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I.L. Ishchenko

Kharkiv National University of Radioelectronics, Kharkiv

ENHANCING OF REAL-TIME LIGHTNING FOR OUTDOOR AUGMENTED REALITY

Knowledge about illumination conditions in a real world scene has many applications, among them Augmented Reality which aims at placing virtual objects in the real world. An important factor for convincing augmentations is to use the illumination of the real world when rendering the virtual objects so they are shaded consistently and cast consistent shadows. This paper provides an overview of several lightning technics and proposes enhancements of real-time image based lightning system for outdoor augmented reality under dynamically changing illumination conditions. Proposed improvements help to increase speed and quality of rendering.

Keywords: lightning, shading, AR, illumination estimation.

Introduction

Imagine a picture of street with a car on a sunny side of the street. Then cloud blocks the sun, whole street is now in shadow. But car still looks like the sun bathes it. And you realize that car is simply a virtual object rendered on top of the picture of a street. That scenario represents typical problem in Augmented Reality applications. So there is a need for a system that can handle dynamically changing lightning conditions.

Augmented Reality is a way to extend the real world with a virtual overlay. This could be simple information about the real world or photorealistic renderings of objects like car prototypes or architectural models. In many AR applications it is desirable for virtual objects to fit seamlessly into the real environment. This requires the virtual objects to be lit consistently with their neighbouring real objects.

To get a photorealistic scene with rendered 3D object a lightning estimation is needed, as well as rendering pipeline that uses the estimation to illuminate the augmented objects.

One of the most essential aspects to make virtual objects look like real ones is lighting. In traditional computer graphics a simple lighting model is calculated with point light sources, which have a distinct position and are infinitely small. In the real world an objects does not only receive photons emitted from light sources, but also photons which bounce off other objects. Image Based Lighting can simulate these effects by using an image of the environment to calculate lighting. Thereby it is also possible to simulate irregularly-shaped indirect light sources

The proposed algorithm can work only with outdoor scene during daytime. The sun should be the only major light source and therefore the only direct light source needing estimation. Sky lightning will be estimated as ambient light. The scene should contain diffuse surfaces that will be used in estimation of the scene lightning.

Most of the approaches to determine the scene illumination require either a light probe, or a calibration object (mirrored sphere). Algorithm proposed by Jensen and Andersen [1] can detect and estimate dynamic light changes without use of a light probe or a calibration object [2].

The goal of this paper is to propose enhancements to Jensen, Andersen and Madsen approach [1].

Illumination estimation

The classical approach to achieving illumination consistency for AR is to employ a light probe image, also called an environment map. A light probe is an omni-directional image of the scene, acquired at the location where a virtual object is to be inserted. The light probe image must be acquired in High Dynamic Range (HDR) to capture illumination sources without pixel saturation. This approach was pioneered in (Debevec, 1998) and has later been employed as the basic illumination technique in a multitude of real-time AR research.

While the approach of using a captured HDR environment map of the scene allows for really realistic illumination interaction between real and virtual scene elements, it is of course totally impractical for an adaptive real-time system to require such environment maps. They must be captured where an augmentation is to be made, and the basic idea cannot be used for scenes with dynamically changing illumination.

Another family of research into AR illumination is centered around manually creating detailed 3D model of the real scene, including the sizes and positions of the light sources, combined with one or more images of the scene. Using inverse rendering techniques virtual objects can then be rendered into views of the scene with consistent illumination. The amount of manual 3D modelling required by these techniques, combined with the need for multiple views of the scene (for some of the methods), make them unrealistic for general purpose real-time illumination adaptive AR systems.

Other work is based on estimating the illumination using shading information from images of glossy spheres in the scene. Some work combine the information from both shadows and from shading. Again, these techniques are impractical in the fact that they require an object in the scene for which perfect geometric information is available.

The final category of related work we mention is quite related to the research presented in this paper in the sense that it also addresses outdoor daylight scenarios. Under the assumption that two different views of a static outdoor daylight scene are available, and assuming that there are shadows from vertical structures in the scene, the camera can be calibrated to the scene and the direction vector to the sun can be estimated, (Cao & Foroosh, 2007); (Cao & Shah, 2005). In that work manual identification of essential object and shadow points is required. Shadows from virtual objects onto real scene surfaces are generated using information extracted from semi-manually detected real shadows, under the assumption that the shadows fall on uniformly colored surfaces.

The 3D model of the environment needs only to be a simple representation, containing only the main surfaces of the scene. In the first step shadows of dynamic objects are detected. Such dynamic objects can be people, cars, tree leaves, etc. In the second step color information from shadows combined with depth information are combined in a scene lightning estimation. In this step also estimation of color and intensity of sky and sun is performed.

Using an HDRI mapping of the environment is a common approach in the field of Image Based Lighting to getting a realistic shading of virtual objects based on the lightning of the surroundings. Such an environment map would represent the light reflected off the various surfaces in the scene, plus the sky [3].

The sun position is computed from several sensors: GPS for detecting the location on Earth compass for detecting North direction and accelerometer to detect device inclination [1]. Since modified approach is intended to use on mobile devices requirement of those sensors can't be considered as limitation as most of the popular devices have such sensors. The sun position is calculated only when one of sensors report changes.

It is assumed that the sunlight is purely directional. This is not correct in reality but that assumption doesn't lead to significant error in calculations while it helps to speed-up calculations.

Another assumption made by Jensen, Andersen and Madsen is that buildings surfaces are close to being diffuse so they are used to get illumination parameters [4].

The result of calculations is passed to the renderer as RGB intensities for direct and ambient (from sun and from sky respectively) lightning and vector to the sun.

To increase speed of illumination estimation we propose following algorithm. Based on camera field of view we create lightning map that represents light conditions in each sector of 360-degree panorama. The function for generating sector light map can be rough and should be simple to calculate since it should be called in each frame. Illumination conditions will be re-estimated only if calculated sector light map is different from stored one.

Most of modern mobile devices support multi-threading so illumination estimation should not be performed on main thread. Since illumination estimation is initiated on changing light conditions it may be calculated not immediately but using multi-threading will improve user experience.

Rendering

After estimating scene lightning that information is used to place and illuminate virtual object in the scene. This is done by placing the virtual object within the scene. Using Blinn-Phong shading model results in realistic images.

While Blinn-Phong model can be seen as approximation to the Phong model, it can produce more accurate models for many types of surfaces. It is less efficient than pure Phong model, since it contains a square root calculation. However, as many CPUs and GPUs contain single and double precision square root functions and other instructions that can be used to speed up rendering, the time penalty for this kind of shader will not be noticed in most implementations.

However, Blinn-Phong will be faster in the case where the viewer and light are treated to be at infinity. This is the case for directional lights. In this case, the half-angle vector is independent of position and surface curvature. It can be computed once for each light and then used for the entire frame, or indeed while light and viewpoint remain in the same relative position. The same is not true with Phong's original reflected light vector that depends on the surface curvature and must be recalculated for each pixel of the image (or for each vertex of the model in the case of vertex lighting).

To achieve the illusion that virtual 3D object is a part of the real scene shadows play a big role. Shadows are important to determine proportions and relative positions of objects. Every real object in a real scene casts shadows. Virtual objects usually do not and so they are easily identifiable as virtual. In pure virtual environments approximated shadows may look visually acceptable. In Mixed and Augmented Reality environments virtual shadows can directly be compared to shadows of real objects. In this case they have to match the real shadows in shape as well as in color, softness and direction to look realistic [5].

To achieve that three-step mechanism is used: shadow detection, shadow-protection and shadow

generation [6]. In the first step the shadows of the real objects are automatically detected using the texture information and the initial estimate of the shadow region. In the second step protection mask is created to prevent rendering in shadow regions. In the third step virtual shadows are generated using shadow volumes or shadow maps and a pre-defined scaling factor that adapts intensity of the virtual shadows to the real shadow. First two steps actually performed with first step of illumination estimation [7]. Information about static objects shadows can be cached when object appears in the scene at the first time and than shadows can be generated from cached information and information about device location and position that can be obtained from device sensors.

Conclusions

Proposed enhancements will help to increase final picture quality while proposed performance enhancements will keep speed at acceptable level to use this method on mobile devices.

Method itself shows the ability to adapt the lighting to correspond to the surroundings, as well as displaying the necessity for a global illumination approximation for the ambient part of the shading, when the object is positioned in shadow.

One of the most important optimizations - bypass the relighting of environment maps, and relight the key point samples instead, in the vicinity of where the shaded object is positioned.

References

1. Tommy J. Madsen *Real-time image based lighting for outdoor augmented reality under dynamically changing illumination conditions* / Jensen Tommy, Mikkel S. Andersen, Claus B. Madsen // *Proceedings: SIGGRAPH 2001*. – 2001. – P. 121 – 129.
2. Sato I. *Illumination distribution from shadows* / I. Sato, Y. Sato, K. Ikeuchi // *Proceedings: CVPR99*. – 1999. – P. 143.
3. Debevec P. *Rendering synthetic objects into real scenes: Bridging traditional image-based graphics with global illumination and high dynamic range photography* / P. Debevec // *Proceedings: SIGGRAPH 1998*. – 1998. – P. 53 – 59.
4. Greger G. *The irradiance volume* / G. Greger, P. Shirley, P.M. Hubbard, D.P. Greenberg // *IEEE Computer Graphics and Applications*. – 1998.
5. Whitehurst A. *Depth map based ambient occlusion lighting* / A. Whitehurst. – 2001. – 448 p.
6. *Estimating and Applying Dynamic Light Changes to Environment Maps in Real-time for use in Image Based Lighting* // *Shadow Algorithms for Computer Graphics. SIGGRAPH '77: Proceedings. Aalborg University Crow, F.C., 1977*. – P. 45 – 52.
7. Kanbara M., *Real-time estimation of light source environment for photorealistic augmented reality* / M. Kanbara, N.Yokoya // *Proceedings of the 17th International Conference on Pattern Recognition, 2004*. – P. 132.

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Рецензент: канд. техн. наук, проф. О.Г. Качко, Харківський національний університет радіоелектроніки, Харків.

МЕТОДИ ПОКРАЩЕННЯ ОСВІТЛЕННЯ У ДОПОВНЕНІЙ РЕАЛЬНОСТІ НА ВІДКРИТОМУ ПРОСТОРИ В РЕЖИМІ РЕАЛЬНОГО ЧАСУ

І.Л. Іщенко

Знання про умови освітлення реальної сцени має багато застосувань, у числі яких доповнена реальність, ціль якої є розташування віртуальних об'єктів у реальному світі. Важливим фактором створення доповнення є використання освітлення реальної сцени під час відображення віртуальних об'єктів таким чином, що вони отримують та відкидають тіні. У даній роботі наведено огляд методів освітлення та запропоновані шляхи покращення системи освітлення на основі зображень у реальному часі для застосувань доповненої реальності, які використовуються на відкритому повітрі за умови динамічної зміни параметрів освітлення.

Ключові слова: освітлення, затінення, доповнена реальність, оцінка освітлення.

МЕТОДЫ УЛУЧШЕНИЯ ОСВЕЩЕНИЯ В ДОПОЛНЕННОЙ РЕАЛЬНОСТИ НА ОТКРЫТОМ ПРОСТРАНСТВЕ В РЕЖИМЕ РЕАЛЬНОГО ВРЕМЕНИ

И.Л. Ищенко

Сведения про условия освещения реальной сцены имеют много применений, в числе которых дополненная реальность, цель которой расположение виртуальных объектов в реальном мире. Важным фактором создания дополнения является использование освещения реальной сцены во время отрисовки виртуальных объектов таким образом, что они получают и отбрасывают тени. В данной работе приведен обзор методов освещения и предложены пути усовершенствования системы освещения на основе изображений в режиме реального времени для приложений дополнительной реальности которые используются на открытом пространстве при условии динамического изменения параметров освещения.

Ключевые слова: освещение, затенение, дополненная реальность, оценка освещения.