Demonstration of light reflection concepts for rendering realistic 3D tree images

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Abstract. With advancements in computer graphics, creating natural images has always been the main purpose, image rendering is all based on principles of physics. So, understanding the physics of image rendering will enable us to create the most realistic images. A ray of light hit a surface with different orientation and reflects as per the rules of physics. It is difficult to calculate the light reflection of complex foliage, such as trees, so, the reflection of this natural complexity needs to be adapted to rendering situations. In this research, the researchers provide demonstrations to enable students to understand the light reflection in nature, light calculation in computer graphics and methods to apply them to render realistic tree images. The researchers assign students to render 3D realistic tree images to assess the students' understanding by applying the diffuse reflection value, specular reflection value and surface normal direction to render realistic tree images. The researchers find that most students understand of diffuse reflection, specular reflection, and surface normal direction causes the rendering results to be most realistic.

1. Introduction

With advancement in computer graphics for rendering realistic image nowadays, creating natural images has always been the main purpose of computer graphics. With the geometric complexity of plants, the complex light interactions, especially inner foliage is leaves, make a realistic and efficient display of plants extremely challenging [1], especially in various visualization applications, such as virtual environment and computer games that occur in nature with trees. These image rendering is all based on principles of physics, therefore, understanding the physics of image rendering will enable to create the most realistic images. In the development of digital art, by combining science and technology, it can bring unprecedented development through fully applying the physics concepts and technology in computer graphics, which can create high-quality 3D computer graphics works, the importance and necessity of learning method and technology in 3D computer graphics design are fully reflected [2]. A polygon is a collection of vertices, edges and faces that defines the shape of a polyhedral object with material and texture. In 3D image rendering, these values need to be adjusted correctly based on an understanding of the physics concepts of light reflection which is the imitation of natural phenomenon. However, physics of light in computer graphics has limitations in calculating the reflection of rays of light because, light flows continuously in nature but does not in the computer graphics.

Over the years, with the rapid development of digital technology, teaching physics theory, the fundaments of rendering concepts, has drawn much attention. Lecturers have innovated teaching methods to improve students understanding of physics concepts. Physics is a principle that any natural phenomenon may be explained, which can also encourage students' curiosity. However, students often lack conceptual understanding of basic concepts when studying concepts of light. Students are mostly focused on the examination and performance outcomes rather than learning. They only memorize the important points get high grades in examinations rather than inquiring for scientific facts [3]. Therefore, lecturers should focus on teaching students to understand the whole process and all contents linked together.

With the rapid development of computer technology, modern computer-based software tools in classrooms are often used to assist in the teaching, helping students to understand physics concepts and equations [4]. Therefore, with the difficulty of rendering 3D realistic tree images, the researchers propose learning activities to understand the physics concepts of light reflection. To create 3D realistic rendering, students need to understand light reflection both in nature and computer graphics. In order to assess students' understanding, the assessment are given to students with the learning activities present in the research so that it can help students that lack understanding of the concepts. Also, it allows students to focus on what to do and helps with their thinking process to create their work.

2. Methodology

The researchers represent the learning steps to students to render realistic 3D tree images. In table 1 shows the overall students' learning activities in our research, which we divided into 3 steps.

Table 1. Steps of overall learning activities.

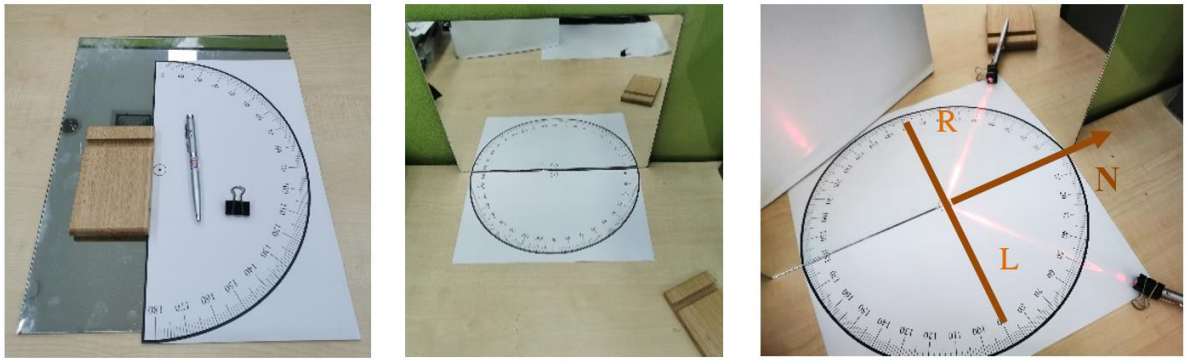
Step	Learning activities
Step 1. Understanding the law of light reflection in nature	Lecturers use a mirror, paper, and a laser pointer to demonstrate law of reflection. Then, students do an experiment in group and observe the law of reflection results.
Step 2. Understanding the light reflection in computer graphics	Students watch a short animation video about light reflection in computer graphics. They also learn the difference between diffuse reflection and specular reflection. Then, students discuss and calculate the light reflection of diffuse reflection value and specular reflection value using the equation.
Step 3. Applying light reflection concepts to render 3D realistic tree images by themselves	Each student creates a 3D tree model, renders the 3D realistic tree images, and adjusts the value that is referenced from the light reflection concepts from step 1 and step 2.

2.1. Light reflection demonstration

For the first step, students must understand how light reflects in nature. A ray of light hits a surface with different orientation and reflects as per the rules of physics. If the ray of light can be observed by approaching and reflecting of a flat mirror, then the behavior of the light as it reflects would follow a predictable law known as the law of reflection [5]. According to the law of reflection, the ray that hits the surface is called the incident ray, or L, and the ray of light that leaves the mirror is known as the reflected ray, or R. At the point of incidence where the ray strikes the mirror, a line that is perpendicular to the surface of the mirror is known as a normal line or N. The normal line divides the angle between the incident ray and the reflected ray into two equal angles.

For the learning activities of the law of reflection, the researchers use a plane mirror and a laser pointer. The experiment in figure 1 shows that when emitting the laser beam to the plane mirror, the laser reflected in an equal angle in accordance with the law of reflection. Students are able to observe the activities results. Students also do the experiment in groups and observe the law of reflection

results. After the learning activities, the researchers assess the students' understanding giving a quiz to calculate the light reflection angle.



(a) (b) (c)

Figure 1. Light reflection demonstration (a) Experimental instruments consist of a laser pointer, plane mirror, paper, and a paper clip (b) Experiment set up (c) Shooting a laser beam to the plane mirror to observe incidence ray (L) and reflected ray (R).

2.2. Light reflection calculation in computer graphics

The second step is understanding the light reflection in computer graphics. The main difference is to simulate the real-world reflection, light will reflect into two types - specular reflection and diffuse reflection. Once a normal surface at the point of incidence is drawn, the angle of incidence can then be determined. The light ray will then reflect in such a manner that the angle of incidence is equal to the angle of reflection. Reflection of smooth surfaces, such as a plane mirror, is a type of reflection known as specular reflection. Reflection of rough surfaces, such as clothing and paper, is a type of reflection known as diffuse reflection [6]. In figure 2 shows the overall learning activities in this step.

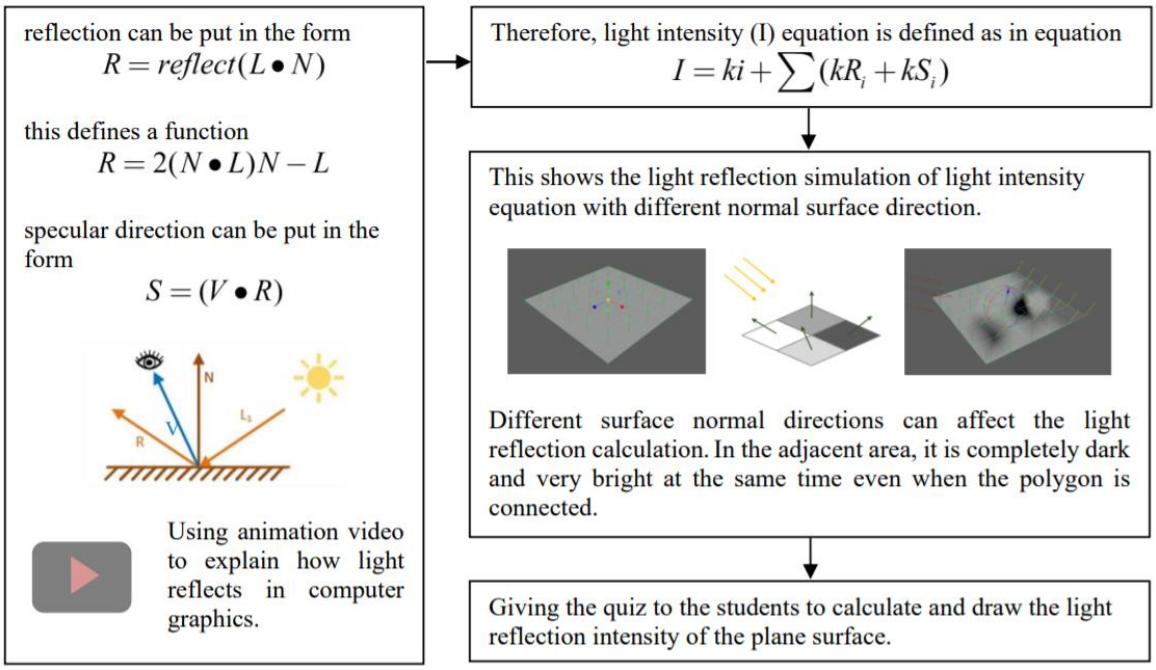


Figure 2. Overall learning for light reflection in computer graphics.

The learning activities consist of three parts as follows: first, the researchers use an animation video to demonstrate how light rays reflect the surface and bounce [7] and show the light reflection equation. It is important to understand that specular reflection of the eyes only sees the image of the object that reflection direction coincidences with the view direction. Second, the researchers explain the equation to calculate light reflection with Phong lighting model [8] with the reflection value from the first part. In this part, students must see the relationship and nuances of light reflection in nature and in computer graphics. We use the computer rendering software to demonstrate how light calculation works in 3D rendering. It represents that different normal direction will affect the light reflection calculation. When the normal line is at zero degree to the direction of light, it will make the surface as bright as possible. On the other hand, if the normal line is at an angle opposite to the direction of light, it will make the surface as dark as possible. Last, the researchers assess the students' understanding using a quiz to calculate the intensity of the light that will occur when the direction of the normal on the surface is different.

2.3. Applying light reflection concepts to rendering realistic tree images

The last step is to apply the light reflection concepts from step 1 and step 2 to render 3D realistic tree images. The sample is third-year bachelor's degree students from Animation and Digital Media Program at Bansomdejchaopraya Rajabhat University that are enrolled in Shading Lighting and Rendering subject. The assignment is given to the students to rendering 3D realistic tree images with the condition that students have to setup the scene and assign the appropriate variables. In figure 3 shows the example of 3D tree model setup with surface normal direction.

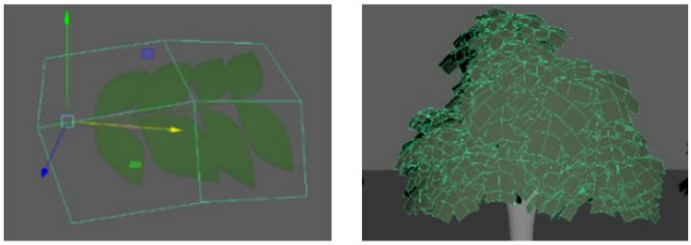


Figure 3. 3D tree model setup (a) A single tree leaf. (b) Leaves join together to form a tree.

The main variables for realistic 3D tree rendering are lighting, surface normal direction, diffuse value, and specular value. We define each variable as follows: 1) Lighting is the light setup in the scene which consist of light from the sun and sky to be the main light source. 2) Surface normal direction is the direction of the leaf surface which is important to calculate the light intensity. 3) Diffuse reflection value is the color value that light reflected to viewer's eyes in every direction which is green color. 4) Specular reflection value controls the reflection of light that reflects into the viewer's eyes. Specular reflection value depends on the angle of viewer. The students' assessment criteria of understanding are shown in table 2.

Table 2. Assessment criteria.

Level of understanding	Criteria
Clearly understand	Lighting, edit surface normal direction, diffuse reflection value and specular reflection value
Partially understand	Lighting, diffuse reflection value and specular reflection value
Not understand	Lighting and diffuse reflection value

3. Results

The researchers analyze the understanding from the assignment of 42 students to assess the students' understanding. It is found that 83 percent of the sample understands clearly, 10 percent understands partially, and 7 percent of the sample does not understand.

Students who understand can correct the surface normal direction which make the tree light intensity in bush look clearly separated and look more diorama to give the most realistic rendering results. They also adjust the diffuse reflection value and specular reflection value correctly which can make the rendering results look more realistic with the same appearance at the bottom of the bush, which is typically dark. Students who partially understand can adjust the diffuse reflection value and specular reflection value but they cannot correct the surface normal direction to be most realistic. For example, it can be seen that all bush area has almost the same brightness, which makes the rendering image tree look flat. Students who do not understand cannot adjust the surface normal direction and cannot adjusted the surface normal direction and specular reflection value. The random surface normal direction can cause wrong light reflection calculation. They also do not know the relationship between the values. In figure 4 compares the students' rendering results in each level of understanding.

Figure 4. Comparing 3D tree image rendering results for (a) clearly understand, (b) partially understand and (c) not understand.

4. Discussion and conclusion

In conclusion, the learning activities show that the students are interested in and pay attention to the demonstration in all steps although the physics concepts of light reflection is difficult to understand. However, visual activities will make students understand more, develop more skills, become more engaged in doing activities [9] and they also increase students' interest in the subject. Dividing the learning activities into 3 steps will give students a good understanding of the physics concepts of light reflection in both nature and computer graphics, and also the relationship between each variable. The researchers are aware that some students do not understand some of the light properties presented in depth, but they discover some aspects of light reflection demonstration that can build up their interest [10] in learning. Explaining the overall concepts allows them to better understand the purpose of the learning activities. Finally, the result shows that most students can understand the physics concepts of light reflection to render 3D realistic tree images.

For further research, it is expected to be able to use more diverse learning activities to demonstrate the light reflection concepts and make the learning activities in each step more connected. Also, creating 3D image rendering may not require realism in some cases of rendering because the beauty of the rendering results depends on personal judgement, which should have more specified criteria to assess the image rendering results.

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