

3D techniques for presenting lighting parameters

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Abstract

Light plays an essential role in a person's perception of the world. Light determines how people sense and relish every element: hue, consistency, space, and shape. In the global lighting society, products require the creation of more intelligent lighting control systems that can adjust many parameters. New opportunities are created with the development of computer technology to design more accurate visualizations and simulations of the three-dimensional world. These lighting control systems can be viewed in a computer-generated 3D environment.

This report aims to study the lighting parameters that can be performed virtually. The idea is to facilitate the learning of both students and instructors of lighting design. 3D visualization and testing make it easy to experiment with lights from a design perspective.

At the end of the report, conclusions and some recommendations from the research are drawn and formulated.

Index Terms: lighting virtual laboratory, e-learning, education, system engineering software, lighting parameters.

1 Introduction

The perception of the realization and design of each element such as color, texture, shape and space depends on the illumination. There are many different types of light sources, creating different illuminations of objects and surfaces. In general, they are divided into two main groups: natural and artificial. The natural sources of the world include the sun, stars, thunder, jellyfish, lamps, etc. Artificial light sources can be: light bulb, fire, candle, lamp, etc. In order to achieve the desired effect, it is necessary to study the properties and characteristics of light.



The rapid development of humanity's digitization in recent decades has invariably affected lighting as well. Until recently, there were two different approaches to lighting design. In the first approach, also called engineering, the design of the lighting installation was carried out taking into account the needs of the person in order to create the necessary levels of illuminance and quality of lighting. In the second - design approach, the person trying to create some object that will be adjusted on the spot according to the lighting installation [1]. Through the popularization of computer graphics in design, it became possible to create a virtual image of the designed object. This naturally requires a rigorous calculation of the light distribution and illuminance, taking into account all the processes of light reflection and transmission. In turn, these calculations and developing led to the emergence of a new profession: lighting design [1].

Applying 3D environments in education and practice leads to a new level of perception and understanding of the surrounding world. These environments offer highly immersive and interactive learning. Students can engage with subject matter more tangibly and realistically by providing a three-dimensional representation of objects and worlds. This enhances their understanding and retention of complex concepts. On the other hand, testing their knowledge through virtual environments provides an interesting and motivating approach to learning and self-assessment [2].

The integration of three-dimensional technologies has been successfully applied in studying object illumination parameters, environmental perception versus light source type, and experimental deployment of artificial light sources.

Using real-world lighting references is the best approach to achieving realistic 3D lighting. In the 3D industry, HDRI (High Dynamic Range Imaging) lighting is used to create lighting scenarios inspired by real life. The quality of HDRI lighting depends on the HDRI map used, which significantly impacts the results we can achieve with HDRI lighting [3].

HDR Light Studio is a 3D lighting software providing unlimited unique lighting designs and setups in 3D scenes that can be rendered in all standard 3D software solutions used in the industry [3].

3D environments foster a sense of exploration and discovery. Users can navigate and manipulate objects, simulate experiments, and participate in virtual scenarios that are inaccessible or impractical in classroom or practice settings. This hands-on approach encourages active learning, critical thinking, and problem-solving skills.

In practical terms, the potential is limitless, albeit costly, when confined solely to learning objectives. Virtual learning applications are widely used to enable distance learning for students, especially during the pandemic. The popularity of apps that depict real-life objects and three-dimensional environments is growing. Computer technology advances have paved the way for more accurate visualizations and simulations of the three-dimensional realm, opening up new possibilities. The

integration of three-dimensional technologies has entered various industries and educational environments. This paper discusses one approach to developing a training program focusing on illumination techniques and their application in e-learning.

2 Theoretical part

When the international "SI" system was compiled, the numerical measurement of light technical quantities was of great importance. Here are some of these basic quantities [4]:

- Light intensity – J, cd (candela);
- Thermodynamic temperature – Θ , K (Kelvin).

1 cd – the intensity of light emitted in a perpendicular direction from the surface facing $1/600000$ of an absolute black body at the solidification temperature of platinum at a pressure of 101325 Pa (Pascal). In lighting technology, it is accepted that the light intensity is denoted by I instead of the letter J.

Thermodynamic temperature is an absolute measure of the average total internal energy of an object or objects [5]. This internal energy generally represents the energy of motion of the object/objects, also known as kinetic energy, plus the contribution of other factors.

2.1 Luminous flux

Luminous flux Φ is that part of the radiant flux that the visual analyser perceives as light. Luminous flux is the visible part of the energy emission of a light source per unit time. It is measured in the unit of lumen (lm).

It was found that a uniform radiant flux with a wavelength of $\lambda = 555$ nm (maximum value of yellow-green color) and a power = 1 corresponds to a light flux $\Phi = 683$ lm. in connection with this, the so-called light or photometric equivalent $K = 683$ lm/W. It gives the relationship between the "luminous watt" unit, in which electromagnetic radiation is measured, and the lumen unit.

The luminous flux of 1 lumen is obtained from an absolute black body with a surface $S = 5305$ at a platinum (Pt) solidification temperature, which is $T = 2046$ K [4].

2.2 Light intensity

Light intensity quantitatively characterizes the spatial distribution of light flux. It is calculated according to the formula (1):

$$I = \frac{d\Phi}{d\Omega} \quad \left(I = \frac{\Delta\Phi}{\Delta\Omega} \right) \quad (1)$$

where $d\Phi$ is the fraction of the light flux that is emitted uniformly through a solid angle $d\Omega$.

A light source has a luminous intensity of one candela when it emits one lumen in a certain spatial angle, i.e. in a globe photometer, emits 12.57 lm [4].

2.3 Illumination

The illumination E serves as a quantitative assessment of the degree of illumination of a given surface. In general terms, this represents a density distribution of the luminous flux on the illuminated surface. It is calculated according to the formula (2):

$$E = \frac{d\Phi}{dS} ; \quad \left(\text{or } E = \frac{\Phi}{S} \right) \quad (2)$$

where Φ luminous flux, lm;

S – the area of the illuminated surface on which the light flux Φ falls, $1m^2$.

Illumination is measured in units of lux (lx); $1lx = 1lm/1m^2$.

Thanks to the adaptability of the human eye, the interval of illuminance values in which a person is able to see varies in a large range: from 0.0003 lx (moonless night) - 10 lx (at night or in dark rooms) to hundreds of thousands lx (clear sunny day). Experiments have shown that the ability to see increases logarithmically with the increase in illuminance, i.e. when the illumination increases ten (10) times, the ability to see doubles.

Illumination, together with brightness, is a basic standard quantitative characteristic of lighting systems. It is standardized by national standards [4].

3 Computer-aided design

The software is developed as a portable application, so it does not require prior installation. The user is required to do nothing more than launch the application and begin their training.

The user can click in the viewport and drag the mouse to rotate the camera, allowing them to see the background and atmosphere in the scene. The ground texture can be turned on and off by the "Checker: On/Off" button (Figure 1).

From the "Texture Set" drop-down menu, the user can choose one of the textures to be applied to the object, and from "Texture Type", he can view the types of maps that make up the material. When the map is selected, it is previewed in "Texture type preview".

It is not enough to give color to a model and add glitter to create a natural material. Each object has micro details that make it unique. Figure 1 shows an example of asphalt. If only color is added and reflection is removed, the result will be only dark material. In order to avoid such types of problems, textures describing each parameter of the material are used. The set of textures (maps) forms one material, which is called a texture set. Each texture affects material values differently.

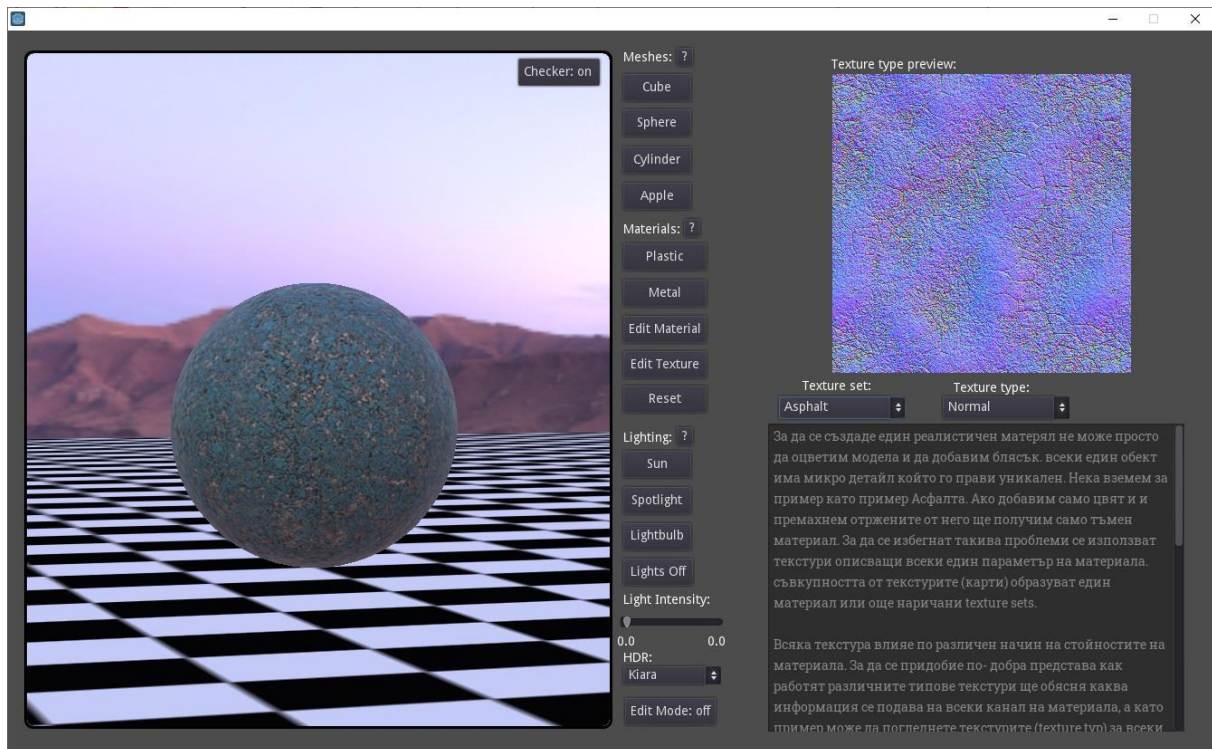


Figure 1. Applied asphalt texture on a sphere

The interface is divided into four main categories:

- Meshes (objects);
- Materials;
- Lighting;
- Light intensity.

The first category, Meshes (objects), explains what 3D objects are and allows the generation of different types of objects based on the name of the buttons.

The second category is about materials, and as in the last part, the "Question" button generates a detailed explanation of the different types of materials and textures in 3D. Each button affects the material applied to the selected model from the previous category. The "Plastic" button applies to the selected object a plastic material using real values (PBR), and the "Metal" button performs the same procedure, applying a metal material. The user can create his material, which can be done after pressing the "Edit Material" button. The "Edit Texture" button allows the user to apply different types of textures to the selected object.

The third category controls the lighting in the viewport. The "Question" button, as with the other categories, generates a detailed explanation of the different types of lighting and a help code. The first three buttons add one of three types of lighting to the scene: sun, spotlight or lightbulb. The "Lights off" button turns off/removes the light sources in the scene.

In the fourth section, the light intensity can be adjusted. The default is set to mountain sunset (Kiara) and can be changed anytime. HDR (High Dynamic Range) – this type of lighting is relatively new to the visual industry. The purpose of this lighting is to simulate the real atmosphere and lighting.

Figure 2 shows the implementation of an apple object with a checker set to off and sunlighting.

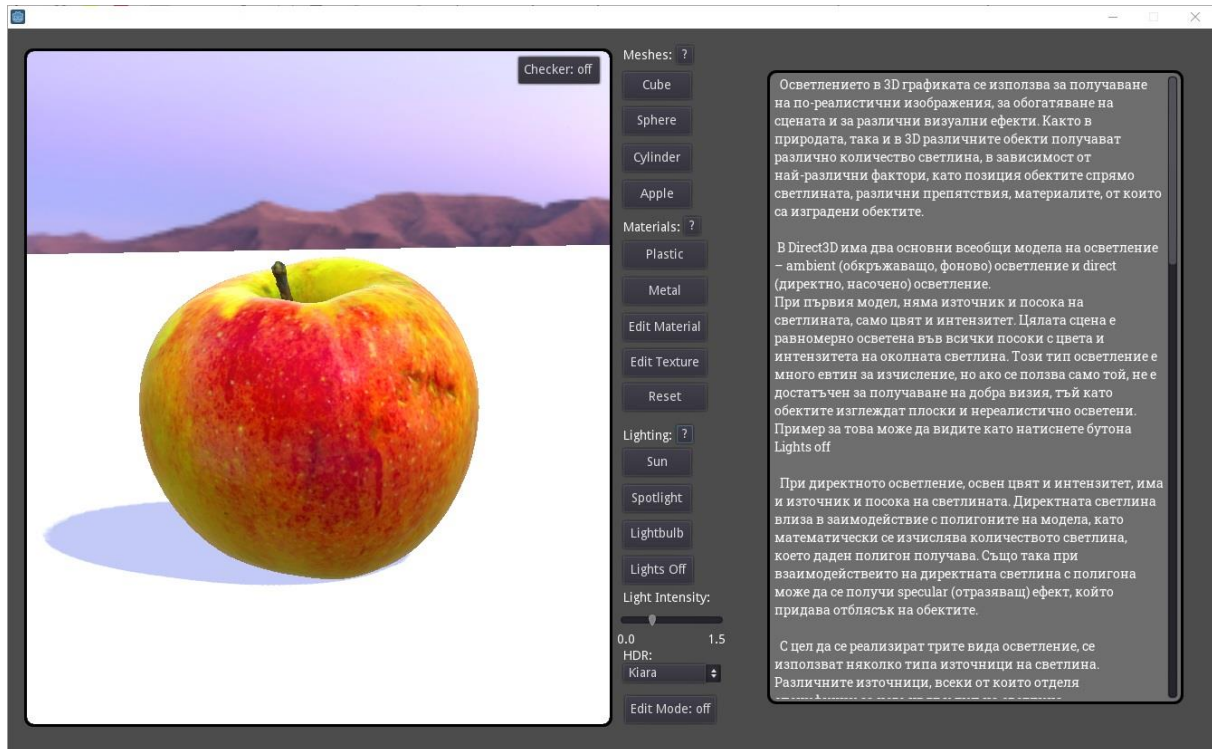


Figure 2. Apple with Sun lighting

Lighting in 3D graphics is used to obtain more realistic images, enrich the scene and for various visual effects. Both in nature and in 3D, different objects receive different amounts of light, depending on various factors, such as the position of the objects relative to the light and different obstacles that the objects are made of.

In Direct3D, there are two main universal lighting models:

- ambient (surrounding, background) lighting;
- direct (direct, directional) lighting.

The first model has no light source and direction, only color and intensity. The entire scene is uniformly illuminated in all directions with the color and intensity of the environment. This type of lighting is very cheap to compute, but if used alone, more is needed to get a good look, as objects look flat and unrealistically lit. An example of this can be obtained after pressing the "Lights Off" button.

In direct lighting, in addition to color and intensity, there is a source and direction of the light. Direct light interacts with the model's polygons, mathematically calculating the

light a given polygon receives. Also, when direct light interacts with the polygon, a reflective effect (specular) can be produced that glares at objects.

4 Conclusion

The 3D-generated objects utilizing computer-designed lighting models and their testing show a variety of approaches to the teaching and thinking of the students.

Such an application enables testing with various materials, illuminances and light sources in a virtual environment. This innovation in experimenting with a computer graphics system is quite a practical relief, given what an expensive and time-consuming process the same would be under real-world conditions. Also, this process would practically need specialized equipment under certain conditions.

There is a way to review the possibilities of lighting design solutions after performing the necessary experiments until obtaining the most optimal and acceptable approach to lighting.

5 References

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