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Adaptive registration algorithm of color images based on SURF

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ABSTRACT

SURF (Speeded-Up Robust Features) overcomes the expensive computation of SIFT (Scale Invariant Feature Transform), but both of them are designed mainly for gray-scale images. To overcome this drawback, color information could be added in the registration. This paper presents a novel adaptive registration algorithm of color images based on the SURF descriptor. Firstly, key points and descriptors are calculated using SURF. Secondly, color information is superimposed upon the key points' descriptor to construct a modified descriptor. Finally, a two-way matching method based on adaptive Euclidean nearest/second nearest discrimination law is designed for image matching. Extensive experimental evaluations show that the algorithm not only inherits the superior performance of the SURF algorithm, but also increases adaptive matching capability for color images.

1. Introduction

Image registration techniques are an important part of computer vision applications. The goal of image registration is to find reliable correspondences between images of the same scene (the images are obtained at different times, different perspectives or different sensors) [1]. The application of image registration mainly includes image stitching, remote image registration, infrared image registration, medical image registration, as well as 3D reconstruction, etc. [2–4].

There exist mainly three variants of image registration: registration based on image features, registration based on gray-scale correlation and transform domain based registration [1]. Feature-based image registration is the earliest study and has the widest adaptability [5] among these. Researchers have made unremitting efforts on it. Feature-based image registration algorithms such as Moravec, Harris, SUSAN, and SIFT are proposed [6–8]. SIFT [9] has been proven to be the most discriminative among the other local invariant feature descriptors. But its descriptor is a $16 \times 8 = 128$ dimension vector and it is mainly designed for gray-scale images. To overcome this drawback, a wide variety of detectors and descriptors have already been proposed in the literature. PCA–SIFT [10] reduces the length of descriptor vector from 128 to 36, but it is proven to be less distinctive. GLOH [11] is proven to be even more distinctive with the same number of dimensions, but it is computationally more expensive. SURF [12] was proposed on the basis of the SIFT by Bay et al. in 2006. Compared with SIFT, the operation speed of SURF algorithm has been significantly improved because of the lower dimensional space vectors (only 64 dimensions). Though it maintains good results, it also does not integrate color information.

Color information plays a vitally important role in the world, and its an important component for distinction between objects. Many objects can be misclassified if their color contents are ignored. CSIFT [13] uses the color information based on the color invariance model. Since only the

Abbreviations: SURF, Speeded-Up Robust Features; SIFT, Scale Invariant Feature Transform; 3D, Three-Dimensional; PCA, Principle Component Analysis; GLOH, Gradient Location-Orientation Histogram; CSIFT, Colored Scale Invariant Feature Transform; SIFT-CCH, Scale Invariant Feature Transform-Color Co-occurrence Histograms.

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photometrical variation of images has been considered, this descriptor seems not to be efficient in practical cases. SIFT-CCH [14]combines SIFT with Color Co-occurrence Histograms [15] in order to get a more distinctive descriptor that efficiently uses the color information [16].

Obviously the SURF algorithm is widely applied in the field of image registration. We hope to combine the advantages of SURF and color information to achieve better results. Article [16] calculates the YUV color information around the key point by statistical methods and appends it to the end of the SURF descriptor. However, Article[16] uses the color information in a way that needs to be expressed according to the neighborhood of key point and color space transformation. These steps may weaken the information provided by the key point itself. On this basis, we propose an adaptive color image registration algorithm which leverages the information of key points of the original information based on SURF and does not change the color space. Firstly, key points and descriptors are calculated by SURF. Secondly, color information is superimposed upon the key points descriptor to construct a modified descriptor. Finally, a two-way matching based on adaptive Euclidean nearest/s nearest discrimination law is designed to register images.

2. Algorithm design

This section describes our adaptive registration algorithm of color images based on SURF. The detailed process is shown in Fig. 1. Feature points and descriptors: calculated by SURF.

Improved descriptors: get the color information of the feature points of the color image and add it to the SURF descriptors.

Adaptive scale factor: in order to increase the universality of the algorithm on a variety of images, this article designs an adaptive method to extract the scale factor.

Euclidean distance two-way matching: one-way matching is commonly used in the method of Euclidean nearest distance and it may not accurately extract the match-pairs. Thus we utilize Euclidean nearest distance to design a two-way matching algorithm to map the feature points.

The procedure for the design of improved descriptors, adaptive scale factor and Euclidean distance two-way matching is explained further in the following sections.

2.1. Improved descriptors

Original SURF algorithm computing is based on gray-scale images, so the descriptors extracted by SURF only contain information of the gray-scale characteristics. Obviously these descriptors will result in the lost of color information and may decrease the accuracy of the matching rate. In order to achieve the support of color image registration, we try to add color information to the SURF descriptors.

Key points in color images have three color values R, G and B. The original SURF algorithm produces a 64-dimension vector which does not include color information. We propose a method to solve the problem by adding three values to the end of the 64-dimension vector. The detailed description is as follows:

Step 1: In SURF, the descriptor window is divided into 4×4 regular sub-regions. Each sub-region has a four-dimensional descriptor vector [12], which is shown in Eq. (1).

$$v_{subregion} = \left[\sum dx, \sum dy, \sum |dx|, \sum |dy|\right] \quad (1)$$

Assuming feature point (x, y) is gotten by SURF, the SURF descriptor vector is shown in Eq. (2).

$$v_{gray}|(x,y) = [v_1, v_2, v_3, \ldots, v_{16}] \quad (2)$$

The vector $v_1, v_2, v_3, \ldots, v_{16}$ is contained in the sub-region vector descriptor, which is described in the literature [12].

Step 2: The color information of the feature points can be obtained by parsing the color image and superimposed to the end of the original descriptors. Assuming the feature point is (x, y) and its color pixel component values are $R_{(x,y)}, G_{(x,y)}$ and $B_{(x,y)}$, we add these values to the end of Eq. (2). Thus a new descriptor which includes color information can be described, as shown in Eq. (3).

$$v_{color}|(x,y) = [v_1, v_2, v_3, \ldots, v_{16}, R_{(x,y)}, G_{(x,y)}, B_{(x,y)}] \quad (3)$$

Step 3: Normalize the color descriptor of Eq. (3).

In order to describe the descriptor clearly, we express a generalized description of the Eq. (4) based on Eq. (1).

$$v_{subregion} = [i_1, i_2, i_3, i_4] \quad (4)$$

Thus Eq. (3) can be represented by Eq. (5):

$$v_{color}|(x,y) = [i_1, i_2, i_3, \ldots, i_{64}, R_{(x,y)}, G_{(x,y)}, B_{(x,y)}] \quad (5)$$

In order to obtain invariant characteristics of rotation, scale and illumination, we normalize the color descriptor shown in Eq. (5). The normalized vector is shown in Eq. (6).

$$\overline{v}_{color}|(x,y) = \left[\frac{i_1}{|v_{color}|}, \frac{i_2}{|v_{color}|}, \frac{i_3}{|v_{color}|}, \ldots, \frac{R}{|v_{color}|}, \frac{G}{|v_{color}|}, \frac{B}{|v_{color}|}\right] \quad (6)$$

In Eq. (6), $|v_{color}|$ is the model of Eq. (5), as shown in Eq. (7).

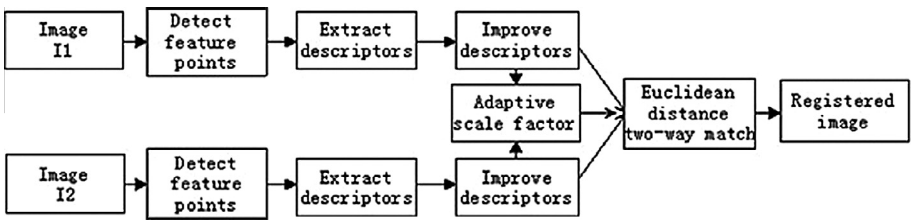

Fig. 1. Flow chart of algorithm.