Randomly Distributed Small Chip Makers

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ABSTRACT

In this paper, we propose a novel marker design and its tracking algorithm for room-sized MR/AR environments. The markers and the algorithm are designed to solve the following practical problems: i) the difficulties in creating and arranging markers and ii) the trade-off between inconspicuousness and robustness of markers. The proposed markers are small chips that are cut off a large paper sheet, and are arranged at random positions in an environment or on objects. This paper shows the design concept and feasibility of the proposed markers.

Index Terms: H.5.1 [Information Intefaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities; I.4.8 [Image processing and Computer Vision]: Scene Analysis—Tracking

1 INTRODUCTION

The recent development of visual SLAM (simultaneous localization and mapping) techniques [1, 2] has been remarkable as one approach for realizing geometric consistency in mixed and augmented reality (MR/AR). In these techniques, users are not required to prepare any room-scale tracker systems or 3D models. Even now that such state-of-art visual SLAM techniques are available, markers are still one important choice for many researchers and developers in construction of early experimental environments if the systems need the absolute world coordinates, or if few features are available in the environments.

Users of existing markers suffer from the following practical difficulties. First, if the markers are not small to hold identification patterns [3, 4], creating each marker precisely is not an easy task because existing markers are frequently assumed to have exact 3D shapes such as plain and sphere for precise registration. In fact, most existing markers have a certain size for high contrast identification patterns. Otherwise, markers with low contrast pattern [5] may sacrifice the robustness. Second, it is difficult to arrange markers at precise 3D positions, or to measure the 3D positions of arranged markers in lab-sized environments. Additionally, assigning identification patterns can induce procedure mistakes if the number of markers are large. Third, it is difficult to overcome the trade-off between inconspicuousness of markers themselves and robustness of tracking.

In this paper, we introduce a novel design of inconspicuous markers for a lab-sized MR environment. The proposed markers are small chips that are cut off a large adhesive sheet, and are used by arranging them at random positions in an environment or on objects, as shown in Fig. 1. Each marker does not have any identification pattern, but we use the positional relationship of neighbor makers themselves [6]. Creating each marker of this design is quite easy so that users are not required to pay attention to making precise shapes. The 3D position of each marker can be estimated by a multi-view triangulation technique which is inspired by feature-based visual SLAMs [7] and multiple marker trackers [8]. This approach is completely different from 2D small marker design [9] which assumes that relative positions of makers do not change on camera images. The SLAM-like approach relieves users from the 3D measurement and ID management. The smallness of each marker obviously contributes the inconspicuousness. Diminished reality techniques such as inpainting can work effectively because of the smallness. The inconspicuousness can be boosted up by using a light-mounted camera and retro-reflective material instead of paper as markers.

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2 SMALL CHIP MARKERS

This section briefly summarises the method to install the proposed markers and the tracking algorithm.

How to Create and Arrange Markers Adhesive sheets with the retro-reflective property cost about 0.6 USD per meter as of July, 2016. There are various colors of sheets such as blue, red, yellow, and even black, and also half-transparent ones [10]. As shown in Fig. 1 (a) and (b), to create markers from an adhesive sheet, our best way to cut the sheet is to use a utility knife so that the shape of each chip becomes a triangle or a quadrangle.

To arrange the markers, users are just required to peel each chip and past it to object or environment. In this process, the randomness of the marker distribution should be considered. Before using these markers, users are required to intentionally move a camera to build a map in the SLAM-like initialization algorithm [7].

Brief Summary of Tracking Algorithm The tracking algorithm using the proposed markers is basically the same as a keyframe-based visual SLAM using sparse features represented by PTAM [7]. In the current implementation, each marker is detected by the simplest binarization with a constant threshold, labeling, filtering by the size, and computing the center of gravity. Matching of markers in the current frame is performed to the keyframe with the closest camera position. Matching each marker is performed by locally likely arrangement hashing using the affine invariant property of neighbor markers [11]. After the matching, the camera pose is computed by solving the PnP problem with RANSAC robust estimation.

3 EXPERIMENT

We have implemented the proof-of-concept system including the algorithm described in section 2 based on ATAM [12]. To give a constant world coordinate system, the checkerboard marker was placed only for evaluation. Images were captured by an iPod touch (sixth generation) as a light-mounted camera (1920×1080 progressive, 30 fps) with fixed gain, shutter speed and focus while displaying the images on the screen with the resolution 1280×720 pixels. The displayed images were re-captured by a UVC HDMI capture device FEBON198 to transmit them to a PC (Intel Core i5-6400 2.70 GHz CPU, 8 GB RAM, Nvidia Geforce GTX 960 GPU) via USB3.0. All the processing was performed on this PC.

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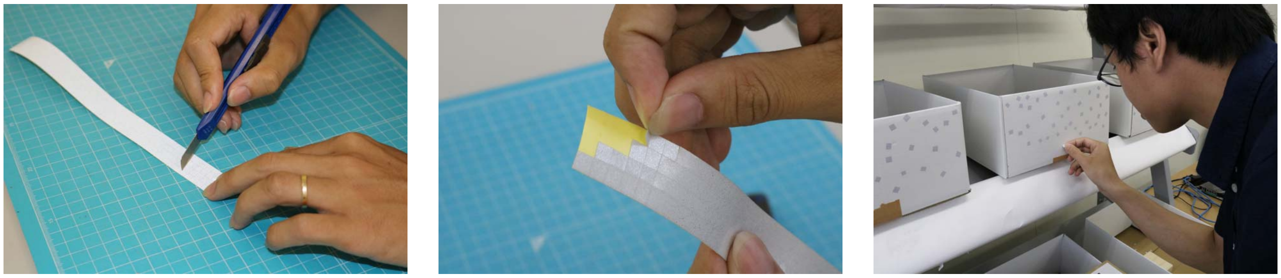

(a) Cutting a sheet. (b) Peeling a small chip. (c) Pasting the chip.

Figure 1: Procedure of environment construction.

(a) Lighting off. (b) Lighting on. (c) Augmented wireframe.

Figure 2: Experimental environment and result.

Fig. 2 (a) and (b) show two adjacent frames captured with lighting on and off, respectively. Note that the markers were inconspicuous from other viewpoints because of the retro-reflective property even when the light is turned on. A sampled image frame of an augmented 3D model is also shown in (c). The stability seemed better than typical visual SLAMs, but the accuracy was a little less.

4 Discussion

This paper introduced a novel marker design that has several practical advantages over ordinal MR/AR markers. Our proof-of-concept system shows the feasibility of the new marker design although the current implementation is quite simple. However, there remain several technical issues and we have strategies to compensate for shortcomings of this marker design.

Repeatability of Detection In most cases, the shape of each piece cut from a sheet or tape becomes triangle or quadrilateral. In the current implementation, the tracking result contains a little jitter because we do not consider the repeatability of the detection positions. Lens flare, motion blur, variation of marker shape should be considered as future work.

Randomness of Marker Distribution In this marker design, the randomness of marker distribution is not guaranteed because the markers are assumed to be arranged by hands. To relax this limitation, we will consider a user interface to visualize the current randomness.

Superiority to Existing Visual SLAMs By arranging the markers, the target objects or environments will have texture where existing visual SLAMs potentially work. To demonstrate the validity of our marker design, we are required to conduct some evaluation at least of the robustness and computational time.

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