Projection-Based Diminished Reality System

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Abstract

Diminished reality is a technique that provides visual convenience by virtually hiding an object. Despite that the promising advances of projection-based vision techniques provided good solutions for vision applications, there has no report of the development of diminished reality systems using projection-based vision techniques. As a first attempt, this paper proposes a projection-based diminished reality system using two essential techniques: image completion technique for removing a target object; radiometric compensation technique for seamless projection onto the target object. Potential of the proposed system is demonstrated through experiments.

1. Introduction

In recent years, improvements in video projector capabilities accompanied with falling retail prices have led many researchers to vigorously study projection-based techniques. Especially, great efforts for resolving fundamental problems of projection-based system [1, 2, 3]: projection images may be geometrically and radiometrically distorted due to dynamic and complex projection surfaces in real environment have enabled to provide good solutions for vision applications [4]. The interest is because projection-based techniques enhance user-immersion by offering visual information in a very natural manner without wearing or watching bulky devices such as head-mounted displays (HMDs) or screen-based displays.

Different from augmented reality (AR) that inserting a virtual object in real world, diminished reality (DR) is a technique of hiding a real object in the world to provide convenience to people and make them immersed in a virtual environment. Lots of studies about DR have been made over the past few years [5, 6, 7, 8], but no study has tried to implement a projection-based DR system in spite of these great researches.

In this paper, we introduce a projection-based DR system as one of approaches toward fully immersive mixed reality. The proposed system provides realistic DR onto real objects directly, not in captured images or video sequences that used in previous approaches.

2. Image completion

Image completion techniques have been widely studied to remove undesired objects in images and complete missing regions with visually natural textures. In general, the image completion techniques can be classified into two representative methods. One is the non-exemplar based method [9, 10] and the other is exemplar-based methods [11, 12, 13]. The non-exemplar based method is effective for small image gaps for example scratches in a photograph. However, if the missing region is large, the result will be unclear. On the other hand, the exemplar-based method can synthesizes complex textures and fill a large region reasonably.

In this paper, we use the exemplar-based method for image completion [11]. A target object that we want to remove is iteratively filled based on the following priority function P:

$$P(p_c) = C(p_c) \cdot D(p_c), \quad \forall p_c \in \partial \Omega$$

where $p_c$ is a point on contour $\partial \Omega$ of a target region, $C(p_c)$ is a confidence value at a point $p_c$, and $D(p_c)$ is a measurement of the structure information surrounding the point $p_c$. The confidence values are initially assigned: the target region is 0 and the other region is 1 and they are iteratively updated until the target region is entirely filled. Structure information is based on the gradient information of neighborhood pixels around the point $p_c$. The priority function takes consideration into both similarities of pixels and continuation of structures, and it encourages the structural regions to be filled first. The result of image completion is shown in Figure 1.
Figure 1. Image completion: (a) original image, (b) selection of a target object, (c) result image.

3. Geometric registration and radiometric compensation

To handle a projected image, the coordinates of a camera plane have to coincide with that of a projector plane first. If a camera and a projector are calibrated [2, 14], a geometric relation between the camera, the projector, and a screen is defined by the following homographies.

\[ I_c = (H_{ps})^{-1}I_p = (H_{ps}H_{sc})^{-1}I_c \]  

(2)

where \( I_c \) is a camera image, \( I_p \) is a projector image, \( H_{ps} \) is projector-screen homography, \( H_{sc} \) is screen-camera homography, and \( H_{pc} \) is projector-camera homography. By the geometric relation, the point on the camera plane is directly mapped to the point on the projected plane. Then, a completion image is precisely projected onto the surface of the target object that we want to hide.

However, a projection image is radiometrically distorted because the object’s color scheme is contained in a part of the projected surface where the object is (Figure 2-(c)). Assuming that each radiometric response function of the camera and the projector is known, a radiometric model between the camera, the projector, and a screen [2, 3] is defined as

\[ I_c = VI_p + e \]  

(3)

where \( I_c \) is a camera image, \( I_p \) is a projector image, \( V \) is color and reflectance of the screen, and \( e \) is ambient light. For radiometric compensation, a projector image prewarped \( \tilde{I}_p \) is computed as follows:

\[ \tilde{I}_p = V^{-1}(I_c - e) \]  

(4)

(Figure 2-(d)). Finally, the projection image is seamlessly projected onto the surface of the target object (Figure 2-(e)).

Figure 2. Radiometric compensation: (a) original image, (b) colorful textured patch, (c) projection image distorted by (b), (d) prewarped image for compensation, (e) result image.

4. Experimental results

The experiment was set up with a projector (Sony, VPL-CX70), a camera (PointGrey, Dragonfly), and a projection screen with a colorful textured patch. The resolution of an image was 1024 by 768. The camera and the projector were geometrically and radiometrically calibrated in advance.
Figure 3 shows the experimental result. In a captured image of a scene, a target object that we want to remove was manually selected (Figure 3-(b)). Then, the target object was naturally completed using the image completion technique. Especially, the structure adjacent to the target object was synthesized without destroying its continuation (Figure 3-(c)).

When the completion image was projected onto the target object without any processing, the projection image was radiometrically distorted (Figure 3-(d)). For radiometric compensation, a prewarped image was computed by the radiometric model of the projector-camera system (Figure 3-(e)) and finally the target object in the real scene was visually disappeared by projecting the prewarped compensation image (Figure 3-(f)).

![Figure 3](image)

Figure 3. Experimental result: (a) target scene, (b) selection of a target object being removed in the target scene (a), (c) completion image, (d) projection image distorted by a colorful textured patch when the completion image (c) is projected, (e) prewarped image for radiometric compensation, (f) result image.

5. Conclusion

The proposed projection-based diminished reality system was well-motivated for realistic diminished reality. Our approach using the two essential techniques, the image completion technique and the radiometric compensation technique, was well-suited for the projection-based diminished reality system. Moreover, the experimental result was acceptable for verifying its feasibility. Therefore, the proposed system could be further developed into one of key applications for fully immersive environment.

Currently, we are trying to further extend our approach to 3-D objects in real scenes and the preliminary result is shown in Figure 4. Although the proposed approach provides promising results, there needs a careful consideration on 3-D real scenes, where critical factors such as occlusion, view-dependent projection, speed-accuracy tradeoff, and etc are being evolved.

6. References


Figure 4. Projection-based diminished reality onto a 3-D object: (a) target scene, (b) result image.


