The Play of Light: Notes on the Modeling of Architectural Illumination

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> Even at the heart of the digital beast, it still seems possible to tease out a latent, albeit crude, critique of the society of the spectacle. . . . when the force of the haptic breaks any trace of the spectacle and marks an absence of the apocalyptic mayhem that follows in the film [Jurassic Park].
>
> — Anthony Vidler[1]

> The history of architecture is also a history of building with light. In spite of today's highly technological architecture light must not only answer the basic need for sufficient and correct lighting required for seeing, it must also have and ethical and moral quality.
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> — Hans Malotki[2]

Digital or physical? Light has become a difficult subject for architects; it is too exact, too much the subject of digital precision. Architectural illumination belongs as well to the dictates of common sense, the accidents of place and history, and the inquiring, speculative gaze with which it is appreciated. Precision itself is not at issue, but instead of a mere precision of means, this essay seeks to understandtheconditions in whicharchitectural illuminationachieves a precision of concept. The translation of lighting design into the digital domain has yielded tremendous advances, and the potential of accurate 3-D models is only just being realized, but all forms of representation involve some abstraction of visual experience. When the questions arenarrowly technical then thecriteriaof reduction can be easily agreed upon, but how do we characterize the full-bodied criteria of architecture? The answer to that question is necessarily rhetorical or topical, it depends on the specifics of the architectural project.' Marietta Millet has examined a number of such topics in architectural illumination, like place, climate, form, structure, and materials.' Keeping in mind the close connection between *topos* (place) and *topoi* (topic or theme), the rhetorical concept of topic indicates a physical site or condition as well as a thematic concept. These are the sites at which architectural invention is always, already occurring and so present themselves as natural sites for evaluating different methods of modeling architectural illumination.[5]

These do not replace pragmatic rules, such as "light the merchandise" in retail settings, nor do they exclude technical measures and criteria. Quite the contrary, topical thinking places technical and pragmatic concepts in context, denying them the final authority, and providing a broadercritical position from which to compare physical and digital representations. The ready opposition between technique and design does suggest that such a shift involves more than a broadening of criteria, simply moving from questions like "how much light?" to "how does the light reveal or conceal the structure?" In the theory of work, productive activities which have a determined end are opposed to those which do not, but this is not a simple mirroring. The opposite state is called leisure, but it is not merely the state of rest that serves as a preparation for work. Inactivity, defined as such, is merely the other face of work. Instead, leisureis that "state of being in which activity is performed for its own sake or as its own end."[6] With respect to architectural illumination, that condition would have to be called the *play of light.* While lighting is generally taught and examined in the spirit of productivity, according to the work it can do and the energy required to do it, the consideration of light at play reverses that mode of inquiry, seeking instead the engagement with topics by which light becomes architectural.

The projects used as examples in this essay were produced for a design studios and a seminar on light at the University of Pennsylvania over the last five years, though some have been elaborated by students subsequently or as part of an independent lighting consulting practice. The subjects of those studies have ranged from the narrowly analytical to the broadly speculative. They begin with investigative surveys of existing situation and proceed to final design projects, for which questions of modeling are central.

MODELING, REPRESENTATION, AND EXPLANATION

All forms of representation involve selections, reductions, and abstractions of richly complex phenomenal conditions, either according to the nature and limitations of the media being used, or because of the specific conceptual focus. In common usage, the term drawing refers to 2dimensional depictions, while model suggests 3-dimensional ones, and animation indicates the inclusion of time (with or without motion). These are not well-defined distinctions, especially as models are often represented in two-dimensional form, but the term model and modeling will be used to describe three dimensional studies, in whatever form they are presented. The rest of this essay will compare the different models currently used in the seminar tounderstand architectural illumination. Although the list is not comprehensive, it reflects the particular state of digital transition occurring at Penn. In general, there are three kinds of models used and discussed: full-scale mockups or interventions in existing conditions. physical scale models, and 3-D digital models. Each type offers some benefit and has some limitations, the poles of which seem to be the facility of visualizing luminous phenomena or assisting with inventive thinking.

Full Scale Models

Full scale interventions are used early in the seminar to help students learn to observe and understand luminous phenomena. Photographs and light meter readings help make the differences between illuminance and luminance more vivid, but real engagement with the situation only seems to occur when they intervene directly in the situation. Deploying even the simplest portable light brings a sense of magnitude to the concept of light, while directing it within an existing room makes evident the radical differences of effect that can be achieved. Recently those lessons have been reinforced by a class visit with a theatrical lighting designer, and it may only be there that many students understand either the mixture of colored light or the relative softness or crispness of different sources. Full-scale mockups are also used by the students designing actual luminaires or investigating some specific lightmaterial interaction such as tile reflectivity, or water-air interfaces. Full-scale models provide great accuracy and detail, precisely relating the magnitude of light to real materials. The limitation, of course, is the cost and difficulty of modeling anything of complexity at full scale, and there are consequences to the loss of abstraction. Phenomenal details presented at full scale can be distracting. and lose the design focus provided by scale models.

Scale Models

Until recently, most of the research and design projects were studied with large scale physical models (generally 1/2"=1'0"). They were photographed outdoors with siide film using a simple sundial to model different times of day and year.' This is very accurate for sunlighting, and somewhat less so for daylight, but the students develop and immediate and intuitive understanding of the relationships. Occasional studies have been made with smaller photographic prints, and there is a noticeable difference because of the size and the lack of luminosity in the image. The use of digital camera's and projectors is generally similar to that of slides, but neither the resolution nor the sensitivity to light have been as good, and occasionally they have been distracting. The advantage of digital photography, however, is that it permits immediate evaluation of the phenomena being modeled and so lends itself to in-class exercises. The primary benefit of photographing physical scale models is the sense of illusion that they provide. There is a vast difference between viewing a model directly and viewing a well-shot photograph. By framing the image appropriately, a projected slide of a reasonably detailed scale model can achieve an almost complete illusion of reality. That illusion can also distract, but it generally directs attention to the issues of illumination rather than the model. The additional benefits of scale models is their ability to incorporate real materials and to use modeling techniques that are still common in the design studio. Their single biggest limitation is the difficulty of incorporating or modeling artificial sources of illumination.

Digital Models

Beginning last year, we began using Lightscape to study illumination in digital models. Although some simplifications limit its accuracy for daylight analysis, the combination of radiosity calculations, ray-trace rendering, and the easy incorporation of photometric data from luminaire manufacturers have made it a very useful teaching tool.[8] Most of the digital models are built in FormZ, which has a good Lightscape translation, though the lack of a reverse translation makes the process somewhat cumbersome. The shift to digital analysis has both extended the reach of the course and called into question many of the assumptions previously embedded in the tools and techniques of physical modeling. Thequestion of precision and of what kind of result or understanding is sought quickly became an issue because of the easy production of information that had previously been the object of laborious calculation (illumination, luminance, etc.), and especially because of the easy proliferation of digital images. The ability to test alternatives rapidly looses its benefits in the face of an infinity of possibilities, and for this topics become especially helpful.

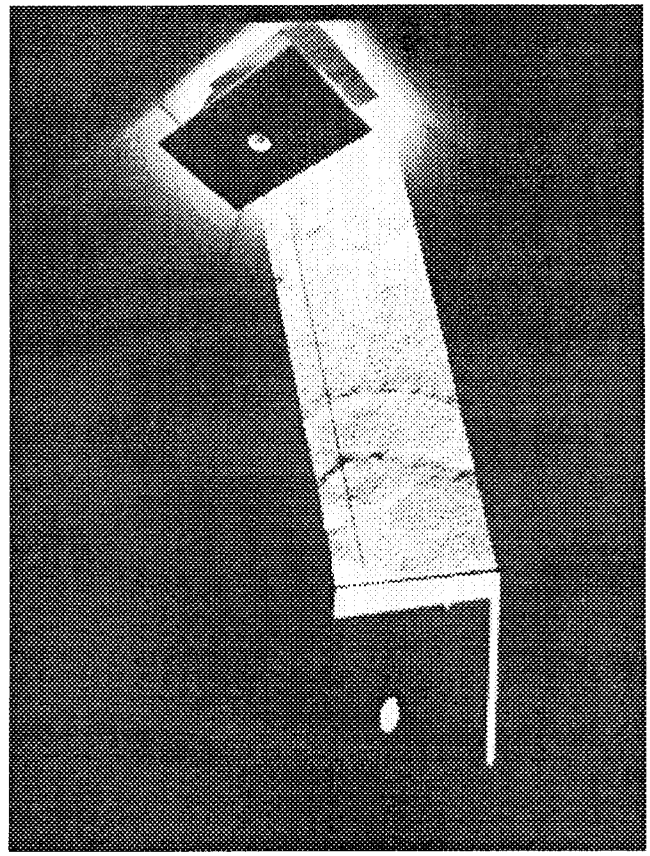

Fig. 1. A. Cavellero, "Registration on wall."

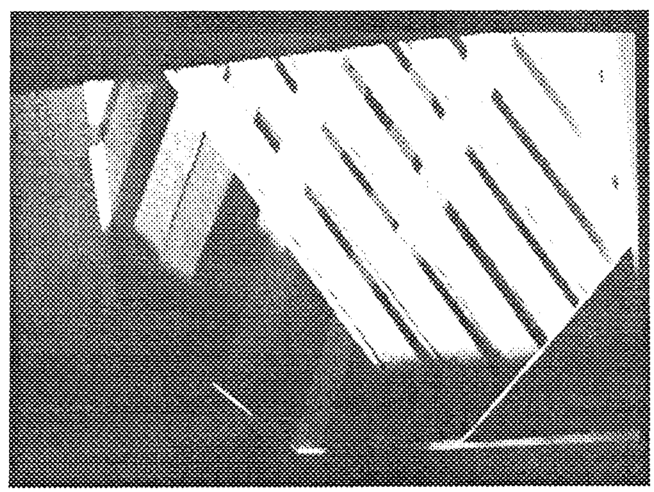

Fig. 2. S. Plant, "Stair Wall."

Explanation

Discussions durinp final course presentations. in particular, forced the use and clarification of the terms elaborated here. It is necessary. but not sufficient, to understand the physical processes of illumination, construction, and perception. Indeed, the act of modeling a phenomena is itself anexplorationanddemonstsationofthe physical processes. The explanations of the other qualities evident in the projects – the play of light and material – directed our attention to a number of topics that were drawn from the work rather than imposed on it and they have slowly became guideposts for the subsequent participants in the seminar. Three topics that have played a role are

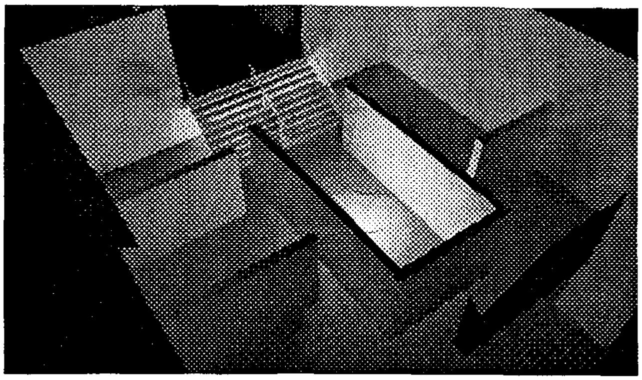

Fig. 3. D. Mahanger and P. Hanfling, "Projected stair."

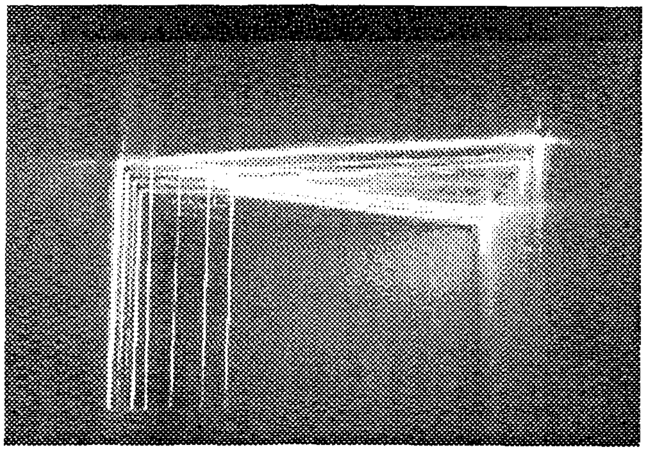

Fig. 4. C. Chung. "Planar optics."

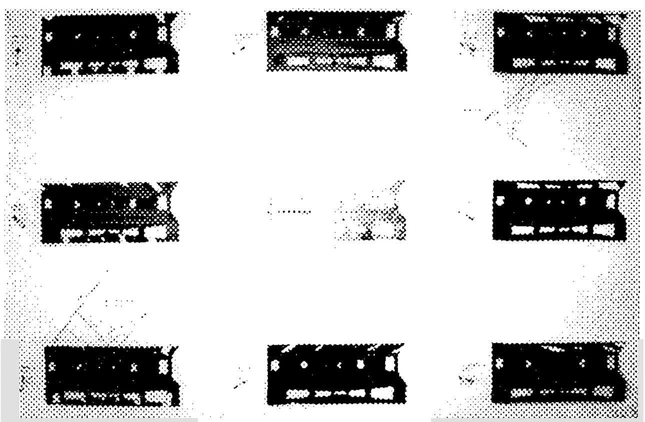

Fig 5 M Cho, "Room with Eleven Windows"

Registration (making visible), Mechanism (concealment or display), and *Times-of-Day*. The topics are not entirely equivalent; attention to *Registration* and to *Times-of-Day* are nearly fundamental conditions of architectural lighting, while the Concealment or *Display of Mechanism* appears to be but one useful topic among others.

REGISTRATION (MAKING VISIBLE)

Registration is generally understood as a permanent recording: ink registers on paper, luminous images register on film, and births and deaths are registered in logbooks. The word can also suggest registrations that are transient or impermanent: surprise registers on a face or temperature registers on a thermometer. It is that sense which is developed here. Light in-and-of-itself is invisible, having no presence until it illuminates some material, whether solid or ephemeral. On the one hand, this is a trivial fact of lighting, we do not "see" radiant flux, but only illuminated objects or surfaces, so any luminous condition that we can discuss has already been registered. On the other hand, we can conceive remarkable manipulations of light, but they do not exist until they are registered and their character is determined by the specifics of that registration. Registration is a "making visible" of the sources of illumination and their mechanisms of production, and using Millet's terms, it can conceal or reveal difference aspects of the architecture. That observation reveals nothing so much as the dramatic nature of lighting: different registrations illumination can tell radically different stories about a project, whether those are rationalized tales about structure and form, or romantic stories about the phenomenological characteristics of attic, cave, and basement.

Among the most enduring distinctions present in architecture is that between form and material. It has been argued that the hylomorphic (matter-form)privileging of form constitutes the disciplinary basis of architectural history and so too of the explanations that architects of the modern period have available to understand their own work.' Not surprisingly, it offers an insightful distinction among kinds of registrations: those that reveal or conceal form and structure, and those that conceal or reveal material qualities, including color. The language available for discussing articulations of form is rich and well developed, while that for examining materiality is much less so. Similar difficulties appear in the modeling of the two different kinds of registration. Both physical and digital models use abstractions and simplifications in their simulation of material properties, while the depiction of formal relations draws on the long tradition of perspectival and post-perspectival representation. Except for a few well-defined phenomena like surface reflection, it is only possible to examine complex material registrations with large or full scale studies.

The ability to easily manipulate artificial sources in digital models, projecting complex photometric fields onto equally complex surfaces, has been revolutionary. It is now possible to explore the design possibilities of sophisticated lamps and luminaires directly throughdigital modeling. In both the seminar andconsulting projects, we have found that the new imaging techniques make illumination startlingly visible and accessible in ways previously unimaginable. Clients have reported that his was the first time they fully understood the implications of a lighting design before it was built. At that same time, these simulations can produce such an illusion of reality that conceptualization and judgement seem suspended; students often fail to recognize or inquire about the principles and purposes of the illumination and in some cases we have limited the use of texture-maps to emphasize the conceptual nature of a model.

With physical scale models many of the most successful and compelling projects began with the detection of an unexpected or unusual phenomena: the glint from the edge of a piece of glass or the color of a shadow. It is those phenomena that are often lost in digital simulations. While it is often possible to model them, they are omitted from digital simulations in the interest of computational efficiency. Digital models simulate what we expect to see, while even small-scale physical models preserve the possibility of unexpected, material discoveries. So, too, with many surface effects, especially those in which complex spectral phenomena are subsumed under the simplified digital description of color. The RGB (Red-Green-Blue) space of the computer monitor provides a barely adequate representation of well-understood and familiar phenomena, largely missing those that are more intricate or variable. These phenomena occupy the attention of the best research on color appearance models, but it will be a while before digital simulations on readily available machines can rival the color modeling of the simplest physical model.[10]

A full scale examination of formal registration was conducted with simple reflector lamps by C. Ames and C. Devlin, flattening and heightening the detail in the neo-classical ornament and at the stair nosings. M. Peters brought worked to make existing columns and stairs advance and recede from the shadows. In a digital model S. Lim inserted a skylight into an existing highway deck to illuminate and emphasize the deep overhead beams currently concealed in shadow and by contrast. An example of material registration was produced early in the seminar by C. Haley, who executed a study of glass etching, studying the interaction between patterns inscribed on the two surfaces of a piece of glass. The "shadows" of the outer etching appear as reversals on the inner etched surface, andcombine in their projection onto the adjacent rooms surfaces. The most startling discovery was made when the sunlight used for the study shifted to catch one edge of the glass (not concealed in a frame). The coil pattern visible in the image was produced by reflections from the very slight irregularities of the cut edge of the glass. It achieves such formal presence because it is splayed across the inner surface of the etching, magnifying both its irregularities and its motion. The topical lesson was simple. The smallest feature in the interaction of material and light can be made visible if the registration accommodates it. And having observed the effect, we could then undertake to digitally model the reflection and refraction produced by the facets at the broken edge.

That particular example occupied the attention of the entire class for quite a while. No one could understand the mechanism producing the phenomenon from the slides, and only after retrieving the model and exposing it to sunlight could we satisfy our collective curiosity. That occasions caused us to recognize that the concealment of the luminous mechanism, in this case the internal reflection from the cut edge, gave the *registration* of the reflection an independent interest not present in directly visible reflections. We were witnessing a pure *play of light.*

MECHANISM (CONCEALMENT AND DISPLAY)

Registration of the sun's motion proved decisive in recognizing the topic of Mechanism. As the animated window advertisements on television illustrate, the sweep of sun through a room is dramatic, but its familiarity only attracts our attention when it is animated and accelerated. That is not say that sunlight is uninteresting, but rather that as a luminous event considered for its own sake its everyday occurrence either encourages no further notice or it only offers speculation about the sun itself. When the source and mechanisms of the light are concealed, then its movement registers as an independent phenomenal entity.

In an example developed from those observations, A. Cavallero undertook to model a skylight which would produce both everyday illumination and a dramatic luminous transformation at a specific date and time. The everyday light was achieved by reflecting or directing sunlight onto the sloped ceiling surfaces, whose texturedmodeled here with paperóproved to be a surface of surprising interest. The singular event was achieved with a beam of light projected from a slot in the skylight. On the "event" day it passes though a whole in the opaque upper surface of a platform into the translucent material below, illuminating and enlivening it. (Fig. 1)

Concealment of Mechanisnz differs from *Registration* in the implicit inclusion of its opposite– theexplicit display ofmechanism. L. Katzmann produced a compelling study of luminaire constructed in two parts, a projecting and a receiving part. The entire piece revolves around the relationship between the two parts and beaming of light. *Concealment* and *Display* always imply or invoke each other, and both change the context of the resulting *Registration* of light. One example that relied on a concealed mechanism that transformed the motion of the sun was a modified skylight by S. Plant. She placed an array of vertical glass fins at slight angles to one another to alter the passage of sunlight through a skylight. She was modifying an existing stair whose wall is briefly bathed in light each day. The installation of the fins above the skylight allowed them to catch and reflect light that would not normally enter the stair. Initial studies aligned the glass planes in a parallel fashion, but while shifting the model the delicately balanced pieces of glass shifted slightly away from the parallel. The resulting arrangement produced a nearly random splaying of light across the wall of registration below. The result was a wall whose illumination varied more-or-less unpredictably from hour-tohour and day-to-day. Moreover, the use of raised fins to catch low angled light yielded a more efficient, productive skylight. (Fig. 2)

As these examples illustrate, physical modeling offers an unexpected and surprisingly rich source of material interactions, but this should not be misconstrued as a dismissal of digital modeling, far from it. The first application of digital modeling to the projects in the course yielded discoveries that would not have been possible with simple physical models. The first digital exercise asked the students to deploy light sources within a model of the main exhibition space at the school. Most of the solutions repeated the terms of the in-class exercise, and were largely disciplined by the assumptions bound up with standard fixtures: downlights shine down, wallwashers wash walls, and so forth. In a few instances, however, students were able to transform the exercise with simple shifts of use and material. The study by D. Mahanger & P. Hanflingachieved aparticular resonance by placing lights under the open stair and changing the color and surface properties of the stair, producing a family of projected illumination. Many of the first digital simulations were surprisingly bound to conventional situations, because the possibilities of the software were so unfamiliar. Even in the analysis of normative conditions, real insight was facilitated by the ability to show the distribution of illumination over the surfaces of the room, eliminating the narrow concern with footcandles at the work surface. (Fig .3)

Material conditions were integral to most of the investigations of Mechanism and, not unexpectedly, the most immediately intriguing material is glass. C. Chung began her project with an exploration of the edge lighting of glass, studying the color shifts produced at different angles of illumination by different types of glass. In the process she noted the beaming and splaying of light produced by the planar optics of the individual glass pieces. She then installed a number of pieces through a south-facing wall in a simple model of a rectilinear room, producing a surprisingly subtle projection and transformation of the sunís motion. The light registers on the surfaces of the room, while the internal reflections of the glass redirects it and, at some angles, multiplies it. That shifting motion and its reclamation lie at the hear of the final topic examined in the seminar. (Fig. 4)

TIME OF DAY, MOTION, AND ANIMATION

The changing position of the sun marks the different times of day and seasons of the year, an observation so trivial that it often escapes observation, but so fundamental that it has inspired projects from Le Corbusier to the Neil Denari. The transformations evident in C. Chung's project exemplify the play of light that the sun's motion makes possible, but it is important to note the role of time. There is a long tradition in European art of representing the four times of day: morning, noon, evening, and night. Michelangelo carved the four figures in the Medici chapel according to this tradition, while engravers from Hogarth to Runge used it as a rhetorical subject with which to display their skill." The convention has its origins in the astrological correspondence of ruling deities and solar position, which was rapidly secularizedat the beginning of the modem period. Hogarth's series, for example, shows the remaining correspondences between time of day and kinds of light, work, and meals. It is these connections that remain vivid today and which can guide the invention of architectural illumination.

A basic design studio exercise suggested some of these connections. Students prepared "developed" interior elevations of their projects at 3 times of day and 3 times of year, showing the projection of sunlight through the eleven windows they were designing and placing. While the basic motivation for theexercise was to examine the lighting effect of the windows, it also led directly to an understanding of thecycles of activity in the project. Thecritical aspect of the exercise was the translation of sun position information to a summary representation, the developed elevation. Similar exercises are certainly possible with digital simulations, but thecritical feature seems to be the depiction of time of day and year. The ability to include artificial lighting will also allow the studies to be expanded to all four times of day, balancing the exercise and invoking the rest of the times-of-day tradition. An open question for next year is the value of animating these studies. Unlike times of day, which direct attention to a discrete moments and occasions, continuous animations direct attention to the path and motion of the light, suggesting a quite different set of topics. (Fig. 5)

Attention to the play of light may offer one of the ihaptic breaksî mentioned by Vidler in the opening quotation. The topical engagement in luminous play may not inoculate its results from commodification in the society of the spectacle, but it does offer an ethic closer to the spirit of building well.

NOTES

[1] "Anthony Vidler: Dinosaurs, Buildings, and Digital Effects," *AA News* (Spring 1998): 4.

[2] Hans T. Malotki, "Toward an Architecture of Light." *Daidalos,* 27: 66-85.

[3] David Leatherbarrow, *The Roots of Architectural Invention: Site, Enclosure, Materials* (Cambridge: Cambridge University Press, 1993).

[4] Marietta Millet, *Light Revealing Architecture* (New York: Van Nostrand Reinhold, 1996).

[5] An earlier version of this paper was presented as: "Registration and Concealment: Rhetorics of Architectural Illumination," *Proceedings,* ACSA Technology Conference, Dallas, Texas (March, 1997).

[6] Sebastian de Grazia, *Of Time, Work, and Leisure* (New York: The Twentieth Century Fund, 1962), p. 17.

[7] The sundials and methodology were drawn from: Fuller Moore, *Conceptsand Practices of Architectural Daylighting* (New York: Van Nostrand Reinhold, 1985).

[8] For information on Lightscape visit: http://www.lightscape.com/. Lightscape does make a simplification in its modeling of windows and theskydome, whichmakesit'ssimulationless than perfect. For more accurate daylighting, we are waiting for the windows version of Radiance: http:/!www.pge.com/pec/daylight.

[9] The hylomorphic tradition was traced in: David Summers, "Form and Gender," *New Literary History*, 24 (Spring, 1993): 243-71. A revised version can be found in "Form and Gender," *Visual Culture: Images andlnterpretations* (Wesleyan University Press, 1994).

[10] Mark Farrchild, *Color Appearance Models* (Reading, Massachusetts: Addison-Wesley, 1998).

[11] My informationon the times-of-day traditionlargely comes from the Doctoral research of Tonkao Panin. See for example, Sean Shegreen, *Hogarth and the Times-of-the-day Tradition.*