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SEMI-AUTOMATIC IMAGE REGISTRATION

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Abstract

Whenever more than one images of the same area are involved in a study, they must be co-registered, so that a point in one image can be accurately identified on other images. The manual method of image registration involve identification of easily identifiable points, called ground control points (GCPs), on the images and then computing the transformation parameters based on these GCPs. This process is very tedious and time consuming. We can take the help of computer in identification of these GCPs or some other thing else like image object, feature, characteristic etc. instead of using human expertise. Totally elimination of human involvement require a very robust system which is difficult to program and would require a lot of computational power; but using human intelligence for supervisory roll to start the process and finally accept (or reject) some intermediate position, a viable registration system can be designed. Such a system can be easily implemented on any modern PC. The present paper investigate the processes involved in image registration and proposes design of such a system, which is more suitable for registering satellite images but may be used for medical images also.

Keywords: Image registration, image rectification, multi-modal registration, non-rigid registration

1. Introduction

When we take an image of any area, the image is not really true representative of that area. Many errors creep in during the image acquisition process. These may be due to view angle (prospective distortions), platform instability, motion of the target area or change in the illumination conditions or intervening atmosphere. These errors make it difficult if we have to compare (analyze) two or more images simultaneously (as the errors in the two may be different). To overcome this difficulty we have to register the images. Also, it is necessary to relate remotely sensed images to a reference coordinate system (datum), to a map or another reference image if they are to be used in any Geographic Application. Details of the process involved and survey of various techniques is discussed in excellent review papers like that of Lisa Gotterfeld Brown [1], R. E. Kennedy, Barbara Zitova, Jan Flusser [2] and W. B. Cohen [3].

Image Registration is the process of computing a transformation so that there is a one-to-one correspondence between the pixel representing same area in the two images. In other words, the process of relating an image to another reference image or map of the same area taken from different viewpoints, at different times and/or and by different sensors is called image registration. Image registration is used in diverse fields like Computer Vision & Pattern Recognition - segmentation, object recognition, shape reconstruction, motion tracking, stereo-mapping, character recognition; Medical Image Analysis - tumor detection, disease localization, classification of microscopic images - blood cells, bacteria; and Processing of Remotely Sensed Data – target location, mosaic images, fuse images, study changes, or integrate information in GIS. According to the needs of the application at hand, the registration problems can be classified into different categories such as:

Multi-modal Registration

When the images to be registered are taken by sensors having different characteristics like spatial resolution, radiometric resolution, operating in different regions of the electromagnetic spectrum or sensing different parameters/ physical characteristics. In this case the images are essentially different but represent the same area/object. This class of problem mostly occurs in medical imaging where images of the same organ taken using different imaging technologies are to be studied together to identify the disease/problematic area. In remote sensing the when the images taken by different sensors like optical sensors and SAR sensor are to be registered or low resolution multi-spectral image is to be fused with high resolution panchromatic image; multi-modal registration is required. Different sensors give information on different aspects of the target (scene). For example optical, far infra red and SAR images. It may also be used to enhance image resolution of multi-spectral sensor from a pan sensor.

Template Registration

The problem is related to locating positions and orintations of known features e.g. runways. The images in such cases are generally taken from different angles/orientation by same type of sensor/camera.

Viewpoint Registration

If we are interested in registering images taken from different view-points for 3D shape reconstruction or finding depths/heights –e.g. creation of DEM, then the registration is viewpoint registration problem. The two images are of same/nearly same area taken at same time(nearly) from different viewpoints/view angles. For example 3D Viewing, image mosaicing. Errors are mainly of perspective type.

Temporal Registration

When we are interested in studying the changes in our area of interest over a time, the images taken at different times are to be registered. This is a major class of interest in remote sensing studies. Images of same area taken at different times. This is used for modeling, monitoring, or change detection studies. Different types of errors may be - illumination difference, different atmospheric conditions, platform and sensor errors.

Image to Model Registration

Image of an area registered with some model (DEM, map) of the area.

After registration, the image may be re-sampled so that the grid of new image align with the reference coordinate system. This is called image rectification or geometric correction process. If the reference image is in some map coordinates or the image is to be referenced to a map, the process is called Geo-rectification. Where-ever two or more images are to be processed together to get the final information, image registration becomes a crucial step in the image analysis procedure.

Image registration aims to remove all the differences among the images of the same area which results from the difference in acquisition conditions and really does not represent an actual change in the scene. That is, it tries to remove the distortions/ extraneous changes in the target (data) image which are there due to changes in acquisition conditions.

Main types of differences in images due to change in acquision conditions are:

- ♦ Systematic Geometric errors:
  - Earth rotation, Sensor movement
- ♦ Non-systematic geometric errors:
  - Platform movement, topographic undulation
- ♦ Difference in projection system of the images
- ♦ Radiometric changes:
  - Change in illumination - time & season of acquision
  - Change in atmospheric conditions
  - Changes in sensor response over time

Normally, image registration/geometric correction tries to remove all geometric distortions/deviations. The radiometric errors are handled separately in a pre or post processing step, if needed.

2. IMAGE REGISTRATION

The image registration process involve identifying some features in the reference image and corresponding features in the image which is to be registered (say raw image);

estimation of transformation model to register the raw image properly on to the reference image and finally transform and re-sample the raw image into the reference coordinate system. When we try to automate the process, we have to answer a number of more subtle questions as explained below.

Feature Identification/Detection

Which type of features we are interested? The potential candidates are points, corners, lines (linear features/edges), regions etc. We have to find a method to define them; then a method to identify them. Once we have fixed our choice, then the next question is the search space – where to look for the next feature. This is linked to our requirement perception, how many features are needed to compute the transformation model, and what should be their distribution in the image. Once we have identified sufficient features in both the images, we have to identify which feature in the raw image correspond to which feature in the reference image *i.e.* correspondence detection or feature mapping. This leads to another question how to identify the corresponding (conjugate) features. We should have some similarity metric, with the help of which the correspondence problem can be solved. Similarity metric may be like maximization of cross-correlation or mutual information or minimization of some distance or difference etc.

Transformation Model Estimation

Before the transformation model is estimated from the location of corresponding features, we have to decide about the choice of transformation model itself. This choice depends on the assumed/probable type of the geometric errors in the raw image. If the errors are of simple translation, rotation or scale change then simple similarity transformation will do but we may need perspective transformation for perspective errors or higher order polynomial transformation if the errors are complex in nature. If the errors are same throughout the image, a single global transformation model may be used for the entire image; such transformation is called a rigid transformation. On the other hand, if there are some local deformations/distortions, the transformation model may be modified to take them into account in various regions of the image. Such transformations are called non-rigid. Rubber-sheeting and elastic transformation models are also non-rigid transformation models. There are many techniques through which the model may be modified to suite local requirements and maintain continuity at the same time.

Image Transformation and Re-sampling

Once we have computed the image transformation model, the raw image can be transformed accordingly. As the pixel location in new reference coordinates are not on the grid of the old raw image, the raw image is to be re-sampled to the new coordinate system. The decision, whether the re-sampling is to be nearest neighbor or some interpolation based, is based on the potential use of the registered image and computational power available. If we need to preserve the pixel values for some physical modeling requirements, nearest-neighbor is used which is the fastest re-sampling method. This method introduces some artifacts and produces aliasing effects specially at sharp intensity changes. The visual quality of the resulting image is not very good. If the image is to be interpreted by a human operator, bi-linear interpolation or cubic convolution or thin spline interpolation is a much better choice, as they have an inherent smoothing process to dissolve the aliasing effect. The first is fastest and the last is slowest.

Now let use take up each of the image registration steps in more detail and explore where automation is possible. The most tedious and time consuming part of the image registration process is CP selection and their matching. Any automation in this effort will significantly reduce the human intervention and effort. So, this area is the target of most of the semi-automatic image registration schemes. Generally, no effort is being made to fully automate the process as the other parts of the routine (like selection of initial two three CPs, transformation model and re-sampling method selection) are quite trivial from human point of view but quite difficult to implement on machine, and the chances of committing blunder by the fully automated method is significant.

3. SEMI-AUTOMATIC REGISTRATION

The proposed image registration process consists of a number of steps. The steps can be completed using one of the already known and published algorithms for that purpose. The details of steps are given below and represented pictorially in the flow chart given in figure 1.

(i) Use sensor model information (GCPs and ephemeris information) form satellite data, if available, to create a polynomial transformation model.

(ii) If the image to be registered is already projected, use the projection information of the source and reference images to create initial transformation model.

(iii) Take first 3 control points manually

(iv) On a sparse grid, using feature matching in plain area and region matching in hilly or desert area, find new CPs. For feature matching, the region must have enough distinctive and easily detectable objects. Lines, points, corners etc. are good candidates. Illumination changes in reference and target image do not pose any problem in this case as intensity of the object under consideration is not important. If the image has sufficiently large number of linear features, take line feature as registration feature. We may force the normal distance

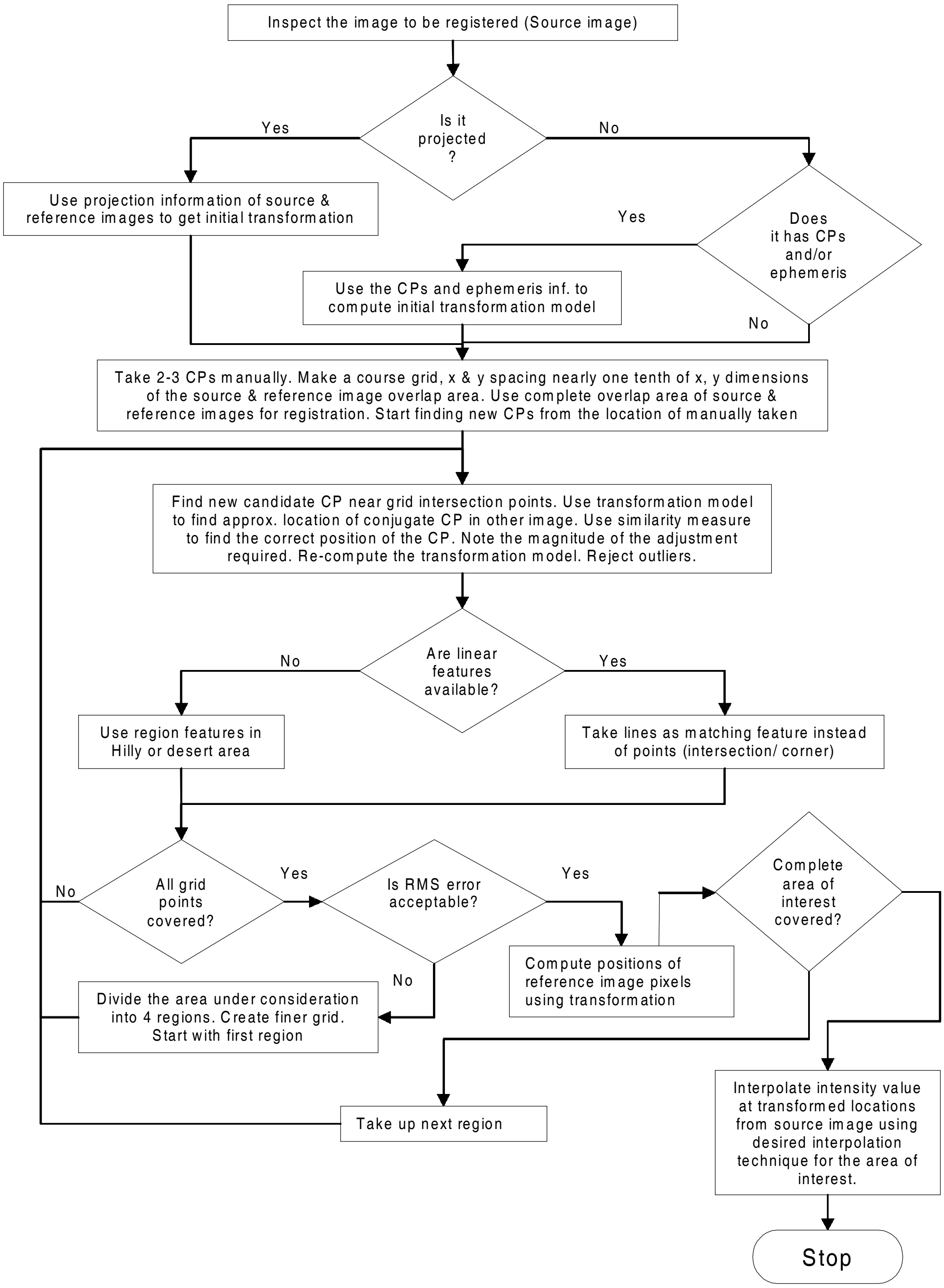

Figure 1: Flowchart for Image Registration Process

between end points of a line segment in reference and corresponding line segment in target image, after transformation, to be zero. The segment endpoints need not be conjugate. Rank the line segments by length so that the larger segments are more important. Using the current transformation parameter values as approximate, update them (one at a time) so that the current line segment under registration fits properly. Line segments in different parts of the image may be used to update different parameters as suggested by Habib *et al*. [4]. Where significant linear features are not available, prominent points or corners may be used for registration.

(v) Starting from the initial control points taken manually, identify candidate control points on a regular coarse grain grid.

(vi) Use similarity/affine transformation model to predict conjugate control points, once a candidate CP is identified in one of the image. Utilize DEM, if available, to improve the transformation parameters.

(vii) The Control point detection may be done in an iterative three step style:

(a) Find approximate tie point using triangulation method (based on a grid)

(b) Refine the tie point (using optimization of some similarity measure in a small neighborhood)

(c) Validate the tie point

(viii) In hilly or desert area, linear features, points or corners may not be easily identifiable. In such areas region matching techniques may be applied to compute transformation parameters of the intended transformation model. For this purpose, correlation or template matching methods or Fourier Methods or Mutual Information Optimization methods (in multimodal images) may be used. Venu Govindu and Chandra Shekhar [5] has proposed a good framework for such work.

(ix) Create local overlapping transformation models for different parts of the image and repeat the procedure on a finer grid, if required.

(x) Use non-parametric or parametric non-rigid registration method for better control and registration accuracy in the final registration iteration.

(xi) Using the transformation parameters, compute locations of each reference image pixels on the source image coordinate system.

(xii) Resample the image to be rectified by interpolating the source image pixel values at locations computed in previous step, using thin-plate spline or cubic convolution or nearest neighbor method. The choice of re-sampling method depends on the intended use of the registered image and computational resources available. The re-sampled image will be in the reference image coordinate system and will correspond to it.

Idea is to iteratively create better transformation model for sub-pixel registration accuracy. As recommended by Bryant [6] the source mage is re-sampled only once to avoid image quality degradation.

In this paper a methodology of operational semi-automatic image registration is presented. The image's inherent information (the sensor model/GCP contained in metadata along with ephemeris, if it is a raw satellite image, or projection information if it is already projected) provide a good starting point. The second step of manually taking few GCPs ensure that no big blunder is committed. The expected RMS error is of the order of 3-5 pixels and max error of the order of 5-8 pixels at this level. The use of linear features for registration ensure that the images fits properly without any apparent misalignment. The use region-wise transformation models ensure that distortions in one region do not affect the results in other region. Automated discovery of GCP gives us a capability to get a large number of GCPs so that the RMS and maximum errors are both reduced significantly. At this level we can expect an RMS error of the order of 1 pixel and maximum error of 2-4 pixels; which is good enough for a large number of applications. If still better result is required, the final step of non-rigid/elastic transformation may be performed, which is quite compute intensive. Due to the earlier steps, the search radius for elastic registration will be of the order of 5-6 pixels (slightly larger than the maximum error) which will reduce the registration time significantly. The expected final RMS error is of the order of 0.25 pixel and maximum error of the order of 1 pixel.

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