From the Association of Computer Aided Design in Architecture Conference Proceedings (ACADIA 2001) edited by Wassim Jabi, Oct. 11-14, 2001, University of Buffalo, Buffalo, NY

Depicting Daylighting: Types of Multiple Image Display

Nancy Yen-wen Cheng and Edwin Pat-Yak Lee
University of Oregon, USA

Abstract

This study looks at how interior daylighting can be understood through Web page representations. It examines how image size, sequence vs. simultaneity and interaction mode affect legibility. We formatted a set of daylighting images into different presentations using still images, animations and Quicktime Virtual Reality (QTVR). Querying architectural designers about the formats allowed us to identify usability issues, refine the alternatives, and characterize their attributes.

Viewers generally preferred interactive selection of a single large image from multiple thumbnails over two or more smaller still, animated or interactive views. Smaller multiple images allow perusal of the range of lighting conditions and identification of situations for more detailed study. By rating and graphing interface, image and usability characteristics, we illustrate how photo-realistic, symbolic and analytical images complement each other. We found that combining complementary representations in simultaneously or in sequence provides greatest legibility.

1 Introduction

In order to understand how buildings work, we need to look at them under different conditions. Dynamic factors such as inhabitation patterns, climatological and seismic stresses test a building's robustness. As a changing natural force, daylighting is well suited for a digital representation study because inputting a simple sun-angle can generate unintuitive results. Radiosity rendering makes it possible to see how daylighting affects both qualitative appearance and quantitative illumination. Lighting simulation studies that vary time, season, viewpoint and configuration can generate a rich series of related images or animation frames. But how can we best use the images to tell the story of changing daylight?

This study looks at how the multiple conditions of a daylit interior can be displayed on Web pages. While immersive virtual reality environments can create powerful simulations of daylighting, we need more accessible ways to show the breadth of lighting conditions and facilitate deep examination. This paper documents critical factors for representing daylighting and provides ideas for more effective Web presentations. By understanding the factors that contribute to a more legible display of daylighting, we can begin to understand how to represent the multiple facets of complex phenomena.

2 Problem Description

Our objective has been to compare representational methods, to find critical variables and to tune these variables for more effective representations. We want our analytical understanding to serve the creative process. By understanding the variables, we can make more expressive interfaces.

Within daylighting, we concentrate on room interiors because radiosity rendering portrays interior diffuse reflections well and interior spatial envelopes have a well-defined, limited scope. Interior daylighting depends on building geometry, time of day and season of the year. Representations of daylighting also depend on view location and the method of depiction. Different aspects are revealed when a project is shown, for example, in axonometric versus plan or in diagrammatic lines versus ray-traced surfaces.

We wanted to see how well the representations communicated if we varied critical aspects of sequence vs. simultaneity, image size, and interactivity method. When given a choice, in what context is it better to use a large animation over two side-by-side images? Is a pull-down menu better than a matrix of thumbnails? As the project evolved, we became interested in ways to arrange related images and ways to use naturalistic, quantitative or symbolic images.

3 Background of related work:

In digital lighting, summarizing solar behavior into an accessible format can contribute to better design solutions. Lighting software usability studies (Wei 2000, Ng 1999,) show how harnessing lighting software intelligently can boost the design process. Sun-path animations and solar envelope volumes (Setiadarma 1995) clarify exterior shadow conditions for urban design.

For the more complex interior condition, two projects translate illumination levels into concise analytical graphics. By displaying only floor plane data, the projects reveal that only part of complex multi-variable information can be legibly presented at one time. Sumption and Haglund (1991) graphed light levels on the z-axis, creating three-dimensional meshes floating over floor plans. Animated still meshes show changes over time. Color-coding enhances legibility of dimensions and discriminates between artificial and natural lighting.

Glaser and Hearst (1999) created a dynamic grid technique, Space Series, to show temporal and spatial aspects of daylighting data. Their interactive table is a type of detail-in-context display technique that locally enlarges an area of interest while preserving context (analogous to a fish-eye lens). Interactive detail-in-context techniques dynamically distort the arrangement of information according to user selection. (Leung 1994, Murtaugh & Davenport 1996, Van der Heyden et. al. 1998) With Space Series, a user initially sees the average illumination values for the floor of a test room as a matrix of different times of the day vs. seasons of the year. Users interactively expand a row or cell of the matrix to reveal how the light is distributed in orthogonal spatial zones. The method as demonstrated abstracts floor plans into a square 4 x 4 grid.

Artistic projects have explored how multiple images, interactivity and animation can tell the story of light. For example, artist Jan Dibbets' photographic study shows a window as a matrix of images taken through lighting changes of one day. (1970) Levin and Debevec show Rouen cathedral's facade under changing light by juxtaposing and combining Monet paintings with historical and contemporary photos. (1996) They derived the cathedral's geometry from photos with image-based modeling techniques and then texture mapped a variety of images over the model to generate images and animations. An interactive kiosk installation allowed visitors to blend images, or select time of day and location by dragging a finger along brass plates.

While not specifically focused on lighting, Columbia University's website on Amiens Cathedral provides a strong model for presenting architectural information through photographs, architectural drawings, synthesized renderings and text. It thoughtfully uses both key plans and local navigation icons to steer the user through a deeply detailed visual and textual database. (Murphy 1996)

Experimental methods for presenting related information can provide useful conceptual leaps in displaying multi-variable data. Work in interactive cinema could be useful since alternative designs are analogous to alternative plots. For example, Elliott (1992) looked at compiling frames of a film like slices of a loaf of bread rather than the usual end-on-end strip of film, creating a concatenated visual index of scenes and crosscuts. By re-thinking the relationship of frames into new spatial and graphic terms, he allows film to be intuitively understood in a different way.

Our challenge is to see how interface ideas from multimedia can invigorate traditional architectural representations. Rather than generating a new high-tech method, we are interested in how accessible tools and methods can be intelligently employed. So, we have been using the tools at hand: Autodessys FormZ, Lightscape Visualization System 3.2, QuickTime Virtual Reality (QTVR) Authoring Studio, Adobe Premiere, Adobe Photoshop, Adobe GoLive & PowerCadd running on desktop PC's. We looked at how simple technology could be used: primarily image maps, Object QTVR panoramas, and Quicktime animations; with consideration of alternatives using Javascript actions and Flash.

Our study builds on the direction of visualizing quantitative lighting data as photorealistic renderings for understanding of environmental design factors (Moeck 1995), and for artistic portrayals (Larson 2000, Debevec 1999). Perspectives convey the inter-relationships of geometric form and lighting levels better than orthogonal views. The photo-realistic methods we have explored could be used to present photographs of physical daylighting models or photographs of real spaces, although digital simulation images carry the added potential of automatic generation and display.

4 Methodology

Our comparison of different Web interfaces followed from the second author's design studies. We took naturalistic renderings of a proposed chapel space at 10:00 a.m., 12:00 noon and 4:00 p.m. during June, March / September and December from two different vantage points. We looked at how to display the renderings on Web pages with different numbers of simultaneous images, methods of interactivity and sizes of images. In refining the Web pages, we used an iterative process: creating a set for comparison, then discussing the pages with colleagues and students and then creating another set for comparison. We refined 3 sets of representations and queried 24 designers for reactions to the pages.

Parallel to the discussions, we described the representations according to the kind of interface, nature of the images and usability criteria. Graphing our descriptive ratings on a numeric scale gave us a way to visualize the similarity and differences between the representations.

Figures 1 and 2 show our first set of representations:

a) Single frame 800 x 640 pixel Quicktime animated slide-show (images taken every 2 hours)

b) Dual frame 400 x 640 Quicktime animated slideshow showing two views throughout a day and seasons

c) Dual sets of 1000 x 240 QTVR images simultaneously showing 4 times during a day; with scroll through seasons

d) Scollable thumbnail filmstrip image map spawning a large single image

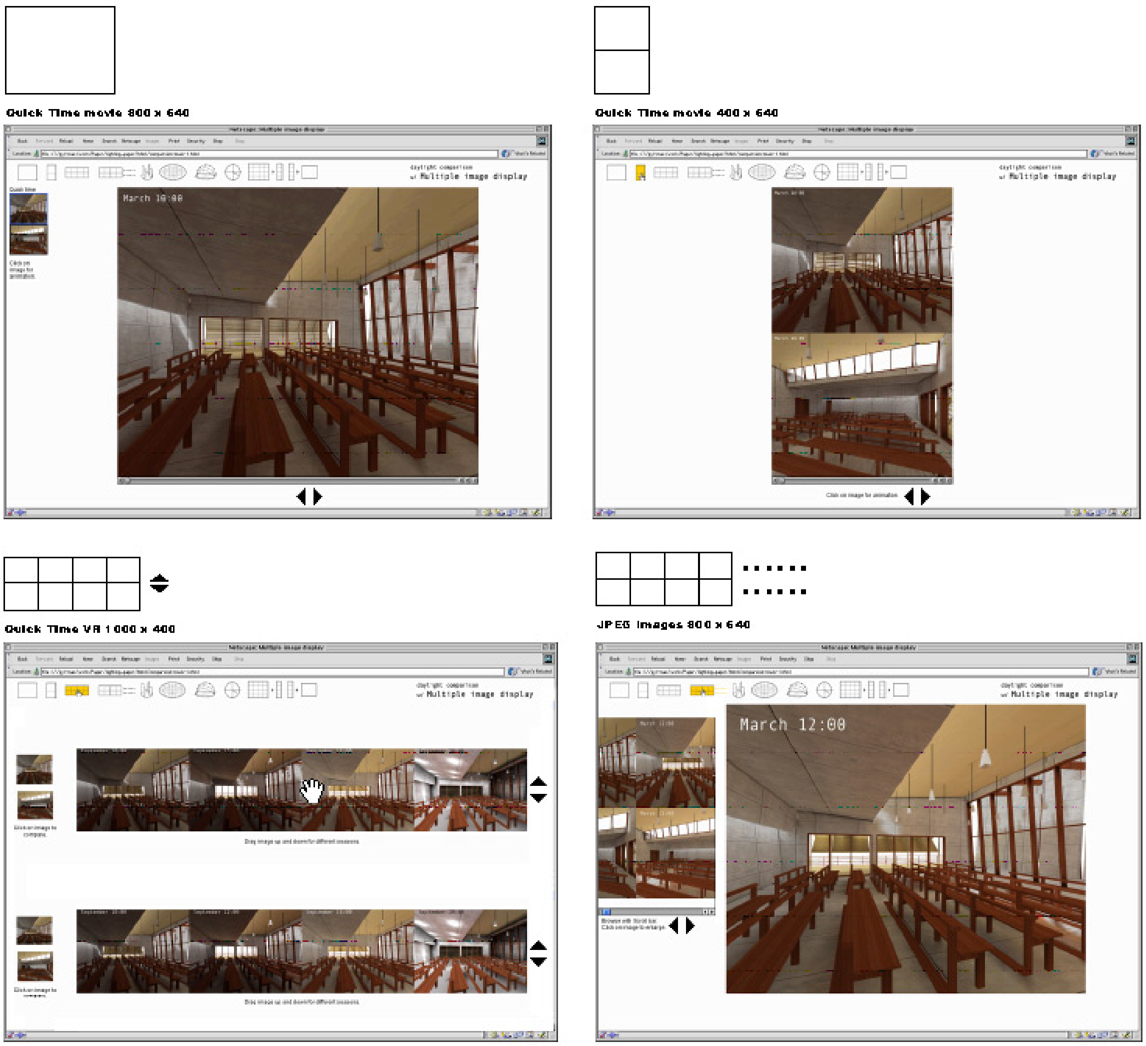

Figure 1. Representational images of different sizes with different interactivity

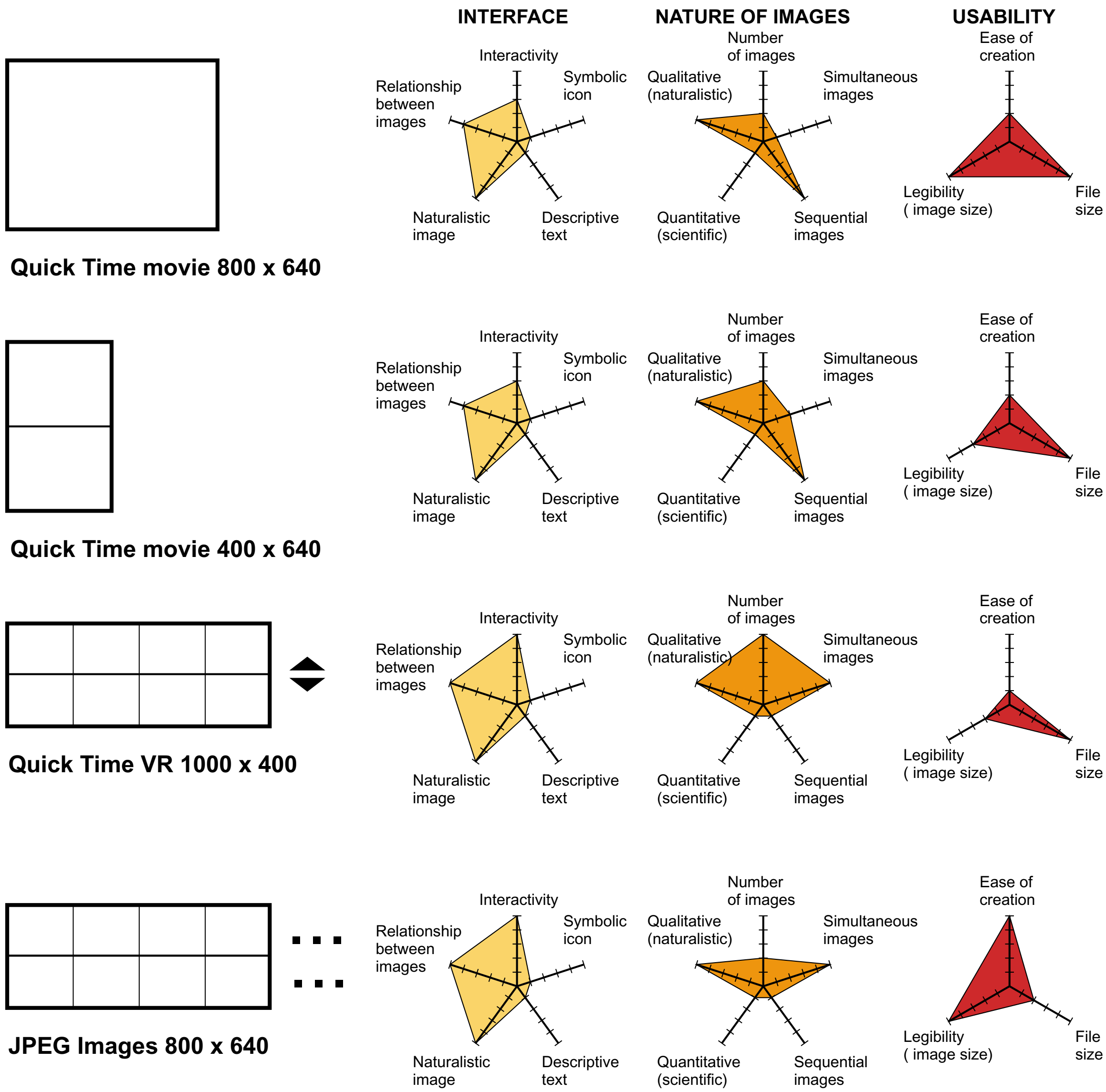

Figure 2. Analytical graphs of representational interfaces shown in figure 1

Because the animations rolled through a March day dawn to dusk, followed by days in June, September and December, they gave a good overview of the project. Viewers preferred manually controllable Quicktime animations over automatically timed Flash animations. Interactively starting, pausing or scrolling through frames allowed careful comparison.

We quickly found that legibility decreases as the number of images increase. The smaller images showed the interiors poorly and too many images were overwhelming. Although the multiple images allowed easy comparison, viewers generally preferred viewing single 800 x 640 images in sequence. Due to screen real-estate limitations, the dual frame images are only ¼ the area of the single screen and have much less presence.

From seeing the trade-off between multiples for easy comparison and large frames for close inspection, we created a set of interfaces that together would allow different kinds of viewing. The zoom-in interface shows still images, starting from a matrix overview and leading to a single image. Figure 3 and 4 show how the three methods contribute to a more complete understanding.

e) Matrix of multiple images

f) Two column comparisons with pull-down menus

g) Selection from the two-columns would show a single enlarged image.

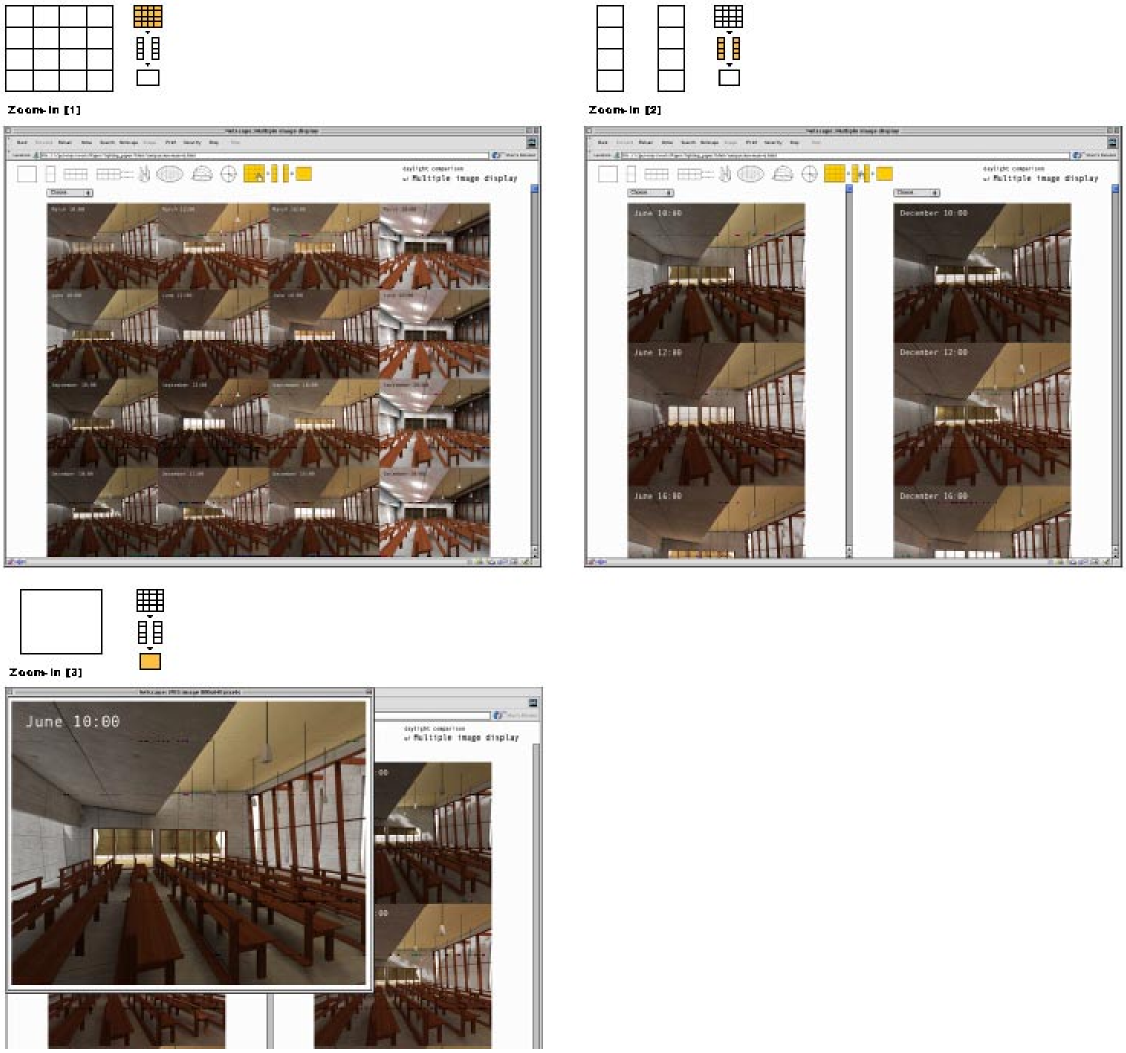

Figure 3. Zoom-in method moves from large matrix to 2-column comparison to single image

Zooming in from many images to one image effectively overcomes the matrix's shortcomings and provides a dynamic view of the data with simple means. In the two-column format, the limited interactivity of still image selection is sufficient to give users a feeling of control. Two columns can display a related group of images (such as hours in a day) while allowing constraining selection (i.e. season, viewpoint, design variation). Pull-down menus work best with clear labels and few choices.

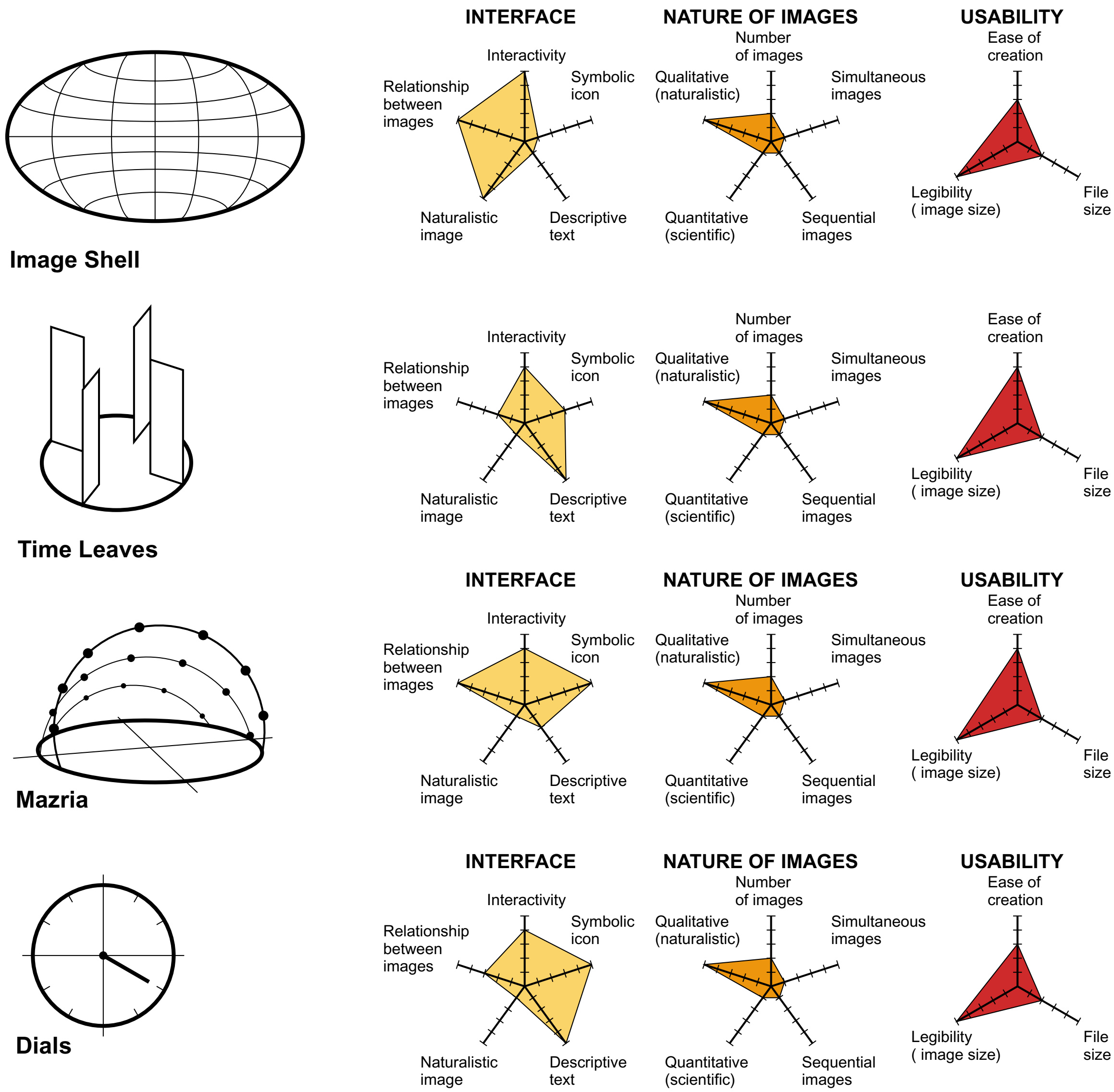

Figure 4. Analytical graphs of Zoom-in method

In reviewing methods a) through g), we felt that the diurnal and seasonal relationships between images could be more obvious. So in the next stage, we tried three-dimensional representations to spatially connect images according to seasonal and hourly adjacencies. We thought that texture mapping the images onto a three-dimensional form would provide order to the images in the way that binding pages into a book gives a linear sequence. With Virtual Reality Markup Language (VRML), a form could be toured or used as a selection tool for a larger image. But we found that squeezing together many rendered images onto a physical form made the visual information obscure identities of time and season. In sketching the images' relationships, we saw that text would be more legible than representational thumbnails. (figure 5)

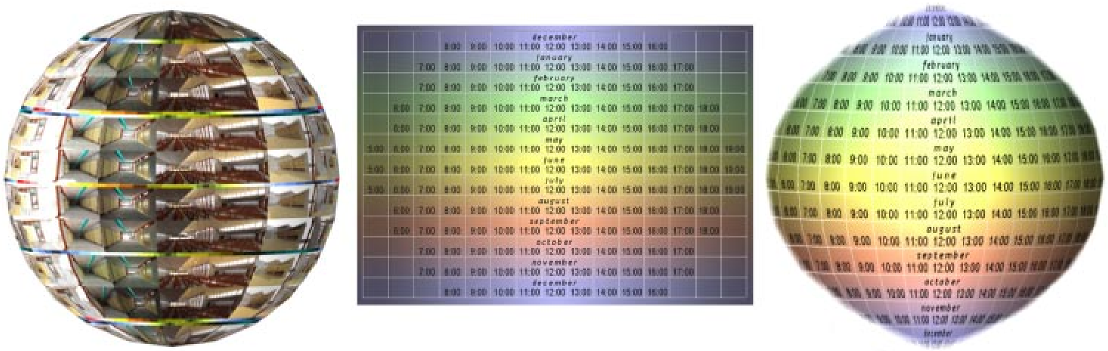

Figure 5. Sphere texture-mapped representational images & hour and month grid

We then looked at how abstractions using text or diagrams could help the user see relationships between the images and time or solar orientation:

h) Matrix of times

i) Time leaves as in a Munsell color wheel

j) Sun path diagram as in Mazria (1979, p. 307-311)

k) Dials with pull-down menus

For this effort, we mocked up pages with image maps or Flash animation in the upper left corner that place a daylit rendering in the main frame. The user selects a desired time and season and sees the resulting image. (figures 6 and 7) Compared to the purely representational Web pages, these pages with analytical diagrams have simpler interactivity (still images rather than animations or QTVR) and more clearly illustrate the relationship between daylighting effects and seasonal and diurnal cycles. Among the abstract diagrams, the Mazria sun path diagram shows the relationship of time, season and lighting most clearly since it shows the geometric basis for sun angles. Alternatively the separate dials (k) for time of day and month of year facilitate focusing on one factor at a time. Adding a key plan and section with sun angles would further clarify the context of the experiential perspectives.

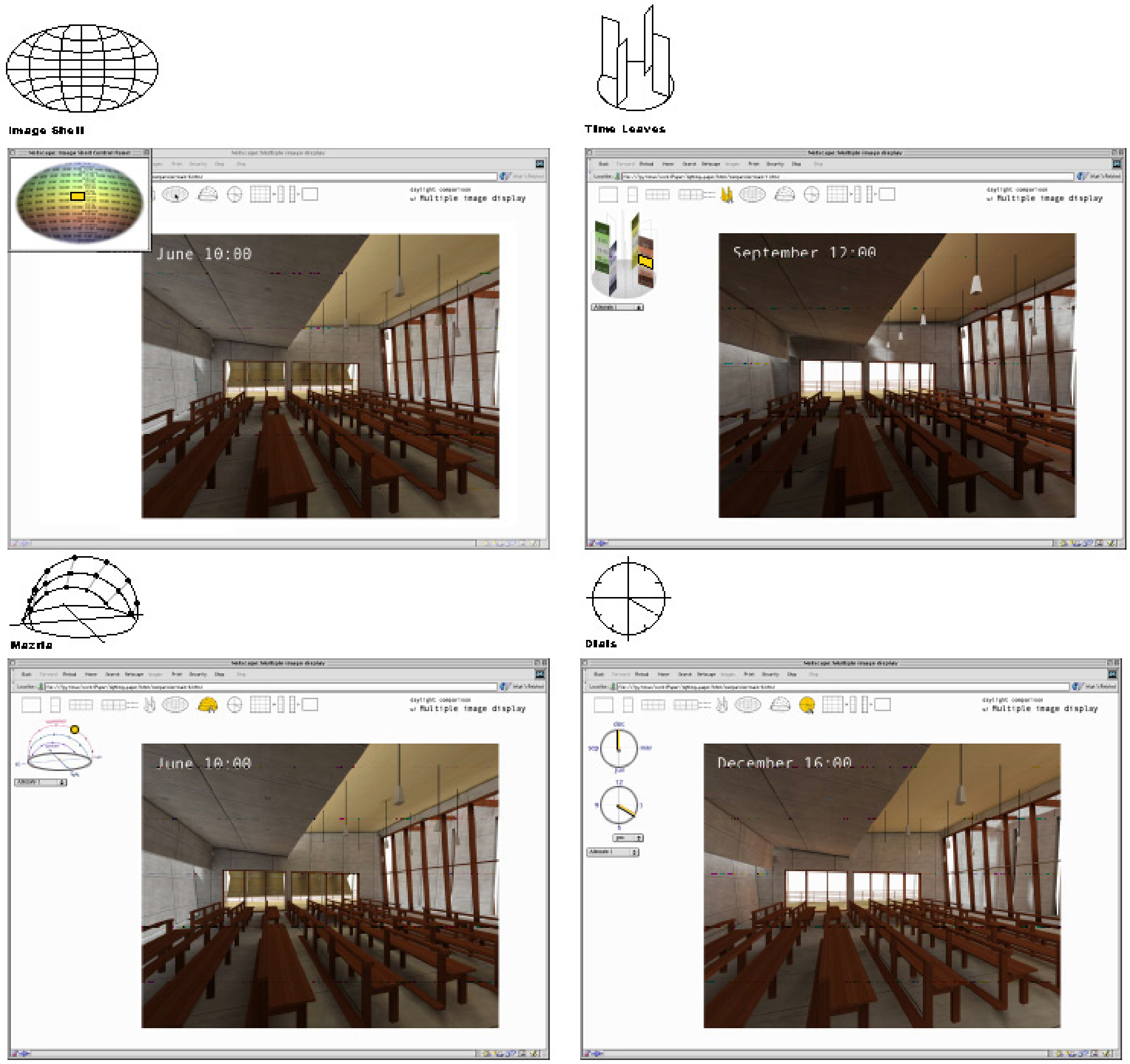

Figure 6. Abstract icons for selection of single large image

To better understand all the interfaces, we rated each interface from 1 to 4 in terms of critical interface design, image attributes and usability aspects. (see figures 2, 4 & 7) To characterize the interface design, we looked at whether the interface included naturalistic images, descriptive text or symbolic icons and rated the relationship between images and the amount of interactivity. We characterized the interface's images in terms of number of images, qualitative (naturalistic) vs. quantitative (scientific) and use of simultaneous or sequential ordering. For usability, we looked at how easy it was to create the interface, how legible the images were in terms of size and how bulky the created files were.

We mapped these ratings onto multi-variable graphs to see similarities and differences between the representations. The graphs characterize the representational interfaces (figure 2) and the abstract icon set (figure 7) as being very different, while illustrating strong family resemblances within each group.

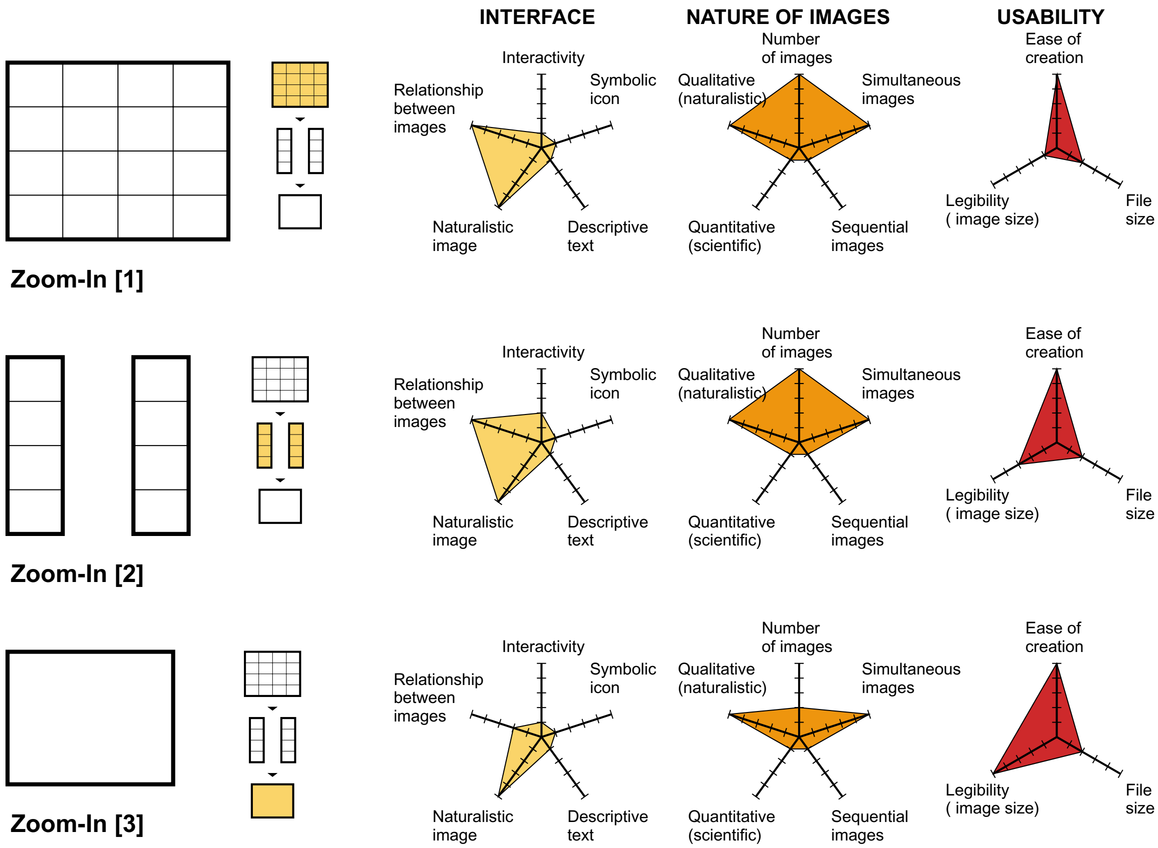

Figure 7. Analytic graphics of abstract methods shown in figure 6

5 Discussion

From querying designers on their preferences among the presentations, we identified the following issues as critical to effective Web presentations of daylighting.

5.1 Size and number of images

For both overall understanding and close inspection, large images are essential. Large images engage the viewer and reveal lighting details such as veiling reflections and sparkle. Because displaying as few as two similarly formatted non-overlapping images drastically shrinks the display size, early in the study we defaulted to a large single frame supplemented by either smaller images or analytical diagram. The single frame standardizes viewing conditions of each image, but makes comparison more difficult, especially if the order of images is fixed and the number of images is large.

Designers prefer side-by-side comparisons to examine alternative environmental conditions or design options. A matrix of many images facilitates comparison at the cost of individual presentation. Since a matrix provides a quick overview of the range of visual conditions, it could help a designer find minimum or maximum light levels & glare. It can help identify unexpected situations for closer examination and development.

Overlapping windows or rollover substitutions could give a compromise between image size and simultaneous viewing than side-by-side viewing. To solve screen real estate problems, a hand-held device with selection options could be used in conjunction with a large screen display.

5.2 Interaction

Users were interested in getting as directly as possible to the desired information. They preferred the direct control of simple image selection over more elaborate animation or QTVR presentations. They wanted to be able to manually control frame content, image size and number. They did not voice strong preferences about using pull down menus over visually scrolling through images.

Our Quicktime animations in methods a) & b), QTVR files in method c) and strip of thumbnails in method d) gave subtly different ways to scroll through a linear series of images in a fixed relationship. The simplest of the three techniques, the strip of thumbnails, provided more effective navigation by revealing parts of adjacent images during panning. Adding frames to the animation and using a matrix rather than linear form of QTVR components would sharpen the distinction between the cases.

5.3 Modes for understanding.

The Web pages show the utility of the different modes of representation. Arranging images in order relates them through adjacency. Text or icons for time and season can clarify the adjacency rationale. Iconic navigation tools can illustrate both the relationship between a set of images and the relationship between images and the sun position. Relating the experiential images to sun path can provide a more direct understanding of how building forms affect perception of daylighting.

For viewing on a color monitor, simple linear or grid displays had higher legibility than images of three-dimensional projections. (figure 5) The spatial interfaces may be more effective when viewed with other hardware.

5.4 Graphing for layered approaches

Our graphs help confirm that while matrices of small images and animations of moving images provide good overviews, they need to be complemented by large, still images for careful study. The need for clear navigation, comparison and close inspections could be met through interfaces employed in serial fashion. A zoom-in interface using a comparative two-column format could provide necessary selection and display size control. (figures 3 and 4) Adjacent related images could be tagged with sun-path diagrams or key plans and sections to facilitate navigation.

For presentations to an audience of newcomers, a layered approach could also be effective. Initially, a large-scale animation of the space throughout 4 days in a year would provide a general overview. Next, the user could use sun-path diagrams to select dates and times to examine as large still images. Finally, the whole range of solutions could be viewed as a matrix for selection of exemplars or problems. Overlaying our analytical diagrams for these interface techniques show that they have complementary features – the auto-run animation is complemented by user-selected images in the other two modes. (figure 8)

While our results suggest that simultaneous presentation of complementary depictions can foster understanding, questions remain about how much and what kind of information can be simultaneously comprehended. Since understanding of new interfaces depends on both innate capability and learned conventions, interface innovations may need time and practice for user acceptance.

Knowing more about the effects of display techniques on perception of luminous spatial environments could contribute to more effective representations. Digital simulations can be effective at simulating specific moments of lighting experience (Eissa et. al. 2001), but since perception of lighting depends on gradients of illumination (Ashdown and Frank 1995), temporal and spatial contexts are critical. For example, condensing a full year of daylighting into a few minutes of time-lapse animation exaggerates the subtle and gradual experience of changing light.

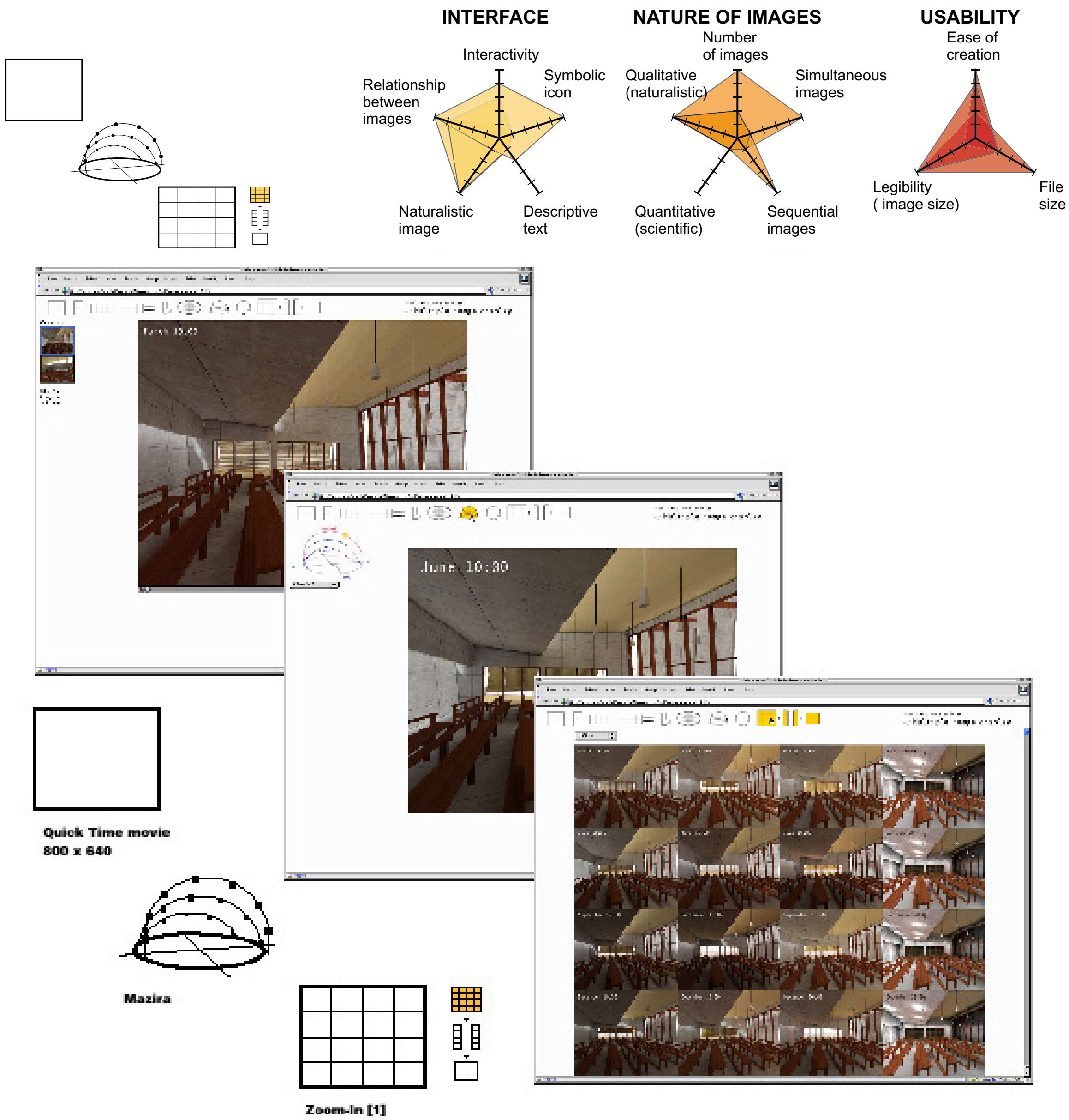

Figure 8. Sequential use of complementary views provide a complete representation

6 Conclusion

Our study combines creative exploration and methodical examination to illuminate representational principles for the display of related images. Using Web pages with daylighting renderings, we illustrate how large single frames enhance close inspection, selectable side by side images facilitate comparison, and analytical diagrams contextualize perspectives. To elucidate differences between Web representations, we categorized them and created graphical analyses of interaction, image and usability factors. Our descriptive graphs show how methods reveal different slices through the data and provide alternative selection methods. We demonstrate the utility of the graphs through the sequential use of complementary representations.

Both artistic experimentation and methodical study could further the effectiveness digital lighting representations. Creative experiments could integrate analytical images, diagrams and text with experiential images to make multi-faceted presentations. Automating the generation of these presentations would make it possible to use them in the iterative design process. More generally, work could be done in articulating how to effectively employ naturalistic, quantitative, and symbolic images together in interactive presentations.

Acknowledgements

Virginia Cartwright and G.Z. Brown provided valuable feedback for this study. The University of Oregon Foundation, the Intel Corporation and the Frederick Baker endowment provided support for this work.

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