Trial Evaluation of a Marker-based Geometric Registration Method Using a TrakMark Data Set

Yukiko Kubo*, Shinya Komurasaki, Fumihisa Shibata, Asako Kimura, and Hideyuki Tamura
Ritsumeikan University

Abstract

This paper describes an evaluation of a semi-markerless MR tracking method which we have proposed by using a TrakMark data set. We have proposed a novel image-based geometric registration method using unobtrusive markers, and we called our approach "Semi-Fiducial INvisibly Coded Symbols" (SFINCS) [1]. One aspect of SFINCS is a geometric registration method, called SFINCS-PM (Poster Masquerade), which employs posters as AR-markers. This method detects posters from a camera image, based on the rules about the design of the posters. For the evaluation of SFINCS-PM, we selected a dataset named "Nursing Home Package 01," embedded SFINCS-PM posters into the dataset, and computed the error of 3D rotation and translation with a ground-truth transformation matrix. We also made a comparison between our proposed method and Parallel Tracking and Mapping (PTAM) [2], using PTAM as an example of other registration and tracking methods. With these evaluations, we confirmed the usefulness of this method.

1. Introduction

Geometric registration and tracking are essential technologies that underlie mixed reality, and many methods pertaining to it have been proposed. Above all, various image-based methods have been proposed because of their easy-to-use approach. Image-based methods are roughly classified into two groups: marker-based methods and natural-feature-based methods. In particular, marker-based methods, which are typified by ARToolKit, provide users and developers an easy way to build AR/MR applications. However, there are many claims that such fiducial markers are not visually appealing, because they usually are displayed with "eye-catching" colors and shapes to improve their detection rate. Therefore, we have proposed a novel image-based geometric registration method using unobtrusive markers to achieve a good balance between the elegance within the environment and robustness of the registration, and we called our approach "Semi-Fiducial INvisibly Coded Symbols" (SFINCS) [1]. One aspect of SFINCS is a geometric registration method, called SFINCS-PM (Poster Masquerade), which employs posters as AR-markers.

In this poster, we report the experimental results using a "modified" TrakMark dataset named "Nursing Home Package 01" for the evaluation of SFINCS-PM. For the evaluation, we asked members of Dr. Kurata's research group, who are some of the original contributors of TrakMark dataset, to embed SFINCS-PM posters into the dataset, named "Nursing Home Package 01," to create a TrakMark dataset with the image sequences made with the same camera path. In other words, we reproduced the same camera movements that captured the sequences in the TrakMark dataset in the 3D model where SFINCS-PM posters are put up on the walls. Examples of the dataset with SFINCS-PM posters are shown in Figure 1.

We executed the SFINCS-PM method using the reproduced sequences and computed the error of 3D rotation and translation with the ground-truth transformation matrix, which is released from TrakMark.



Figure 1. Dataset embedded with SFINCS-PM

*kubo@rm.is.ritsumei.ac.jp

2. SFINCS-PM

SFINCS-PM is a geometric registration method that embeds position and posture information into posters masquerading as AR-markers. The posters, which are used for registration, are designed in advance according to the rules of its own marker type. We defined this rule as the "Design Rule." By using the rules, it is possible to detect posters from a camera image and identify the ID of detected posters. The position and posture of the camera is calculated using the shape of the poster in the camera image.

2.1. Design Rule

Besides the posters used for SFINCS-PM, there are commonly designed posters used as advertisement in indoor/outdoor environments. Because SFINCS-PM posters are designed according to the rules of their own marker types, our method distinguishes the SFINCS-PM posters from other posters, on the basis of these rules. The significant advantage of our method is that posters can be verified and identified from a camera image on the basis of the rules that represent the design of the posters (design rules) instead of using template-matching techniques. In our method, the layout of components and the coloration of specified area in posters are used as design rules. Figure 2 shows an example of the SFINCS-PM poster and its design rules.

2.2. Processing

Figure 3 shows the processing flow and required data. SFINCS-PM method consists of two processes: detecting posters and tracking posters. First, our method detects a poster from a camera image and calculates the position and posture of the camera. After the first detection, our method tracks only four vertexes of the detected poster to accelerate processing. Moreover, we achieved the detection of posters that appear for the first time by performing a concurrent processing of poster detection and tracking. The process of detecting posters consists of three steps.

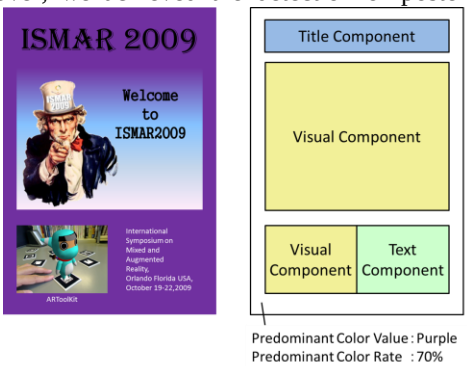


Figure 2. An example of a SFINCS-PM poster and its design rules

1. Segmentation Step

Our method extracts candidate regions of posters using common rules. The method picks up quadrangle regions that are larger than an appointed size as candidate regions of posters.

2. Verification Step

Our method sifts the detected candidate regions of posters to detect only regions of posters. First of all, in order to deform into the shape as seeing the poster from the front face, our method applies inverse projective transformation for candidate regions of posters. In this case, the aspect ratio of SFINCS posters is used.

Next, by applying verify rules of the poster to candidate regions, our method verifies whether or not the candidate regions of posters satisfy the design rules. When a candidate region of a poster fulfills all the rules, our method recognizes the region as a SFINCS-PM poster.

3. Identification Step

Our method estimates the ID numbers of the detected poster on the basis of the poster ID rules. It applies all ID rules to the poster and then compares the results with information that has been created in advance in the database. Then, it uniquely identifies the poster ID.

3. Experiments

We evaluated the SFINCS-PM method using a TrakMark dataset. First, we compared the position and posture acquired from the SFINCS-PM method with the ground truth given in a TrakMark dataset. Then, we contrasted our proposed method with PTAM, using

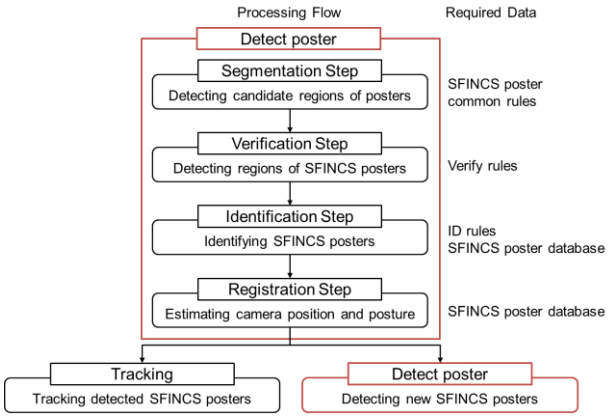


Figure 3. Processing flow and required data

PTAM as an example of other registration and tracking methods. PTAM is a typical method that uses natural features and has been actively studied in recent years.

3.1. Evaluation of SFINCS-PM

For the evaluation of SFINCS-PM, we asked members of Dr. Kurata's research group, who are some of the original contributors of TrakMark data set, to embed SFINCS-PM posters into the dataset named "Nursing Home Package 01." SFINCS-PM posters were placed so that they satisfied the following conditions: (1) to record the image sequences using the same camera paths used for the original TrakMark dataset, and (2) to enable the system to make use of SFINCS-PM for a guide application. It is possible to freely determine the size of posters, but for this evaluation, we specified the size as A2 (420×594mm).

In the 3D model that included SFINCS-PM posters, we reproduced image sequences using the same camera movements that were used to record the sequences in the TrakMark dataset and executed SFINCS-PM using the sequences. For the evaluation, we executed SFINCS-PM using the image sequences and computed the error of 3D rotation and translation with the ground-truth transformation matrix released from TrakMark. From an image sequence captured by a single camera, we obtained an estimation of the 6-DOF camera pose relative to a world coordinate system. A part of the experimental results are shown in Figures 4–6, in which translation and rotation values of our proposed method and the ground truth are plotted.

As a result, when SFINCS-PM posters are in the scene, geometric registration is largely successful. Errors between the estimation and the ground truth are shown in Table 1. When the camera is located near and in front of the poster, the number of errors of the estimated position and posture is small. Conversely, the number of errors of the estimated position and posture is larger when the angle between the camera and the poster is small or the poster is partially out of the camera's FOV. Thus, accuracy depends on the distance between the camera and posters and the angle at which the camera views the poster.

Table 1. Errors between the estimation and ground truth

	Error of translation (mm)
7th frame	91.16443
22nd frame	263.1142
All frames	143.3083

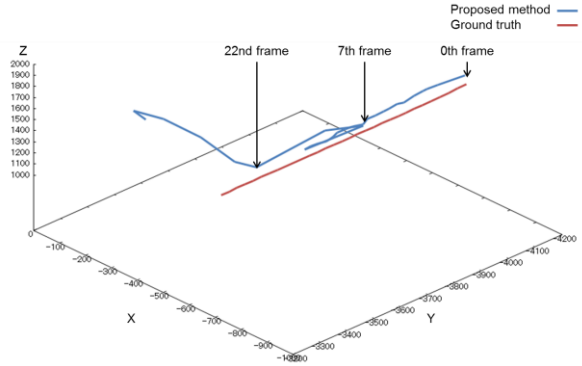
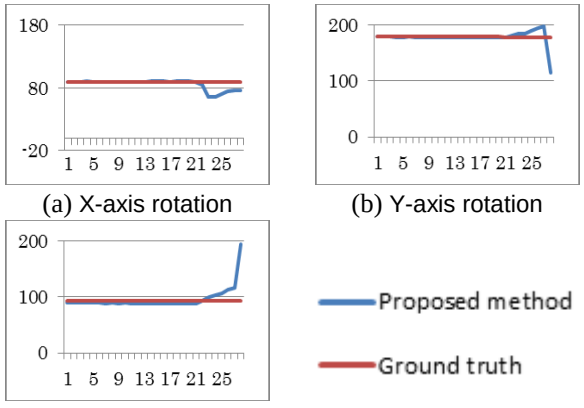


Figure 4. Results of camera translation

3.2. Comparison with PTAM

Next, we calculated the camera position and posture using PTAM as an example of other registration and tracking methods, and contrasted the results with results from SFINCS-PM. Hayashi et al. [3] describe the detailed procedures used to evaluate the accuracy of the camera's position and posture in PTAM. When evaluating the TrakMark dataset, the camera tracking of PTAM did not succeed for most of the sequence "Nursing Home B," because the camera moved quickly and did not add new key-frames to the map. Therefore, when the movement of the camera was fast, PTAM had difficulty registering. Even in the environment where PTAM could not be used, our proposed method could



(a) X-axis rotation (b) Y-axis rotation

(c) Z-axis rotation

Figure 5. Results of camera rotation



Accurate estimation of the camera position (7th frame)



Part of the poster was out of camera view,which resulted in an inaccurate estimation of the camera position (22nd frame)

Figure 6. Some of the sequences used in the experiment

register by putting up posters, because it was a marker-based method.

Moreover, we slowed down the moving velocity of the camera to allow registration with PTAM and then performed the experiment again. A part of the experimental results are shown in Figures 7–9. While the number of rotation errors between PTAM and ground truth are small, the number of translation errors are large. We also found that errors that occurred during the translation of Y-coordinates particularly increased in Figure 7. When PTAM was executed with the dataset, the initialization of PTAM was performed using the feature points from a distant location, because natural features points were not detected near the camera position (Figure 9 (a)). Then, during the tracking, it appears that registration errors becomes large, because there are not enough natural features detected near the camera position because of the white walls of "Nursing Home" (Figure 9 (b)). In such places, a natural-feature-based tracking method hardly works well. Conversely, SFINCS-PM is a marker-based geometric method; therefore, it was largely successful, and the number of registration errors was generally small when SFINCS-PM posters were in the scene. We think it is difficult to achieve geometric registration and tracking on the basis of natural features in every situation. In such a case, we think a geometric registration method using unobtrusive markers, such as SFINCS-PM, would be an effective alternate method.

4. Conclusion

We carried out the trial evaluation of the geometric registration method that we proposed using a modified TrakMark dataset. For the comparative experiment, we asked Dr. Kurata and his colleagues to embed posters into the dataset named "Nursing Home Package 01" to reproduce the image sequences using the same camera movement as used for a TrakMark dataset. We confirmed that we could evaluate a marker-based geometric registration method using the TrakMark dataset by embedding markers into the 3D model of the dataset. As a result, when SFINCS-PM posters were in the scene, geometric registration was largely successful. We also made a comparison between our proposed method and PTAM, using PTAM as an example of other registration and tracking methods. As a result, we found that a marker-based method could estimate the camera pose in the scene where PTAM had difficulty tracking. Natural-feature tracking is not necessarily effective in every situation, and therefore, a geometric registration method using unobtrusive markers, such as SFINCS-PM, would be an effective alternate method.

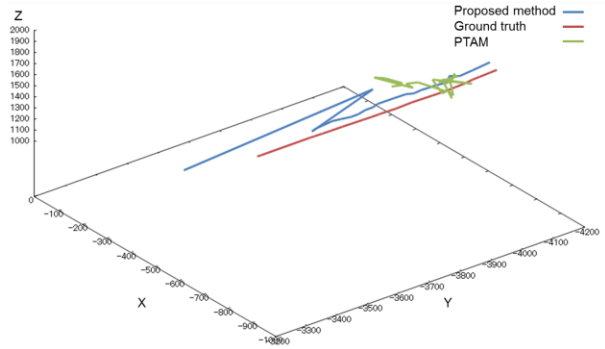


Figure 7. Results of camera translation

References

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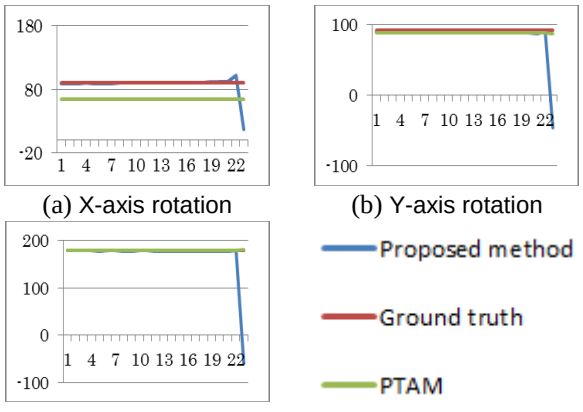
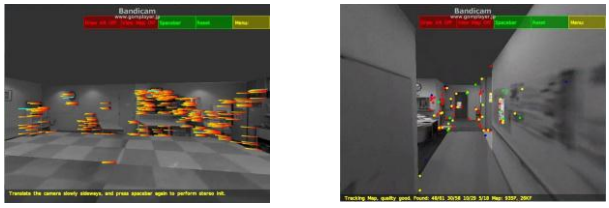


Figure 8. Results of camera rotation



(a) Initialization (b) Detecting natural features

Figure 9. Some of the sequences used in the experiment