Visually Elegant and Robust Semi-Fiducials for Geometric Registration in Mixed Reality

Ryuhei Tenmoku* Yusuke Yoshida† Fumihisa Shibata Asako Kimura Hideyuki Tamura
Graduate School of Science and Engineering, Ritsumeikan University

Abstract

This paper describes a novel image-based geometric registration method using visually elegant and robust semi-fiducial markers in mixed reality (MR). Most traditional visual markers stand out against the background, i.e., they can be recognized and identified easily. Here, we try to construct new visual markers for MR registration, which achieve a good balance between visual elegance and robustness. As the first step, we propose "two-tone colored markers". These markers have the following characteristics: 1) color similar to that of the background object, 2) placed at the corners of real objects in an inconspicuous manner. This paper describes the registration method using two-tone colored markers and a few experiments.

CR Categories: H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities—

Keywords: Mixed reality, Visual marker, Geometric registration, Semi-fiducials

1 Introduction

Many geometric registration methods for mixed reality (MR) have been proposed in previous ISMAR and other conferences. Among them, image-based registration methods, which use markers placed in the real scene, have more potential because they do not require any sensor except a camera. In particular, ARToolKit [1] is globally known for its high quality and portability. However, there are many claims that such fiducial markers are not visually appeasing. To solve this problem, few other methods have been proposed such as using natural feature points [2], translucent retro-reflective markers [3], or pattern-coded wallpapers [4]. However, these registration methods are not widely used since they have low stability, they require other sensors, or are not flexible.

Therefore, we propose a novel vision-based geometric registration method using discreet markers that are visually appeasing. We call such markers "Semi-Fiducial INvisibly Coded Symbols" (SFINCS). They achieve a good balance between the elegance with regard to the environment and robustness of the registration. In this paper, we propose the registration method using "two-tone colored markers" as the first product of SFINCS. This paper also describes some experiments using the proposed methods.

2 Geometric Registration Using Two-tone Colored Markers

2.1. Overview

Figure 1 shows the conceptual image of the proposed method. Our two-tone colored markers are similar in color to that of the background objects. These markers have the same hue value as the background color and slightly differ in brightness. We visualize these markers to be placed at the corners of flat colored plain surfaces of actual objects. T, L, I-shaped, and triangular markers are used. We call these markers "marker-elements." To estimate camera position and orientation, our proposed method uses four marker-elements. We call such sets of four marker-elements "marker-units." The combination of marker-elements, their colors, and the background object determine the marker ID.

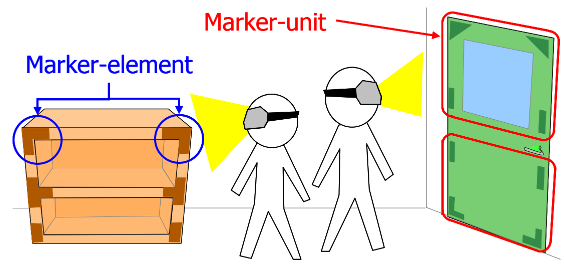

Figure 1.Conceptual image of two-tone colored markers

2.2. Geometric Registration

The following processes are carried out sequentially in every frame.

(1) **Detecting marker-elements**
The background colors which have been registered in the marker database are searched in the input image. If there are adjacent points slightly different in brightness, regions whose densities are different are extracted using contour tracking. In the extracted regions, which are possible regions for markers, vertices are detected using piecewise linear approximation. The marker regions are classified into I, L, T-shapes or triangles according to the number of vertices. If the possible region is not classified into any shape, the system recognizes that the region is not a marker-element.

(2) **Detecting marker-units**
For all sets of four marker-elements that are selected from detected marker-elements, it is investigated whether they construct a rectangle and whether they correspond to registered marker data.

(3) **Estimating camera position and posture**
The system estimates the camera position and orientation based on the positions of marker-elements in the screen and world coordinate systems.

When the camera position and orientation is estimated successfully in the previous frame, the processes are accelerated by tracking marker-elements. In short, the detecting of marker-elements is skipped, except in the regions adjacent to where the marker-elements were found in the previous frame.

3 Experiments

We performed two experiments: 1) evaluation of recognition rate and measurement accuracy, 2) overlaying of the CG using the proposed markers. A notebook PC, DELL XPS M1210 (CPU:

* e-mail: tenmoku@rm.is.ritsumei.ac.jp

† Current Affiliation: Murata Manufacturing Company

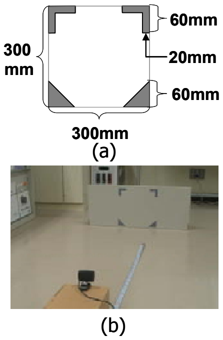

Figure 2.Experimental Environment

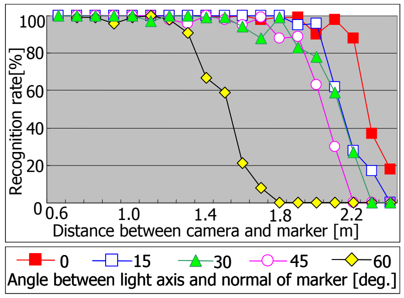

Figure 3.Recognition Rate

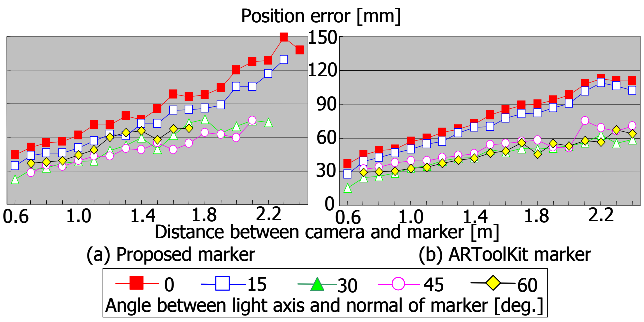

Figure 4. Position estimation errors

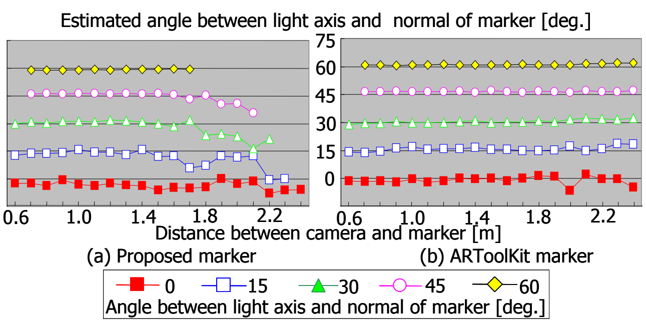

Figure 5. Estimated camera orientation

Intel Core 2 Duo 2.0 GHz, memory: 2.0 GB) and a camera, ELECOM UCAM-N1D30MBK were used in both experiments.

3.1. Evaluation experiment

The marker-unit shown in Figure 2 (a) were used for this evaluation experiment. We measured the marker recognition rate, and camera position and orientation while adjusting the distance between the camera and the marker-unit, and the angle between the light axis of the camera and the normal of the marker. Figure 2 (b) shows the experimental conditions. Figure 3 shows recognition rates of the marker-unit. Each recognition rate was calculated as the number of frames in which the system could recognize and identify the marker-unit accurately per 100 frames randomly selected. Figures 4 and 5 show estimation results of the camera position and orientation, respectively, using either the proposed marker or the ARToolKit [1] marker. In this experiment, a 30 cm square ARToolKit marker was used. We calculated the average distance between the estimated camera position and the ground truth as the estimation errors of position. The ground truth data were measured manually. These results show that our proposed marker is as accurate as the ARToolKit marker as long as the following two conditions are satisfied: 1) the camera is not too far from the marker (within 1.8 m) and 2) the angle between the light axis of the camera and the marker normal is not more than 45 degrees.

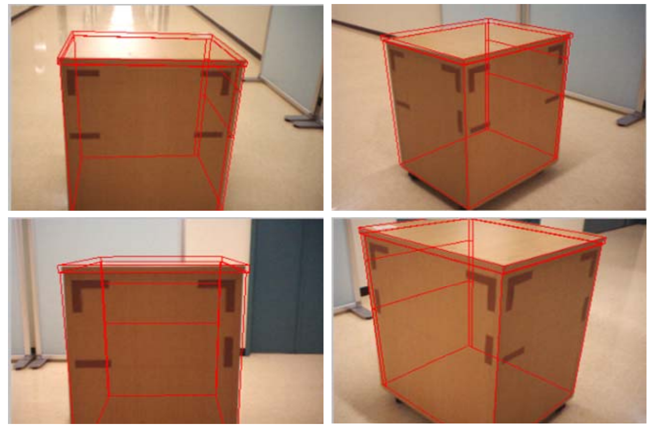
Figure 6. Examples of generated image.

3.2. MR image synthesis experiment

This section describes an MR image synthesis experiment in which the computer-generated wire-frames are overlaid on the real scene images based on the camera position and orientation estimated using the proposed markers. Three marker-units are placed on three side surfaces of the wooden cabinet. Figure 6 shows examples of the generated images. When the size of input images is QVGA, the average processing time to generate these images is 6 ms; however, it takes about 12 ms when the system has to scan the entire area of input images. The experimental result shows that the proposed two-tone colored markers are suitable for MR applications. We have also confirmed that the system could track the markers as long as the camera captures at least one marker-unit.

4 Summary and Future Work

This paper proposes a new marker that can be used for MR applications. Our markers aim to be discreet, while maintaining the recognition rate. We evaluated the performance of the proposed marker. In future, we will try to enhance the proposed marker. For example, we wish to make our marker robust for the variable lighting conditions. Eventually, we will develop the toolkit for the proposed markers.

Acknowledgements

This research was partially supported by a Grant-in-Aid for Scientific Research (B) of the Ministry of Education, Culture, Sports, Science and Technology, No.17200039, 2005.

References

[1] H. Kato, M. Billinghurst, K. Imamoto, and K. Tachibana: "Virtual object manipulation on a table-top AR environment," Proc. Int. Symp. on Augmented Reality, pp. 111 - 119, 2000.

[2] K. W. Chia, A. D. Cheok, and S. J. D. Prince: "Online 6 DOF augmented reality registration from natural features," Proc. Int. Symp. on Mixed and Augmented Reality, pp. 305 - 313, 2002.

[3] Y. Nakazato, M. Kanbara, and N. Yokoya: "An initialization tool for installing visual markers in wearable augmented reality," Proc. 16th Int. Conf. on Artificial Reality and Telexistence, pp. 228 - 238, 2006.

[4] S. Saito, A. Hiyama, T. Tanikawa, and M. Hirose: "Indoor visionbased localization using coded seamless pattern for interior decoration," Proc. IEEE Virtual Reality 2007, pp. 67 - 74, 2007.