CREATING A COORDINATE DATABASE FOR THE LIGHTING OF THREE DIMENSIONAL ART OBJECTS

A THESIS
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By

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May, 2003

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts.

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ABSTRACT

CREATING A COORDINATE DATABASE FOR THE LIGHTING OF THREE DIMENSIONAL ART OBJECTS

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This thesis proposes a Lighting Coordinates Database for the illumination of three-dimensional art objects. Finding and defining the weak points of current lighting methodology reinforces the importance of the need for such a database. The two methods of obtaining data for this database, the computer software and hardware method are described. For the case study, the head of Michelangelo’s David is chosen. By using the software method, the scanned image of David is illuminated and an example database is created. As the second method, a prototype of a lighting model, David’s scaled model is illuminated by using LED light sources and another example database is created.

Keywords: Lighting, Museum and Art Gallery, Exhibition Lighting, LED Technology, Lighting Coordinates Database.

ÖZET

ÜÇ BOYUTLU SANAT NESNELERİNİ AYDINLATMAK İÇİN KOORDİNAT VERİTABANI OLUŞTURULMASI

Ekrem Erhan Dikel

İç Mimarlık ve Çevre Tasarımı Bölümü

Yüksek Lisans

Tez Yöneticisi: Doç. Dr. Cengiz Yener

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Bu Tez, üç boyutlu sanat nesnelerinin aydınlatılması için bir Aydınlatma Koordinatları Veri tabanı önermektedir. Günümüz müze ve sergi aydınlatmasının eksik yönleri irdelenmiş ve böyle bir veri tabanına duyulan gereksinimin önemi vurgulanmıştır. Veri tabanı oluşturmaya yönelik olarak iki yöntem önerilmiştir. Bilgisayar yazılımı kullanma ve bir ilk örnek olan aydınlatma donanımını kullanma. Deneysel çalışma için, Mikelanj'ın Davut adlı eseri seçilmiştir. Davut, ilk yöntem olan bilgisayar yazılımını kullanarak belirli koordinatlardan aydınlatılmış ve bir örnek veri tabanı oluşturulmuştur. İkinci yöntem yardımıyla eserin ölçekli bir kopyası, donanım altında LED ışık kaynakları yardımıyla aydınlatılmış ve ikinci bir örnek veri tabanı oluşturulmuştur.

Anahtar Kelimeler: Aydınlatma, Müze ve Sanat Galerisi, Sergi Aydınlatması, LED (Işık Yayan Diyod) Teknolojisi, Aydınlatma Koordinat Veri tabanı

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1. INTRODUCTION

The Illuminating Engineering Society of North America (IESNA) defines a museums' highest responsibility as "to study and take care of its collection and to manage the collections' effective public display" (7-33). In order to display a collection effectively, museum directors or curators should carefully plan a visitors' traffic flow, the objects' security and preservation, exhibition units' design as well as their lighting scheme. When we look from the side of lighting issues, *effective public display* in a museum is a challenge of designing and thinking about two parties together. On one hand there is the artists' creation, the *object*, and on the other hand the *need* to illuminate object by using an artificial light source. The successful approach is the one which finds a solution to the need of illuminating the object with the closest appearance on artists' mind.

When we look at the current lighting methodology, curators or lighting designers illuminate art objects according to their own cultural backgrounds, design skills and creativities by using current lighting techniques and technologies for a specific exhibition or display. Naturally, because of this straightforward approach, the same object can be illuminated very differently by various people in another exhibition or museum. Artists, despite the fact that they created the objects, have no control on the lighting design and the resulting effect of their creations. However, “transmitting the artist’s values on objects, to spectators through lighting techniques without changing the meaning”, is defined as the scope of lighting designers’ profession (IES Lighting 1-1).

The aim of this study is to propose a database, which enables artists to have control on appearance of their creations in exhibitions, and guide curators and lighting designers by giving them the coordinates of the locations of light sources. This proposed system, which is called Lighting Coordinates Database (LCD), can be established for art objects by either using computer software or a three-dimensional lighting model prototype, Spherical Lighting Positioning System (SLPS).

In future exhibition designs, the desired illumination effect in the artists’ mind will be created when we install the light sources according to the coordinates defined in LCD of a specific art object. A predefined database of lighting coordinates can help to create a standard appearance of an art object in every exhibition, and it can help curators while designing the lighting scheme.

The first LCD establishing method, which will be described in detail, is using computer software. It is possible to digitize the external shape and surface characteristics of a physical three-dimensional object or its scaled model by using laser rangefinder technology. By this process, it is possible to illuminate a three-dimensional art object from every coordinate by virtual light sources.

Many computer software, such as 3D Studio Max®[1], Lightscape®[2], LitePro®[3], Radiosity®[4] ,Radiance®[5], and Adeline®[6] enables us to find the coordinates of the light sources' location by three axes x, y and z.

The other method is using a physical lighting model. A prototype of an SLPS device is introduced in this study. It has a base and a head, which are connected together by vertical tubular ribs. Those demountable ribs can be put into any hole on the head and base, to find out the azimuths[7]. Light sources are movable and to find out the altitudes[8], they are slid on the ribs. Every light source, which is located on the SLPS, has a specific coordinate, and lighting designers can turn on, off and dim the light sources on the model.

While using SLPS, lighting designers are not the only authority to decide the appearance of the object and they must be supervised. If the artist of the object is living, he becomes the supervisor. In many cases, the creator is deceased, unreachable, or unknown. Then, a committee of art historians who are qualified about a specific artist or era can become supervisors to find out the most satisfactory lighting coordinates.

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1 **3D Studio Max is registered trademark of Discreet™ Company.**
2 **Lightscape is a registered trademark of AutoDesk Inc.**
3 **LitePro is a registered trademark of Hubbell Lighting Inc.**
4 **Radiosity is a registered trademark of Carnegie Mellon University, School of Computer Science.**
5 **Radiance is a registered trademark of Lawrence Berkeley Laboratories, in Unix**
6 **Adeline is a registered trademark of IEA**
7 **The angle between the projection of the solar ray on the horizontal plane and the true South.**
8 **The angle between the ray of the sun and its projection on the horizontal plane.**

Each museum or art gallery can develop its own SLPS device, with desired technology, scale, and material in accordance to their budget. In future, their devices can be integrated with computer systems and can be much more easy to use.

Due to the advantages that will be given in detail on the following sections, Light-emitting Diode (LED) technology is chosen as the light source for this lighting model prototype. SLPS is used together with LED technology to identify the coordinates of light sources to achieve the best satisfactory lighting result for the supervisors.

Chapter two of the study mainly focuses on display and exhibition lighting in museums and art galleries. This chapter includes principles of exhibition lighting and some common lighting design criteria about how to illuminate the museum objects. Defining the boundaries of museum and art gallery lighting is essential to understand the necessity of an LCD.

In the third chapter, the substance of the study is shaped. While exhibiting their art objects, many artists have an idea of the location of light sources, and the overall lighting scheme on the exhibition. If the artists are living, they generally try to communicate with lighting designers or curators, and their objects are illuminated according to the skill of lighting designer. It is a fact that the final illumination of their artworks are generally different than their thoughts. To emphasize this situation, three artists and their artwork were chosen in an exhibition held in Bilkent University. With personal interviews and illustrations, the importance and necessity of this miscommunication is studied.

If the artist is deceased or the exhibition is far away from him, he has no control on the illumination of his object. This is the current lighting situation in museums and art galleries and the need for a technical documentation, in the study proposed as LCD, is essential. This chapter continues with explanation of the proposed *Lighting Coordinates Database* and its working principle by comparing the proposal with the current lighting methodology. The importance of LCD for the art objects is tried to be highlighted. The two methods of obtaining coordinates: the computer software and physical model will be introduced briefly in this chapter.

The fourth chapter is about the first LCD establishment method, using computer software. Major software, which is being used widely in the current computer-aided design market, will be introduced. The description of the digitizing process of transformation of a real art object into virtual data and the method of obtaining lighting coordinates are the major parts of the chapter.

The next chapter is about the second method, namely the proposed lighting model, SLPS. This fifth chapter explains the description of such a model as well as the most appropriate light source that should be used in both model and actual exhibition cases, in the future. In this chapter, the chosen lighting technology, LED will be described by their light emitting principles, physical, and chemical components, most common applications, their advantages and disadvantages.

In the sixth chapter, the conducted case study is explained. As a model for the case study, the head portion of Michelangelo's David is chosen. Because Michelangelo is deceased, his artwork is tried to be illuminated by the thoughts of art historians. The special characteristics of Renaissance era and the history of sculpture are the guides for establishing an example LCD. In addition, the theme of the sculpture, a young shepherd boy who is going to kill a giant with his sling and a stone, is examined. By this way, the appearance of David's face and require lighting effect is figured out. Illuminating this model by SLPS and computer software separately creates two example LCD's. The evaluation of the two methods, while creating this example is discussed.

The two methods of obtaining coordinate data, using computer software and physical model, have their strong and weak points. The seventh chapter is dealing with this comparison and the discussion of the two methods.

2. EXHIBITION LIGHTING IN MUSEUMS AND ART GALLERIES

Light in museums is one of the essential factors to perceive an object. The conscious organization and design of lighting equipment emphasizes the appearance of texture, form and colors of objects. This chapter explains light in museums and art galleries, its quality and requirements as well as the harmful radiations, which must be in control.

2.1. Exhibition Lighting

In order to talk about the necessity and the methods of establishing an LCD, properties of exhibition lighting have to be examined beforehand.

Lighting designs in museums and art galleries differ in some important aspects from other types of lighting design.

The aim in museums is different from other display lighting settings. One major mistake in museum lighting is that sometimes their lighting design becomes similar with shop display windows. On storefronts, the aim is to attract the customers in order to buy a product. In the case of museums, however, the important thing is to highlight the perception of form, texture and three-dimensionality of the object.

Exhibition lighting design affects several important groups including museum curatorial, educational and conservation staff, lighting designers, and visitors. Effective lighting scheme must balance the concerns of each group. The aim is to have this balanced lighting design in museums. Groups in a museum are in close relation with each other, and a failure of one group causes a chain reaction, results a problem in perception of objects. For instance, if a curator misunderstands the concept of a specific Renaissance sculpture, the lighting designer is guided incorrectly. Visitors will not be able to feel and to live the humanism of that era.

Exhibition lighting is difficult, because it has a complexity in its context. There is no specific lighting method for the museums, and creating general rules about lighting is impossible. A huge variety of material types and the number of objects requires very different lighting techniques and all these issues can not be collected under a headings or rules.

2.2. Lighting Quality

Without light, we cannot see anything. Light, which is reflected from the object reaches our eyes. This leads us to see the object. Therefore, the quality of light is the major requirement for good visual conditions especially in a place where the visual medium is an art object.

In order to reach satisfactory visual conditions, required illuminance levels for museum and exhibition lighting should be obtained. These data can be found in different tables. Especially the International Council of Museums (ICOM) has published the lighting requirements for each type of museum object and material, their quality and exposure time. However, one should not forget that the aim of illumination is to satisfy good visual conditions, not to obtain a required illuminance level by just transferring the data from table to lighting schemas (Tural 43).

Veitch defined lighting quality as a term “used to describe all of the factors in a lighting installation that are not directly connected with quality of illumination” and she proposed that “it exists when the luminous conditions support the behavioral needs of individuals in the lit space” (126). Although she is not describing quality of light in exhibition environments, the relation between the visitors’ need and the museum objects are debatable in her definition. Another definition of lighting quality is done by Lam (70).

> One cannot derive any simple quantitative formula to predict either the meaning, which will be given to a particular stimulus, or the emotional and evaluative responses, which it will trigger. The higher the strength, quality, and information content of desirable visual stimuli the better we can see. People perceive information and visual relationships, not absolute intensity levels of light. The final impression, which will be lodged in the brain, is principally determined by the whether the stimulus is meaningful or meaningless, clear or ambiguous, relevant or irrelevant, expected or unexpected. These are the real questions, which must be decided in the course of lighting design.

According to IESNA, “good-quality lighting can support visual performance and interpersonal communication and improve our feelings of well beings, however, poor-quality lighting can be uncomfortable and confusing and can inhibit visual performance" (10-1).

The quality of light has to be suitable for the setting. It is a fact that, each object requires different lighting quality. These can be lines and shapes on planar surfaces, colorful objects, objects with shiny surfaces, or the ones, which have important or little details.

The quality of light is the fundamental subject of contemporary lighting issues. It is having strong relationship with the visual perception of the illuminated object by its formative, dimensional, textural, surface, and color properties. When we are talking about the quality of light, people responsible from the lighting design should not forget all these important facts about the object.

In exhibition lighting, the property of the lines, shapes, letters and colors on planar, and two dimensional art objects like paintings, photographs, and miniatures should be stressed by using light. As indicated in *IESNA Lighting Handbook*, the direction of illumination is especially important when viewing three-dimensional objects (2-31). It is indicated that "there should be some distinction of strong and weak illumination, such as a spot light from one side and a flood light from the other" (IES Lighting 7-33).

If a light source is used for signaling, chromaticity and luminance are the only things we should think of because of the fact that, people are looking directly at the light source. However, when we illuminate an object under a light source, color rendition, in other words the color appearance of the object is important (Mueller 339). In these conditions where good color rendering and detail acuity is necessary, the spectral distribution of the light source must be selected carefully. While exhibiting artifacts like gold or brass, their yellow dominant color should be stressed. Therefore, we should use incandescent lamps such as halogen, in order to illuminate them. While illuminating silver or metallic colored objects, it is a mistake to use incandescent lamps. We should use light sources with high color temperature, which will reveal their bluish-white metallic colors.

Museum or art gallery lighting installations should produce all the lighting effects appropriate to the character of the objects exhibited, and at the same time fully underlining the original intentions of the artist or exhibitor.

2.3. How to Illuminate Objects

Museum display lighting tends to be principally oriented at objects or artwork. Shadow is the most fundamental necessities for creating right visual conditions in three-dimensional objects. In the *IESNA Lighting Handbook*, the shadow is explained as follows: "A degree of shadow, which is desirable should not be so dark as to conceal significant details or to produce distortions in appearance, but the shadow is a significant visual clue to the solidity of an object" (7-36). In order to perceive a three dimensional object, smooth shadows on the inside and outside surfaces are very important. If the edge of shadows on a sculpture is sharp, all the properties of object disappear and more important, people perceive it as a different image. With a smoother edged soft shadow, its curvilinear form will become visible (Kılıç 29). Lighting must reveal the plasticity and as much surface detail as is appropriate to the object.

At least three light sources should be used to reveal the third dimension when illuminating three-dimensional art objects. These light sources are called key, fill and back lighting. Key lighting is the main light and it is like the sun in the sky. The dominant light comes from key light. It certainly creates harsh shadows. Here fill lights are used to soften the shadows and balance the bright light of the key light on the object. Fill light is considered as the reflected daylight from the surroundings in our daily life. The third light, back light, is used to separate object from the background and help spectators to differentiate objects silhouette (Figure 2.1.).

Figure 2.1. Effects of Key, Fill and Back lights on a three dimensional object.

The balance between light and shadow is important in the right perception of forms. The linear direction of light causes in different shape and property of shadows, which affect the visual perception (IES Museum 3). In Figure 2.2, an example of a figurative object, which belongs to the classical era is given. The illuminated object has plasticity, as the shadow created by a light coming from the top is decreased by a secondary light source located at the bottom.

Figure 2.2 An example for smooth shadow.

It is important to emphasize the third dimension by reinforcing light and shadow difference. No matter which lighting technology is being used its spectral properties and spread beam is important. Therefore, while using a light source, it is advantageous to choose point light sources with narrow spread angle with a local distribution.

There are two valid techniques commonly used for the display of sensitive or expensive objects. The first method is to illuminate object by a light source, which is located in the showcase, the second method is to use a ceiling mounted lighting fixtures aimed at the case from well above head height (Figure 2.3).

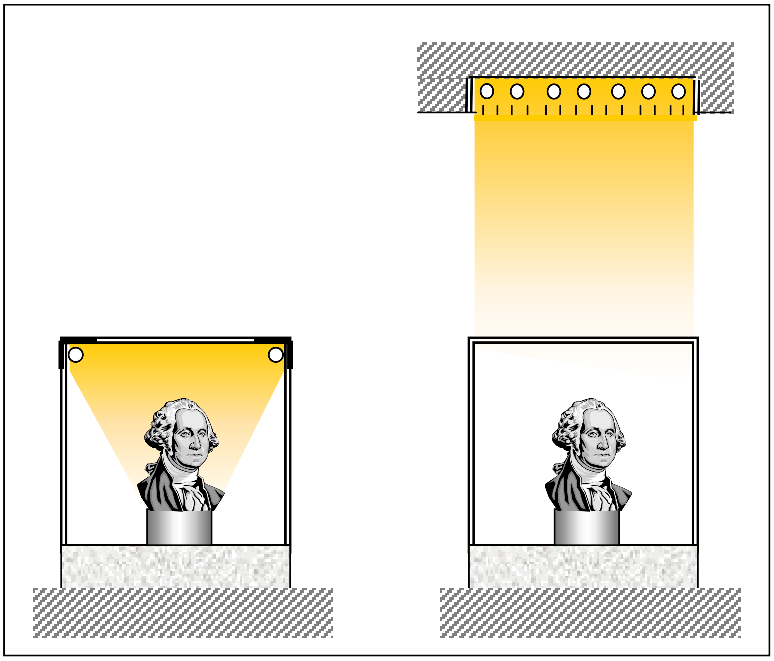

Figure 2.3. The two methods of illuminating an object in a showcase.

These two methods are currently being used to illuminate three-dimensional objects in showcases. However, more important than the technique of illuminating the objects, one should think about the final appearance of the object.

2.4. Harmful Wavelengths

The IESNA Lighting Handbook defines museum objects as "often unique in size, shape, texture and color and many are extremely sensitive to light damage". It is highlighted that lighting design becomes a selective visibility process that governs what we see, how we see it and when we see it (14-2).

The main purpose of exhibition lighting is to enrich the museum experience by establishing a balance between exhibition and conservation needs.

It should be kept in mind that lighting can cause or accelerate degradation of certain kinds of museum and art gallery objects. Although location of light sources may cause problems on perception of objects, the only thing that is important than this misperception is the possibility of occurrence of any damage by the light sources. No matter on which coordinate the light is located, if it produces infrared wavelength, for instance, it will cause irreversible damages to a cultural heritage. In other words, right and complete perception of objects is a serious problem that should be solved within the context of saving art objects to future generations, without forgetting the importance of protecting objects from harmful wavelengths.
In order to talk about the harmful wavelengths, it is essential to explain the visible and non-visible radiations. Light is simply an electromagnetic radiation. Visible radiation, produced by a light source, which has wavelengths between 380 and 780nm is called light. The eye of a young and healthy human can perceive the radiations in between those boundaries, and send signals to brain. Although there are no sharp boundaries for the upper and lower limits of harmful wavelengths, the invisible radiations, below 380nm and above 780nm are accepted as the harmful wavelengths.

The invisible wavelengths, which are above 780nm, are called infrared radiation. If the light source carries infrared radiation, it causes an increase in the surface temperature of the illuminated object. These kinds of harmful wavelengths can increase the speed of endothermic reactions as well as occurrence of expansion between the two surfaces that are different from each other by color, texture and material. Currently there are many light sources, which carry infrared wavelength in their emission such as incandescent bulbs. When a museum is open to public visits, all the light sources are turned on and they direct their radiation to objects for better viewing conditions. When the public visits end, and the light sources are turned off, the surface temperature is decreased in order to reach the room temperature. This shift of radiation exposure results in the differences on surface temperatures of the objects and causes cracks on the surface.

Ultraviolet is the name of the harmful wavelengths, which are below 380nm. When a surface is under the exposure of a light source, having ultraviolet wavelengths, the pigments on its surface will have a photochemical reaction and they will degrade by time.

Using light sources without ultraviolet or infrared is a rule of thumb for exhibition lighting, however many museums still use light sources with harmful wavelengths and try to block them by using special filters. For instance in the Sakıp Sabancı Museum, which is one of the most modern museums in Turkey, lighting fixtures have specially designed infrared filters. These filters are located in front of the halogen light sources and due to the increase in temperature, lamps' life is decreased by 50 percent (Balcıoğlu)

In order to illuminate sensitive objects, light sources, which are free from harmful radiations, must be selected. In the past, special fluorescent lamps were found to be the only solution in the case where good color rendition and harm free environment is necessary while illuminating the art object.

Currently fiber optics are the preferred light transmitting mediums, especially in the exhibition of very old organic art objects (Michalski 55). It is certain that many new lighting technologies are under development and without using any filters or special coatings, a light source can find its place on museum and exhibition lighting. LED technology, for instance, can be accessed to illumination issues, because LEDs produce neither infrared nor ultraviolet wavelengths. The working principle, light-emitting theory, some applications, and discussion of LED light sources are the scope of sections 5.2 and 5.3.

Although the damage level depends on both the material of the object and the spectral distribution of the light, which is used to illuminate them, protection of an art object of any material is necessary in all exhibition designs (Sirel 2/13).

3. LIGHTING COORDINATES DATABASE

The aim of this study, as indicated earlier, is to propose a database of lighting coordinates for the art objects. This chapter reveals the unknown and usually disregarded part of artists, their thoughts on the illumination of their objects. To understand the necessity of LCD, the current lighting methodology and the need of a database is explained. It is beneficial to enlighten its establishing procedure and methods of application, which are in the scope of Chapter 4.

3.1. Artist, Light, and the Object

Light is a very strong influential tool on the perception of artwork exhibition. By using light, a wise curator or lighting designer can change the overall effect of a piece of art. Designers can prefer to choose some common methods on lighting, like key light or fill light, and a three-dimensional art object can be presented to spectators very different. For instance, imagine an artist, stylized a human figure with a smiling face. This happy face can easily become a horrible figure by locating the key light, illuminating the face from bottom. If the theme of the exhibition is happiness, this dramatic effect can surely interrupt the overall quality and impression of the exhibition. The effect of light on the perception of three-dimensional object is best observed on the outdoor sculptures. The different effects of sunlight during a day from 08:00

am to 05:00 pm on a small statue looking at Northwest are seen on Figure 3.1.

Figure 3.1 Different effects of sunlight on sculpture

If the artists are responsible from the creation of their art works, they should also have an idea of its exhibition, which is the presentation of a work or an ideology to spectators. Some parts of an artwork may have more emphasis than other parts, or the artist may want sparkles on a specific part of the artwork. Highlighting, concealment of details and many other effects are all can be done by illumination.

The two facts, creating the artwork in atelier and exhibiting to public view in museums or art galleries, cannot be completely separated from each other. Probably, some artists are not aware of this notion. They do not know what kind of an effect they want in the exhibition, or they probably never think about which part of their artwork should be highlighted.

Gifted and creative artists always have the control of their artwork, during both the creation and exhibition process. The artists having those notions make artists more respectful people in the society.

In an exhibition held in the Bilkent University Exhibition Hall on 28 April 2003, the theme *pain* is chosen. The artworks of more than 20 artists, related to the chosen theme were open to public visit (Figure 3.2).

Figure 3.2. Panoramic view of the exhibition, with theme <u>pain</u>

The personal interviews were conducted with three artists: Ahmet Özsalar, Başar Büyükkuşoğlu, and Serhat Selışık. All of them have ideas on the presentation of their artworks. These three artists tried to guide the lighting designers, but when we look at the result, the objects are illuminated differently than their desires. In order to compare the lighting in artists mind and the lighting in exhibition, their desires should be analyzed.

The first case to be considered is Ahmet Özsalar, and his artwork <u>Neden Savaş?</u> [War, Why?]. This sculpture is located at the entrance of the exhibition, and it is on a white podium. In the current lighting design, four spotlights, directed at the objects illuminate his art object. The three-dimensionality of the object has been reduced by the uniform illumination (Figure 3.3).

Figure 3.3. Neden Savaş? [War, Why?] by Ahmet Özsalar with the current lights.

Özsalar is opposed to war, and pain. Therefore, he preferred using the figure of a used military boot, which has bloodstains on it. In his mind, it should be no longer be used by soldiers. The reason to locate a white, pure, and clean bottle into the boot is to give a function to the boot, rather than footwear of a soldier. The color of the bottle represents emotions opposite to war. Its white color is the symbol of a pure, white peace. The bottle symbolizes the celebration of the end of the last war in earth, and will be left unopened until that time.

The desired lighting effect on Özsalar's mind is emphasizing the white bottle and highlighting the red paints on the surface of boot with the lights coming from left and right side of the object. “What is important for me” he told, “is to highlight the exterior of the boot with lights coming from two sides. The inside has no importance. It is a boot, which is not used any more, so the old blood stains should be illuminated” (Özsalar). He wishes to leave the inside of the object dark. Perception of three-dimensionality is another important factor. In Figure 3.4, the desired lighting effect on Artist’s mind is tried to be achieved by using Photoshop[9] computer software. By using this photo enhancement software, it is possible to create the desired effect on the artist’s mind, at least on a two dimensional illustration.

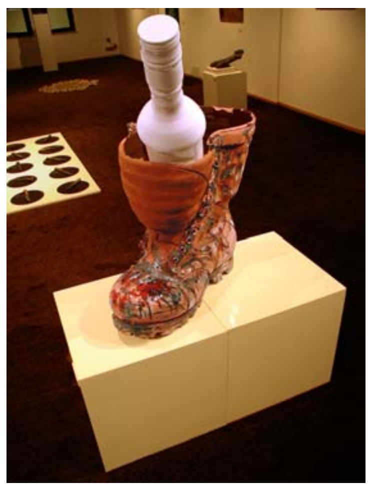

Figure 3.4. Neden Savaş? [War, Why?] by Ahmet Özsalar with the desired lights.

When we compare the current result and the desired effect on artist’s mind, there is no similarity. There are some reasons for this mismatch. One reason is the lighting fixtures, which are not suitable for illuminating objects, due to the lack of flexibility and wide spread angle of the light. Designers cannot dim

[9] **This program is a widely used two-dimensional photograph and graphic enhancement software.**

the light sources accordingly. Another reason is the lack of communication between the artist and the lighting designers.

Although he told the effect he had in his mind, there is no written or schematically drawn document, in a technical language, to guide the lighting designers. Despite the fact that, lighting designers in the museum respect the thought of the artist, leaving decisions on words, and adding human factor to the lighting process results in the failure of the overall exhibition of the object.

One very important issue that appeared in the interview was the tolerance of the artist. While talking about the problems of the current illumination and the perception of the object, he said the lighting effect in the exhibition is not the same with the one in his mind, but it is not a problem for him. He knows the technical quality of the lighting fixtures and he is satisfied with the current exhibition. An artist with this tolerance deserves a better lighting effect on his object.

If the exhibition hall had more opportunities and Özsalar had a technical documentation describing the lighting scheme of his object, <u>Neden Savaş?</u> [War, Why?] would be illuminated as in the artist's mind.

The second interview is conducted with Başar Büyükkuşoğlu. His artwork in the exhibition was named as <u>Distress</u>.

This object has a valve, turning endlessly on the top, symbolizing the draught of ideas on the human brain. The body and the legs are stylized by the pipe fittings. Legs of the figure are embedded into the white marble base. The overall message of the object is “the lack of ideas ends the freedom of a person, stuck in time, and stops the development. It gives pain” (Büyükkuşoğlu) (Figure 3.5).

Figure 3.5. Distress by Başar Büyükkuşoğlu with the current lights.

The pain is the stoppage of movement and the legs stuck into white marble depicts this. So the artist thought that, it should be highlighted. In Figure 3.5, when we look at the current lighting scheme in the exhibition, a similar problem with that of Özsalar’s artwork occurs. Due to the wide spread angle of the fixtures, the lighting on the object is like a general lighting. No portion of the object is highlighted. Büyükkuşoğlu wants lighting designers to emphasize the connection of pipes to the marble with the help of lighting. Figure 3.6. illustrates the lighting scheme in artist’s mind, which is obtained using the Photoshop software.

Figure 3.6. Distress by Başar Büyükkuşoğlu with the desired lights.

The last example is Serhat Selışık and his composition İzleyen İzlenilen [Spectators Spectacle]. His creation is different from the previous two artworks. This time, a combination of several little figures are subject to discussing the object-light relation. There is a group of small figures in a black box, isolated from the crowd of their copies laid on the floor. Some of the laid figures on the ground are squashed by a human foot. In this composition, pain is the loss of an individual in a society (Figure 3.7).

Figure 3.7. İzleyen İzlenilen [Spectators Spectacle] by Serhat Selışık with the current lights.

The desired lighting in the artist's mind is to highlight the figures in the black box by directly illumination from top. He wanted the illuminance level to decrease gradually from the black box to the figures on the ground. A spot should create a circular lighting pattern on the floor, defining the boundary of the crowd. He also wished to use the hotspot of the light source to emphasize the squashed figures on the center of the crowd.

Different from the previous examples, this time the lighting scheme in the exhibition is closer to the one in the artists' mind. A spot located on the top of the box illuminates the black box. However, in addition to the box, the entire podium and the immediate surrounding such as carpet and wall are all have same illuminance level. The gradual decrease of light on the figures from box to ground is not achieved. There is no light rack on the top of the figures laid on the ground, so a spot on the adjacent wall illuminates the figures, with a distorted oval light pattern. The center is not emphasized and a boundary of crowd is not well defined.

With the interview conducted by the artist, the desired lighting effect in Selışık's mind is illustrated on Figure 3.8.

Figure 3.8. İzleyen İzlenilen [Spectators Spectacle] by Serhat Selışık with the desired lights.

The aim of this part of the study is neither to speculate on the existing lighting fixtures of the exhibition hall nor to evaluate the skills of lighting designers. In the three examples given, the objects are illuminated differently than the artists' thoughts. The lighting scheme of objects are not well designed to stress the message, which the artists wanted to give. Discussing the reasons of these problems is the subject of Section 3.2.

It is a fact that some artists are thinking about the lighting of their works of art. The exhibition shows that the desired lighting was not reached the spectators. A lack of a system to fill the gap between the creator and exhibitor is obvious.

3.2. Current Lighting Methodology

In Section 3.1, the problem of a lack of communication between the artists and the lighting designers has been emphasized by giving actual examples from an exhibition. This part of the study concentrates on the general methodology of lighting in the museums, and discusses the common problems of the artist, light and his creation.

Before discussing current lighting methodology, it is essential to focus on the structure of a typical museum management. LCD is a proposal, to be used by the staff, who design the exhibition. If we want to find out, who is responsible for exhibition lighting, we should examine the structure of organization in museums. As Edson explains, most museums have a management structure that includes at least three components; administration, curation and operations (15). Administration of a museum includes personnel, responsible for accounting, general services, fund-raising, and public relations. Curation and operation divisions come hierarchically after administration. Curation includes collection registration, collection care, conservation, and research. On the other hand, operations division is responsible from exhibitions, public education, technical services and facility management as well as security.

When we examine the job descriptions of museum personnel, the director is responsible for professional practices such as acquisition, preservation, research, interpretation, and presentation. A curator, as Kavanagh et al. defines, is an important person in the museum and who, on the publics' behalf, studies a collection, adds to it, documents it, interprets it and enlarges a body of knowledge for a wide audience with very different needs (127). On behalf of director and curators, there are many other positions in museum organization; here an exhibit designer is the key person in lighting design.

An exhibit designer “translates curatorial and educational staff ideas into permanent, temporary, or circulating exhibitions through renderings, drawings, scale models, lighting, and arrangement of objects and signage” (Edson 21). An exhibition designer designs the exhibition case, arrange the object in it, and design an illumination scheme according to the “ideas” from curatorial and educational staff.

“Museum workforce must work as a team” says Pearce in her book *Museums, Objects, and Collections* (34). Currently, this lighting methodology has to be in museums, as literature advises.

When we think about this methodology, there is a minor factor of artists’ idea and decision on the illumination of his/her art works. If a curator is a wise person, he studies on the specific artist or era, and tries to design exhibitions according to the results of this investigation.

Although a museum is composed of a hierarchically arranged group of people from diverse fields with different backgrounds, the lighting effect has to have a guide to be right and unique, without leaving to a persons’ decision. Illuminating of art objects is such a serious subject that, it cannot be left into the hands of curators or lighting designers.

3.3. Lighting Database

When artists create the art objects, they are parts from their soul. The material, form, and the tools they used during creation are all under their control. The product, in this case the art object, is their signature. Pearce classifies individual pieces in museums and art galleries as object, thing, specimen, artifact, and good. Object as something perceptible by one or more of the senses, thing as an individual object, specimen as a representative of the class of things to which it belongs, artifact as an object produced or shaped by human craft, and good as an object produced or shaped by human craft. In addition to those well-known and familiar terms, she adds a new one as *material culture*. She explains the basis of these terms as “all of these terms share common ground in that they all refer to selected lumps of the physical world to which cultural value has been ascribed … each comes from distinguishably different tradition of study” (4).

According to her, sculpture, created by an artist becomes a *material culture* because through its selection and display it has become a part of the world of human values, a part that, evidently every visitor wants to bring within his own personal value system (Pearce 5). This material culture should be exhibited in a well-organized exhibition by using light sources without harmful wavelengths, with lighting intensities and exposure times limited by formal institutions like ICOM.

As we examined the current lighting methodology, an object, or *material culture* is illuminated by a lighting scheme, designed by exhibition designers, under guidance of curators and educational staff. It is a fact that, this causes an art object to be illuminated very different in each museum, by each lighting designer-curator team.

Making the lighting coordinates constant can be an advantage for the standard appearance of an art object, and it can help curators while designing the lighting scheme. On the other hand, artists, whether a living or recently deceased may have their control on the appearance of the objects under exhibition lights.

IESNA defines lighting design, as a creative process to produce lighting methods and solutions for safe, productive and enjoyable use of built-environment, utilizing available illuminating engineering technology (IES Lighting 1-1). It is a requirement that a person, who is responsible from exhibition design, should have a clear idea on the effect he wants to achieve while exhibiting the object. He has to know the effect he aims to create and use a specific technique to achieve this aim. It is possible to demonstrate the resultant effect previously by conducting parametric lighting experiments (Kılıç 29). LCD is based on this kind of experience whether by using software or hardware method.

3.3.1. Fundamentals of LCD

Art objects need extra care in the environment where they are being preserved or exhibited. This care should be taken by the museum personnel with the guidance of some information about its material, current and previous treatments. Like people in a society, art objects in museums also need identification cards, which gives detailed data about them. Every object, that is a part of collection in a museum or art gallery, must have an object information card. On this card, name, identification number, country, material, date, artist, or maker, description, and dimensions are written (Table 3.1).

Object:____________________ID# __________
Country:________________Material:________________
Date:________________Artist\ Maker:________________
Description: ______________________________
Dimensions: Height:______ Width:______ Depth:______Diameter:______
Comments:______________________________
Source:______________________________
Location: Room:__________ Case: __________ Shelf: __________

Table 3.1. Object Information Card (Pearce 141).

When an object moves from one museum to another, its identification card also comes together with it. A museum cannot accept an object to its collection unless it has an identification card. If the object is an archeological object from a current excavation, its identification card is prepared in the shortest possible time. The proposed LCD must be a part of this essential object identification card, either as an attachment or as an extension of it.

The coordinates of light sources should be written on this identification card like other important data such as its material or dimensions. The character of the database is in close relation with the method of establishing the data. The coordinates can be listed according to the degrees of azimuths and altitudes if SLPS technique is used. The x, y, z coordinates is given, if computer system is the method of finding the coordinates. In addition to the coordinates of light sources, their spectral distribution (SD) properties should be written. The properties of the light, emitted by the light sources need to be involved in the data base, such as the correlated color temperature (CCT) and color rendering indices (CRI) (Table 3.2).

Object:______________________________ID# ____________
Country:_________________Material:___________________
Date:__________________Artist\ Maker:_________________
Description: ____
____
____
____
Dimensions: Tall:_______ Wide:______ Deep:______Diameter:_____
Comments:____
____
Source:____
Location: Room:__________ Case: _________ Shelf: __________
Orientation:_____________Locaiton of the Refernce Zero Point:______

LIGHT **TYPE**	LIGHTING COORDINATES			Propertıes Of Lıght Source		
	X axis	Y axis	Z axis	SDAngle	CCT	CRI
Key Light						
1st Fill Light						
2nd Fill Light						
3rd Fill Light						
Back Light						

Table 3.2. Object Information Card and LCD.

The main issue is the usage of this data. When an object and its identification card comes to a museum, curators or lighting designers use the coordinates of light sources to locate their lighting equipments. This LCD gives clue about the final appearance of the object, and helps curators to guide the lighting designers.

3.3.2. Methods of obtaining data

The LCD is created as a result of a communication between the creator and the lighting designer. If the artist of the object is living, lighting designer is the guide of first hand. Artists whether having any notion on lighting issues or not, guide the lighting designers to reach the effect on their mind. In other cases, where the artist is deceased, or unknown, a committee of art historians will guide the establishment of the database.

There are two methods of obtaining data for the LCD. The first method is using computer software and the second method is using SLPS.

4. USING COMPUTER SOFTWARE

With technological development, computer software is now being able to demonstrate three-dimensional objects with realistic graphics. 3D Studio Max®, Lightscape®, LitePro®, Radiosity®, MayaFusion®[10], MicroLux®[11], and Rhinoceros®[12] are the software, which have been specially designed for rendering three-dimensional objects, illuminating or animating them for movies, and architectural presentations. Among them, 3D Studio Max 5.1® is chosen for the software in case study, because it is considered as the widely used popular animation modeling and rendering solution for film, television, games, and design visualization used in Turkish CAD market.

4.1. The Software Used

The 3D Studio Max 5.1® software enables designers to create and render three-dimensional objects on virtual design templates. There are many options about the rendering of objects, their surface characteristics, or even the surface reflectance. It has an option, called *global illumination*, which helps software users to control the exposure parameters of lights. This

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[10] **Maya Fusion is a registered trademark of PrintingForLess. com.**
[11] **MicroLux is a registered trademark of LuxArt Conception Inc.**
[12] **Rhinoceros is a registered trademark of Robert McNeel and Assoc.**

software has a feature called “render to texture”. This feature enables complex procedurals and material trees to be built and rendered into one flat texture map for use in real-time displays. Render to texture property allows game and visual effects artists to build more surface details on their meshes and use low-polygon objects to represent high-detail scenes. It is an advantage for people working with higher detail in the view ports. Another important feature is the photometric lighting feature. By using this feature, realistic lighting effects can be achieved easily. This gives pathway to the designers to build the most realistic three-dimensional views. Advanced lighting features give the option to create higher quality renderings. Easily build realistic environments through Global Illumination algorithms that mimic how light works in the real world. This software works on the x, y, and z coordinate systems. Every light source on the virtual space around the object has a value regarding to this three coordinates (Discreet Incorporated)

4.2. Using Software to Obtain Data

In order to use the software for creating the LCD, first we need the numeric data of the art object. By using laser range finding technology, three-dimensional objects can be transferred into a set of data. Although the laser scanning process is an expensive and long process, the result is the exact replica of the object in virtual space. The recent laser scanning technology enables to scan 0.05 millimeters of surface depth. This means even the smallest chisel mark of the sculptor can be seen on the scanned object. A case study, which is the subject of the sixth chapter, is conducted by using the laser scanning data of Michelangelo's David[13] (Figure 4.1).

Figure 4.1. Scanned image of Michelangelo's David. Photo courtesy of Marc Levoy, Stanford University, The Digital Michelangelo Project.

To use the software, the program has to be installed into a computer. The minimum hardware configuration of the computer has to be at least one GB RAM, with a Pentium 4, 1000 MHz CPU. The hardware configuration of the computer has to be at least as the recommended minimum, otherwise software will not work properly. When the data from laser scanning applied onto the software, light sources, with or without color filters with a variety of color temperature and other spectral properties can be located around the object (Figure 4.2).

[13] **The Digital scanning data of Michelangelo's David is used with the written permission of Marc Levoy, head of Digital Michelangelo project, Stanford University.**

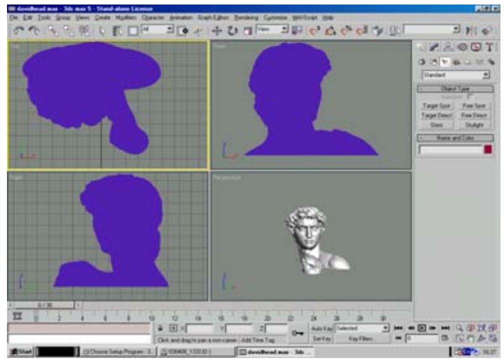

Figure 4.2. Screen shot from a lighting positioning process on 3D Max® software. Photo Courtesy of Discreet Company.

Although theoretically the object is in an unlimited virtual space, the resulting effect of illumination is just like the real world. Every light source has a specific coordinate in this virtual space. This computer software has its own coordinate system, based on *numeric coordinate basis* on three axes. In order to talk about this coordinate system, a *reference zero point* should be defined. This reference zero point should be a visible and easily defined place on the object to be illuminated. In our case, tip of the nose of David's head is considered at the intersection of three axes, and all the light sources around the object are located away with an amount of distance. This distance is the data on the LCD.

5. LIGHTING MODEL (SLPS)

The second method of creating the LCD is the SLPS, hardware method. By using this device, the coordinates of the light sources, can be established by their altitudes and azimuths.

5.1. Definition of SLPS

The Spherical Lighting Positioning System (SLPS) device is a prototype, which has been developed for the establishment of LCD. Prototype is designed for this study and its material, scale, and details are not subject to discussion. Its main aim is to establish a LCD for the object to be tested in case study.

During the case study, to establish a sample LCD, prototype of SLPS is used to illuminate the chosen art object. This model is demountable for the ease of carrying. It is designed to be practical and functional. The main aim of obtaining the coordinates in the case study is always kept in mind while designing it.

When we look at its technical specifications, the components of the SLPS prototype are the head, base, object stand, vertical ribs, and the LED light sources (Figure 5.1).

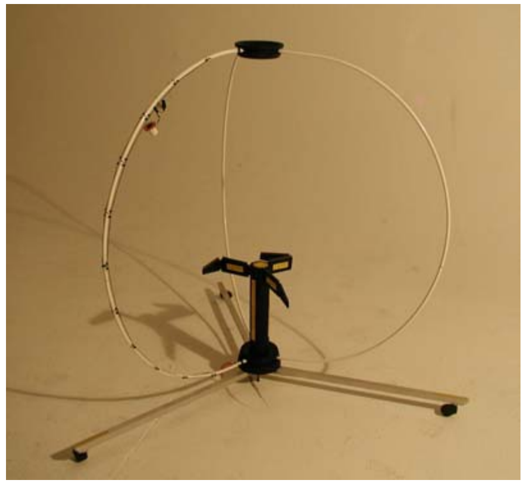

Figure 5.1. SLPS Prototype.

The head and base are made of hornbeam wood, which is lightweight and highly durable. Any other material such as aluminum or Teflon® could be used but for a prototype in this simple scale, wood was the cheapest available solution. The head piece has a diameter of 12 cm with a thickness of 3 cm. Although head piece is made from a lightweight material, its inside part is turned and a piece with 8 cm diameter and 2 cm thickness is taken out from the piece. This piece has 12 holes for the ribs, with 30° apart from each other. In Figure 5.2, the photograph of head piece, with three ribs fixed to 210, 240 and 330 degrees is shown.

Figure 5.2. The head piece of the SLPS prototype

The base piece, on the other hand is designed to be strong. Strength is a more important issue on the base piece than weight. Its thickness is 5 cm with a diameter of 12 cm. The base and head pieces have two features in common. Both of them have drilled and tapered exterior surfaces. This approximately 10° of tapering is designed for the ribs to be plugged in.

The object stand is designed to be adjustable. The height is adjusted to 45 cm for the case study. Height adjustability of the object stand is useful when the theoretical center of the object is below or above the actual center of SLPS. It can be adjusted during the test, and by the help of the lock mechanism, it is possible to lock the height. Another flexibility is in the size of the object base. By three adjustable object-holding clamps, it is possible for an irregular based object to be stabilized on the SLPS without the risk of damage, which can be happened to the object (Figure 5.3).

Figure 5.3. Adjustable base and object holding clamps.

Both the head and the base have 12 holes, drilled 30 degrees apart from each other for the installation of vertical ribs, and each hole has a label, showing the azimuths from 0 degrees to 360 degrees.

The vertical ribs are tubular hollow pipes, which are made of aluminum and have a diameter of 5 mm. Hollow pipe is specially chosen because of its relatively high strength and low weight, which are the major criteria of a rib. On the vertical ribs, there are two important features. The first is the wiring for the LED light sources, which will be explained on the later parts of this chapter, and the other are the labels, which show the altitudes. Because LEDs are emitting light under direct current in a certain setting, positive and negative poles are important to differentiate in the electrical layout of the model. Red colored wires are positive and black wires are negative poles. 1mm copper wires with plastic insulation coverings are chosen due to the lightweight, durable characteristics, and thin appearance.

In order to use SLPS to obtain data for LCD, the setting where the SLPS is located plays a very important role. There should be no light other than the light sources on the vertical ribs. The device should be located in a room, where no light penetrates. Preferably, the tests should be conducted at night.

The safety of the object is important than the illumination accuracy. So it must be placed safely on the object base and before the tests, the lighting designer must be sure that the object is in safe position and not in any risk of falling. For this important issue, safety labels are designed. On those labels, the maximum load bearing capacity and the optimum location place of the object are indicated as well as a reminder to check objects' safety. After locating the object, the head piece and vertical ribs should be placed. At the beginning, in order to avoid head piece from falling on to the object, minimum of three vertical ribs must be placed, with the largest angles between them, preferably 120 degrees from each other.

The most important stage is the placement of light sources. During the placement of LEDs, an artificial light source to illuminate the environment can be preferable for the security of both object and SLPS. This may also be acceptable because, in museum exhibitions, objects can be affected by the neighboring exhibition cases. However, after locating all the LEDs, the environmental lighting should be turned off and the final check should be done with only LEDs as light sources.

As the final step, the coordinates found should be transferred to the LCD part of the Object Identification Card.

The light source, which will be used on the SLPS, should be lightweight, and compact. Although the vertical ribs of the model conceals the light sources, the light sources and their equipment should obstruct object as little as possible. While using a light source, it is advantageous to choose point light sources with narrow spread angle with a local distribution.

Fiber optics or LED technologies are the two light sources, which can be used in the model. Although Fiber optics is the favorite light-transmitting medium of the exhibition lighting designers and curators, it has a couple of weak points. Fiber optics needs a cable to transmit the light. This cable is not very thick for one light source, but if more than four or five light sources used, these cable thickness may cause a problem. Some specially designed lenses can be used, but this would increase the cost and in the authors' opinion, this kind of high technology is not required for finding the coordinates.

However, when we look at LED technology, its size and flexibility, spectral distribution properties, light output characteristics, long operation life, dimmablity without any change in correlated color temperature[14] (CCT) are the major reasons to chose LED technology for the light source in SLPS model prototype. On the other hand, LED technology is appropriate for the illumination of art objects in museums and art galleries. Dikel and Yener, have proposed to use LED technology in the illumination of art objects due to the advantages listed above.

There are different white LEDs on the market. However, Tridonic-Atco's LED product with a catalogue number of LED P 006 has been preferred because of its continuous spectral properties and narrow distribution angle. For the study, a sponsorship for the LEDs has been obtained from Tridonic-Atco.

[14] **Color temperature in degrees Kelvin (K) of an electric light source expresses its warmth or coolth not spectral energy distribution or the physical temperature (Egan 76)**

5.2. Definition of LED

In simple terms, LEDs' are solid-state semiconductor devices that convert electrical energy directly into light. LEDs' *cold* generation of light leads to high efficacy because most of the energy radiates within the visible spectrum (Bierman 12). Mitsuo Fukuda, in his book about semiconductors, explains a light emitting diode as an optical device in which spontaneous emission that originates from an injection excitation is efficiently applied to optical fiber transmission, display or illumination (29).

Encarta Encyclopedia describes the physical components of an LED as follows: LEDs' are made of a combination of elements from column III of the periodic table, such as aluminum, gallium, and indium and column V of the periodic table, such as phosphorus, arsenic and antimony. LEDs' are made of semiconductors called III – V compounds semiconductors. In order to change the characteristics of the LED, including color, the elements that compose the semiconductor and the ratio of column III elements are changing by the LED manufacturers (Light-emitting diode).

In the online web page of *Physics Today*, LEDs' essential elements are explained as an electron carrying n-layer and a hole carrying p-layer. One fundamental component of an LED is the epoxy encapsulant, it reduces the refractive index mismatch and allows more light to be emitted (Bierman 2).

5.3. Discussion on LED Technology

On the web page of *The Economist*, the signals of LED technologies penetration of our daily life is underlined by comparing this new light sources with other common light sources: “The lighting industry thinks that the light bulb is dead and that the days of the fluorescent tube are numbered. It predicts that the future will be illuminated by light-emitting diodes” (Science and Technology).

LED light sources have started to penetrate into lighting market for shorter than a half decade. Regardless of the fact that LED is a new technology, it is a subject of discussion about its advantages and disadvantages. Like every light source, LED technology has advantages and disadvantages.

When we talk about its advantages, LED technology, in contrast to other settled and non-developing conventional light source technologies, are on a rapid development in the laboratories of firms and universities. The most obvious improvement is a ten times or better mean time between failure (MTBF) (Bergh 14).

In a report prepared by U.S. Department of Energy, the potential benefits of solid-state lighting (SSL) are listed as follows:

1.It is estimated that by 2025 SSL could reduce the global amount of electricity used for lighting by 50 percent.

2. The cumulative savings potential in the US alone over 2000-2020 could amount to save 760GW of electrical power (Bergh 1).

Although it has many advantages, there are some factors like its luminous flux, color quality, and price, which are subject to discussion.

Today's lighting applications, which require a light source to illuminate a desk, a screen, or a room, demand not only high efficiency and long life, but also high flux, all at a low unit cost (Equipped to Survive). The efficiency of an LED is far beyond an incandescent or a halogen light source but it takes a couple of years of research and development for LED to reach the efficiency level of a typical Fluorescent lamp.

As in any new technology, in the early years LED solutions will be considerably more expensive than conventional solutions. To justify their selection, the higher initial cost has to be compensated with lower operating costs or other tangible benefits (Haitz 9).

As with any relative immature technology, in the early years LED solutions will be more expensive than incandescent solutions. To justify their selection, the higher initial cost has to be compensated by a combination of benefits such as energy savings over the product life, switching speed, ruggedness, operating life etc. (Haitz 8).

White LEDs now cost about 0.20USD/lm. If red LEDs can be taken as a guide, and the cost per lumen of white LED lamps falls by a factor of 10 each decade, then white light produced by LEDs will cost 0.05USD/lm by around 2005 and 0.01USD/lm by about 2012. With this predicted cost, a 50 lm/W LED lamp will pay for itself through energy savings over 3000-10.000 hours in 2005 and over 500-1500 hours in 2012 (Physics Today).

In any case, the bluish white color is far different from that from a typical incandescent bulb. No matter what type incandescent it is, there is a yellow cast to the color, to one degree or another. The white LEDs' color is far closer to that of natural sunlight, thus colors are rendered more naturally. However, some find this color "unnatural" since it is so different from what they are used to from a conventional bulb. It can take a while to get comfortable with the color (Equipped to Survive).

LED modules are used in the SLPS prototype. However, using them only as a reference light source is not right. They have many advantages, which are essential requirements of museum and exhibition lighting. Conventional light sources in museums need to have color filters or special coatings, LEDs' need only 12 Volts of direct current to illuminate priceless art objects.

Currently, LED technology is not used by museum curators or lighting designers. Especially in Turkey, application of LEDs' are limited only for center high mounted stop lamps (CHMSL) of cars or indicators of electronic equipments. In Istanbul, LED lamp modules are used in traffic lamps, indicating the rapid penetration of LED in our daily life. LEDs' will continue to see accelerated growth in new and emerging markets and will find use in applications that would have been considered impossible just a few years ago (Krames 185).

Usage of LED in task lighting is subject for many researches in laboratories all around the world. The total flux of LED technology will be used in museum lighting in a very near future.

6. CASE STUDY

LCD is a proposed system to establish the lighting of three-dimensional art objects. To test and evaluate this proposal, a case study has been conducted by using both software and hardware methods. This chapter includes the description of chosen art object, and evaluation of data from each method.

6.1. The Chosen Art Object

The major criterion for the case study was to choose the same object for the two methods. It is illuminated by using the computer software and the SLPS hardware. By using SLPS, it is possible to illuminate any physical object directly. However, for the computer software, the object has to be translated to a data set in order to be defined in the virtual space of computer software.

For software method to obtain the data set, laser scanning is required. This is an expensive and time-consuming process. If available, to use a pre-scanned art object was more advantageous. Thus, data of a scanned art object was obtained from a research conducted in Stanford University (The Digital Michelangelo Project)

Marc Levoy, Associate Professor in Computer Science and Electrical Engineering Department of Stanford University, and 30 of his students and colleagues spent the 1998-1999 academic year with a study on laser scanning of Michelangelo's art works. They scanned the sculptures in Medici Chapel, and the fragments of a giant marble map of ancient Rome, Forma Urbis Romae. In addition to those art works, one of his masterpieces, David, was also scanned.

The aim of illumination is to reveal an emotion or a theme of an art object. David's head has both of the two expressions and more. While illuminating the head portion of that statue, the resulting effect has to reveal the emotion and the theme, Michelangelo tried to give.

During the establishment of an LCD, a lighting scheme has to be designed. The overall effect of an object under exhibition lights is controlled by the location of light sources. In the case study, there are two kinds of data, which guided us during the planning stage of the lighting scheme. The first one is the historical and biographical record of Michelangelo about the creation of David, as well as the compilation of the ideas of art historians. The second data come from the orientation of the statue in accordance with the solar path.

First, to understand the emotional message of David, we should concentrate on its story.

Michelangelo was commissioned to carve a marble statue of David by the City of Florence and he created it between the years 1501 and 1504 (Bull

74). This huge statue over four meters tall, is now located inside the Gallerie dell' Accademia in Florence (Figure 6.1).

Figure 6.1. David by Michelangelo.

A Renaissance artist, sculptor, and poet Giorgio Vasari depicts the influence of David on 16th century Florence: "…without any doubt this figure has put in shade every other statue, ancient or modern, Greek or Roman…such were the satisfying proportions and the beauty of the finished work… to be sure, anyone who has seen Michelangelo's David has no need to see anything else by any other sculptor, living or dead" (Hibbard, 37). The Giant David impressed and going to impress many people. If Renaissance is the rebirth of antiquity, says Hibbard, David is the best example for this period (39). With its ill-proportioned hands and head, David is a naturalistic representation of adolescence (Hughes 71). In short, it is not an ordinary Renaissance sculpture.

The two important portions of David is a subject of discussion throughout the history of art. His powerful out-of-scale right hand, and proud looking head. His hand, although out of the scope of this study, is a symbolic depiction of power, due the fact that he is going to kill Goliath[15] by the strength of his right hand and arm. It also reinforces the adolescence issued formerly (Figure 6.2).

Figure 6.2. Right hand of David.

The head of David, which is the subject of case study, is the second impressive part of the statue. “The thick, strained neck, furrowed brow and leonine hair all seem to indicate apprehensive defiance,” says Hibbard (37). The impression on his face is showing wonder, and fear of an anxious and hopeful young shepherd boy going to fight with Goliath. “One outstanding novelty of the David, apart from the startling transformation of a boy hero into a nude giant, is the moment Michelangelo chose to depict a psychologically

[15] Goliath was a giant of Gath and was used by the pagan Philistine army to defy the armies of Israel (I Sam. 17: 1-4). Goliath was probably of Avvim race, as they had lived at Philistia. Goliath was about eleven feet tall (I Sam. 17: 4). In view of the weight of his armor, Goliath had enormous strength (I Sam. 17: 5-7). He was defeated by the sling of David, a young shepherd boy (http://www.biblequestions.org/archieves.htm)

charged pause of apprehension before doing battle with Goliath. Previous sculptors had shown placid young boy after his victory" (Poeschke, 31) (Figure 6.3).

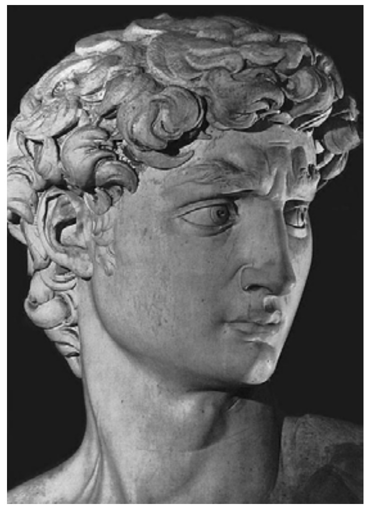

Figure 6.3. The head portion of David.

According to Wallace, mop of hair, furrowed brow, deeply set eyes, long, straight nose, and prominent lips are all features that send intensity to the face (61). From those observations, we can predict Michelangelo's thoughts about David, and the impressions he would want to create on his face by using artificial light sources. With software and SLPS methods, these features are tried to be revealed.

Secondly, when we think about the original orientation of David, a committee, which was made up of technical experts such as Leonardo Da Vinci and Sandro Botticelli, decided on the location of the statue in 1504 (Hughes 70). Although the final decision is not only Michelangelo's, he told his thoughts, discussed them with the committee and accepted the final, common decision. Therefore, we can say that, Michelangelo decided David's location.

The statue had originally being commissioned by the Committee of Works of Florence Cathedral, the Duomo, and it was located in front of the main façade of the Palazzo Vecchio. To protect it from exterior conditions and vandalism, it is now in the Gallerie dell' Accademia in Florence, and a replica is now standing in the place of original David. Although it is now located in the interior of a building, David was designed to be located in front of the façade of Palazzo Vecchio. It is supposed to be located under the bright sunny sky of Florence, and Michelangelo, as well as other technical experts were aware of the effect of sunlight. In Chapter 3, the effect of sunlight and orientation on a sculpture was explained. The replica of David, which was created to take place of the original one, is looking to Northwest and its face is turned towards West

In order to find the position of sun, on which David is best perceived, a Sun Dial and the scaled replica of David's head was used. The appearances of David, for 21 March, between 11 am and 4 pm are created, as if it is in the original location, in front of the façade of Palazzo Vecchio (Figure 6.4).

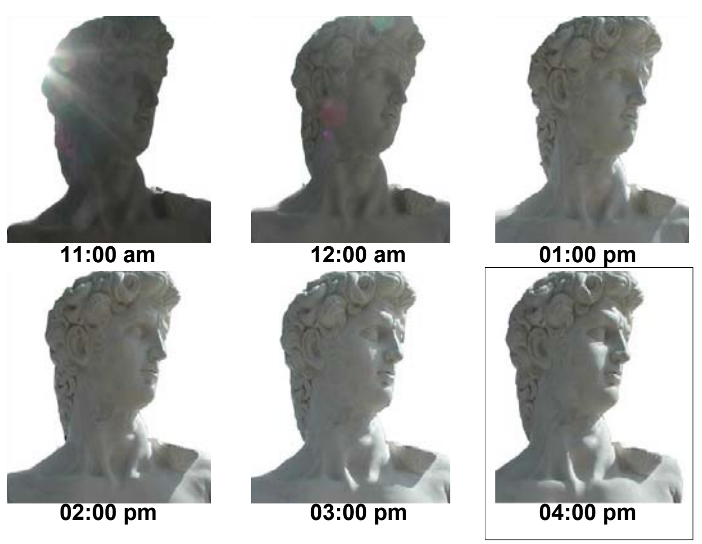

Figure 6.4. Phographs of David under sunlight.

In the author's opinion, either by using the LEDs' of SLPS or virtual light sources of computer software, the main goal should be to achieve the effect of David under 4 pm because the shadows and expressions of face is perceived better than other times of the day. While locating the artificial light sources the location of key light, which is the main light source, is important. Here, by having the reference of 4 pm, key light will have the altitude and azimuth angles, same with the sun at 4 pm at Florence.

We have two sets of data, one set from the theme of the sculpture, and second from the orientation of David in Florence. While locating the light sources of software or of SLPS, these data will guide us during the designing of a lighting scheme.

I would like to point out two important issues. One, is the fact that, probably David will not be moved to another museum or exhibition, so creating an LCD for its head may not be necessary. However, this is a lighting case study and the aim is to create an example LCD for an art object. Instead of David's head, another art object could be subject to the case study, but David is a well-known sculpture, and has many documents written about it. More important than others, it has a set of digital data obtained from laser scanning.

Second, from theoretical point of view, the replica of David's head is not the exact copy of Michelangelo's David. The only way to have a nearly exact copy is to use Computer Aided Manufacturing (CAM) technique. By transferring the digital data of David, it is possible to carve a similar copy. However, this process is very expensive and it is far beyond the aim of the study. The only aim is to test the validity of the two methods of establishing LCD. Object, produced with a similar material is chosen for the case study, just because the major purpose is to try to achieve similar lighting effects. Illuminating a metal sculpture by using computer software and a classic marble statue by SLPS will not have any meaning for the test of LCD.

6.2. Data Obtained From Computer Software

By using the software, it is possible to find out the lighting effect and create an sample LCD. However, this method has some disadvantages, such as the cost and challenge of scanning a three-dimensional object, the technological requirements, and problem of creating a completely realistic lighting effect.

If the scanned image of David were not ready to use, to perform a laser scanning would be very difficult and expensive. When we leave its cost to a side, the labor for scanning an object is a challenge. For instance, it took 34 days of working with a group of seven people to scan David. At the end, Michelangelo’s David turns into a data set of more than 700 Gigabytes of 1’s and 0’s (Figure 6.5).

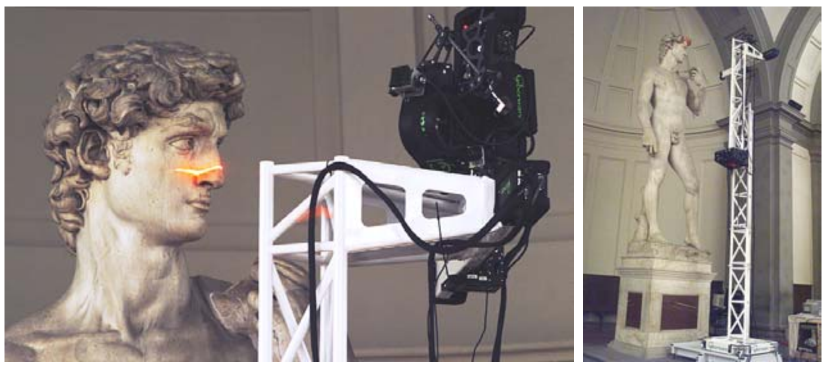

Figure 6.5. Technical equipment, designed for the scanning process of David. On the left, the laser-scanning device is sending laser rays to its nose. The picture on the right shows the scaffold, built specially for the scanning process.

On the other hand, in order to use the data, a well-equipped computer is essential. Otherwise, the software will not work properly. This may cost a fortune for the museums, however a well-organized museum can find a sponsorship from a computer manufacturer, and obtain one of the fastest computers in the market.

It is essential for the users of software to follow the technological developments and continuously update packs for their software, which include additional lamp modules, color filters, textures, or surface properties, as well as hardware configurations for better performance to obtain more realistic results.

It is a possibility that, in the near future computer software, which are specially designed for museum objects to find their LCDs will be in market.

People using the software have to use a display medium, here a monitor with a wide screen, to see the illumination effect. This limits users to be satisfied by the overall effect of the perception of light on the object. It is also predictable to say that viewers will not get the exact impressions like the real world, when illuminated under virtual sources, in an artificial space. Although by using projection techniques, the size of the image and resolution can be increased, the result is still a simulation of an artificial three dimensionality on a two dimensional presentation.

When we talk about the reality of the lighting effect, as Taşçı cited from Ivan Sutherland, “the screen is a window through which we see a virtual world. The challenge is to make that world seem real and to make it behave as if it were real” (77). Realism is the major problem for computer software of the first or second decades of the 21st century to be solved. The object can be turned 360° in all possible axes, but it is far beyond being real. When we look at the exponential development of computer technology, in the future, reality may not be a challenge for digital methodology.

Currently, the main advantage is the comfort of the lighting designers, here the software users. They use the software and locate virtual light sources while drinking their coffees, sitting on their comfortable chairs.

The advantages of software method mainly concentrate on the base of futuristic probabilities, discussed above. In the future, scanning process of a three-dimensional object may last only for minutes, and the software enable people to feel themselves in such a virtual space that, they cannot differentiate it from real.

After evaluating the software method by its pros and cons, we should look at the results of the sample LCD, created for the head of David, by using computer software.

Michelangelo is deceased, and he cannot tell us the effect, he wants to create on the David’s head especially by using current light sources. Therefore, our reference is its original location, solar geometry, effect of daylight, the art historians and the written sources belong to Renaissance.

This LCD is not an official database for David’s head, and we do not need an approval from a committee. In reality, planning, supervising, evaluation, and approval of the lighting scheme and establishing the lighting coordinates are the responsibilities of committee members. While locating the light sources, the research results in Section 6.1 were adequate for us.

In order to locate any light source, which has a coordinate, it is essential to define a reference direction. A reference is needed while obtaining the coordinates of virtual light sources. For instance, if a light source is having x, y, and z coordinates as 1.23, 1.56 and 3.20, it has no meaning for a lighting designer, while locating the actual light sources. These three data give a location of a light source in space, but to know whether it is on the front or backside of the object, a reference is essential. David is facing towards West, so west direction is accepted as the reference pole (Figure 6.6).

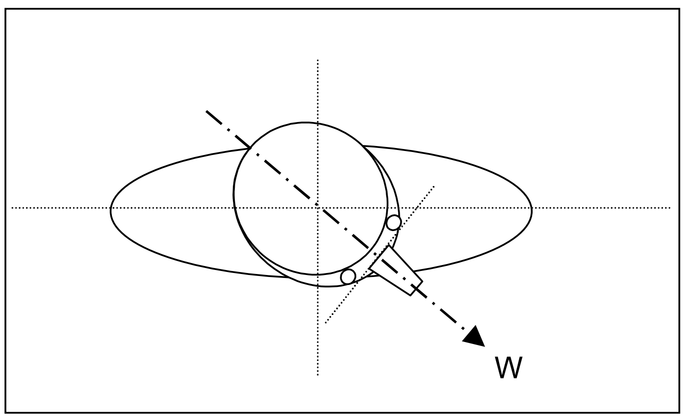

Figure 6.6. Schematic top view drawing of David. its head is looking to left. The black arrow indicates the reference West.

The next step in computer software method is to design the lighting scheme. While designing the overall effect of light sources, the most important thing is to decide on the location of the key light. By locating the key light, the position of the main light source is defined. From the early researches on Section 6.1, we can predict the altitude angle of the main light source, as if it is the sun in the nature. The key light is located at the position of sun, which is at 4 pm, on 21^{st} of May.

On the scanned image of David, after key light is located, locations of other light sources should be found to soften the shadows, as explained on Section 2.2. Here, the next step is to locate the fill and back lights. In order to reach the effect on Michelangelo's mind, necessary virtual light sources are located all around David's head by using the tools, and options of computer software.

After locating all the light sources, the coordinates of each light source are noted. Because of the nature of the software, the final dataset is having three parameters. These parameters are the axes of the light sources in the space, defined as x, y, and z (Figure 6.7).

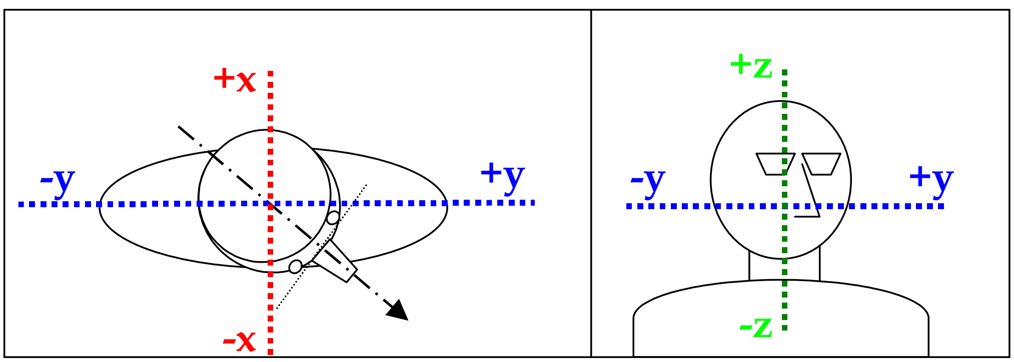

Figure 6.7. Schematic top view and front view drawing of David. The three axes are illustrated by color coding. On the top view, red line is x axis and the blue line is y axis. On the front view the green line is the z axis.

Assuming the tip of the nose of David's head as the point zero, where all three axes are intersecting, the coordinates of light sources are found. A value of x=1.25 means, the distance of light source from the tip of the nose, is 1.25 meters on x axis.

While writing the coordinates of light sources, it is necessary to group them into three light types, which are key, fill, and back lights. The coordinates of light sources are on Table 6.1.

LIGHT TYPE	LIGHTING COORDINATES		
	X axis	Y axis	Z axis
Key Light	-1,980	1,700	1,920
1st Fill Light	-2,050	0,480	-0,830
2nd Fill Light	-1,790	-0,790	-0,790
3rd Fill Light	0,390	1,520	0,380
Back Light	1,190	-0,290	0,370

Table 6.1. The coordinates of light sources obtained by using computer software

The final appearance of David, after locating the light sources at the positions on Table 6.1, is as shown in Figure 6.8.

Figure 6.8. David's head, illuminated by the coordinates from computer software.

When we transfer these coordinates to object identification card, establishment of LCD is completed. The database can either be a special document, attached to the object information card or a table inserted to the rest of the details about the object (Table 6.2.).

Object: Replica of David's head ID# 3332-34R-32
Country: NA Material: Plaster
Date: 01 – 04 – 2003 Artist\ Maker:
Description: This replica of David's head is for an academic study
Dimensions: Height: 28.6cm Width: 16.4cm Depth: 15.8cm Diameter:
Comments:

Source:
Location: Room: Case: Shelf:
Orientation: West Reference Zero Point: Tip of the nose

LIGHT	LIGHTING COORDINATES			Properties Of Light Source		
	X axis	Y axis	Z axis	SDAngle	CCT	CRI
Key Light	-1,980	1,700	1,920	15	2500	95
1st Fill Light	-2,050	0,480	-0,830	15	2500	95
2nd Fill Light	-1,790	-0,790	-0,790	15	2500	95
3rd Fill Light	0,390	1,520	0,380	10	2500	95
Back Light	1,190	-0,290	0,370	30	2500	95

Table 6.2. An example LCD, established by the computer software

6.3. Data Obtained From Lighting Model

One set of data for the LCD of David's head is established by using SLPS. This method has two major disadvantages, which are the risk of objects and the requirements of the setting. On the other hand, it has a striking advantage of reality, and three-dimensionality like the target object.

On the case study, a scaled replica of David's head was used. This replica itself has no divine meaning. Its value is only the price label written by the merchants. If this object falls from the base of SLPS and broken, it will not be a loss for the humanity. In the case of establishing the LCD of a genuine art object, some museums wont probably give permission to put it onto the base of an SLPS device. Even some of the institutions require insurance costs, which are far beyond their budgets. To decrease the risk factors and the percentage of any damage, designers of future SLPS devices may take safety certificates from well-known and accepted institutes. However, while designing the prototype SLPS, adjustable object base, and object clamps are designed according to this safety factors. Like the prototype, the real SLPS devices need warning labels and well-trained personnel.

There are some requirements for the setting of an environment, where tests with SLPS will be conducted. Daylight and any other artificial lights rather than LEDs must be in control. Case study, using SLPS device is conducted in the Building Physics Laboratory of Bilkent University. This place is specially chosen because of its architectural property. The laboratory itself is a room without any windows. This is advantageous while conducting experiments about light. Even if there were windows, experiment would be done after blocking the penetration of any kind of daylight or artificial light to the interior.

People, whether artist or lighting designer can walk around the model to see the effect of lighting on the object. In the case of deceased artists, the committee of art historians and other professionals would prefer this method, due to the incomparable reality. This method gives opportunity to figure out how the object will look like in future exhibitions, in the real museum environment.

Using SLPS to obtain data has some stages. The first stage is to design a lighting scheme.

Throughout the design process of the lighting scheme, two sets of information, which are discussed in Section 3.1, are used. The first set is from the theme of the sculpture and used for the defining of impression, The other comes from the orientation of the statue and is utilized to locate the main light source, which is the key light. In the guidance of these data, the location of key light is figured out. Decision on the location of key light made easy to consider the locations of other necessary light sources, which are fill lights and back light. Designing the lighting scheme and deciding on the location of key light, will lead us to find the lighting coordinates.

After preparing the setting and SLPS for the experiment, replica of David's head is located on the object base carefully. To avoid the risk of falling the approximate center of gravity of David's head is on the same axis with the base of the SLPS device. By securely locking the object clamps, David is ready to be illuminated by the real light sources of SLPS (Figure 6.9).

Figure 6.9. David's head, located on SLPS.

After locating and securely fixing the object, the lighting scheme is designed. Finding out the coordinates is a difficult process. In this stage, a *test and trial* method is necessary, because the lighting scheme on a paper is generally different from the application in real life. The coordinate of a light source on SLPS device has two parameters, altitudes, and azimuths. To find out the altitudes, vertical ribs have to be located on the appropriate holes of base and headpieces of SLPS. Altitudes are the vertical location of light sources on the ribs. On Figure 6.10, the altitude angles are shown.

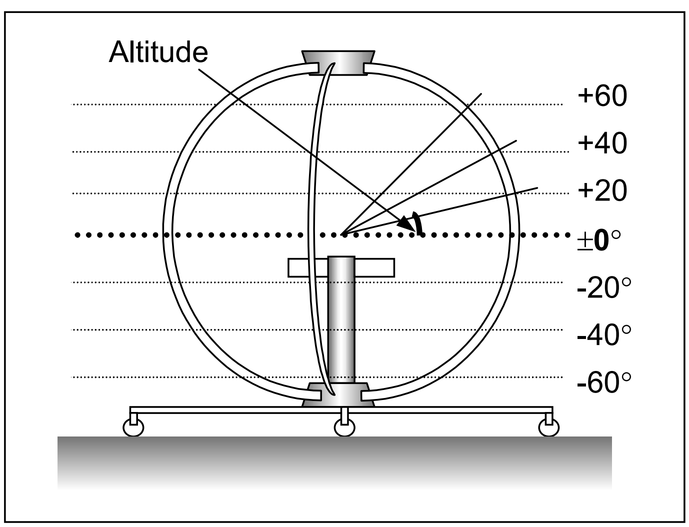

Figure 6.10. Front view of SLPS and the altitude angles.

As discussed in Section 5.2, LED lighting technology is preferred on the SLPS device as the light source. These light sources can be turned off, and dimmed by the built-in dimmers designed together with the LED modules. Each LED has cable connectors to get electricity from the color coded direct current cables on vertical ribs. In Figure 6.11, the detail of an LED module, which is fixed to the white tubular rib, is seen. The blue circular shaped piece is the dimmer, and the black and white connectors are connected to the color-coded, positive, and negative wires.

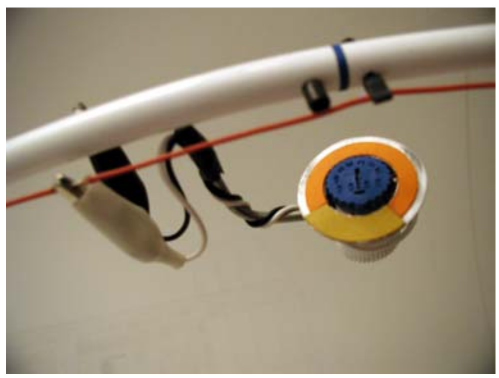

Figure 6.11. Close-up of an LED module.

The scale and dimensions of SLPS are specially calculated for the replica of David's head. It is possible to create any desired effect on its surface easily, however, using this hardware requires a skillful lighting designer to adjust the LEDs', and make their electric connections. To avoid this probability of failure, electric cables are color-coded as seen in Figure 6.11.

Locating the LEDs, beginning from key light to other lights, coordinates of light sources can be found. The reference West direction, as illustrated on

Figure 6.12, is the perpendicular line from its head. Here, by knowing the West, any light source around the object has an azimuth angle in relation to the South.

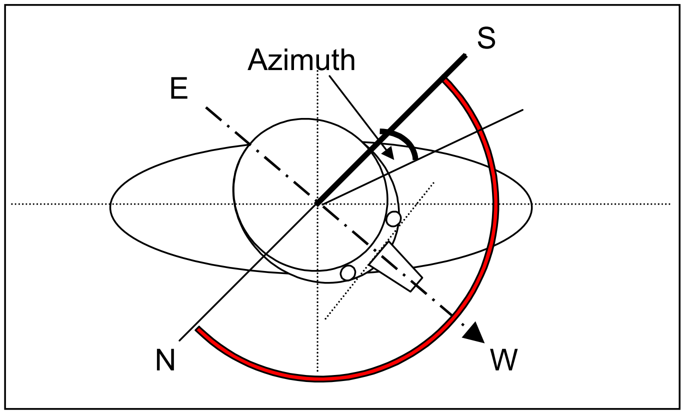

Figure 6.12. Schematic top view drawing of David under SLPS device. its head is looking to left. The black arrow indicates the reference degree, zero.

On Figure 6.13, an LED is emitting its light on David's head.

Figure 6.13. an LED module and David's head under its light.

The final coordinates are on Table 6.3. Coordinates are having two variables, altitudes, and azimuths. The azimuth angles are having values in accordance with the South on Figure 6.12 beginning from 0 to 360 degrees in clockwise.

and altitudes are having positive and negative values as seen on Figure 6.10. By using these coordinates, in future, any lighting designer or curator can be easily illuminate David's head.

LIGHT TYPE	LIGHTING COORDINATES	
	Azimuths°	Altitudes°
Key Light	90	+45
1st Fill Light	115	-40
2nd Fill Light	145	-50
3rd Fill Light	235	+15
Back Light	265	+10

Table 6.3. Data obtained from SLPS method.

7. DISCUSSION

Michelangelo's ideas, the artistic style of the era, on which David is created and orientation of the sculpture was guided us throughout the creation of the two LCD examples.

If, we compare the two methods, SLPS method has an advantage. It is real. No state of art models or methods, which are virtual, can be able to overcome such an advantage. The effect of light sources on an object is best perceived in a the physical model, where people can walk around and perceive it with their own eyes, without using a computer screen.

By using computer software, a reality is tried to be simulated. The success of this virtual reality is debatable. However, Taşçı cited from Donald Greenberg, one of the computer graphics pioneers a, prediction that "…if the progress in computer graphics and hardware technology continue as of today, near the end of 2025 the display and computational capability to produce images that are both physically accurate and perceptually indistinguishable from real world scenes will be available. This means that at that time simulation technology will reach such a level of capability that there will be no difference with real and virtual worlds and verification tools might be needed to avoid confusion between them" (Taşçı 56).

SLPS devices, different from computer software, need less update for better performance or effects that are more realistic. The aluminum tubular ribs may be changed with an ultra lightweight and durable materials or the LEDs can be more flexible and easy to use. Even the movement of ribs and alignment of LEDs can be controlled by computerized systems. In all cases, the pieces are neither changed, nor added to the current model.

Using the computer software, one has the opportunity to locate the light sources almost at any desired angle, with high accuracy. On the contrary, while locating the light sources on the prototype SLPS device that I designed, the angles are located with an interval of 30°. To illuminate an art object for an MFA thesis is not a scientific experiment. It is not so important for a light source, whether having a coordinate of 45° or 45.658°. However, in future, it may be possible to design an SLPS device with closer intervals.

In Figure 7.1, David is illuminated by the virtual light sources located on the software. Due to the high detail level of laser scanning, every little details on his face can be seen and movement of lighting can change the appearance of the impression of this sculpture. On Figure 7.2, the photograph of David is taken after locating all the light sources on the SLPS. Both of the two figures show similar or same appearances of David. However, David under the real lights of SLPS can give the effect of realism, which can never be obtained by using a software.

Figure 7.1. David illuminated by virtual light sources.

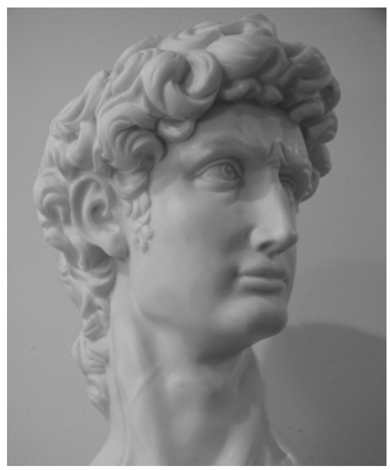

Figure 7.2. David illuminated by LED light sources.

Finally, when we think about the two methods, it is also possible to think computer software and SLPS device working as a team. The lighting coordinates, which are found from SLPS can be used for the data of the virtual light sources.

8. CONCLUSION

An art object, either classical or modern, has to be exhibited for public visits. They have to be illuminated by light sources. Currently, the methodology to illuminate art objects has a problem of ignoring the artists' opinion on the lighting of object. On the other hand, in every exhibition, the same object can be illuminated in a different way by different curators.

The Lighting Coordinates Database, which is proposed in this study, diminishes all those problems, as well as help curators or lighting designers while locating the light sources on the exhibition cases.

Two methods of obtaining data have been explained; namely the software and hardware methods. Each method has its advantages and disadvantages. Institutions can chose any method, the important thing is to feel the necessity of such a database and to use this database for current and future exhibitions.

The case study, done by both methods reveals a very important fact. Before beginning to illuminate, a research should be done on the theme and on the original location. A more detailed study, absolutely, would end up with more information about the story of this masterpiece. The impression of David, Michelangelo tried to give, is tried to be achieved by the location of artificial or real light sources. However, we can never be sure about the exact lighting effect on the creators' mind, because he is deceased. It is only possible to speculate on the thoughts of artists. We can not be sure unless they left a diary about the lighting of their work of art. So creating an LCD, whether by using computer software or physical models like SLPS, is more important for the living artists.

Using an SLPS device and computer software gives opportunity to find out the coordinates of light sources. These coordinates can be the beginning of the lighting schemas of virtual museums in the future. Currently, people can visit museums online from computers via Internet. They share their collections to public access without the risk of vandalism, damage from light sources, or even the environmental conditions of the exhibition halls. Three-dimensional collections of museums can be illuminated virtually from the locations written on their Lighting Coordinate Databases.

The honorable way to present our thanks for the artists for their beautiful creations is to exhibit their artworks in the way they thought, to current and next generations. Creating and using LCD is the only a means of doing this.

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