Projective Illumination Technique in Unprepared Environments for Augmented Reality Applications

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Abstract

Most augmented reality (AR) applications in prepared environments implement illumination mechanisms between real and synthetic objects to achieve best results. This approach is beneficial to tracking technologies since additional visual cues provide seamless real-synthetic world integration. This research focuses on providing a projective illumination technique to aid augmented reality tracking technologies that work in unprepared environments where users are not allowed to modify the real environment, such as in outdoor applications. Here, we address the specific aspects of the common illumination problems such as efficient update of illumination for moving objects and camera calibration, rendering, and modeling of the real scene. Our framework aims to lead AR applications in unprepared environments with projective illumination regardless of the movement of real objects, lights and cameras.

Keywords: ***a****ugmented reality, illumination technique, unprepared environment*

1. Introduction

Augmented reality (AR) applications superimpose virtual 3D objects on a real world scene in real-time that change users' point of view. In an ideal world, they appear to user as if the virtual 3D objects actually coexist in the real environment [1]. Implementing AR not only enables users to perceive a synthesized information space, but it also allows them to naturally interact with the synthesized information using frameworks adapted from real-world experiences.

The use of computer vision algorithms in AR applications supports the detection, extraction, and identification of markers in the real scene. Currently, AR applications are successful in prepared environments where they produce best results in achieving pixel-accurate registration in real time [2]. These environments enable system designers to have full control over the objects in the environment and can modify it as required. However, many potential AR applications have not been fully explored in unprepared environments due to inaccurate tracking. These include applications for drivers operating vehicles, soldiers in the field, and hikers in the jungle which could improve navigation, tracking, situational awareness, and information selection and retrieval. Several AR systems rely upon placing special markers at known locations in the environment such as in [3]. However, this approach is not practical in most outdoor applications since one can not accurately pre-measure all objects in the environment. The inability to control the environment also restricts the choice of tracking technologies. Many trackers require placing active emitters in the environment to provide illumination mechanisms for tracking objects. Figure 1 shows how important it is to handle the dynamically changing illumination in outdoor scenarios with the goal of producing a visually credible augmented reality [4].

Figure 1. Three frames from a 3 hour long sequence showing virtual sculpture rendered into scene with consistent illumination [4]

Many problems are still largely unresolved in tracking of arbitrary environments and conditions such as indoors, outdoors, and locations where the user wants to go. More so, illumination techniques in unprepared environments are difficult since the range of operating conditions is greater than in prepared environments. Lighting conditions, weather, and temperature are all factors to consider in unprepared environments. For instance, the display may not be bright enough to see on a sunny day. Visual landmarks that a video tracking system relies upon may vary in appearance under different lighting conditions or may not be visible at all at night. Additionally, the system designer cannot control the environment. It may not be possible to modify the environment.

This paper develops a projective illumination framework to aid tracking technologies for augmented reality applications. This framework is based on infrared filtering (IF) aimed to work in unprepared environments. The illumination technique addresses illumination updates, rendering, and camera calibration. Additionally, this study focuses on hybrid tracking technology that combines multiple sensors in ways that compensate for the weaknesses of each individual component. In particular, this research concentrates on the problems related to registration and calibration for real-time systems.

2. Related Works

Most of the AR systems have been applied to indoors and in prepared environments. Few AR systems operate in unprepared environments where the user cannot modify or control the real world. The first known system implemented in unprepared environment is the Touring Machine of Columbia [5] which uses commercially available no-source orientation sensors combined with a differential GPS.

Little attention has been given to the problems of the interaction of illumination between the real and synthetic scenes. Pioneering work in this domain has been performed by Fournier et al. [6]. This has shown how the computation of common illumination between the real and synthetic scene results in a greatly improved graphical environment with which the user can interact. The use of real video images eliminates the need to model complex environments in great detail, and provides a realistic image to the user naturally. In what concerns illumination, the introduction of virtual objects in a real scene becomes much more natural and convincing when light exchanges between real and synthetic objects are present in the composite images presented to the user. The problem of representing the dynamic range of real-world lighting conditions has been addressed by [7]. By capturing images at different levels of exposure, the response function of the imaging system may be recovered, and the images combined into a single high-dynamic range photograph. This algorithms use expensive global illumination techniques to illuminate the synthetic objects. With the exception of [8], this technique is not applicable when any form of interaction is required. Also, previous work utilizes the shadows cast by a known object to compute the illumination [9][10[11]. However, the disadvantage with these techniques is that it is necessary to place a known object, e.g., a cube, in the scene, and the techniques are based on an assumption that the known objects casts shadows on some known geometry in the scene, typically a planar surface. Other work is based on estimating the illumination using shading information from images of glossy spheres in the scene [12][13]. Some works combine the information from both shadows and from shading [14]. These techniques are impractical in the fact that they require an object in the scene for which perfect geometric information is available. Moreover, most of these algorithms for AR systems were applied in prepared environments.

3. Hybrid Tracking Algorithm

Various technical challenges are facing various applications of AR systems. One of the key challenges is the accurate tracking that measures the position and orientation of the observer's location in space. Without accurate tracking which positions virtual objects in their correct location and time, the illusion that they coexist with real objects are not possible. Central to the function of a tracking system is the exact alignment of virtual information with the objects in the real world that the user is seeing. This requires that the exact viewing position and viewing direction of the user are known.

This study first presents a hybrid tracking algorithm to aid in the process of creation, identification, and tracking of patterns to be used in unprepared environments. This type of environment is defined by the properties of IF light and retro-reflexive materials used to accentuate the markers from the rest of the scene. The algorithm is shown in Figure 2.

This algorithm was developed to work in an unprepared environment to avoid generation of false markers that would limit its performance in real-time. With the aid of IF pass filter and illumination, it discards the occurrence of false markers and enhances its performance. This algorithm performs invariant calculation to support AR applications. This can be useful in applications for adding or visualizing information over previously marked objects, where the main problem is the necessity of large patterns in the scene. The invariant feature in the hybrid tracking application can be used to generate a specific format serving as a filter to discard several candidate groups of 4 test patterns that do not fit the format. Additionally, generation of a bounded area around the pattern position in the current frame is a technique to reduce computational cost. Once the pattern is found and validated, the system creates a bounding area, used as a simple way to predict and restrict the area where a well recognized pattern may appear.

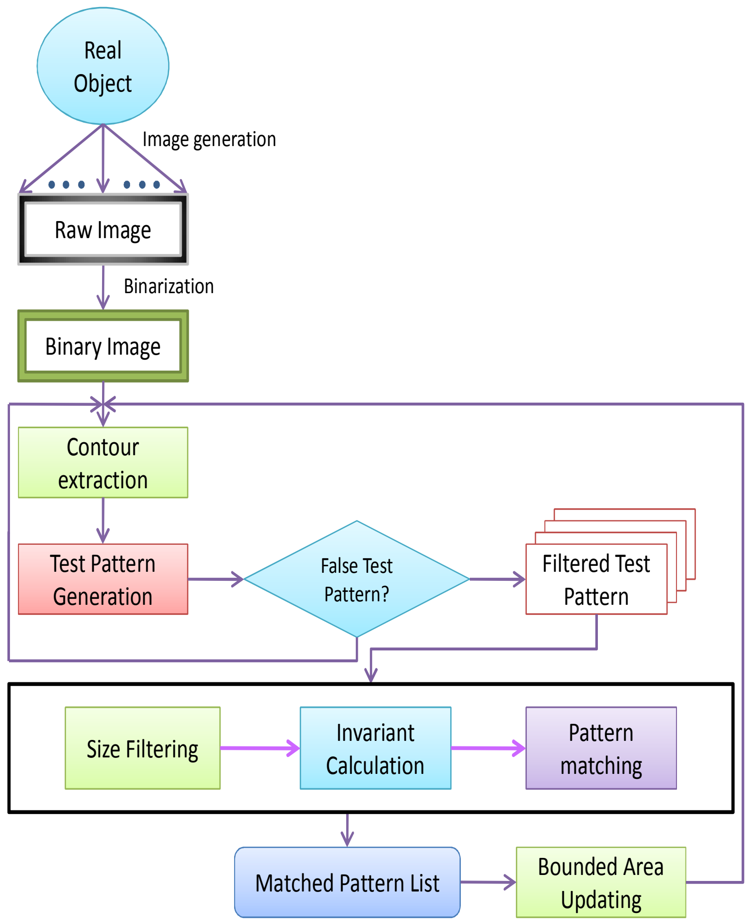

Figure 2. Hybrid tracking algorithm

4. Implementation Design

Here, we present the proposed setup of the hybrid tracking system. Infrared emitting diodes with optimized line densities served as illumination sources for the tracking of objects. A camera and a laptop is used for position tracking and to record video data, respectively. Global positioning system (GPS) receiver unit can provide measurement of the position of any point on the Earth. Other sensors such as rate gyroscopes, compass, and tilt sensors can predict motion and provide orientation. Position as well as orientation tracking is needed. Orientation tracking is much more critical than position tracking as a small rotation of the head will have a larger visual impact than a small movement to the left or right. The system also composes of a lightweight head mounted display that offers the viewing of real and virtual objects. Figure 3 shows the flow of data in the system.

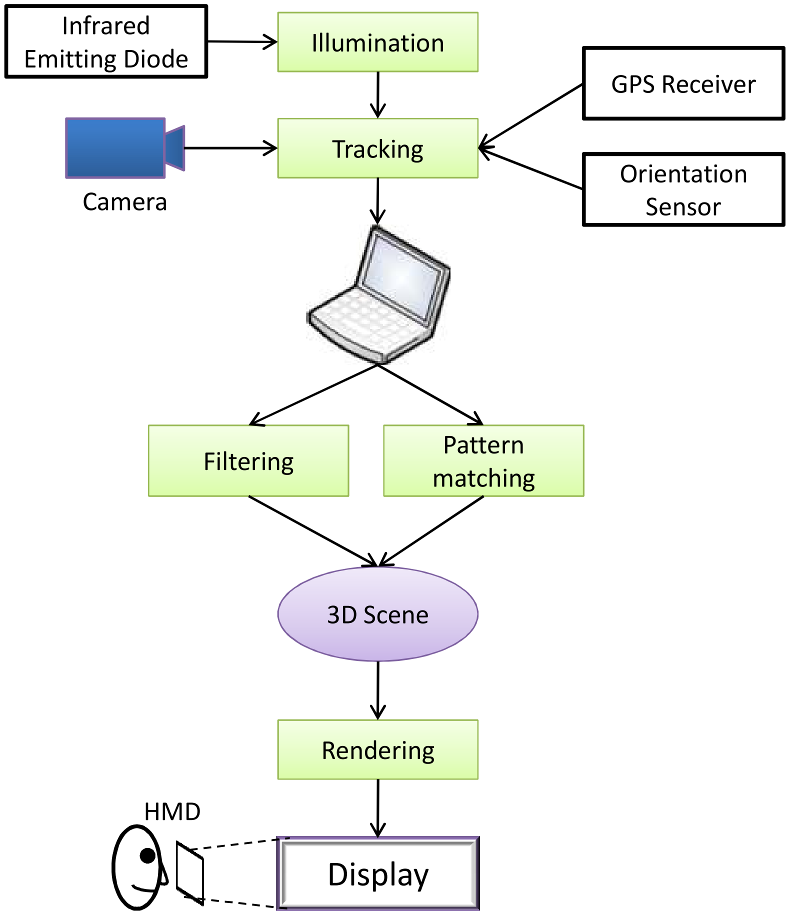

Figure 3. Data flow diagram

5. Camera Calibration

One of the requirement of the system is the computation of the intrinsic parameters of the camera such as focal length and aspect ratio using an image of a calibration pattern [15].We then took one image of a non-planar calibration pattern, for instance, a real object with visible features of known geometry. With minimal interaction an estimate of the camera parameters is computed. This estimate is then refined by maximizing over the camera parameters the sum of the magnitudes of the image gradient at the projections of a number of model points. The output of the process is a PRQTS matrix which is decomposed as the product of a matrix of intrinsic parameters and a SRQUS displacement matrix.

6. Projective Illumination and Image Acquisition

This section deals with the image acquisition and illumination techniques to correctly illuminate synthetic objects. This study performs illumination at a single position in the scene and assumes that this is a good approximation of the actual light illuminating each synthetic object. The image acquisition process begins with the capture of the background image. We employ a standard calibration algorithm to determine the position and orientation of the camera [16]. Then we construct a high-dynamic range omni-directional image that represents the illumination in the scene which is achieved in a similar fashion to [17], whereby multiple images of a shiny metallic sphere are captured at different exposure levels. These images are then combined into a single high-dynamic range image.

Once an omni-directional radiance-map has been captured, it must be manipulated into a form suitable for rendering. As each synthetic object is drawn, we use hardware-accelerated sphere-mapping to approximate the appearance of the object under the captured illumination conditions.

In [18] it was proposed that an omni-directional radiance-map could be pre-integrated with a bi-directional reflectance distribution function (BRDF) to generate a sphere-map that stores the outgoing radiance for each surface normal direction. This pre-integration which needs to be performed for each different BRDF, is too slow whenever an application requires the interactive manipulation of materials.

We compute a diffuse irradiance map, as well as specular maps for varying values of the surface roughness parameter. At run-time, we combine these basis maps according to the particular reflection model coefficients associated with each material, and generate the appropriate sphere-map. The final step of sphere-map generation is the application of the camera response function to translate the radiance-map into a texture map that can be utilized by the graphic device.

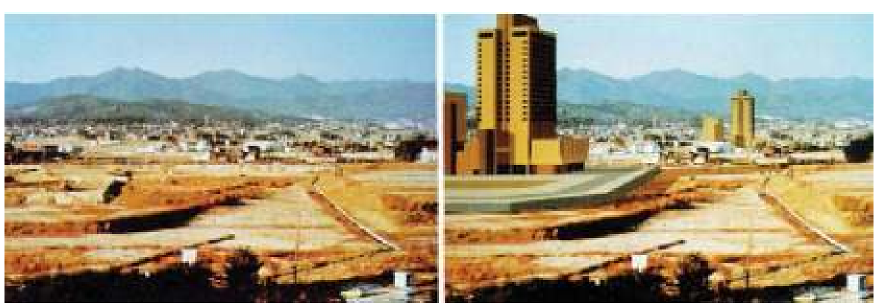

Figure 4. The first image depicts the background scene while the second shows the augmented scene where the illumination of the augmented objects is matched to their surroundings.

7. Case Study

This section presents one of the earliest algorithms for compositing synthetic objects into background images as proposed by [19]. Their solution involved estimating the location of the sun and levels of ambient light to illuminate synthetic architectural models rendered onto background photographs. An example is shown in Figure 4 [19] which shows the illumination of augmented objects being matched with the surroundings.

8. Conclusion

In this paper we have presented a framework for dealing with the problem of illumination between real and synthetic objects and light sources in unprepared environments. Much remains to be done to continue developing system that work accurately in arbitrary, unprepared environments. Our framework will hopefully lead to AR applications with efficient update of illumination without restrictions on the movement of real or synthetic objects, lights, and cameras. This research aimed to have easier modeling and calibration, faster illumination updates and rapid display of AR scenes.

For future work, we will focus on removing the restrictions one by one, to achieve projective illumination technique to other scenarios such as moving camera, moving lights, and moving real objects. We will also investigate the issues regarding pre-recorded video sequences, before taking the plunge into real-time acquisition.

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