Proposal of a Spectral Random Dots Marker using Local Feature for Posture Estimation

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Abstract

We propose a novel marker for robot's grasping task which has the following three aspects: (i) it is easy-to-find in a cluttered background, (ii) it is calculable for its posture (iii) its size is compact. The proposed marker is composed of a random dots pattern, and uses keypoint detection and a scale estimation by Spectral SIFT for dots detection and data decoding. The data is encoded by the scale size of dots, and the same dots in the marker work for both marker detection and data decoding. As a result, the proposed marker size can be compact. We confirmed the effectiveness of the proposed marker through experiments.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities;

1 Introduction

In a picking task by robots, sticking a marker whose posture to an object can be estimated, is very useful to recognize the object and its grasping point. ARToolKit marker and Random Dots Marker [5] could be solutions for this application, but both of them are not well detected in cluttered background environments; ARToolKit marker cannot cope with occlusion, and Random Dots Marker cannnot work well in an environment, where there are many edges around. The marker presented in this poster presentation named "Spectral Random Dots Marker" works well in cluttered background environments.

2 Related Work: Random Dots Marker

Random Dots Marker is composed of a random dots pattern and use the area ratio of the triangles from dots as a geometry feature. Since this feature is affine invariant, it can be detected in various postures. For the rapid retrieval of this feature, LLAH [4] is used. This also makes the Ramdon Dots Marker robust to occlusion.

3 Proposed Marker: Spectral Random Dots Marker

The proposed marker makes two improvements to Random Dots Marker. The first is the application of Spectral SIFT [2] for dots detection, combinaed with a filtering process which extracts only the marker's dots. Hereby it can detect the marker's dots efficiently. The second is the representation of the encoded data by the scale size of the marker's dots. Since the same dots are used for marker detection and data identification, the size of the marker can be compact. The procedure of the proposed method is shown in **Fig. 1**.

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2017 IEEE Virtual Reality (VR)
March 18-22, 2017, Los Angeles, CA, USA
978-1-5090-6646-9/17/$31.00 © 2017 IEEE

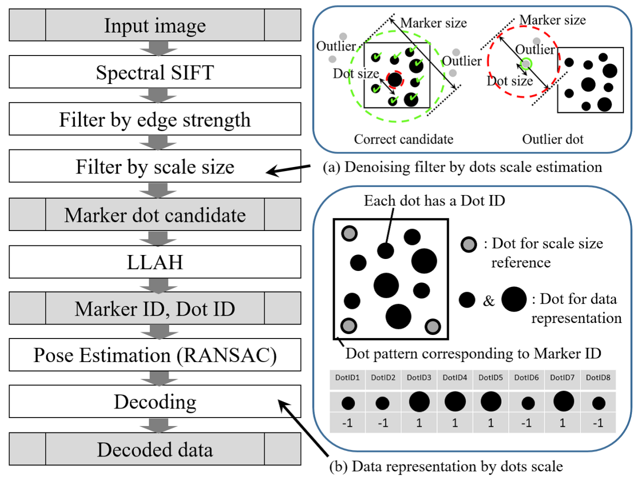


Figure 1: Procedure of using the proposed Spectral Random Dots Marker.

Keypoints extracted by SIFT [3] appear in convex and concave points of brightness. We have previously proposed [1] an easy-to-find marker with a circle pattern by using SIFT-localization. Even if the marker is placed at an angle, it can be detected within approximately 60 deg. A SIFT keypoint is detected by making DoG images [3] in a discrete scale space and seeking extreme points in the DoG image pyramid. In the discrete scale space, all of the dots cannot be detected depending on the marker size in an image and the step size of the scale as setting parameter. On the other hand, Spectral SIFT [2] can cope with an arbitrary scale. By using this Spectral SIFT, the dots can be detected regardless to the marker size (dot size in an image) and the marker can be placed in an arbitrary distance from a camera. Hence, our approach uses Spectral SIFT for detecting Random Dots Markers and its data decoding.

3.1 Dots Detection by using Spectral SIFT

Dots detected by Spectral SIFT include many dots other than the marker's dots. In order to remove these noisy dots, we applied a denoising process composed of the following two steps: The filtering by edge strength, and the filtering by dots scale estimation.

3.1.1 Denoising Filter by Edge Strength

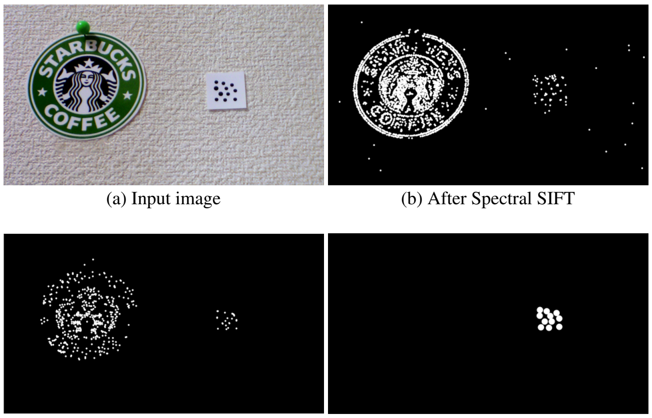
Irrelevant dot candidates are filtered out by referring to the gradient information around the keypoints. A keypoint with a strong edge remains as a candidate while the others are removed. Concretely, a candidate that follows $|\mathrm{Det}(\boldsymbol{H})| > 100$ (where the max value of brightness is 255) remains. Here, $\boldsymbol{H}$ is the Hessian matrix of the DoG image as in [3]. Conventional SIFT process reduces the keypoints on the edge, but the proposed method selects the keypoints on the edge.

3.1.2 Denoising Filter by Dots Scale Estimation

Spectral SIFT can estimate the dot scale. There are two types of dot sizes, which are large and small. The ratio between the marker size

(a) Input image (b) After labeling

Figure 2: Dots detection in Random Dots Marker



(a) Input image (b) After Spectral SIFT

(c) After filtering by edge strength (d) After filtering by dots scale estimation

Figure 3: Dots detection in Spectral Random Dots Marker

and the large dot size is fixed preliminarily. By referring to each dot candidate assuming that its size is the large one, the marker size can be roughly estimated. In the case there are over 8 dots inside the marker's area and the scale of each dot is within the correct size (the difference is within 30% of remarkable dot's scale), we consider these dots as the marker's dot candidates. The other dots are excluded as outliers. Besides, if the dots are close to each other within the range of their dot scale, we integrate their locations into one mean dot. This step is illustrated in **Fig. 1** (a).

3.2 Data Representation by Dot Sizes

Data in the proposed marker is represented by the scale size of dots; A large dot is represented as "1", and a small dot as "-1". According to the order of Dot ID, the arrangement of large and small dot scales are represented as a code sequence as shown in **Fig. 1** (b). The number of a marker dots is 11, which includes 8 dots for both data representation and detection, and 3 dots in the corner for detection. We use these 3 dots as the reference of the dot size to distinguish between the large and the small sized dots.

4 Experiments and Result

We performed three experiments using an USB camera with a resolution of 1,280 * 720 pixels. The marker size was 2.5 cm square. The first experiment was performed to confirm the effectiveness of using Spectral SIFT and the denoising filters. The second one was to check if the data representation by dot scale sizes work under various placements of the markers. The last one was to evaluate the accuracy against the distance to the marker from the camera.

4.1 Comparison of Dots Detection Algorithms

Regarding the dots detection, we compare the Random Dots Marker and the Spectral Random Dots Marker. As shown in **Fig. 2** (b), in the case of the Random Dots Marker, many edges are detected and many dots are labeled as an input to LLAH. Meanwhile, the Spectral Random Dots Marker detects only the marker's dots. As shown in **Fig. 3** (b), first, concave points of brightness are selected by Spectral SIFT. We can see that all of the marker's dots are detected. However, since there are other texture patterns and many small bumps on the wall, many concave points reacted against them. The results of denoising filters are respectively shown in **Fig. 3** (c) and (d). We can see that the filter extracted the marker's dots clearly.

An important point here was to remove noisy dots and to extract only the marker's dots as input to the LLAH. This can reduce the computational cost and boost its accuracy in the LLAH. The proposed algorithm including Spectral SIFT ran faster than 1 Hz in our experiment with an Intel Core i5 CPU.

(a) Input image (b) Markers detection and their decoding

Figure 4: Decoding in various placements.

4.2 Robust Data Decoding in Various Placements

The result of the identification of markers and the data decoding are shown in **Fig. 4** (b) . Each marker was placed approximately 70 cm in front of the camera and had various postures by being sticked to different objects. We can see that decoding of each marker worked successfully. Even though the marker's placements were in various angles, the proposed method could estimate their correct postures.

4.3 Performance against Distance to Markers

The marker could be detected up to a distance of 100 cm from the camera when the marker size in the image was 45 pixel square. The recall was 85.2% and the precision was 91.2% through 1,000 frames. The dots detection could work under an arbitrary distance to the marker within 100 cm.

5 Conclusions

We proposed a novel Random Dots Marker and its detection method using Spectral SIFT with denoising filter. The proposed Spectral Random Dots marker is easy-to-find in cluttered backgrounds, can take arbitrary distances from a camera and also can be detected in various angle placements. These are very useful for the picking task of a robot to recognize the objects and their postures. In addition, dots scale estimation by Spectral SIFT leads the representation of the encoded data by the scale size of the marker's dots. So, by sharing the dots in the marker for both detection and data decoding, the size of the proposed maker can be compact.

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