Balancing Design Freedom and Constraints in Wall Posters Masquerading as AR Tracking Markers

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Abstract. This paper describes how to construct a mixed reality (MR) environment by adopting a geometric registration method using visually unobtrusive flat posters on the wall. The proposed method is one of the several approaches of the semi-fiducial invisibly coded symbols (SFINCS) research project, the purpose of which is achieving a good balance between elegance with regard to the environment and robust registration. In this method, posters tentatively used for geometric registration are designed to blend with the environment. However, they are recognized as markers based on certain design rules. Posters in a real scene can be found in real time using these design rules. This paper introduces procedures for developing poster design rules using toolkits developed by us.

Keywords: mixed reality, geometric registration, poster, semi-fiducial, authoring tool.

1 Introduction

Mixed reality (MR), which can merge the real and virtual worlds in real time, have been suggested as a new technology for presenting the information [1, 2]. Geometric registration between the real and virtual worlds is one of the most important problems for realizing the MR environments. A variety of registration methods have been proposed worldwide.

In general, traditional methods can be classified into three types: sensor-based methods, image-based methods, and hybrid methods that integrate sensor-based and image-based technologies. Among them, image-based registration methods, which use markers placed in a real scene, have more potential because they do not require any sensors except a camera. In particular, ARToolKit [3] is globally known for its high quality and portability. However, there are many claims that such fiducial markers are not visually appealing.

Accordingly, we propounded semi-fiducial invisibly coded symbols (SFINCS) that are able to achieve a good balance between elegance with regard to the environment and robust registration. We attempted to realize SFINCS using the following two approaches: (1) using markers that are harmonious with the real scene, and (2) embedding information into objects that naturally exist in the real scene. Based on approach (1), we proposed a registration method using two-tone colored markers [4].

This method is named SFINCS-TT. 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 differ slightly in brightness. T-shaped, L-shaped, I-shaped, and like markers are placed at the corners of flat colored plain surfaces of actual objects. On the other hand, as a concrete method based on approach (2), we developed a geometric registration system using visually unobtrusive flat posters arranged in the real world. This method is named as poster masquerading method (SFINCS-PM), which uses posters that have some common characteristics for geometric registration. These characteristics are used for finding the posters in real time.

This paper describes how to construct an MR environment using SFINCS-PM, i.e., how to decide the design rules, prepare the posters and calibrate them. This paper is structured as follows: Section 2 describes some related work. In section 3, an outline of the SFINCS-PM is described. Section 4 shows methods of constructing MR environments based on the SFINCS-PM. In Section 5 the present work is summarized and the future works are discussed.

2   Related Work

This section shows some traditional geometric registration methods for MR using computer vision techniques and the associated construction methods of an MR environment. A variety of vision-based methods have been proposed because of their affinity for video see-through displays.

As mentioned in the previous section, the most convenient vision-based method for MR is based on fiducial markers [5–7]. Such markers should have a common and obtrusive appearance so that they can be found from input images and should include unique IDs for identification. For example, ARToolKit markers [3] have black square frames of a certain width that can be identified based on the patterns placed inside the frames. These inside patterns are linked to the marker's position and angle in the world coordinate system. These fiducial markers are easy-to-use and robust, but are rigid for designing and affect the environment to a greater extent. In order to construct MR environments, where fiducial markers are arranged in the real world, the system requires a database of marker ID numbers and their 6DOF positions in the world coordinate system. In the case of ARToolKit markers, this database corresponds to the look-up table of the inside patterns and marker positions.

On the other hand, registration methods using natural feature points in a real scene [8–11] differ from the fiducial marker methods. These methods do not affect the environment, and on comparing with the fiducial marker methods, most of them do not show stability and robustness. These methods can be classified roughly into the following two technologies: 1) camera tracking without any environmental information [8, 9], and 2) measuring the absolute position and angle of the camera using a pre-constructed database of environmental information [10, 11]. Simply putting, the former technology estimates the camera position of the current frame, relative to that of the previous frame, by comparing the current image and previous camera images. In the latter method, it is somehow necessary to estimate the initial camera position.
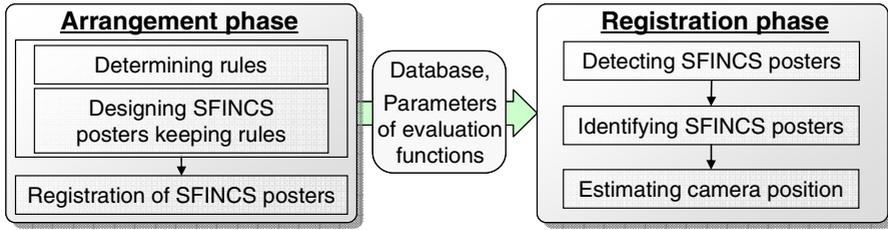
Fig. 1. Workflow of the arrangement phase and registration phase

Taketomi et al. [11] used a landmark database that included image templates around natural feature points and their 3D positions. However, constructing such a database requires much time and effort.

Consequently, some research projects try to maintain both eye appeal and robustness. Our SFINCS project is one of them. Nakazato et al. used retro-reflective markers on the ceiling and an infrared ray camera that focuses on the ceiling [12]. Saitoh et al. used pattern-coded wallpapers [13] to masquerade the coded patterns in the environments. In order to construct MR environments, the requirements for these intermediate methods are the same as that for the fiducial marker methods. However, in some methods [13], their IDs are not simple because of their unique complex encoding systems. The proposed method, described in this paper, SFINCS-PM, also adopts a complex encoding system.

3   SFINCS-PM

3.1   Outline of SFINCS-PM

SFINCS-PM is a geometric registration method that utilizes wall posters that can exist in the real environment naturally as augmented reality (AR) markers. This method holds the middle course between fiducial markers and natural feature points. The main idea of this method is that certain constraints for poster design are defined in advance to aid detection of posters. More specifically, design constraints are on the color or layout of components of the poster. We call these constraints as design rules.

The workflow of SFINCS-PM has two general phases, the arrangement phase and the registration phase (Fig. 1). In the arrangement phase the design rules are determined by the provider of the MR application by employing the proposed registration method. The provider also prepares wall posters that are used for geometric registration. We call such posters as "SFINCS posters." The order of these operations is determined depending on the rule scheme, as described in section 3.2. After these operations, the provider constructs a database that includes the ID numbers of SFINCS posters, their features, and their installation locations in the world coordinate system. The database and some parameters of the evaluation functions are handed over to the registration phase.

The following events take place in the registration phase sequentially. First, the SFINCS posters are detected from the input image. The detected SFINCS posters are

Fig. 2. Example images of SFINCS-PM

then identified according to the database and lastly, the absolute position and angle of the camera is estimated. Fig. 2 shows example MR images using SFINCS-PM.

As shown in Fig. 2, we assume that there are many notices and posters, including SFINCS posters, in the environment. In such a situation, it is important to determine how to detect only the SFINCS posters. In this research, the design of posters is restricted to enable detection of SFINCS posters. Accordingly, the degree of freedom for designing the posters decreases.

Here, we define some words that are used henceforth.

- **SFINCS poster** is the poster used for geometric registration in SFINCS-PM.
- **Design rules** are used for detecting SFINCS posters from the candidate regions displaying posters.
- **ID rules** are used to identify SFINCS posters. These rules change according to the design rules.
- **Common rules** are for all design rules. In the present system, we define the following two rules:
  - The shape of the SFINCS poster is rectangular whose aspect ratio is $1:\sqrt{2}$. (This is the popular paper aspect ratio in Japan.)
  - The background colors of SFINCS posters are not the same as that of the background object. This is based on the idea that all posters should be eye-catching.
- **Rule scheme** is the framework for establishing design rules and ID rules.
- **Rule set** is a set of design rules and ID rules established in the rule scheme.

3.2 Designing Rule Sets Using Rule Scheme

In the current system, we prepare a layout rule and a coloration rule scheme based on the idea that the design of each poster is determined by the layout of components and coloration. We think another rule scheme could be achievable.

Layout Rule Scheme. A Layout Rule Scheme uses a layout of poster components. We defined three types of components that are typical of posters, as follows:

- **Title component:** A title component is a single- or double-lined string drawn by a single color. The title color is highly visible against the background color.
- **Visual component:** A visual component is composed of a photograph. It uses multiple colors and has an outline box.
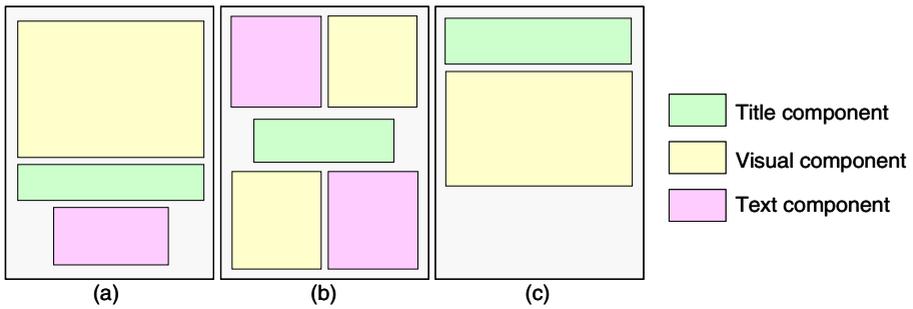
Fig. 3. Example design rules using layout of components

- **Text component:** A text component consists of multiple-lined strings drawn by a single color.

[Design rules]

Design rules are determined by a layout of these components. Some example of design rules using the layout of these components are shown in Fig. 3. If design rule (a) is adopted, the system recognizes posters that obey the following rules: the upper half is a visual component, the title component is below the visual component, and a text component is at the bottom.

[ID rules]

The provider can embed ID numbers into one or more of the following features: the hue value of the poster background, the title component, the text component, and the mode hue value of the visual component.

Coloration Rule Scheme. The coloration rule scheme uses coloration characteristics in a poster. For design rules, the system uses constraints on color histograms of the poster.

[Design rules]

Design rules are defined as conjunction of multiple constraints on the histograms of posters. Basic forms of these constraints are prepared in advance, and the provider has to decide the threshold of each constraint. Some examples of basic forms of constraints are listed below. Key colors A and B indicate the most-used and second-most-used chromatic color in the poster, respectively.

- The hue value of the key color A (B) is more (less) than x.
- The component ration of the key colors A (B) is more (less) than y.
- The sum (difference) of the component ration of key color A and B is more (less) than u.
- The component ration of chromatic (achromatic) colors is more (less) than v.

[ID rules]

The provider can embed ID numbers into one or more of the features noted in the design rules above.
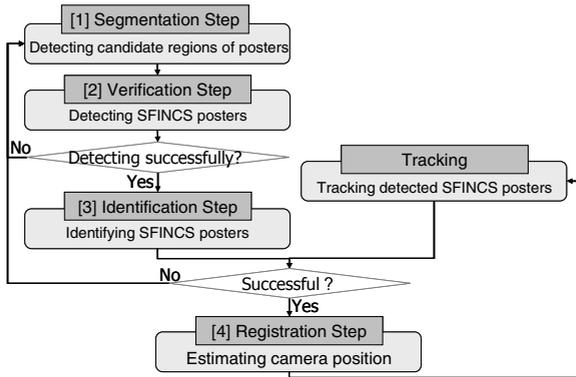
Fig. 4. Flowchart of the registration phase

3.3   Geometric Registration for Mixed Reality

Fig. 4 shows the flowchart of the registration phase in which four steps are processed sequentially. When the camera position in the previous frame is estimated, a tracking process runs to reduce the processing time and stabilize the detection of SFINCS posters. A camera tracking method using natural feature points [8, 9] is used for tracking the posters. The details of these steps are described below.

[1] Segmentation Step

As the first step, the system detects candidate regions of posters using the common rules. The system detects quadrangular regions whose areas are above a certain threshold as candidate regions. In order to detect quadrangular regions, the system operates the following processes:

- It applies an edge detector for the entire input image.
- It detects vertical line segments whose lengths are above a certain threshold.
- Every combination of two vertical line segments is investigated to see whether a line segment between each end point exists.
  The system detects a quadrangle if line segments between both upper and lower end points exist.

[2] Verification Step

Second, the system sifts detected candidate regions to SFINCS posters. This is realized by the following operations:

- The system applies inverse projective transformation for candidate regions of the posters. Here, the aspect ratio of SFINCS posters is used.
- The system verifies whether the candidate regions of the posters satisfy the design rules. Here, the common forms of evaluation functions are prepared beforehand. The parameters of these functions are passed from the arrangement phase. When a candidate region of a poster fulfills all design rules, the system recognizes it as a SFINCS poster.
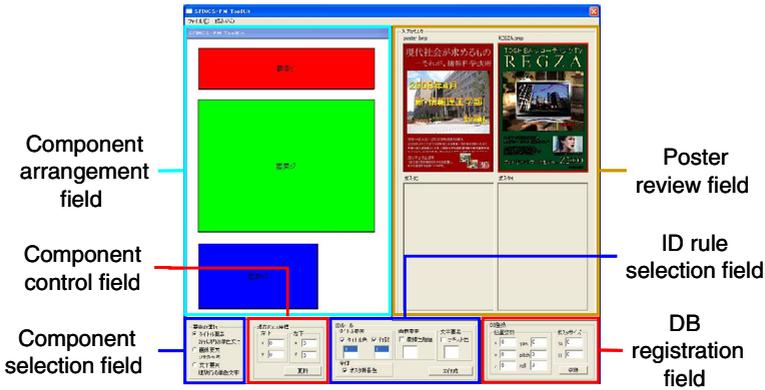
Fig. 5. Support tool for layout rule scheme

[3] Identification Step

Third, the system estimates the ID numbers of detected SFINCS posters based on the database. Features of the detected posters are compared with those registered in the database to identify the detected posters. Here, the number of features used for identifying posters is n, the jth feature of the registered poster whose ID is i is defined as G_{ij}, and features of the detected posters are defined as G_j. The ID number of the detected poster is i which minimizes E_i in formula (1).

$$E_i = \sum_{j=1}^{n} |G_{i,j} - G_j| \qquad (1)$$

[4] Registration Step

The position and angle of the camera in world coordinates is calculated based on the four corner positions of SFINCS posters registered in the database.

4   Constructing MR Environments

In order to construct an MR environment using SFINCS-PM, the three operations of the arrangement phase, described in Fig. 1, must be performed after the provider selects the layout or coloration rule scheme to be used. This section describes the procedures of the arrangement phase using the layout and coloration rule schemes.

4.1   Constructing MR Environments Using Layout Rule Scheme

When the layout rule scheme is selected, we assume that the provider creates MR environments as follows:

1. Determine design rules.
2. Design SFINCS posters that meet the design rules.
3. Define ID rules.
4. Register SFINCS posters.

We prepared an authoring tool that supports these procedures. Fig. 5 shows a sample image of this tool.

Fig. 6. Support tool for coloration rule scheme

First, the provider determines the design rules. Then he/she arranges the components in the component arrangement field. Radio buttons are used in the component selection field to choose the components. The provider can move and change the size of the arranged components using the component control field. After designing SFINCS posters, the provider can check whether the designed poster observes the design rules using this tool. In this case, the poster is presented in the poster review field. If the poster does not satisfy some rules, the unsuitable areas are shown by the authoring tool. For registration of the SFINCS posters, the provider has to input 6DOF parameters of the SFINCS posters and their sizes using the DB registration field.

Further, the tool generates the database including the ID numbers, some feature quantities, and position of each SFINCS poster. At the same time, the parameters of evaluation functions of SFINCS posters are decided. In the layout rule scheme, evaluation functions of the title, visual, and text components used in the verification step of the registration phase are prepared beforehand, and the system applies these functions based on these parameters. In the verification step, if all evaluation functions return "true," the system recognizes the poster as a SFINCS poster.

4.2 Constructing MR Environments Using Coloration Rule Scheme

In the case of the coloration rule scheme, the provider proceeds as follows:

1. Design posters.
2. Determine design rules by viewing posters.
3. Define ID rules.
4. Register SFINCS posters.

The tool supporting these procedures is shown in Fig. 6.

When the provider selects the coloration rule scheme, he/she has to prepare some posters at the beginning of the whole procedure. Next, the provider determines the design rules while viewing the prepared posters. Here, our tool enables an overview of these posters, shows detailed information, and the color histogram of the selected poster in the poster review field, the detail information field, and the histogram field, respectively. The design rules are represented as conjunctions of multiple constraints
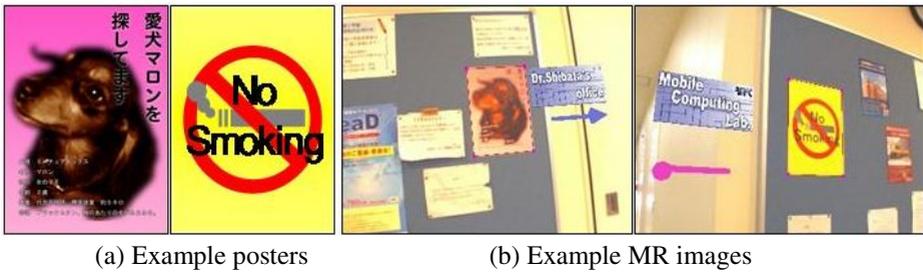
(a) Example posters   (b) Example MR images

Fig. 7. Posters and MR images

on the histograms of posters. The provider can add or clear any constraint freely. Each constraint is designed by complementing the rule forms by choosing from options and filling in the blanks in a manner similar to that of a smart play list in iTunes. Defining ID rules and registration of SFINCS posters is the same as in the layout rule scheme.

In the coloration rule scheme, all possible evaluation functions, which check that the poster observes each constraint described in Section 3.2.2, are prepared in advance. The parameters of these functions (x, y, u, and v) are decided here.

4.3 Experiments of Constructing MR Environments

We made some rule sets and SFINCS posters using the support tools to validate our proposed procedures in constructing MR environments. The rule set of the coloration rule scheme is introduced here.

[Design rules]

- The component ration of chromatic colors is more than 50% of all colors.
- The sum of the component rations of key colors A and B is more than 80% of all colors.

[ID rules]

The posters are identified using the hue value and the component ratio of the key colors A and B.

Example posters of this rule set are shown in Fig. 7 (a), and example images of the MR guide application using SFINCS posters based on this rule set are shown in Fig. 7 (b). Through these experiments, we validated that our proposed procedures can construct MR environments using SFINCS-PM.

5   Conclusions

This paper describes a method of constructing MR environments using SFINCS-PM. In SFINCS-PM, wall posters are used for geometric registration as AR tracking markers. These posters are designed in the framework of two rule schemes, the layout rule and coloration rule schemes. This paper introduces these two rule schemes and the associated procedures in constructing MR environments.

We assume a trade-off between the degree of freedom for poster design and the constraints used for detection. In other words, if the provider defines strict design rules, the degree of design freedom becomes low. Consequently, all SFINCS posters closely resemble each other. On the contrary, if the provider defines loose design rules, the degree of freedom increases. Accordingly, the provider should achieve a good balance of the two.

In the future, we will polish the proposed registration method. We will also construct other rule schemes.

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