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A fast and high accuracy registration method for multi-source images

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ABSTRACT

Aiming at the problem of low registration accuracy and poor real-time performance which are caused by traditional SIFT and SURF algorithm in multi-source image registration, a fast and high accuracy registration method is proposed. It makes full use of the flexibility of NSCT for image decomposition and the accuracy of SURF for feature location, as well as the quickness of SURF for feature extraction. Firstly, two images are decomposed by NSCT and SURF features are extracted in low frequency images. Secondly, feature points are matched bilaterally by using the ratio of the closest neighbor and second closest neighbor to avoid one-to-many matching. Then RANSAC is applied to refine the matching. Finally, image registration is realized quickly and accurately. Experimental results show that the proposed method is better than traditional SIFT and SURF in registration accuracy and computation time. It has the validity.

1. 1 Introduction

As the imaging mechanism of various sensors is different, multi-source images of the same scene exist obvious difference, and often present different characteristic, this seriously affects the result of image registration. Domestic and foreign scholars have proposed many multi-source image registration methods, such as the literature [1,2], these methods extract the invariant features in original images directly, which may cause long computing time and low registration accuracy. In order to reduce the computation time and improve the registration accuracy, subimage obtained by decomposing the source image is used to finish registration. In [3], authors use decomposed image by BEMD to finish registration for visible and infrared image, but due to optimization procedure, this method has a large amount of calculation. Chahira Serief [4] proposes a feature point-based registration algorithm, which extracts feature points in high frequency images acquired by NSCT. However, it ignores the low frequency image which contains a large number of effective information, and it is easily affected by high frequency noise, as well as has complicated calculations. A registration method based on SIFT and Contourlet Transform is found in [5], it effectively utilizes low frequency image and high frequency image, and improves registration accuracy. Unfortunately, this method is time-consuming. Refs. [6] and [7] respectively combines SIFT and Wavelet Transform or SWT (stationary wavelet transform) to realize image registration. Low frequency image concentrates the main energy of source image, and these two methods detect SIFT feature points in low frequency image, which not only effectively restrain the high frequency noise, but they also improve the registration accuracy and the speed to some extent. Nevertheless, wavelet transform is short of translation invariance, so the two images for registration should be decomposed at the same layers simultaneously, otherwise will not be able to carry out registration. Although SWT possess time shift invariance, it does not fully express image information effectively for lack of direction. In order to further enhance registration accuracy and computing speed, a registration method based on NSCT and SIFT is put forward in [8], which takes advantage of flexibility of NSCT for image decomposition. However, there are common shortcomings in [6–8], that is, SIFT features have strong robustness and high stability, while a plenty of feature points and high dimensional feature vectors extracted by SIFT algorithm lead to large amount of calculation and lack real-time.

In this paper, we present a fast and high-accuracy image registration method for multi-source images. SURF feature is a kind of local characteristics which springs up in the field of computer vision in recent years, and has the very good stability to image translation, rotation, scaling, affine and perspective changes, etc. SURF algorithm is widely used in image registration and object recognition because it is superior to SIFT in accuracy of feature location and computing speed, and so on. Firstly, we detect SURF features in low frequency images obtained by NSCT instead of original images; second, we match features using bidirectional nearest neighbor ratio method which enables a one-to-one matching and RANSAC which

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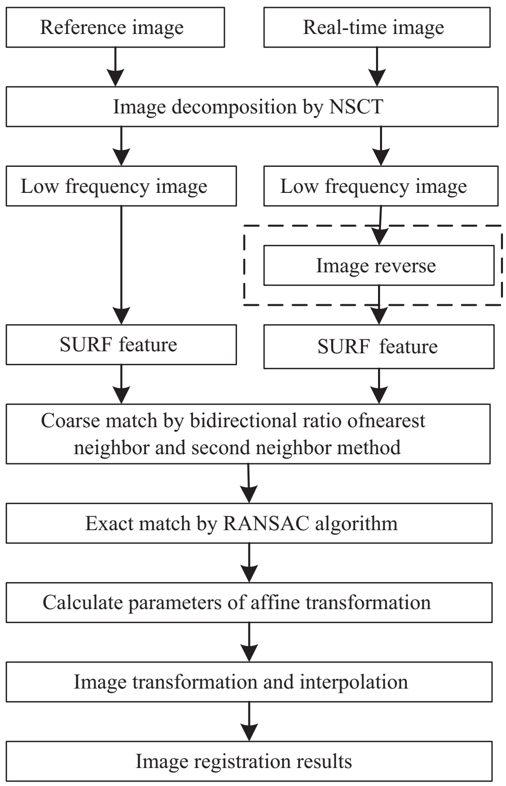

Fig. 1. Overall structure of the proposed algorithm.

makes sure of more accurate feature correspondences. Finally, multi-source images registration is achieved quickly and accurately.

2. The proposed algorithm

Fig. 1 shows the overall structure of the proposed algorithm. The algorithm steps will be as follows:

(1) Decompose the reference image and real-time image respectively by NSCT, based on the flexibility of NSCT for image decomposition.
(2) Take negative image (255 minus gray value of each pixel) of low frequency image of real-time image when two low frequency images have great difference, otherwise, extract SURF features in low frequency image.
(3) Adopt the ratio of nearest neighbor and second neighbor approach to match SURF features bilaterally to avoid a one-to-many matching, then use RANSAC to refine the coarse matching results for the purpose of exact matches.
(4) Calculate affine transformation matrix from precise matching points by the least square method.
(5) Transform and interpolate the real-time image by bilinear interpolation to implement registration for multi-source images.

3. The principle of the proposed algorithm

3.1. Nonsubsampled contourlet transform

Considering contourlet transform has frequency aliasing and shift-variant problem, M.N. Do et al., nonsubsampled contourlet transform (NSCT) was proposed. Since it has not only multi-scale and time-frequency characteristics like wavelet transform, but also shift-invariant, multi-directional and anisotropic, so it can capture the geometric structure information of image very well.

The NSCT combines the nonsubsampled pyramids (NSP) which provide multi-scale decomposition and nonsubsampled DFBs (NSDFB) which provide directional decomposition. First a nonsubsampled pyramid split the input into a lowpass subband and a highpass subband. Then a nonsubsampled DBF decomposes the highpass subband into several directional subbands. The scheme is iterated repeatedly on the lowpass subband outputs of the nonsubsampled pyramids.

NSCT draws on à trous [9] in image decomposition and reconstruction, and hence subimage and the source image are in the same size. Low frequency image is an approximate representation of the source image, which expresses the fundamental change tendency of source image, so low frequency images of two source images for registration have more similarity, and reduce the influence of the details such as noise. Therefore, extracting features in low frequency images is favorable for multi-source image registration.

3.2. Speed-up robust features

SIFT [10] is a feature detection algorithm proposed by David G Lowe, which has good robustness to image rotation, scaling, affine etc. However, extensive feature points and high-dimensional feature vectors take plenty of time, so that it cannot meet the real-time requirement. For the above defects, Bay et al. SURF algorithm which is a new image local invariant features detection method on the basis of SIFT. SURF excels in the accuracy and robustness for feature location than SIFT, what is more, it improves the computing speed greatly. SURF makes two improvements relative to SIFT. First, the integral image and box filter are introduced into SURF to enhance computation speed. Second, SURF feature vector contains 64 components, which is half of SIFT. Consequently, SURF further increases the calculation speed with keeping good performance of feature.

SURF algorithm mainly includes two parts: feature points extraction and feature points description.

(1) *Feature points extraction:*

SURF locates feature points through calculating local maximum value of determinant of the approximate Hessian matrix in scale space. Hessian matrix has good performance in computation time and accuracy.

Given a point $X(x, y)$ in an image I, the Hessian matrix $H(X, \sigma)$ in X at scale σ is defined as follow:

$$H(X,\sigma)=\begin{bmatrix} L_{xx}(X,\sigma) & L_{xy}(X,\sigma) \\ L_{xy}(X,\sigma) & L_{yy}(X,\sigma) \end{bmatrix} \quad (1)$$

where $L_{xx}(X, \sigma)$ is the convolution of the Gaussian second order derivative with the image I at point X, and similarly for $L_{xy}(X, \sigma)$ and $L_{yy}(X, \sigma)$.

As the Gaussian second order derivative is replaced by box filter in SURF, the simplified form of determinant of the Hessian is defined as:

$$\mathrm{Det}(H_{approx}) = D_{xx}D_{yy} - (0.9D_{xy})^2 \quad (2)$$

where D_{xx} is the convolution of the box filter with the image, and similarly for D_{yy} and D_{xy}.

(2) *Feature points description:*

In order to be invariant to rotation, we identify a principal orientation for each feature point based on gradient distribution characteristics of neighbor pixels of the detected feature points. Then we construct a square region which is oriented along the principal orientation and center around the detected point. The region whose size is $20\sigma \times 20\sigma$ is split up regularly into smaller 4×4 square sub-regions. For each sub-region, we compute respectively the Haar wavelet response dy in horizontal direction and dx