

Documents of Light: Three Case Studies and a Preliminary Model for Organizing Light Knowledge

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Abstract: The proposed area of Documentation studies offers a useful framework for the consideration of transdisciplinary subjects that do not respond fully to critical theories currently prevailing in the humanities and social sciences. This paper will apply a documentation approach to the study of light by examining case studies drawn from theatre, architecture and computer science. Scholars, scientists and lighting practitioners create and employ documents that encode illumination knowledge, which can be understood as the manifestation, simulation or manipulation of light to a particular end. A model encompassing the human body in illuminated space will be suggested as a means of classification, and different document types will be interrogated to suggest the sort of visual arguments and artifacts that can be constructed to demonstrate and communicate illumination knowledge.¹

1. Introduction:

Let us begin by imagining glowing documents of light. As we hold one in our hand, we notice that it illuminates nearby objects. Light flares around our fingers where we touch it, and diminishes in intensity as it falls off down our arm. As we move the document towards our eyes, our face grows brighter and the specular highlight in our eyes widens. We begin to manipulate the document's shed radiance, and note that as we move it closer to smaller objects their shadow softens and grows more diffuse. This imaginative exercise prepares us for a more abstract grasp of documents of light, one which is dependent neither upon physical artifacts, nor upon light effects in real space. Broadly conceived, we may say that documents of light encode and organize the illumination knowledge of lighting practitioners working in real or virtual space. Arguments can be constructed from light documents of all types: expense accounts, theatre lighting plots and wiring plans, graphic and photographic materials, or digital lighting algorithms, to name a few. One goal of understanding light documents is the literal or imaginary reconstruction of illumination environments that allows us to grasp the lighting knowledge of the practitioner. But we will notice that documents of light demonstrate different levels of abstraction, and admit varying degrees of visualization. An expense account from a renaissance court, for example, that notes the quantity of candles purchased for a performance does not in itself allow that illuminated hall to rise up before our eyes. What is called for is a nuanced manner of classifying light documents that allows for useful understandings about light to emerge, and we will find that envisioning the human body in illuminated space goes a long way towards providing these terms of reference. Once we have developed a more sophisticated eye, we may turn back to our

imagined light documents, and find that each glows in a unique manner, some bright and some richly dark, others with subtle coloration or complex patterning.

2. Documentation studies and the study of light

The transdisciplinary study of light serves as a quintessential test of our commitment to question existing disciplinary boundaries, and to form new disciplines that better serve human needs. Indeed, light is in many ways an ideal subject for our times. Light remains a puzzling scientific limit case to in so many ways: it represents the ultimate in speed, though researchers have recently succeeded in stopping it by sending it through clouds of supercooled particles. Its nature as both wave and particle make light the quintessence of modern uncertainty. As a design substance it could be claimed that light will be the construction material of the 21st century.ⁱⁱ Illumination has long been acknowledged as the basis for our perception of form and space, but there is a renewed awareness of its importance in the world of digital design. Through laser technology, the control of fiber optics and the phosphors of new digital media, light will bear the imprint of communication, record and expression. Light and its effects are richly evocative—light can be studied and manipulated as sense phenomenon, as mood regulator, electromagnetic radiation, or as the binding element of filmic media and architecture. Light is simultaneously physical and metaphysical. As a multifaceted phenomenon, light offers a perfect locus for developing new interdisciplinary discourses that attempt to bridge the gap between art and science that has drawn so much attention over the last 40 years (Snow, 1993).

But the study of light has been awaiting new critical tools. Light as a transdisciplinary subject responds incompletely to two common interpretative models within the humanities and social sciences: semiotics and media theory. Although at least one writer has productively explored “codes” of illumination, it can be argued that the linguistically-derived study of signs offers a constrained, even counter-intuitive starting point for a deeper exploration of how a physical phenomenon such as light can “subconsciously matter (Boone, 1997).”ⁱⁱⁱ The limitations of semiotics as a means of interpreting sense experience has in fact recently spurred critical efforts aimed at decoupling our understanding of the senses and sense phenomena from linguistics, and insisting upon exploring the way in which the body creates its own meanings (Howes, 2005). This approach acknowledges the contributions of McLuhan, whose media theory places the human body and sensorium in a central position.

Any consideration of light from a purely media theory perspective, however, quickly founders upon the fact that light can be either naturally occurring or artificially produced, and thus does not really qualify as a “medium” (one could, perhaps, substitute the older, more painterly definition of medium as a “binding substance”). McLuhan’s simplest usage can serve as a test: a medium can be defined as a human process or artifact that functions as an extension of the senses (MacLuhan, 1998).^{iv} Moreover, the strength of media theory is in exploring the ways in which meanings arise within, and are inflected by conversations between media (Bolter and Grusin, 1999).^v The difficulty here of course is that light is manifested both within and outside of our experiences of media. We

encounter illumination in representations, simulations and real space. The relationship between the domains is crucial. Let us presume a situation in which one views a movie of a dark alley, then leaves the theatre and walks down a dark alley. Are the two experiences analogous?^{vi} If so, then media theory cannot provide an exclusive vocabulary for our response to light. Some portion of our experience of light can survive abstraction to the film screen (to a 2d plane), scaling (to a portion of our visual field) and dislocation in time and space. A transdisciplinary light studies can begin to provide terms of reference to help us understand this relationship.

So in order to move forward, it is clear that the study of light requires an expanded critical toolbox. One could begin by drawing from other obvious sources in the social sciences, including perceptual psychology, as well as natural sciences. But if one is to avoid fragmented and confusing arguments, it is also important to identify a framework of scholarly practice that can provide a kind of intellectual superstructure. Documentation studies, as outlined by Niels Windfeld Lund, can supply this sort of scaffolding:

“Documentation Studies is defined as a new discipline dealing with forms of documentation by studying the production as well as reproduction of documents of all kinds (Lund, 1999).” One of the sources of Documentation studies’ appeal is that it grows out of library and information sciences, and so is a capacious practice. As such, the discipline offers the “possibility to transcend the borders of film, literature, paintings, and other media, which are normally dealt with in a number of specific scientific disciplines for each kind of documentation (Lund, 1999).” Another benefit of Documentation studies’ roots in LIS is that it inherits some of the taxonomic rigor of the parent practice. This is especially useful when dealing with the subject of light. A survey of writings on light uncovers a tendency towards flowery and poetic excesses, perhaps an unavoidable overcompensation that results when attention is directed towards a phenomenon whose omniscience and subtlety of effect leave it frequently ignored. Indeed, the sketching of sense phenomenon taxonomies is one of the key tasks in the post-semiotic effort to recognize and reclaim our sense experience. Finally, documentation studies offers a vocabulary for moving beyond the prevailing reception theories, and allows us to redirect attention to the processes of making and using artifacts (Lund, 1999).^{vii}

As a means of testing a capacious, rigorous intellectual practice that allows us to explore the processes of the documenting light scholar and lighting practitioner, I propose examining case studies drawn from three diverse and challenging domains: Shakespearean theatre scholarship, night architectural illumination, and computer lighting algorithm construction.

3. Lighting the Shakespearean stage

Imagine the plight of the Elizabethan theatre scholar: almost all of her conclusions regarding illumination in Shakespearean performance must be drawn from the indirect evidence of court expense accounts, second-hand reports from travelers’ journals, and a few graphic sources. It is only in the past few years that theatre reconstructions (such as the new Globe) have enabled scholars to take of photometric readings in environments that are themselves the result of speculation on physical and documentary evidence.

Faced with these constraints, the theatre historian has had to become a masterful interpreter and manipulator of documents. In *Lighting the Shakespearean Stage*, R. B. Graves argues that the illumination qualities in outdoor and indoor theatres were not as different as previously thought, and that, unlike the highly directional lighting to which we are accustomed in the contemporary theatre, “early English lighting emanated from all around the actor, surrounding him with soft, indirect light. . . . The actors moved in the same light all Londoners moved in everyday (Graves, 1999).” The organization of each of Graves’ chapters follows a similar pattern: an argument is constructed that ultimately allows the visualization of an illumination environment. This from the conclusion to his chapter on illumination of the outdoor playhouses: “The general picture of the amphitheatres that emerges is one of a well-shaded stage with neither artificial light for general illumination nor the extreme contrasts of light and dark due to direct sunlight. As an actor came forward toward the foot of the stage, the light would increase slightly because the cover overhead intercepted less light.” Besides the rigor of his arguments, Graves’ work is compelling because it allows us to more fully imagine the conditions of Elizabethan performance.

Although one can certainly savor the line of Graves’ arguments, it is important to list the types of documents that he marshals to defend his thesis, and note the manner in which he employs each type. Graves’ reasoning tends to move from what is known about an illumination environment to what can be deduced or must be argued, then back to more direct photometric evidence and interpretation. In his chapter on “Daylight in the Indoor Playhouses,” for example, he begins by interrogating the written evidence concerning performance times, as this information allows the author to determine exterior light levels, given time of day and presumed atmospheric conditions. He then looks at court expense accounts to determine patterns of candle purchase, which allow for arguments on artificial light levels.^{viii} The next step is to examine existing examples of halls whose dimensions are similar to those of indoor playhouses, noting the placement of windows and predominating light qualities, as well as taking photometric readings of the light levels. Graphic sources are employed to several ends: architectural cross sections demonstrate spatial relationships and suggest illumination directions from windows, and an engraving from a book frontispiece shows the sort of relationship between window light and artificial sources that may have existed. Graves’ concludes that though light levels were lower in indoor than outdoor playing spaces, the difference was well within the range of human visual adaptation: “In consequence, we must not think of the adult private theatres as dim, at least not in the early afternoon. On the contrary, we may imagine them as satisfactorily lit even by our own standards and entirely adequate by medieval and early modern standards.”

We may draw several broad conclusions about Graves’ use of light documents:

1. **Written evidence** is often (though not always) used to support arguments about light levels, the quantity of light present in the environment.
2. **Graphic evidence** is often employed for spatial understanding, and to answer questions such as: where were lights positioned with reference to the stage? Where were windows located? Where would shadows fall? Given that light

intensity diminishes as it moves from its source, how much light could be expected to reach the acting area? What was the predominating light direction?

3. **Photometric evidence** is used to determine absolute illumination levels, and interpreted in conjunction with what we know about human visual response to light.

By nimbly manipulating these types of light documents, Graves is able to conjure up for us a vivid imagining of the qualities of light under which Shakespeare's work was first performed.

4. Writing light

But scholars aren't the only ones who must master documents of light. Lighting practitioners who rely upon documents to communicate their designs to clients must, by necessity, be quite knowledgeable about what documents can, and cannot communicate about light. The conditions of night illumination offer a particular challenge to the documenting lighting practitioner, as nocturnal contrast ratios are often beyond the capacity of most filmic materials, and photographic results do not correspond well with the eye's visual range and capacity to adapt. Lighting designer Louis Clair has produced a number of large-scale light installations for urban spaces in Europe, Asia and Canada. In "*Écrire la lumière*," Clair wrestles with the limitations of different kinds of light documents, and proposes a technique of describing light "ambiances" as a means of constituting a communicable "light writing" that can eventually aspire to the precision of musical notation (Clair, 2000) Clair's development of the concept of illumination ambiances grows out of his dissatisfaction with the current media of light representation: "The lighting designer . . . creates images to present his project, but the images themselves remain subject to interpretation. They are unable to fully simulate contrasts of color or the perception of light in real space." Though digital media offer the semblance of greater fidelity, 3d graphics fall short for similar reasons. "Digital images remain, in spite of this precision, approximations, for, like other techniques, they can communicate neither the effects of vision in real space, nor the capacity of the eye to perceive gradations of light much greater than analog or digital media can reproduce."

Clair seeks to expand the realm of light documentation by moving away from imaging media towards literary description and the development of a taxonomy of light effects. His survey of light documents begins with the standard documentation that accompanies a project proposal. The light plan is "an inventory of elements to illuminate and several recommendations regarding the urban context in which they are found." Far more important to the designer's intent, however, is the development of the appropriate ambiances. Clair derives the term ambiances from cinematography, but his use of the term is strongly influenced by literature: "The client couches his expectations in literary terms describing the feelings inspired by the light environment. The lighting designer must translate these terms into the values and vocabulary of light in order to create ambiances." Clair outlines eight types of ambiances: festive, convivial, majestic, discreet, romantic, theatrical, poetic and functional. Each term is associated with specific social models and light qualities—"Festive ambiances are those which preserve the illumination

qualities of festivals, fairs, etc. They are characterized by the presence of numerous sources of multicolored light in the space, quite brilliant, even aggressive.” The “values and vocabulary” of light through which the ambiances are conveyed include:

1. **Characteristics of light:**
 - quantity of light: flux in lux
 - quality of light: color rendering index (IRC)
 - color of light: color temperature in degrees Kelvin
 - colored lights: expressed in usual terms, or in spectral curves (or in terms of color filters)
2. **Lighting direction:**
 - elevation: high, low, frontal
 - plan: face, profile, reversal of daylight
3. **Shadows:**
 - density, edge quality of shadows
 - existing shadows or those imposed by sources
4. **Contrasts:**
 - hardness, positive or negative contrasts
 - contrasts of color temperature or filtration
5. **Illumination** in the visual field:
 - qualities of the illuminated areas
 - composition of illuminated areas
6. **Character** of light sources:
 - quality of the sources
 - disposition of the sources
7. **Animation** of light and shadows:
 - used infrequently in permanent installations

Clair thus attempts to impose a higher-level taxonomic order upon the shared, often parametric vocabulary of the lighting designer. If his effort falls short, it is because his 8 ambiances—though perhaps useful—certainly cannot be considered an exhaustive list of the illumination environments one might want to create, and the mapping between higher-level ambiances and basic light parameters is not always made explicit.

5. The Phong algorithm

Night illumination and digital lighting algorithms share an important condition: it is always night in the computer. All computed illumination simulations must take into account everything we know about light, and instantiate that knowledge in a way that imposes various economies upon the highly complex behavior that we observe in real space.^{ix} Lighting algorithms, then, demonstrate a kind of abstract, meta-level, though incomplete organization of light knowledge. The Phong shading algorithm can serve as an example. In 1975, Bui Phong at the University of Utah proposed a shading technique which proposed to advance the quality of computer generated images of three-dimensional scenes: “Human visual perception and the fundamental laws of optics are

considered in the development of a shading law that provides better quality and increased realism in generated images (Phong, 1975).”

Here is a shading algorithm based on Phong’s work (Manchester University notes on computer rendering):

$$I = k_a I_a + \frac{I_p}{d+d_0} [k_d (\mathbf{N} \cdot \mathbf{L}) + k_s (\mathbf{R} \cdot \mathbf{V})^n]$$

The algorithm exhibits several key elements:

1. Vectors (N, R, L, and V), which represent **spatial information** about position of the viewer (V), the reflected ray (R), position of a light source (L), as well as the orientation of the surface at the point being shaded (N).
2. Exponential and fractional terms, the remnants of the inverse square law, which introduces falloff to the solution, the diminishing of **intensity of light** as it moves away from its source.
3. Material constants (ka, kd, ks) that represent the **characteristics of the surface** being shaded.

What sets Phong’s function apart from previous solutions (including Gouraud) is the more accurate rendering of the specular highlights that appear on glossy surfaces:

“The first step in accounting for the specular properties of objects and the position of the observer is to determine the normal to the surface at each point to be shaded . . . it is only with this knowledge that information about the direction of reflected rays can be acquired, and only with this information can we model the specular properties of objects.” (Phong, 1975)

Phong tested his algorithm by comparing computer renderings with photos of glossy spheres to demonstrate the presence of specular highlights.

As a system of organizing light knowledge, the algorithm draws upon three main historical threads. The observation that light bounces off a shiny surface at the same angle as it approaches was noted in a text on mirrors ascribed to Euclid, the *Catoptrics*, which had practical applications for those wishing to start fires (Park, 1997). The vectors (R), (L) and (N) instantiate this knowledge in the algorithm. The second historical document present in the algorithm—the inverse square law—is drawn from Newton’s body of work, and applies to forces in addition to light (such as gravity) that emanate from a point source. The final historical echo is Johann Lambert’s cosine law, which describes how the bright a diffuse (matte) surface appears depending on its orientation to a light source, first published in the *Photometria* from 1760 (Seds.org). The dot products, surface constants and vectors represent Lambert’s insight in the algorithm. But of course it was Phong’s elegant solution that brings the knowledge together in a form that allows a subset of light’s behavior and effects to be efficiently demonstrated in computer renderings.

6. A Preliminary model for organizing light knowledge

The shading algorithm's character as a kind of meta-document gives us clues as to how to begin organizing light knowledge, though to be truly useful we must expand our model beyond Phong's more limited intention. . In insisting on a richer conception of the receiver of light than Phong's simple view vector, we can hope to accommodate more capacious understanding of light's significance and meaning to people. As we have seen in our examples of thought on light from theatre history, night illumination and computer graphics, light documents can be organized by imagining the human body in illuminated space. More particularly, we can examine light documents with respect to the way in which they encode the following kinds of knowledge about light:

- 1. Knowledge of the body and embodied mind**
- 2. Spatialized knowledge of light**
- 3. Knowledge of light sources**
- 4. Knowledge of surfaces**

Knowledge of the body and embodied mind obviously incorporates everything we know about perception and psychology, the visual and non-visual effects of light, our ways of thinking about light and its associations. Spatialized knowledge of light behavior informs our understanding of how light reverberates through a space, and, as we have seen in our survey of writings on light, can be extracted from graphic materials or encoded in algorithms—as Phong did—through the language of vectors. Knowledge of light sources encompasses everything we can observe and conceive about sources themselves, often expressed through measurements such as color temperature and photometric readings, but also able to accommodate our poetic and artistic understanding. Finally, our knowledge of surfaces, so important to our evolutionary development and survival (Gibson, 1987), accommodates both our tacit knowledge of things and all the ways we have developed to describe, represent and make surfaces. Obviously, many types of documents encode more than one type of light knowledge, so the model is something less than a rigorous taxonomy, but at least it can begin to help organize discussions about light between those who care about it.

7. Conclusion

Anyone proposing to reorganize existing knowledge structures has the burden of demonstrating the potential benefits of the task. I would argue that cutting a fresh cross-section through existing knowledge structures will have the benefit of bringing lighting practitioners and documents into conversation with one another in a way that does not privilege existing disciplinary practices. A quick survey of current lighting design and research shows a range of recording practices. Cinematography and film lighting still exhibit a guild-like organization in which light knowledge is often tacit and passed from masters (or directors of photography) to apprentices (grips, gaffers, camera operators, etc). There is no such thing as “cinematography research.” Much of the lighting knowledge of great cinematographers inheres only in their film work, and accessing that knowledge is a very different task from, say, reading the sort of documents that emerge

from the current scientific research on light. It is the aim of a study of light documents to facilitate the transfer of light knowledge from one group to another. The potential benefit of this transfer would be the application of light knowledge to new domains of illumination practice, with the goal of enriching our experience of light in our daily lives. It is through this sort of exchange that light can fulfill its potential as the construction material of the 21st century.

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9. References

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ⁱ My use of the word “demonstrate” in this article draws upon the etymological presence of the word in the Latin roots of the word “document,” as pointed out by Niels Winfeld Lund: “the word document is originally composed of two parts, the verb *doceo* and the suffix *mentum*. *Doceo* means to show, to demonstrate, to instruct, to make a play (drama).” From *Documentation in a complementary perspective*.

ⁱⁱ Perhaps the most poignant example of recent light architecture was the memorial to the World Trade Center and its victims in the fall of 2001.

ⁱⁱⁱ Boone aims “to demonstrate how lighting-as-sign is functioning at the three basic levels of semiotic signification.” (p. 85). Part of the power of light, to my way of thinking, is that it does not “communicate” in the traditional manner of sign systems, and so we might need to expand our approach to the subject beyond semiotics to truly understand the way in which light can “subconsciously matter” (Boone quotes theatre lighting designer Tharon Musser on page 86). But Boone’s handling of theatre lighting documents is particularly sensitive: “Three resources primarily inform my speculations on Rosenthal’s use of light in *West Side Story*: production photographs, the focusing charts for the 1959 national tour of the show . . . and stage directions as they appear in the 1958 acting edition of the script. In order to speculate on the contributions made by Rosenthal’s lighting design, I use both indirect evidence found in the focusing charts, color charts, and stage directions as well as the more direct evidence provided by production photographs” (p. 84).

^{iv} McLuhan cites the electric light as a limit case early in *Understanding Media*: “The electric light is pure information. It is a medium without a message, as it were. . . . Whether the light is being used for brain surgery or night baseball is a matter of indifference. It could be argued that these activities are actually the “content” of the electric light, since they could not exist without the electric light. This fact merely underlines the point that “the medium is the message” because it is the medium that shapes and controls the scale and form of human association and action.” McLuhan (1998), pp. 8-9.

^v This is the argument of Bolter and Grusin (1999): “No medium today, and certainly no single media event, seems to do its cultural work in isolation from other media, any more than it works in isolation from other social and economic forces. What is new about new media comes from the particular ways in which they refashion older media and the ways in which older media refashion themselves to answer the challenges of new media.” (p. 15)

^{vi} The anecdotal evidence from cinematographers would suggest yes. In his memoirs, famed cinematographer Henri Alekan, who created the images for Cocteau’s “Beauty and the Beast,” ascribes his education as a cinematographer to observation of light in nature, as well as to examinations of paintings. (see Alekan’s great book on cinematography, *Des lumières et des ombres*)

^{vii} Lund (1999). “Doc.Studies is primarily focusing on the producer or sender of the message and secondly on the use or reproduction of the documents.”

^{viii} Graves (1999), p. 129: “As it happens, the best estimate of candlelight employed indoors comes from a proposed article of agreement between housekeepers and hiring actors at Salisbury Court in 1639. In the agreement, the housekeepers agreed to pay half the cost of the lights, “both wax and Tallow, which halfe all winter is near 5 s a day.” As will be discussed in the next chapter, it is from such a figure that we can make a more-or-less intelligent guess about the number of candles used at Salisbury Court in the winter. Depending on their size and the proportions of expensive wax candles to cheaper tallow ones, the total number works out to about two to four dozen candles for each performance—a goodly number, to be sure, but in actual brightness not even equal to the power of one sixty-watt bulb.” One convenient fact about studying candles as a light source is that their output corresponds to a common unit of measurement—the footcandle.

^{ix} Producing a computer-generated rendering begins with the process of defining a geometric model expressed within Cartesian space. The visual characteristics of every surface must be determined and the

position of lights specified. The renderer then employs lighting and shading algorithms to produce a 2d image of the computer generated environment.