Circular 3D Feature Descriptor for RGB-D Images

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1. Introduction

The complementarity between the color information and the geometry information promotes the application of RGB-D images in object detection, object recognition and classification feature description and 3D reconstruction. The feature vectors generated by the conventional RGB-D feature descriptor have high dimensionality and computational complexity. We proposed a circular descriptor of the 3D feature points of the RGB-D image by utilizing the rotation invariance.

2. Circular 3D Feature Descriptor with Rotational Invariance for RGB-D Images

2.1 3D feature detection of RGB-D images

In order to detect the local features at different scales, a multi-scale representation of the image, i.e., the scale space of the image, needs to be constructed[1]. The scale space can be expressed as the following diffusion equation.

$$\begin{cases} \frac{\partial f}{\partial \sigma} = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} \\ f|_{\sigma=0} = I_0 \end{cases} \quad (1)$$

Given the image I_0, multi-scale representation of the image can be obtained to construct the RGB-D scale space with iteration. Karpushin et al. [2] proposed a parametric representation of the object point in the camera coordinate system. The following difference form was also proposed,

$$\partial_{uu} f = \frac{\partial_u + f - \partial_u - f}{\|\vec{r}(u+h,v) - \vec{r}(u-h,v)\|} \quad (2)$$

Based on the RGB-D scale space, the 3D feature detection method can be established via four steps: extreme value detection in the RGB-D scale space, precise location of extreme value point, extreme point selection and normalization of the scale.

2.2 Circular 3D feature descriptor for RGB-D images

The traditional SIFT method is complicated in the orientation computation. We present a circular descriptor for 3D feature. According to the rotation invariance, the orientation assignment can be avoided by replacing the rectangular area of the feature description with a circular area. The cumulative value of these 12 orientations in each circular area is calculated, and the 48-dimensional feature vector is generated to replace the 128-dimensional vector of the conventional SIFT algorithm, which improves the efficiency of the algorithm.

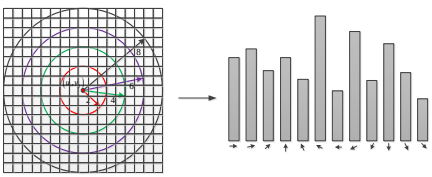


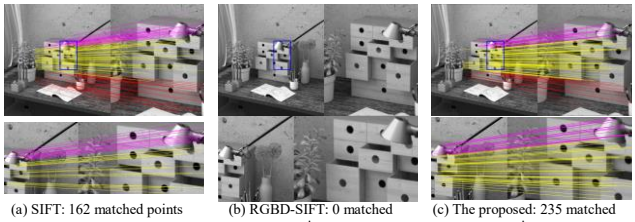
Fig. 1 The generation of RGB-D circular descriptor. The left is a circular area and the right is a histogram of orientations.

The process of circular descriptor for 3D feature point of RGB-D image can be described as follows:

(1) The circular area of the feature descriptor is centered on the feature point and divided into four circular sub-areas with radius of 2, 4, 6 and 8 respectively; (2) The circle is evenly divided into 12 orientations, and the modulus of the gradient and the orientation of the pixels in each circular area are calculated respectively; (3) Take the 12-dimensional vector of the first outsider circular area as the first 12 elements of the feature vector and the 12-dimensional vector of the second circular area as the next 12 elements of the feature vector; (4) Order the feature vector to guarantee the rotation invariance; (5) The feature vectors are normalized to reduce the influence of illumination.

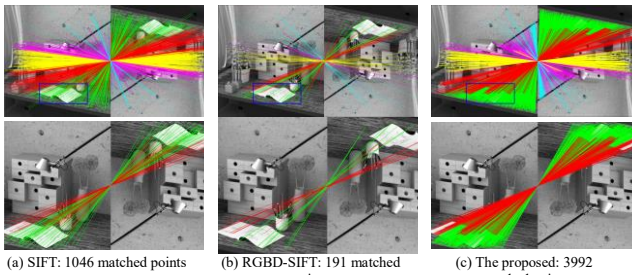
2.3 Experimental results

The performance analysis was given by comparing the matching results of SIFT, RGBD-SIFT and of the proposed descriptor.



(a) SIFT: 162 matched points (b) RGBD-SIFT: 0 matched points (c) The proposed: 235 matched points

Fig. 2 Feature point matching results in the case of scaling the Table scene



(a) SIFT: 1046 matched points (b) RGBD-SIFT: 191 matched points (c) The proposed: 3992 matched points

Fig. 3 Feature point matching results in the case of rotating the Table scene

3. Conclusions

We use the rotation invariance of a circle to establish a circular descriptor method for 3D feature points of RGB-D images. The proposed method can be further applied to 3D scene reconstruction and 3D panoramic imaging. The proposed method could provide new approaches for feature extraction of the 3D point cloud.

References

[1] Lowe D G, IJCV, 60(2):91-110, 2004.
[2] Karpushin M et al. IEEE Transactions on Multimedia, 18(9):1762-1771, 2016.