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Abstract. This study proposes a novel tiling approach to capture an image of an entire object. Multi-spectral and multi-temporal satellite images are obtained a priori, and these individual image pieces can then be joined together at a later date to form an image of the entire object. The effectiveness of the proposed technique has been studied by tiling partially overlapping satellite mosaic images of the Island of Cyprus. The images were captured by the recently-launched LandSat-8 satellite.

Keywords: Satellite image tiling, image mosaicking, LandSat-8, lighten method.

1 Introduction

Processing satellite images is harder than processing any other images. It is even harder when it comes to image stitching or registration. There are a number of reasons for this. (1) Bad weather and atmospheric conditions such as clouds, fog and smoke affect the sensors and prevent them from acquiring measurements accurately. This also affects information extraction: It is hard to define objects with their precise borders and edges. (2) Satellite images are naturally poor in color variations. In low-resolution images, the colors are mostly greenish and brownish. This is related to the previous poor-definition group. (3) Satellite images from different sensors usually have different spatial resolution. (4) They are called multi-spectral images; images have different spectral characteristics, so that contrast information is different for the same imaged object. (5) They are mostly captured by the sensors at different time intervals. This is called spatiotemporal differences; and it affects the success of matching process in image stitching and registration. Issues 1 and 2 are general problems in satellite image processing. However, issues 3, 4 and 5 are especially related to the challenges faced when performing image stitching and registration.

In the image registration process, there are two major and important issues that need to be solved together. One is accuracy and another is efficiency. When you want to make the process more accurate, then you pay for the efficiency, and vice versa. Given the remotely captured large size images, the important thing is to reduce the

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computational time which is required to execute each of these steps while keeping precise alignment. It is therefore crucial that the registration process produces an image that is visually and numerically accurate.

In this paper, we are trying to find a way to get over aforementioned problems in image registrations in remote sensing domain by considering domain specific natures and characteristics of satellites and satellite images. We are proposing very fast and efficient registration method. But, in this approach there might be some faults in terms of numerical accuracy. The proposed framework and technique can be used efficiently in applications in which the performance and visually correctness has the highest precedence than the numerically correctness. Numerical correctness is called as exact pixel to (lat, long) address matching. In some real-time and internet based distributed applications accuracy can be tolerable to some extent for the sake of high performance.

After presenting the registration algorithm we increase the quality of the outcome image with a smoothing technique. In the mosaic result, the overlapping region shows the important brightness difference with the residual of the mosaic. We will apply a 'blending technique' to rarefy this effect. These methods are used to flat the overlapping area.

The study presented in this paper is based on mosaicking of the images obtained from an UAV (Unmanned Aerial Vehicle). UAV is referred to as a remotely piloted aircraft, when it flies in the sky to capture images remotely, and these are serially shot by digital camera installed on UAV. There are two methods used for image matching i.e. Rough Matching and Fine Matching. In the rough matching technique, firstly it determines the overlapping areas approximately and applies stitching.. This approximation is based on the mathematical calculations in which speed of UAV and some other parameters related to camera installed at UAV. In fine matching techniques, pixel based high cost feature detection algorithms are used. Techniques are mostly based on feature extraction and feature matching. To achieve a successful result, objects in the images need to be clearly determined. These approaches are affected by the problems presented in the beginning of this chapter.

The proposed tiling architecture is a kind of rough matching but also utilizes fine matching approaches to some extent. When coordinate values and all other required metadata about the satellite images are known and fed into the system, we can achieve much more efficient and successful results. In the proposed architecture, we handle the image stitching problems stemming from the spatiotemporal differences of satellite images. The architecture is also based on geometrical and coordinate based stitching by utilizing coordinate reference systems on which the satellite images are created.

The remainder of this paper is organized as follows. Section 2 gives relevant works about image stitching. Section 3 explains the proposed technique for registering the remote sensing satellite images. Section 4 presents the results of the experiment obtained by applying the technique on the Island of Cyprus mosaic image tiles. Section 5 concludes the paper.

2 Related Works

The methods used for image registration can be grouped according to the different perspectives and information used for registration. Mostly, they are grouped into two categories: feature-based and area-based methods [1]. In area-based methods, prominent features in images are not necessarily detected. Area-based methods are affected by the intensity distributions of the images. In intensity-based methods different electromagnetic reflectance is present, that's why these methods are not good for multi spectral satellite image registration [2]. On the other hand, the featured-based methods do not depend on the distribution of image intensity values. As an alternative, they use salient features which are extracted from two images, in this scenario it works more suitable where intensity changes and geometrical deformation are encountered. These feature based techniques have been widely used in remote sensing image registration.

In the literature, a number of registration techniques have been proposed, especially for use on satellite images. Yi et al. [2] proposed a SIFT [3] based multi-spectral remote image registration technique which is actually similar to the SURF technique [4]. Song and Zhang [5] presented a method to optimize SURF by defining a similarity measure function based on trajectories generated from Lissajous-figures. They aimed at increasing the feature matching rate. Lee [6] proposed a technique for registering remote sensing images which involved carrying out Haar Wavelet Transform (HWT) before applying the SURF algorithm to the images. Wahed et al. [7] proposed a technique in which median filtering is applied to remote sensing images before performing the SIFT algorithm to register the images. El-Rube et al. [8] presented a technique combining SIFT and multi-scale wavelet transform to register satellite imageries. The control points (or interest points) are selected using three levels of wavelet transform. Manera et al. [9] used the SURF technique to register digital images acquired from digital cameras attached to an unmanned aircraft.

In our previous work [10], a technique to register LandSat-8 satellite images using a combination of well-known image processing algorithms was proposed. In the feature extraction phase, interest (key) points are obtained by means of SIFT and SURF technique. For feature matching, RANSAC algorithm [11] is used. After the application of linear gradient alpha blending method, final image is created. This preciously proposed technique cannot overcome registering more than two mosaic (tile) image because of memory capacity. So, we suggest new methodology to solve this problem in this paper.

Nowadays the procedure based on soft computing techniques such as artificial neural network (ANN), genetic algorithm and fuzzy logic etc. are used for image stitching. Generally Network Architectures are classified into two main classes: First approach is feed-forward networks in which links have no loops (e.g., multilayer perceptron (MLP) and radial basis function neural networks (RBF) .Second approach base on recurrent networks in which loops occur (e.g., self-organizing maps (SOM) and Hopfield networks).Similarly there are different computational techniques used for image stitching for example Radial basis functions [12, 13], self-organizing maps [14], Hopfield networks [15].Correspondingly other proposed technique in this scenario [16] based on a three-layer neural network to determine the registration matrix for 3D surface image stitching. Li and et al. [17] described the use of image regions which lie on an application of pulse-coupled neural network to multi-sensor image fusion problem. Shang and et al. [18] used principal component analysis (PCA) neural network for CT-MR and MR-MR registration. Zhang and et al. [19] illustrate a 3D surface-based rigid registration system for image-guided surgery on bone structures. Sharma and et al. [20] proposed an algorithm that finds the major overlapping area in the images to be mosaicked using neural network (Kohonen's self-organizing Map (KSOFM)). These approaches are mainly applied on medical images rather than satellite images.

3 Architecture

Image registration is the process of aligning two images of a particular area. They correspond to each other on an exact pixel-by-pixel basis [21]. Type of image is an important feature in image registration. Method of image registration varies according to the type of image. This study contains remote sensed images. These types of images usually contain two types of distortion which are radiometric distortion and geometric distortion. In this section, we explain the way of correcting geometric distortion.

In this paper, registration of high-resolution satellite images consists of seven steps. These steps can be listed as; (1) reading image with geographic corner coordinate as latitude, longitude, (2) the calculation of pixel values corresponding to latitude longitude, (3) selection of the most precise value to be calculated in previous step, (4) calculation of width and height of the image to be registered, (5) corner coordinate as (x,y) of each tile image, (6) according to coordinate to be calculated in previous step blending of each tile image to final image using lighten method and finally (7) saving image as jpeg format. This architecture can be seen in Fig. 1 schematically. We will explain these steps in detail later on.

In the first step, high-resolution images to be registered and their geographic corner coordinates as NW, NE, SW and SE are read. These images are obtained from LANDSAT-8 satellite launched by NASA more recently. Each corner coordinate consists of latitude and longitude. For those images, memory is allocated. The more it has been registered number of satellite image, the more it has been allocated amount of memory. More specifically, we can say that if the number of pixel of the satellite image increases, it is necessary to have more memory space. The memory should be used effectively while reading image. To calculate memory space of any image, its dimension and every pixel size are taken into consideration. For example memory space of Fig. 3 is 446 MB (7641 x 7651 x 8 = 467690328 byte). If the size of one image to be registered is about 446 MB, four images are the size of 4x446 = 1784 MB (about 2 GB). Therefore, 2 GB of memory space should be free. Nowadays, it is too hard for a computer to allocate 2 GB memory size for only one application. Unused objects in memory should be de-allocated for optimal usage. This process runs automatically in Java by garbage collector. Although it is not highly recommended, application developers can call the garbage collector. To work actively this process, references of objects to be de-allocated must be removed from memory. If memory has that object reference, the object will continue to occupy memory space. Therefore, firstly the object reference should be removed then garbage collector is called to de-allocate memory space.

In the second step, equivalent of each pixel is calculated as latitude and longitude by using Equation (1) and (2). To register satellite images correctly, their resolutions should be same. In the third step, pixel values belonging to each satellite image are compared with each other and the most precise pixel value is selected to reduce the error rate.

$$X = image\_width / (NE\_latitute - SW\_latitute) \quad \textbf{(1)}$$

$$Y = image\_height / (NW\_longitute - SE\_longitute) \quad \textbf{(2)}$$

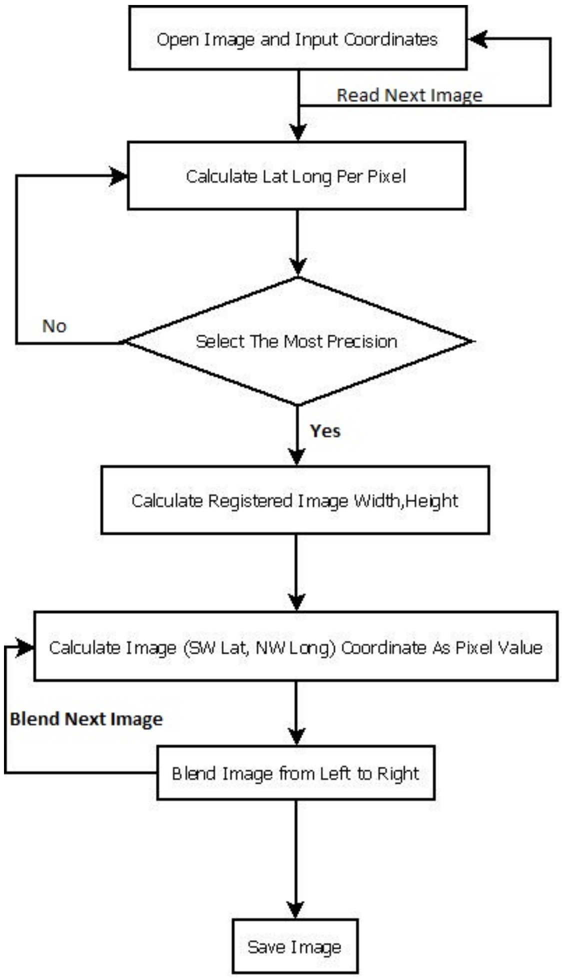

Fig. 1. Workflow of the processes in the architecture

In the fourth step, width and height of registered image are calculated. To calculate image width, it is necessary to determine the most left and the most right longitude. Similarly, to calculate image height, it is necessary to determine the most bottom and the most top latitude. In fifth step, top left point (SW_latitute, NW_longitute) of each satellite tile image is converted into x and y coordinates to find starting point of each tile image on registered entire image. In the sixth step, each satellite tile image is drowned to the registered image by starting from those points. If these tile images are registered directly, a part of black background overlaps with other one part of image which will not be a successful registration. To overcome this problem, color of overlapped part should be set correctly. While blending overlapped parts of image, max (RGB) function is used as shown (3). This method is called “lighten”.

R = Resulting pixel value,

S = Pixel value of first image’s overlapped part,

D = Pixel rgb value of second image’s overlapped part,

$$R = \max(S,D) = [\max(Sr,Dr),\ \max(Sg,Dg),\ \max(Sb,Db)] \quad (\mathbf{3})$$

After processing these steps, registered image is obtained finally.

4 Experimental Results

The proposed technique was tested on LandSat-8 satellite images. LandSat-8 OLI has 8 multispectral bands (440-2200nm), spatial resolution of 30m, and a swath of 185km. LandSat-8 was launched in February 2013. The satellite images obtained can be searched interactively and downloaded free for use in academic studies from the United States Geological Survey (USGS) website (http://glovis.usgs.gov/). In order to register this type of high resolution images, some requirements must be accomplished. This application runs on java platform built on JVM (Java Virtual Machine). Also, JVM parameters must be set to–Xmx2g –Xms2g to allocate 2 GB memory space for JVM. We realized experimental tests on a JAVA virtual machine installed on a machine with a 2.3 GHz Intel i7 2820QM 8MB Cache, 6GB Memory, and Windows Home Premium 64 bit operating system.

The satellite tile images of Island of Cyprus with its dimensions are shown in Fig. 2 to Fig. 5. Also, the geographic coordinates of these satellite images are listed in Table 1.

While registering tile images above; if lighten composition method -replacing target image pixels with lighter pixels from the foreground image for overlapped parts- is not used, the registered image is shown in Fig 6. However, if lighten method is used, the registered image is presented in Fig 7.

Fig. 2. Tile-1, North-West (7641x7651)

Fig. 3. Tile-2, North-East (7651x7801)

Fig. 4. Tile-3, South-West (7641x7791)

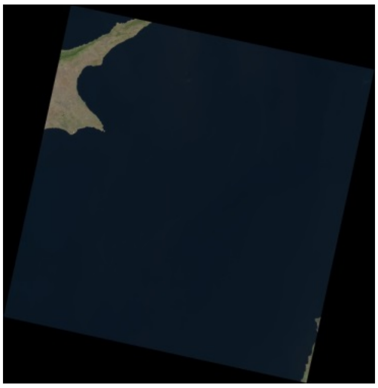

Fig. 5. Tile-4, South-East (7631x7431)

Table 1. The geographic coordinates of part satellite images of Island of Cyprus

Images	North West		North East	
	Latitude	Longitude	Latitude	Longitude
Fig. 2	37.0960	32.72594	36.7015	34.80635
Fig. 3	37.0960	34.27671	36.7015	36.35717
Fig. 4	35.6625	32.32869	35.2720	34.37137
Fig. 5	35.6625	33.86668	35.2720	35.90891
	South East		South West	
	Latitude	Longitude	Latitude	Longitude
Fig. 2	34.9760	34.28345	35.3695	32.2481
Fig. 3	34.9760	35.8343	35.3695	33.79888
Fig. 4	33.5447	33.86304	33.9347	31.86247
Fig. 5	33.5448	35.40051	33.9348	33.40038

Fig. 6. High-resolution satellite image (13465x13181) before performing Lighten method

Fig. 7. High-resolution satellite image (13465x13181) obtained after performing Lighten method

5 Conclusion

Image registration provided an important element in data processing for remote sensing in the midst of many applications by means of wide range of solutions. Regardless of substantial exploration, the field has not yet settled on a definitive solution. In many applications the numbers of questions still need explanation for appropriative and efficient results. Satellite image mosaicking, a process of stitching or aligning several satellite images to produce a single large scale and high resolution image, is thus an important scheme to extend the usability of satellite imagery in practical applications. However, speediness for image matching, at the same time, assuring the accuracy, i.e. precision, is a key question in the technology of image matching.

This paper proposed an architecture utilizing domain-specific knowledge of geometric transformations and image content. We have used the coordinates of the reference systems, their conversion to screen pixel addresses, etc. Thus, we have increased the performance significantly.

In the future, we will enhance the scalability of the overall system by using physical storages as caches. Thus, a set of high resolution satellite images summing up to terabyte will be able to handle efficiently. We will also consider ANN with proposed technique to obtain more accurate results.

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