Laser Projector in Augmented Reality

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Abstract: *Projection-based augmented reality (AR), also known as spatial AR and projection mapping, merges real and virtual worlds seamlessly. Because it usually assumes non-planar projection surfaces, laser projector holds an advantage regarding depth-of-field over other types of projectors. This invited talk covers a recent research of introducing laser projector in AR.*

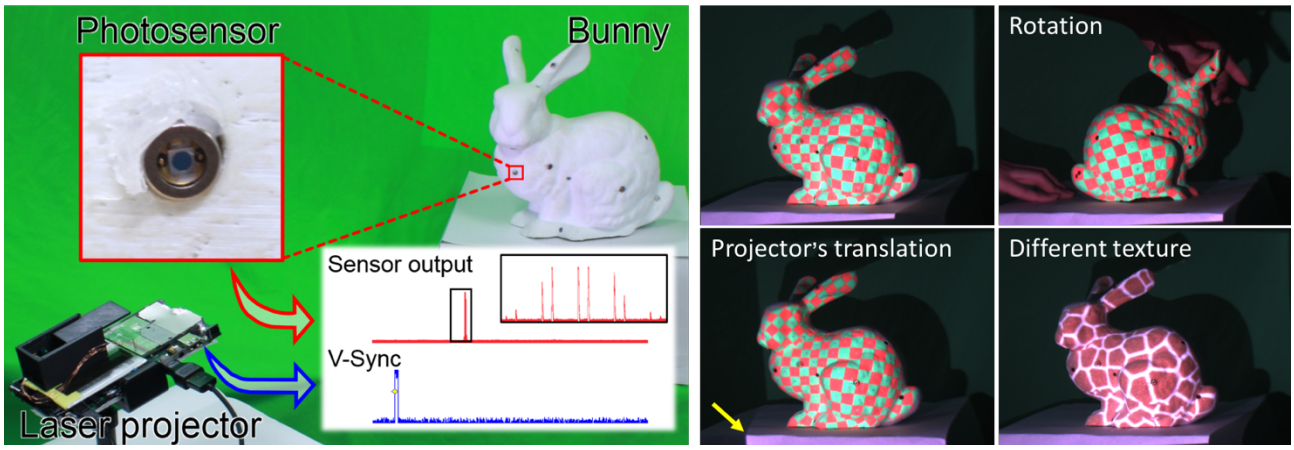

Fig. 1. Dynamic projection mapping, or dynamic projection-based augmented reality, of the SPAP (Simultaneous Projection and Positioning) approach: (left) a prototype system of the direct method consisting of a laser projector and photosensors embedded in a projection surface and (right) projection mapping results for different surface poses (rotation and translation) and different textures. The yellow allow indicates the left edge of the projected image that is horizontally shifted towards right due to the projector's translation [8].

1. Introduction

Projection-based augmented reality (AR), also known as spatial AR and projection mapping (PM), is a technology that controls the appearance of an arbitrarily shaped surface by projecting computer-generated images onto it. One of the recent research trends is dynamic PM where the surface and/or projector is moving [1-3]. Even though multiple systems have been proposed, the projectors applied in the majority of these prior systems, such as DLP (digital light processing) and LCD (liquid crystal display), are not suitable in some dynamic PM applications. In these projectors, a light ray from a light source is spatially modulated on a SLM (spatial light modulator) and then projected through an objective lens. To increase the brightness of the projected imagery, the aperture of the projector is normally designed to be large, which consequently leads to a narrow depth-of-field (DOF). A projection surface is expected to move over a wide area range in a dynamic PM scenario; however, conventional projectors cannot project sharp images over such wide areas.

Previously developed defocus blur compensation or DOF extension techniques can improve this situation but only to a limited extent [4,5]. Conversely, in theory, a laser projector has an infinite DOF [6] and therefore is suitable for dynamic PM [7]. In a dynamic PM system with a laser projector, it is inevitable to assume a situation where the distance between the projector and the surface varies significantly. Therefore, we need to geometrically register the projector so that the pixel alignment on the surface is consistently accurate with respect to the distance.

2. Simultaneous Projection and Positioning

In this invited talk, I introduce previously proposed geometric registration approach of a laser projector for dynamic PM [8]. Our approach is an extension of the principle of the light pen [9]. The light pen, in which a photosensor is embedded, can measure its position on a CRT (cathode ray tube) screen at each frame while displaying meaningful image content. The pen detects changes in the brightness of nearby screen pixels when the CRT electron beam scans across them and communicates the timing of this event to the computer. Because a CRT scans the entire screen one pixel at a time, the computer can estimate the pen's position from the latest timestamp. The image forming mechanism of the laser projector is also based on raster scanning. A

MEMS (Micro-Electro-Mechanical Systems) mirror adjusts the direction of a projected beam, and the color of each projector pixel is controlled by modulating the laser diode intensities of different primary colors. Leveraging this mechanism at each frame, we measure the time when a projected beam scanning over a projection surface hits a photosensor that is, for example, embedded in the surface. The time information is then used to estimate the position of the beam in the projector's screen coordinate system when it illuminates the sensor. Because the time information is invariant to the distance from the projector to the sensor, this method does not depend on the distance and therefore meets the requirement for dynamic PM described in the previous paragraph. This principle allows us to measure the position of a photosensor in each frame while projecting meaningful image content and, therefore, is referred to here as *Simultaneous Projection and Positioning (SPAP)*.

The SPAP method estimates the position of a projected beam when it directly illuminates the photosensor. We implement a prototype system as shown in Fig. 1(left) and investigate its geometric registration performance by evaluating the estimation accuracy. The estimation errors are measured by varying the distance from the laser projector to the photosensor, the projected light intensity, and other critical factors. Finally, we implement various dynamic PM applications to show the feasibility of our technique. They include a projector-based texture mapping for a moving 3D surface (Fig. 1(right)) and a drone projection.

3. Drone projection AR

Drone projection is an emerging research topic in which researchers attempt to realize an autonomous projection system that provides SAR anywhere [10,11]. Because a drone on which a projector is mounted generally flies with fluctuations, the geometric registration parameters must be estimated in each frame. In our application, we mounted our projector node on a drone and embedded four sensor nodes in a projection surface (Fig. 2). We applied the wireless system to this application. Estimated pixel positions on the sensors were used to compute the homography matrix used to transform the projection image to align the surface. Fig. 2 shows the result. We confirmed that the wireless system works and that a projection mapping can be achieved even when a projector is flying.

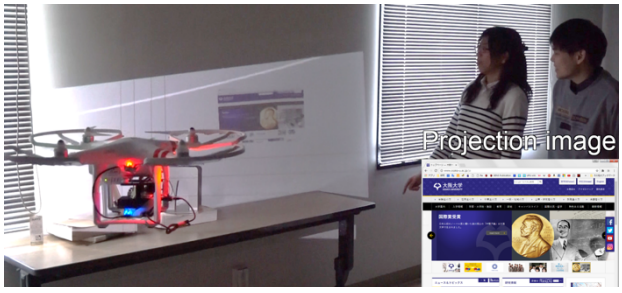

Fig. 2. A prototype of the drone projection [8].

4. Conclusion

Laser projector has a great potential for PM due to its large DOF especially in dynamic situations. This invited talk introduced a geometric registration technique of laser projector in dynamic PM applications. It is expected that laser projectors will be more often applied in PM applications in the near future.

Acknowledgement

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