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A Hybrid Image Registration Algorithm and Change Detection for Remote Sensing Images

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Abstract: *Image registration enables the geometric alignment of two images and is widely used in various applications such as remote sensing, medical imaging etc. Due to repetitive patterns and gray level changes in the remote sensing images, feature point based registration method fails to determine every correctly matched points. The proposed method aims to develop a registration algorithm that exploits point structure information of the image. The method includes the combination of daisy descriptor and modified shape context for feature point extraction. To obtain robust matching point pairs, a daisy descriptor is combined with the modified shape context descriptor. Change in the multi temporal input image pair can be effectively detected using Discrete Wavelet Transform.*
Keywords: *Daisy descriptor, improved shape context, image registration, DWT, thresholding, change detection***.**

1. INTRODUCTION

Image registration is the process of overlaying two or more images of same scene taken at different times by different sensors from different viewpoints. Different registration algorithms are used for different image pairs. Image registration has wide applications in the field of remote sensing, biomedical imaging, computer vision etc. Typically registration is required in remote sensing application for multispectral classification, environmental monitoring, change detection, image mosaicking, weather forecasting creating super resolution images [1].The feature points are extracted for registering two images. Registration algorithm can be broadly classified into area based algorithm and feature based algorithm [2]. Feature point based registration methods fail to determine correctly matched points due to the gray scale changes and repetitive patterns in the images. The point position information included in the feature points are not unique and identifiable. Thus feature point descriptor based on neighbour region and structure information are highly necessary. Descriptors based on the histogram distribution, spatial frequency statics and shape are not applicable universally. Hence the combination of appropriate descriptors has to be chosen carefully. This is the most difficult challenge in remote sensing image registration. For resolving such a difficulty, a hybrid registration method based on point spatial relationship is proposed here along with an advanced change detection algorithm.

Image matching basically includes three main steps. They are feature extraction using DAISY descriptor [3], shape context methods gives structural features and a combination of both for better feature extraction of satellite images in case difficulties faced [4]. The difficulties in registering images are the monotonous background, repetitive patterns and the gray scale changes. It is followed by an advanced discrete wavelet transform (DWT) based change detection algorithm. In remote sensing applications, change-detection is the process of identifying differences in the state of an object or phenomenon by analysing a pair of images acquired on the same geographical area at different times [5]. Such a problem plays an important role in many different domains like studies on monitoring of urban growth [6], identification of vegetation changes [7], land-use/land-cover dynamics [8], burned area assessment [9], monitoring shifting cultivations [10], analysis of deforestation processes [11], etc. Since all these applications usually require analysis of large areas, development of automatic change-detection techniques became of high relevance in order to reduce the effort required by manual image analysis. Proposed change detection steps involve DWT decomposition of input image pair and reconstruction of difference image. Lastly hard thresholding is employed for separating changed and unchanged pixels.

2. DAISY DESCRIPTOR

Daisy descriptor was introduced by Tola and Fua [3].It is a robust way to affine transformation and changes in the image brightness among images other than local descriptors. The daisy descriptor is much more efficient because the weighted sum of gradient norms is replaced by the orientation maps that are calculated as the convolution of the gradients in specific directions with several Gaussian filters. The orientation map for different sizes can be computed at low cost as convolution with a large Gaussian kernel can be obtained from several consecutive convolution using smaller kernels.

The various steps for computing the daisy descriptor are:

- For the given input image, first compute the 'N' no of orientation maps, G_i $1 \leq i \leq N$ in each quantization direction, where $G_o(u,v)$ is the image gradient norm at location (u,v) for direction 'o' ,if it is bigger than zero or else the value is equal to zero. Hence polarity of intensity change is preserved. $G_o=(\frac{\partial I}{\partial o})^+$ is the orientation map

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where 'I' is input and image 'O' is orientation derivative and $(\ )^+$ is the operator such that $(a)^+ = \max(a,0)$.

- Gaussian kernels of different $\sum$ values are convolved with each orientation map to obtain convolved orientation map for different sized region as $G_O^{\Sigma} = G_{\Sigma} * (\frac{\partial I}{\partial O})^+$ with G_{Σ}, a Gaussian kernel.
- For each pixel location from the convolved orientation map, daisy descriptor consist of a vector made of values located on concentric circle centered on the location and where the amount of Gaussian smoothing function proportional to the radii of circles.
- The standard deviation $\sum$ of the Gaussian kernels of is convolved with orientation map at location (u,v) made of values at this location is represented by $d_i(l_j(u,v,R_j)), d_i(l_j(u, v,R_i)) = [G\Sigma1(l_j(u, v,R_i)), \ldots, G\Sigma8(l_j(u, v,R_i))]$. The vector made of values are normalized to unit norm and $\tilde{d}_i(l_j(u,v,R_i))$ is denoted as normalized vectors. To represent the pixel near occlusion correct as possible the normalization is performed in each histogram independently.

Consider images from different view point the descriptor of same point that is close to an occlusion would be different when the descriptor is normalized. The daisy descriptor $D(u_0,v_0)$ for location (u,v_0) is defined as terms of h vectors.

$$D(u,v)=[d_0(u,v), \tilde{d}_1(1_1(u,v,R_1)), \ldots, \tilde{d}_1(l_N(u,v,R_1))\ \tilde{d}_2(l_1(u,v,R_2)), \ldots, \tilde{d}_2(l_N(u,v,R_2)), \ldots, \tilde{d}_M(1_1(u,v,R_M)), \ldots, \tilde{d}_M(l_N(u,v,R_M))\ ]^T \qquad (1)$$

3. IMPROVED SHAPE CONTEXT DESCRIPTOR

Shape context descriptor is used to detect a shape from data base of similar shapes. It is defined as a joint histogram of angle and the log distance of point relative to other points. The main features of shape context are translation invariant and scale invariant. The former uses the relative distance between the points and the later uses the average distance between two points. Even though shape context is sensitive to rotation transformation. In order to eliminate this [12] proposed a method changing each point's positive axis of its coordinate along the direction of tangent. Also noise immunity can be enhanced by using [13], representing the 1-D signal of the angle distribution in a log distance level. The signal is then passed through 1-D Fourier transform. This shape context can made translation, scale and rotation invariant. Also achieves good noise immunity.

4. METHODOLOGY

The input image is basically a multi-temporal image pair which consists of a sensed image and a reference image. The feature points of each of these images are extracted for image registration with the help of descriptors. The descriptor is a combination of daisy descriptor and improved shape context descriptors. The feature points of both the images are simultaneously computed by both daisy as well as shape context descriptors. Out of these features, similar feature points are extracted and are used for the process of image registration. The registered images are then use to find the change between the sensed image and the reference image using DWT. The DWT decomposition components reconstruct the difference image which is then thresholded to detect the change.

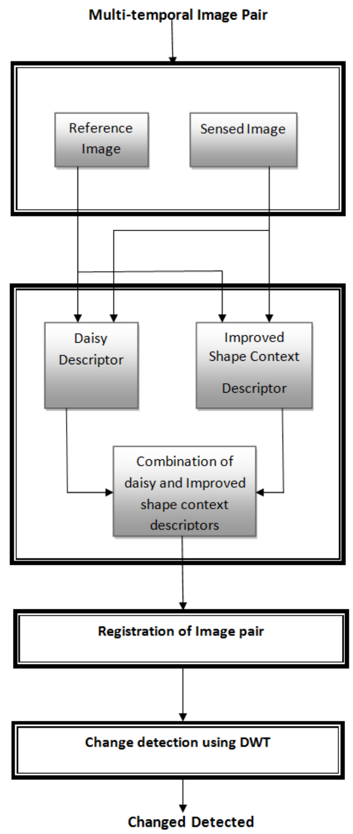

Figure 1: Block diagram.

5. COMBINATION OF DAISY AND SHAPE CONTEXT DESCRIPTOR

Similar patterns cannot be distinguished using local gray gradient descriptor. However, it can be correctly distinguished using an improved shape context method containing a neighbour structure. But significant loss of information may occur during image registration. These disadvantages can be overcome using the combination of gray information and their spatial relationship. The above defects can be best minimizing using the improved shape context and daisy descriptor by simply multiplying similarity metrics. Assuming C1 as the similarity metrics generated by daisy descriptor and C2 the similarity metrics from improved shape context descriptor. Euclidean distance is used for computing C1, while C2 can be computed using $\chi 2$ test statistics [4]. It is because the probabilities in the 2-D bins of the corresponding histogram of

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C2 are independent of each other. Thus the following equation is formulated:

$$c_1 = [\mathrm{sim}]_{ij} = \left[\sqrt{\sum_{k=1}^{H} (D_i(k) - D_j(k))}\right] \quad (2)$$

$$c_2 = [\mathrm{sim}]_{ij} = \left[\frac{1}{2}\sum_{k=1}^{K} \frac{[H_i(k) - H_j(k)]^2}{H_i(k) + H_j(k)}\right] \quad (3)$$

Here M & N are the reference and sensed image feature point respectively. Where $0 \le i \le M, 0 \le j \le N$. D_i is the i^{th} daisy descriptor of reference image and H_i is the i^{th} improved shape context of the same. D_j is the j^{th} daisy descriptor of target image and H_j is the j^{th} improved shape context of the same. The dimension of improved shape context is denoted by k. $\widehat{C_1}$ & $\widehat{C_2}$ are the normalized similarity metrics on multiplication $W=\widehat{C_1} \odot \widehat{C_2}$, $\odot$ represents the product of elements.

6. CHANGE DETECTION

The registered multi temporal image pair is individually decomposed using DWT. The decomposition of image pair result in four sub bands LL LH HL & HH. In this application, the level of decomposition is 1. L & H represents the 1-D low pass and high pass filter respectively. The low pass filtering along rows and columns gives the sub bands LL&LH. LL component is close approximation coefficient and LH, HL & HH are the detailed coefficient. LL component shows close approximation of input image. Progressive subtraction of the corresponding LL components of input image pair produces a new LL component. It is then used along with the detail coefficients to reconstruct and to get a difference image. Finally hard thresholding is applied on difference image to detect changes using DWT.

7. PROPOSED ALGORITHM

Step 1: Find the feature points

- Take the daisy of input image pair.
- Take improved shape context of image pair.

Step 2: Combination of daisy and improved shape context

- $\hat{c_1}$-as the normalized similarity matrix of daisy descriptor.
- $\hat{c_2}$-as the normalized similarity matrix of improved shape context.
- W is the combined similarity matrix: $W=\hat{c_1} \odot \hat{c_2}$.

Step 3: Registration of the image

- Feature points from similarity matrix w are used for registering input image pair.

Step 4: Change detection

- Take the DWT decomposition of registered image pair.
- The difference image is reconstructed.
- By hard thresholding, change is detected.

8. SIMULATION AND RESULT ANALYSIS

In this paper MATLAB software is used for the simulation of registration of input image pair and detects the changes in the image pair. The simulation of each block in the block diagram is done sequentially. The image pair used here is captured at different time of same scene with same sensor. The difficulties in registering images are monotonous background repetitive patterns and gray scale changes. Thus a combination method is introduced in this paper. Change in the multi temporal input image pair can be detected using DWT decomposition technique in the registered image pair. The simulation results are shown in Figure 2.

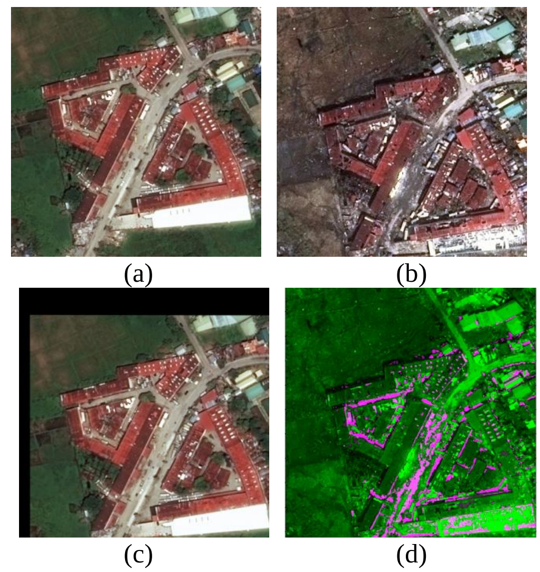

Figure 2: (a) Sensed image (b) Reference image (c) Registered image using combination method (d) Change detected using DWT.

9. CONCLUSION

The proposed image registration method performed well in experiments. A combination of these descriptors overcame the difficulties introduced in registering remote sensing images along with effective change detection. Here we consider the spatial relationship between the image pixel and its neighbouring pixel. All the difficulties of remote sensing image are eliminated during registration. The feature points are successfully extracted using daisy and improved shape context descriptors. We used DWT for change detection among image pairs.

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