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Real-Time Projection Shadow with Respect to Sun's Position in Virtual Environments

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Abstract

This paper proposes a real-time software for outdoor rendering to control the shadow's position with effect of sun's position. The position of sun plays an important rule for outdoor games. Calculation of sun's position, as a result, position and length of shadows require a lot of attention and preciseness. Julian dating is used to calculate the sun's position in the virtual dome. In addition, of computer graphics, building design is another field that this paper contributes on it. To create shadow, projection shadow is proposed. By calculating the sun's position in the specific date, time and location on the earth, shadow is generated. Length and angle of shadow are two parameters measured for building design and both of them are calculated in this real-time application. Therefore, it can be used for teachers to teach some part of physics about earth orbit and it can be used in building design and commercial games in virtual reality systems.

Keywords: *real-time shadow, sun's position, sun light, projection shadow*

1. Introduction

The principle calculations of the sun's positions have been very well known for a long time. The ancient Egyptians were able many years ago to calculate the sun's position so. By digging a large hole inside one of the pyramids, just once a year, on the king's birthday, the sun could shine on the grave of their king.

To create a realistic environment, shadow is the most important effects used to reveal information about the distance between objects in the scene. It is the major factor of 3-D graphics for virtual environment but unfortunately, it is difficult to implement in virtual environments, especially in real-time games. In computer games, shadows give the gamers feelings that trigger the sense that they are playing in the real world, resulting in maximum pleasure. Games which lack shadow are not seen as attractive by gamers, especially since gamers' have had a taste of virtual games, and their imagination now requests more and more realistic situations when they are watching cartoons or playing games.

There are some different shadow techniques, like drawing a dark shape similar to the occluder on a plane. Although it is not precise, it is frequently used, especially in old computer games and some parts of advertisement animation. Another simple method to create real-time shadow is projection shadow algorithm [1] that is still widely used in game programming. In this method, shadow can be created just on horizontal and vertical plants at a time, but to create shadow on two adjacent horizontal and vertical planes need more calculation [2]. To have a shadow on arbitrary objects stencil buffer is appropriate.

In computer games, shadow can reveal real distance between objects in virtual environment and give the gamer's maximum feeling. A computer game without shadow cannot be very attractive even for indulged users when they play games or watch cartoons.

In 1999, Preetham et al. approached an analytic model in rendering the sky. The image that they generated is attractive [3]. They present an inexpensive analytic sky model from Perez et al. (Perez model) that approximates full spectrum daylight for various atmospheric conditions [4].

In 2008, [5], worked on sky color with effect of sun's position. They used Julian dating and Perez model to create sky color. In 2010, Sami M. Halawani et al. published a paper entitled "Interaction between sunlight and sky color with effect of sun's position" [6]. They used Julian dating to control the position of sun. In 2008, Ibrahim Reda et al. introduced precise formulas for Julian day and used it for solar radiation [7].

2. Methods

For outdoor rendering the sun's position, sky color and shadows are most important effects. In this paper, the sun's position and shadow are combined. Projection shadow is high-speed method to create shadow on flat surfaces. The Julian date is one of the accurate techniques to determine the position of the sun.

2.1 Hard Shadows

Projection shadow technique is one of the simple methods to generate a real-time shadow. The most important advantage of projection shadows is high-speed rendering. The most prominent drawback of projection shadow is the fact that it needs a huge calculation to have shadow on arbitrary objects. The main idea of this method is to draw a projection of each occluder's pixels on the shadow receiver along the ray that is started from the light source up to the plane [2].

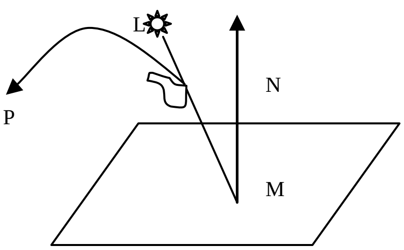

Fig. 1. The scenario of shadow projection

L is light source
P is a pixel of occluder
M is projection of P
N: Normal vector of ground.

$$(\vec{x} - \vec{E})\vec{n} = 0$$

$$\vec{x} = \vec{L} + \lambda(\vec{P} - \vec{L})$$

$$M = L + \frac{E}{NP - D}(P - L)$$

$$\text{Shadow matrix} = \begin{pmatrix} LxNx + E & LxNy & LxNz & -ELx - DLx \\ LyNx & LyNy + E & LyNz & -ELy - DLy \\ LzNx & LzNy & LzNz + E & -ELz - DLz \\ Nx & Ny & Nz & -D \end{pmatrix}$$

By using projection matrix for each pixel of occluder, projection shadow will be appearing on the plane.

2.2 Dome Modeling

Latitude is a distance from north to south of the equator. Longitude is the angular distance from east to west of the prime meridian of the Earth. Longitude is 180 degree from east to west. Each 15 degree represent one hour of each time. For example, if you can travel towards west 15 degree per hour, you can turn off your time and turn on your time up on arrival without having any change in time. The earth spins around the sun in specific orbit once year.

Dome is like a hemisphere in which the view point is located inside it. To create a hemisphere using mathematical formulas the best formula is:

$$f(\theta,\varphi) = cos^2\theta cos^2\varphi + sin^2\theta + cos^2\varphi sin^2\theta - r^2 \quad (1)$$

Where θ is the zenith and φ is the azimuth and

$0 \leq \theta \leq \frac{\pi}{2}$

$\mathbf{0 \leq \varphi \leq 2\pi}$

This ranges is needed for a dome on the above of observer and the rest of sphere is not needed [11].

Before creating shadows in virtual environment, the sun's position must be determined; and this will be described in the next section

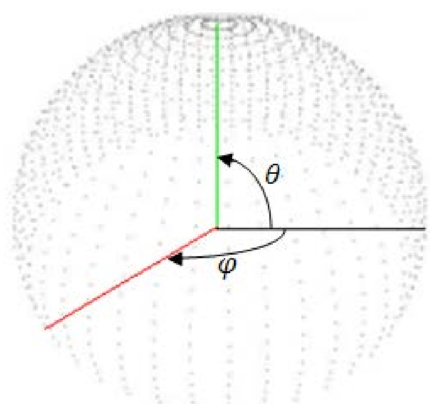

Fig. 2. The zenithal and azimuthal angles on the hemisphere that θ is latitude and φ is longitude

2.3 Sun's Position

The principle calculation of the sun's position is well known long time ago and some exact data are needed. The ancient Egyptians were able in many years to calculate the sun's position so, with digging a large hole inside one of the pyramids, just once a year, when it is also the birthday of the king; the sun could shine on the grave of their king [8].

The earth's oriented North - South line is not exactly perpendicular to the orbit. It has about 23.5° deviation. The diversion of earth during a turn in the orbit around the sun maintains. When earth is located on the right side of the sun, the southern hemisphere, due to the slight

deviation (23.5°), more direct radiation from the sun receives. About six months later, when the earth goes to the other side of the sun, this radiation to the northern hemisphere is vertical.
Longitude and latitude are two most important necessary aspects to calculate the sun's position. The other information that is required is Greenwich Mean Time (GMT). To determine the position of the sun in the created dome, zenith and azimuth are enough.

2.4 Calculation of Sun's Position Using Julian Date

To calculate position of the sun, zenith and azimuth are enough. To have zenith and azimuth, location, longitude, latitude, date and time are needed [9]. Zenith is the angle that indicates the amount of sunrise while the azimuth is the angle that indicates the amount angle that sun turns around the earth.
In 1983, Iqbal [10] proposed a formula to calculate the sun's position and in 1999, Preetham et al.[4] improved it. It is a common formula to calculate the position of the sun in physics.

$$t = t_s + 0.17 sin\left(\frac{4\pi(j-80)}{373}\right) - 0.129 sin\left(\frac{2\pi(j-8)}{355}\right) + 12\frac{SM-L}{\pi} \qquad (2)$$

where
t: Solar time
t_s: Standard time
J: Julian date
SM: Standard meridian
L: Longitude

$$\delta = 0.4093 sin\frac{2\pi(j-81)}{368} \qquad (3)$$

The solar declination is calculated as the following formula:
δ: Solar declination
The time is calculated in decimal hours and degrees in radians.
Finally zenith and azimuth can be calculated as follows:

$$\theta_s = \frac{\pi}{2} - \sin^{-1}(sinl\ sin\delta - cosl\ cos\delta cos\frac{\pi t}{12}) \qquad (4)$$

$$\varphi_s = \mathrm{Tan}^{-1}\left(\frac{-cos\delta sin\frac{\pi t}{12}}{cosl\ sin\delta - sinl\ cos\delta\ cos\frac{\pi t}{12}}\right) \qquad (5)$$

where
θ_s : Solar zenith
Φ_s : Solar azimuth

l : Latitude

With calculation of zenith (θ_s) and azimuth (φ_s) the sun's position is obvious.

2.5 Effect of Sun's Position on Shadows

As the earth moves in its orbit, sun is moved from earth. Shadow's length depends on the position of the sun relative to the view situation. When a part of earth is tilted away from the sun, the sun's position is lower in the sky and shadows are long. On the other hand, when a part of earth is tilted towards the sun, position of the sun is highest in the sky and shadows are short. Longer shadows in a day appear at the sunrise and sunset; and the short shadows appear at the noon. The tilted of the earth axis is a reason that each part of earth can see more or less sun in a day. Different season is a result of different length of days and nights.

3. Result and Discussion

Sun's position and length of shadows in real-time computer games can make a game realistic as much as possible. To keep real position and length of shadows in a virtual environment a substantial amount of precision is needed. Solar energy is free and a blessing of God for us, optimized usage of this blessing needs a mastermind. On the other hand, in building design and architecture, possible recognition of which direction is best to build a building in specific location. In cold places, building needs to stay in a situation that shadows lie in the back of the building but on the contrary, in warm places building should be located in the direction that shadows lie in front of the building.
Figure 3, 4 and 5 show the direction of sun shine and shadow at 7:40, 10:59 (b) and 16:30 respectively, in UTM university on latitude 1.28 and longitude 103.45 in 22 April 2011. The viewer location can be changed by changing the longitude and latitude. Date and time are also changeable. One of the facilities of the software is rendering automatically during a daytime.

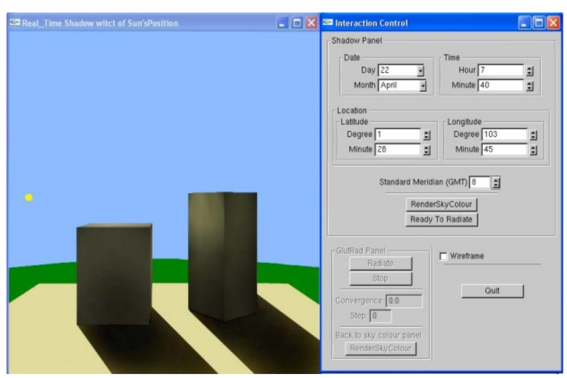

Fig. 3. Result of application at 7:40 in UTM (April 22, 2011)

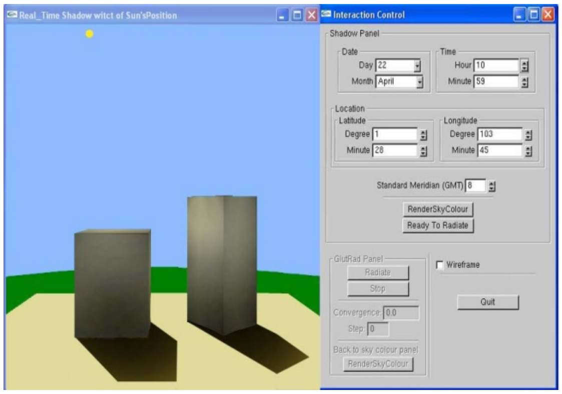

Fig. 4. Result of application at 10:59 in UTM (April 22, 2011)

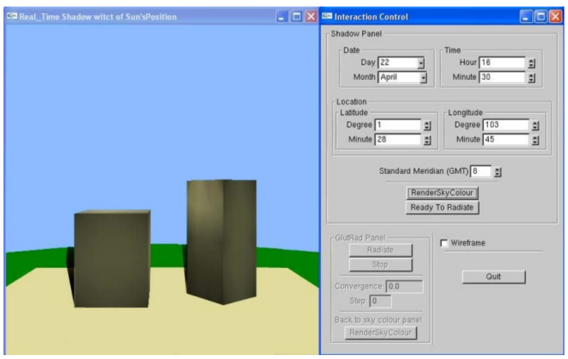

Fig. 5. Result of application at 16:30 in UTM (April 22, 2011)

4. Future work

In this study, we have focused on projection shadow on flat surfaces. Shadow volume and shadow mapping are other techniques to create shadow. To have shadows on arbitrary object, shadow volume using stencil buffer is appropriated. Shadow mapping is more convenient for outdoor rendering because of high-speed rendering but not more than projection shadow. Volume shadow using stencil buffer or shadow mapping combined with sky color can make it as much realistic as possible. Interaction between the sun's position, sunlight, shadow and sky color in the outdoor virtual environment can be more attractive.

5. Conclusion

Since this research targets at shadows and sun's position for game engines and virtual environment, the real-time shadow technique seems appropriate. Subsequently, the hard shadow such as projection shadow was rendered with sun's position to get the precise effect of sun's position in outdoor effects such as shadows. The methodology used in this research combines projection method with sun's position and sky modeling. The first objective of this research is achieved by the use of projection shadow to create hard shadows and to recognize the position of the sun for each viewpoint in specific location, date and time of day.

The proposed application can be used for outdoor games without any hesitation about the position of the sun and location of shadow for each object. Other contribution of this application is for building designer to find the best direction to build a building to save the solar energy. Expert proposed method can also be used to display the sun's position and to describe the amount of shadow changes in some high schools.

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