A sensor based approach to outdoor illumination estimation for Augmented Reality applications on mobile devices

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Abstract

Realistic Augmented Reality applications require integrating virtual objects in the real world in a seamless visual way. The main problem to obtain a perfect visual augmentation is rendering the virtual objects with consistent illumination. In this paper, we present a novel approach to estimate outdoor illumination for Augmented Reality applications on mobile devices based on information acquired from sensors. We use an ambient light sensor to automatically detect in real-time the scene illuminance, which is used to simulate the actual lighting conditions. As outdoor illumination is mostly dependent on the weather, we derived the sky/sun illumination parameters from the light sensor data based on the IESNA sky model. The sunlight direction is estimated based on information from the GPS, date and time of the day. The result is a practical solution for outdoor illumination estimation handling light changes under natural conditions and applying them to the rendering of virtual objects in the real scene.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Graphics systems and interfaces—Mixed/augmented reality

1. Introduction

The major problem to obtain consistent Augmented Reality (AR) images is to estimate the real world illumination. The prominent approaches proposed in the literature to address this problem require either having knowledge of the 3D geometric model of the scene [YDMH99] and/or having an HDR environment map obtained from a light probe placed in the scene [Deb98]. While efficient for indoor scenarios, these techniques hardly can be applied to outdoor scenes as in dynamic scenes the light probe information becomes invalid when changes occur in the illuminations conditions, and reconstruction of the 3D geometry is a very difficult task.

Alternatively, Madsen et al. [ML11] recently proposed a method to estimate the sun and sky illumination from shadows on the ground. Nevertheless, their approach necessarily requires a stereo camera to recover the depth information. In this paper, we propose a method for estimating the outdoor illumination that does not require computational demanding 3D model of the scene geometry or any expensive and hard to find special equipment. Our approach addresses outdoor daylight scenes with natural sunlight and skylight illumination. The sun's direction is calculated from GPS receivers along with information about the date and time of the day. The scene illuminance is automatically estimated based on information acquired from the ambient light sensor (ALS) embedded on a mobile device, which allows to determine how much light in *lux* is available. The outdoor illumination parameters (sky/sun) used for adjusting the rendering of the virtual objects are derived from the absolute illuminance depending on the sky conditions. The result is a novel approach that makes use of data from cheap sensors: GPS and ALS to accurately simulate the real world illumination conditions.

This approach is well suited for mobile devices since today's smartphones and tablets have GPUs, support wireless communication, and come with a growing set of such embedded sensors [LML*10]. Compared with existing approaches, the main contributions of our work include: (1) Visually credible AR images with significantly less computational effort and without using any intrusive objects to collect the data; (2) Fast illumination updates capable of handling with dynamically changes in the light scene conditions under unprepared environments; (3) A new algorithm implementation for derivation of the illumination parameters, from the light sensor, under different weather conditions.

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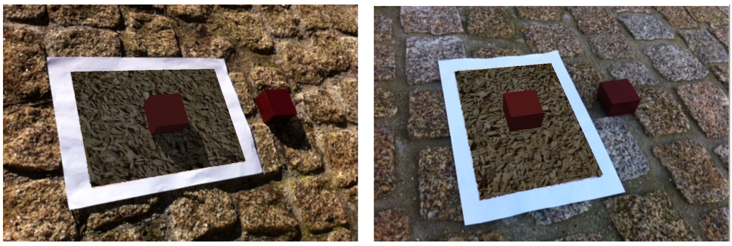

Figure 1: *Experimental results under two different sky conditions: clear sky ($E_t \simeq$ 10000 lx) and cloudy sky ($E_t \simeq$ 800 lx). Each image shows a virtual cube (on the left) and a real cube (on the right).*

2. Illumination Estimation Approach

The overall distribution of light in outdoor scenarios can be expressed as:

$$E_t = E_{sky} + E_{sun} \tag{1}$$

E_t is the total illuminance in a surface, E_{sun} is the direct illuminance from the sun, and E_{sky} is the diffuse illuminance from the sky. In our approach, first the total scene illuminance E_t is obtained from the ALS, then the ratio E_{sky}/E_{sun} is estimated.

We derive the skylight and sunlight intensities based on current weather conditions and state-of-art sky models. Among the available models, we chose the IESNA recommended practice [IES84] because it calculates the daylight availability with simple equations that do not require dew point temperature data. The current weather conditions (*clear sky*, *partly cloudy sky*, *cloudy sky*) are obtained based on the user position on Earth (GPS information) together information about the date and time of the day. Using these information as input parameters to a weather API (Yahoo!) we can get and update the current sky conditions. Equation 2 presents the proposed computation procedure to calculate the sky ratio.

$$\left.\begin{array}{l} \textit{Clear sky}: E_{sky} = 0.15{*}E_t \\ \textit{Partly cloudy sky}: E_{sky} = 0.5{*}E_t \\ \textit{Cloudy sky}: E_{sky} = E_t \end{array}\right\} \tag{2}$$

Accordingly to the IESNA model, under clear conditions $E_{sky} < 0.3\ E_t$. Yet, for these conditions the Bird model also provides good illuminance estimation. Thus, under clear sky we consider the diffuse illuminance approximately 15% of the total illuminance. Partly cloudy sky can range from 30% to 80% of the total illuminance. From the IESNA model and for practicable purposes we estimate at 50%. Finally, under a cloudy sky, the direct illuminance from the sun is approximately zero and only the diffuse illuminance from the sky is distributed around the hemisphere. We consider night conditions when the total solar illuminance from the sensor not exceeds 200 *lx*, which is the extreme of darkest storm clouds. In this case, none virtual object is rendered. In our approach, dynamic shadows on the objects can be detected when the absolute illuminance in a sunny position decreases sufficiently for the different weather conditions, i.e, 85% under clear sky and 50% under partly cloudy sky, because later than receive a shadow the direct sunlight parameter $E_{sun} = 0$.

3. Results

The approach proposed in this paper is been implemented on an iPhone 4. To build the AR scene we used Vuforia and Unity 3D for rendering. E_{sun} is computed as a directional light source and E_{sky} is a uniformly distributed light source. The virtual sunlight is linked to the position and orientation of the AR camera, so we can update the illumination depending on the user view direction. The camera pose is calculated using a visual marker on the scene. Figure 1 presents our proof-of-concept implementation.

4. Conclusion

In this paper, we presented a method for consistent illumination of virtual objects in real camera images for an outdoor scenario. An important contribute is the use of sensors to derive the illumination parameters without involving complex operations providing rapid display of realistic AR scenes under unprepared environments with low computational effort.

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