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Image Registration of Satellite Images with Varying Illumination Level using HOG Descriptor based SURF

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Abstract

Image registration aligns two images geometrically, which is frequently required in medical, computer vision and remote-sensing field. It is a crucial pre-processing step in change detection or growth monitoring using satellite images. Accuracy of change detection depends on accuracy of image registration. For multi-modal, multi-sensor, multi-spectral satellite images one of the challenges for image registration is varying illumination level according to the sensor characteristics. This challenge is addressed by using Histogram of Oriented Gradient (HOG) along with Speeded-Up Robust Feature (SURF). It is shown that illumination variation gives some incorrect matches with SURF only which degrades image registration. Incorrect matches are reduced by using HOG as descriptor in SURF. Supporting simulation results for satellite images are presented which show the improvement in the correct matching rate.

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Keywords: image registration; SURF; HOG; satellite image; illumination variation; multi-spectral

1. Introduction

Image registration (IR) is the process of aligning two images-the target (or reference) image and the source (or sensed) image[1]. Basically IR determines the spatial or geometrical transformation that maps the points in the sensed image to the points in the reference image. IR is very crucial preprocessing step for the image analysis in which the

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final information is obtained from the combination of two images, such as remote sensing, computer vision and medical image analysis. In case of remote sensing applications, registration accuracy of less than 0.2 of a pixel is required to achieve a change detection error of less than 10%[15].

IR methods can be classified as Area (spatial or intensity) Based Methods (ABM) and Feature Based Methods (FBM) [1]. In ABM, intensity of every pixel in both images is used to compute some similarity metric (also known as cost function) to find the optimized geometric transformation iteratively. The computation time, especially for large satellite images, is more as every pixel is taken care of. In FBM, salient features of the images such as points, lines, edges etc. are detected and corresponded to find the required geometric transformation parameters. Relatively, this is faster and works well if salient features are available in the images as only those features are required to proceed further.

There are four steps in any FBM for IR: feature extraction, feature matching (using descriptor of the extracted features), geometric transformation estimation and re-sampling. In IR, depending on application, selection of feature extraction, its descriptor and matching method play important roles. The error in any of the steps of IR will be propagated in the next steps; accordingly it reduces the accuracy of IR.

During the last decade, Scale Invariant Feature Transform[2] (SIFT) and Speeded-Up Robust Features[3] (SURF) have been widely used for point feature extraction. SURF is derived from SIFT, but it is modified using hessian matrix, integral image and Haar response. This results in better performance and three time faster execution. Comparison of some of the feature extraction methods are also found[8,19].

SIFT is used in[4-7, 17, 20] for IR. In[17], for satellite images coarse IR is performed using SIFT to get its advantage of robustness and then fine IR is performed using mutual information to get its advantage of accuracy. Similarly in[21], coarse IR is performed using SURF and fine IR is performed using Harris corner detector. However this strategy of coarse-to-fine IR requires re-sampling process two times, so corresponding errors are added.

In our approach, SURF point features are used. Satellite images may be multi sensor, multi-spectral, multi-resolution or multi-temporal; they are typically large in size. Due to these characteristics of satellite images, conventional IR algorithms used for computer vision or medical images may face some problems. SURF is also giving incorrect matches, and hence improved in[9-12,21] for satellite IR. In[9] the normalized SURF algorithm can extract more accurate matching points than the original SURF algorithm; however the stability and robustness of the normalized SURF method still needs further study. In[10] feature points are extracted using SUSAN algorithm and they are described using SURF algorithm, where marginal improvement is found but results are not shown for challenging satellite images. In[11] performance of SURF for registration of high resolution satellite images captured at different bands is evaluated and then Scale Restriction (SR) method, which has been already proposed for SIFT, is adapted to SURF. In[12], SURF descriptor is modified according to the gradient reversals. This improves the Correct Match Rate (CMR) for multi-modal images but at the cost of reduced CMR for mono-modal images.

In SURF there are mainly three steps: point feature extraction, orientation assignment (optional step) and feature description. Our work is for feature descriptor. In SURF, Haar response based descriptor is used. Some alternatives for feature descriptors are compared in[13]. In[14], Histogram of Oriented Gradient (HOG) is used as feature descriptor for human detection. Because of its nature and as claimed by the authors it is illumination invariant. This is useful requirement for IR of satellite images with varying illumination level. To compare descriptor of SURF and HOG descriptor, around the same point two image patches are selected from the two images with different illumination level as shown in Fig. 1. For both the image patches, Haar based SURF descriptor vectors are plotted in Fig. 2 while HOG descriptor vectors are plotted in Fig. 3.This shows HOG descriptor is more illumination invariant compared to the descriptor of SURF.

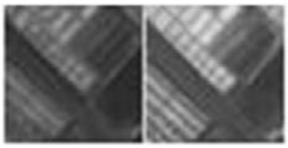

Fig. 1 Small low resolution image patches of size 41X41 pixel with different illumination level (increased in size for proper visual display purpose)