the danger associated with the liberal arts.



Fig. 2. Projecting a planar image onto a spherical segment.



Fig. 3. Hans Holbein, *The Ambassadors* (1533). London, The National Gallery.

The panoramic tripod head (figure 4) allows the camera to rotate around a horizontal as well as a vertical axis. Depending on the focal length of the lens, several images are captured at an incremented heading and pitch. For example, when using a lens with a focal length of 35mm, the software requires the capture of images at three pitches: +45 degrees, 0 degrees, and -45 degrees. For each pitch, 12 images are captured – horizontally – in 30-degree increments for a total of 36 images.



Fig. 4. Panoramic tripod head.

Seaming the Spherical Panorama

Once the images are captured and prepared for seaming, the software loads the images and provides several tools for removing seaming artifacts. Four basic tools are used to correct any inaccuracies: 1) Image lay-down order adjustment, 2) Opacity curve control, 3) Control points, and 4) Individual image focal length.

1. Image lay-down order: Some artifacts can be removed by deciding the order in which the images are layered. The software allows for the adjustment of the layering order.
2. Opacity curve control: Each image has a border in which there is a transition of opacity from fully transparent (at a user-defined outer edge) to fully opaque (at a user-defined inner edge). The border area for a pair of overlapping images can be adjusted to remove ghosting artifacts (figure 5).



Fig. 5. Opacity curve control tool.

3. Control points: In order to better match pixels of overlapping images, the software provides 64 control points that, when moved, distort the image. Using fine adjustments, you can stretch parts of an image to match the one next to it.

4. Individual image focal length: Ideally, all images should be loaded with the same focal length that was used to capture the panorama. However, in some cases, the user will need to slightly vary the focal length in order to enlarge or reduce a particular image for a better fit.

Hotspot Editor

Once the panorama is saved, you can use a hotspot editor to embed links within the panorama. These links can be to an embedded animation, a file, another panorama, or any web address. The links shift intuitively and correctly when the target view shifts. In addition, the Hotspot editor allows you to embed information related to the panorama (photographer, date, copyright information, etc.).

Panorama Viewer

You can view the panoramas using either a standalone viewer or using a web browser with the appropriate plug-in. The viewer provides the standard tools for navigating the panorama as well as zooming in and out. However, perhaps the most interesting feature of the viewer and one that is useful to designers is its ability to sketch over a panorama. The sketching tools are restricted to line, rectangle, and free-hand. However, for quick annotation, this may be sufficient. The interesting characteristic of the sketching tools is that they shift correctly and intuitively when the target view shifts. The result is similar to a user drawing onto the space or floor itself. For example, if you trace a pattern on the floor and then shift your view, the sketched pattern will continue to match the one underneath it (figure 6).

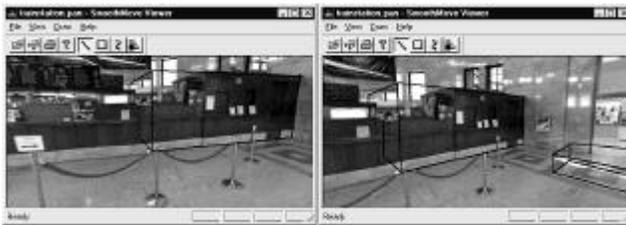


Fig. 6. Sketching on top of panoramas.

Networking panoramas

The Smoothmove viewer integrates with Microsoft NetMeeting collaborative software to network or share panoramas (Microsoft Corporation). The software does not have a concept of a meeting leader or presenter so any user can take control of the panorama at any time. As a conversation takes place and a user moves the view within the panorama, the others can see precisely what the user is focusing on. Initials next to the arrow icon identify each user, allowing each participant to recognize who is directing the movement. The technology updates the visual movement in real time to create synchronous viewing with all users involved. This application supports hotspots and sketching, and has an audio connection that allows verbal dialogue to take place while navigating through the shared files. This was tested using two computers running the NetMeeting software. It worked as expected but it was discovered that the monitors must be set to the same resolution required to run the viewer, and a small time lapse exists between moving on one screen and seeing the update on the other.

Interactive Objects

In contrast to spherical panoramas where the viewpoint is at the center of the sphere, the interactive objects feature of the software, place an object at the center while the viewer's eye is placed at the circumference of the sphere. The user then can rotate the object in any direction as if held in his/her hand.

Panoramic Movies

While spherical panoramas allow views from one static vantage point, panoramic movies allow the viewer to dynamically move the vantage point along a pre-specified

path. However, in contrast to an animation, the viewer can stop the movie at any point along the path and observe the space by looking at any direction. That is, a panoramic movie can be thought of as a series of spherical panoramas. The view is dynamic and seamless and thus provides a truly dynamic and immersive experience using a highly realistic environment. Panoramic movies can be created from real or synthetic images. However, it is far more cumbersome and expensive to create them from real images. Synthetic images, on the other hand can be easily created through a 3D Studio MAX plug-in. The process is simple: The user creates a camera and an animation path as usual, then uses the plug-in to render the animation. The plug-in will then capture a series of spherical panoramas at each animation frame and seams the whole space into a panoramic movie. Using the appropriate viewer, the user can then interactively advance the animation and shift the view while playing the animation in any desired direction. Panoramic movies, like spherical panoramas, can contain hotspots. In addition, several panoramic movies can be linked together. The transition from one movie to another can be done directly through a hyperlink or more smoothly through a pre-rendered transitional animation.

A Library of Spherical Panoramas

In the short term, digital images will replace physical slides as the preferred medium to display visual media in the classroom. For the long term, however, static digital images will augment interactive three-dimensional media such as spherical panoramas and panoramic movies. The aim is to continue to seek funding to travel to important architectural sites and capture them using the available panoramic hardware and software. This effort started by capturing spherical panoramas of two architectural works that happened to be accessible to the author while on a recent trip to Greece: 1) The Acropolis in Athens (figure 7), and 2) the ancient theater in Epidauros (figure 8).



Fig. 7. Unwarped spherical panorama of the Acropolis.



Fig. 8. Unwarped spherical panoramas of the Theater of Epidauros.

Unwarping Space

While it is beyond the scope of this paper to discuss the following topic fully, the potential for this visualization tool in design investigation warrants mention. As the reader can see from the above unwarped panoramas, a curved structure such as that of Epidauros appears straight when unwarped. Straight lines, on the other hand, appear curved. This unwarping or unfolding of space can play a significant role in our understanding of the inherent spatial qualities of a structure. We can conceive of architectural space as a linear structure that has been curved or warped. Unwarping and re-warping the space can also be useful for adding or sketching architectural elements. This can have a significant potential in the design studio and requires further research.

Integrating Spherical Panoramas with a Web-based Virtual Slide Tray System

The Department of Architecture is currently digitizing and cataloging their 30,000-slide collection. In collaboration with the Center for Virtual Resources and the Assistant Dean at the School of Architecture, the University at Buffalo, the author has developed a web-based system for access to, sorting, and display of digital images and media (Apple Computer, Inc., 1999). The custom-developed software is built on top of Apple's WebObjects application server technology to connect to a collection of about 10,000 digital images that have been stored with relevant information in a Microsoft Access database. Using this system, a user can quickly search for a slide using a keyword, preview the slide, and then add it to a virtual slide tray. Once all images are added to the tray, the user goes to a second web page that allows him/her to sort the slides in any desired order as well as remove any unwanted slides. Once the tray is ready, another web page provides an interactive full-screen slide show. The caption of the slide can be interactively displayed and hidden which effectively creates a flashcard system. This is particularly useful as a study guide for students. Finally, the user can specify a time delay for automatically advancing slides.

A Scenario for the Future of Architectural History Education

We are currently integrating spherical panoramas with this system for use in the architectural history course. These two technologies have the potential to revolutionize how we teach architectural history or any class that depends on visual material. In order to clarify how this might happen, we have included a projected scenario of how an architectural history class may be conducted. So, imagine if you will, that you are a student attending what you thought would be a boring History of Architecture class. The instructor turns on the computer and projector, starts a web browser and types in a web address with the word WebObjects in it. Another click on a link named: "Acropolis Virtual Slide Tray" and up comes the first image, an impressive perspective from the Propylaia looking towards the Parthenon. Through the clarity and vibrancy of the image, you admire the carefully regulated proportions and the balance between the boldness of the outline and the delicacy of details. But, on the second image a surprise awaits you. The instructor slides the mouse over the image and it comes alive. It is actually an interactive panorama of the Acropolis. You reach for your portable computer, and connect to the Internet through open ports. You point your browser to the same Web address. You pan up the monumental stairs of the Parthenon, through the austere Doric columns carrying the entablature that contains the metopes depicting the struggle of reason and passion. You pan up further to observe Athena and Poseidon in the pediment fighting for the rule of Attica. You rotate the view dynamically to the left. You see and understand the spatial relationship between the Parthenon and the Erechtheion. You focus on the Caryatids – six maidens sculpted in Pentelic marble – carrying the entablature of the south side of the Erechtheion and establishing through their body posture an axis towards the north side of the Parthenon. You are transported in space and time. You are among fifth century Athenians gazing at their own reflections, their own struggles, and that of their Gods.⁵

What we aim to show through this scenario is that immersive panoramic imaging allows architecture students to more fully comprehend the spatial qualities of a building or site. The smooth transition of a panorama avoids the fragmented and disjunctive nature of sequential slides. In many cases, the slides shown are faded and from peculiar viewpoints that are not helpful to the student. An interactive panorama allows the student to focus on parts of the scene and zoom-in and out at will to study details and relationships.

What Remains To Be Done

In order for these two technologies to integrate, the following tasks need to be completed:

More Historical buildings need to be visited and documented. As of now, only the Acropolis and the Theater of Epidauros are documented. A list of significant buildings that are surveyed in the introductory History of Architecture course needs to be developed. Dr. Vassiliki Mangana is an architectural historian that has taught the survey class in the past and will collaborate with the author to develop the list and guide the proper documentation of the buildings on site. Obviously, documenting all buildings covered in that course is unfeasible, but one can certainly supplement digital images with interactive panoramas for the most important buildings. The author is currently seeking

funding to analyze the greatest concentration of these buildings and document them in one visit to the country of origin. For example, with one visit to Greece or Italy, one can document a large number of historically important structures that are within driving distance from each other.

Virtual Slide system needs development. WebSlides was developed without any compensation or funding, thus it remains at the prototype stage. Any newly added panoramas need to be indexed and correctly listed in the database.

Immersive Panoramas of the same site need to be assembled and connected to each other. The Acropolis, for example, was documented from four distinct vantage points. The four spherical panoramas need to be linked. Also, elements of the scene need to be annotated. The same would apply to the documentation of other buildings.

The integrated system needs to be developed and tested. This integrated system needs to be introduced in the classroom and tested. Based on user feedback, the system features will be revised.

Investigate potential of technology in the design studio. As mentioned earlier, this technology can have a significant role to play not only in visualizing space, but as a design aid. In order to fully understand its implications, further research and testing in the studio is needed.

Acknowledgements

This work was funded by the Educational Technology Grants Program, State University of New York at Buffalo. The author wishes to thank Dr. Vassiliki Mangana for her help in providing historical and architectural information and for editing an earlier version of this paper. The author also wishes to thank Karen Peterson for her help in operating the equipment, seaming the panoramas, and designing the web site that can be found at <http://www.ap.buffalo.edu/~jabi/pi>.

Notes

¹Le Corbusier, *Towards a New Architecture*, (New York: Dover, 1986): 212.

²(Pérez-Gómez and Pelletier, 1997) make a strong case that representation is never neutral. Through a survey of the use of perspective from the seventeenth to the twentieth century, they irrevocably link the tool of perspective to the conceptual ideas behind the projects it is used to depict.

³Apple Computer, Inc. recently announced that their QuickTime VR technology will support capturing and displaying spherical panoramas. The release date is expected to be early 2001. No further details were given. Once the technology is available, we will compare it to the one we have chosen.

⁴If the images were captured using a regular camera, one would need to digitize the images. Otherwise, one can use a digital camera and transfer the digital images to the processing computer directly. Both methods were evaluated and using a digital camera was found to be faster, more convenient, and produces acceptable results. Regular photography is preferred only for very high-resolution and very large panoramas.

⁵This scenario was inspired by Spiro Kostof's analysis of the Acropolis in (Kostof, 1995).

References

Apple Computer, Inc. *QuickTime VR*. Cupertino, CA: Apple Computer, Inc.
<http://www.apple.com/quicktime/qtvr/>

Apple Computer, Inc. "The Future of the Past: Architecture Archive Goes Online at SUNY Buffalo." *Apple University Arts* 2, no. 2 (Fall 1999).
<http://www.apple.com/education/hed/aua0202/pdf/sunybuffalo.pdf>.

iMove, Inc. *iMove Spherical Photo Solution*. Portland, OR: iMove, Inc.
<http://www.imoveinc.com>.

Kaidan, Inc. QPS-1: Kaidan QuickPan Spherical Tripod Head. Feasterville, PA: Kaidan, Inc. <http://www.kaidan.com>.

Kostof, Spiro. "Polis and Akropolis." In *A History of Architecture: Settings and Rituals*. New York: Oxford University Press, 1995: 137-160.

Le Corbusier. *Towards a New Architecture*. New York: Dover, 1986.

Microsoft Corporation. *Microsoft NetMeeting*. Redmond, WA: Microsoft Corporation.
<http://www.microsoft.com/netmeeting>.

Mitchell, William J. and Malcolm McCullough. *Digital Design Media*. New York: Van Nostrand Reinhold, 1995.

Pérez-Gomez, Alberto and Louise Pelletier. *Architectural Representation and the Perspective Hinge*. Cambridge: MIT Press, 1997.