Automatic system for image registration with fit assessment

Dmitry Fedorov[*, 1], Leila M.G. Fonseca[**, 1]
Divisão de Processamento de Imagens
Laboratório Associado de Computação e Matemática Aplicada,
Instituto Nacional de Pesquisas Espaciais (INPE), Brazil.
(*)Mestrado, Bolsa CAPES, e-mail: fedorov@nucleo.inpe.br; (**) leila@dpi.inpe.br

Charles Kenney, B.S. Manjunath
Department of Electrical and Computer Engineering
University of California, Santa Barbara, CA, USA.

Abstract

Image registration is the process of matching two images so that corresponding coordinate points in the two images correspond to the same physical region of the scene being imaged. It's a basic operation needed in different areas of human activities like: remote sensing, medicine, etc. However, this operation is computationally complicated and different algorithms have been developed [1]. As the amount of data is increasing fast reliable registration algorithms are needed. This paper describes a system for automatic registration of spectrally similar images. It has been developed at the Vision Lab (Electrical & Computer Engineering department, UCSB) in cooperation with Division of Image Processing (DPI) at INPE. The system provides tools that allow automatic registration and mosaic of remote sensing images. No previous aligning is needed and the transformation function used to model the distortion between the images is affine.

1. Introduction

The basic description of the point matching algorithm is presented in this section. The algorithm consists of a two-step procedure. In the first step, points in the first image are tentatively matched with points in the second image. This preliminary matching is accomplished by matching features at each tiepoint in the first image with features at each tiepoint in the second image. These features are extracted using optical flow [2] [3]. To overcome rotation effects, we have taken windows about each tiepoint that have been rotated so that their central gradient points downward. The initial feature matching can be used to eliminate points from both images that have no corresponding points. At the same time an initial corresponding points set (control points) in the two images is obtained. The second step refines the initial control points set by using a purely geometric matching procedure in which the location of points and their relationship to each other determine the matching. The geometric matching procedure is similar to the RANSAC algorithm [4]. Because the first and second steps are based on different matching criteria they provide a safeguard against mismatched points. Moreover the preliminary matching in the first step reduces the computational burden of the second step, resulting in a fast combined matching algorithm.

Once the tiepoints matching has been computed we need to verify its consistency. This is done by using three independent tests. In the first two tests, a statistical procedure is used to characterize good and bad registrations. The computed registration is then compared with both good and bad fit estimation in order to determine its acceptability. This "good fit-bad fit" statistical testing is supplemented with a bootstrap parameter variation test in which control points subsets are used to recompute the transformation parameters. Large parameter variation over the subsets indicates the presence of mismatched tiepoints. These three consistency-checking tests provide a powerful mechanism to detect improper registrations.

Extensive algorithm tests have been performed by registering optical, radar, multisensor, high resolution images and video sequences. We have included very difficult image registration examples in order to show the strengths and limits of our approach. We developed a registration system online demo [5] that contains several examples that can be executed using web browser.

2. System description

The registration system is separated in two logical parts. The first part is the main driver for registration and mosaic. It is written using common C++ and Trolltech Qt library for image representation, which provides better platform independence (Linux, Solaris, Windows) and also independence from user interaction layer.

Registration procedure needs only one parameter, which specifies the number of tie points to start with. This parameter is only modified in more complicated registration cases and decreases registration speed exponentially. However, reasonable number of tie points (128) returns almost instant result.

Mosaic procedure contains several useful features like: mosaic both images into separate channels for match verification, equalize the images using simple mean and standard deviation comparation of the overlapping area, etc.

There are two user interaction layers. The first one is a command line module intended for calling from other systems, for example, it's used by CGI demo script. The second is a GUI module written on C++ using Trolltech Qt library. The later module handles all image I/O operations. We developed or modified several image file handlers for Qt 2.x, such as: RAW reader/writer, JPEG encoder/decoder using IJG library and TIFF encoder using libTIFF.

In order to simplify image viewing and handling a universal viewer based on Qt GUI was developed. It provides basic read/write and preview operations, such as: load file, save file, change zoom, image information, full screen preview, clipboard handling, etc. Visualization module also contains a layer to handle special information like tie points.

3. Registration examples

In order to test the system and demonstrate its feasibility for different types of images some preliminary results are presented in this section. Figure 1 shows the registration of two images from the urban area of São Paulo. A SPOT image, band 3 was reduced to 30 m pixel size and registered with Landsat-TM5 image, band 4. Figure 2 shows the registration of Amazon region images taken from TM5 sensor, band 5, in different dates. Finally, Figure 3 shows a mosaic of an aerial video sequence taken from the Amazon region. Others experiments with SPOT and TM images from urban, forest and agricultural areas were performed and in all cases we obtained very encouraging results.

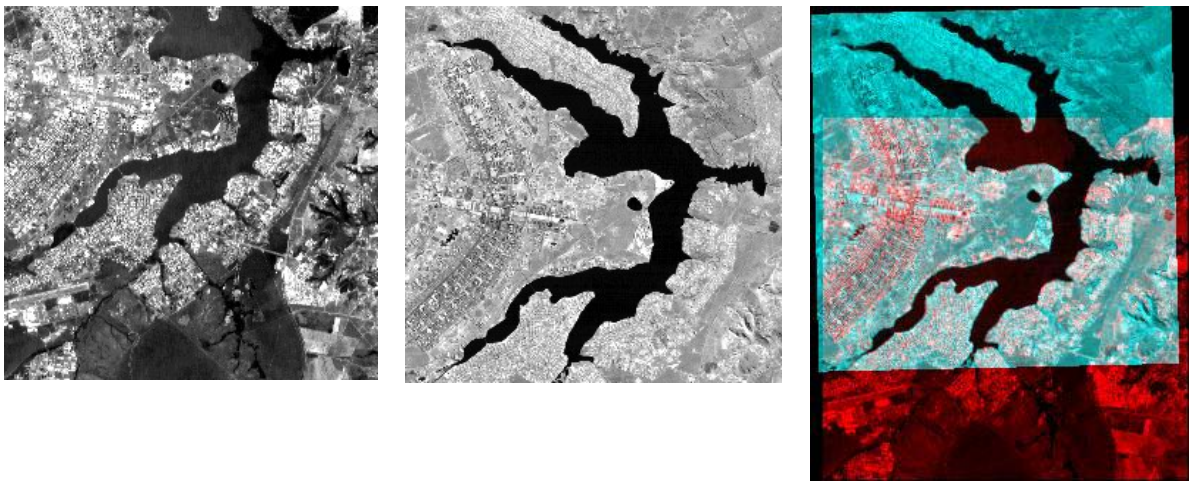

Figure 1: Urban, SPOT band 3 (08/08/95) + TM band 4 (06/07/94), 256x256, Brasilia, Brazil. Good registration with 128 points.

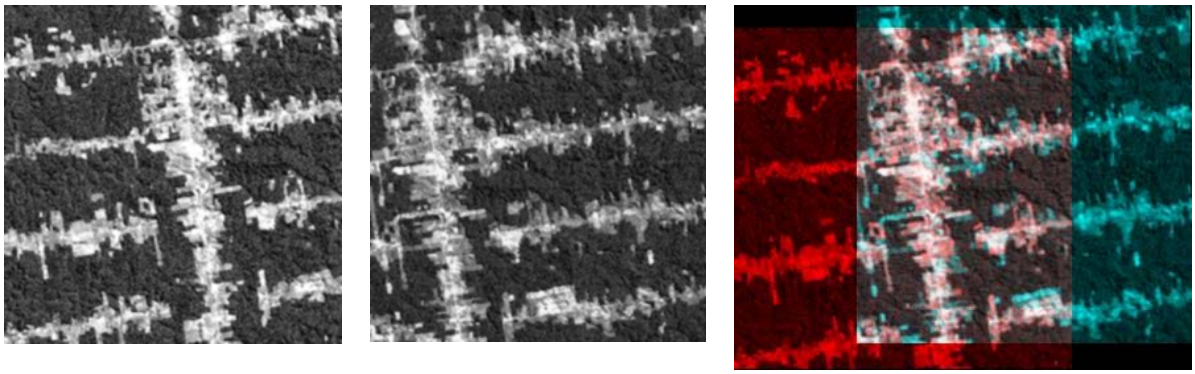

Figure 2: Forest, TM band 5, (06/07/92) + (07/15/94), 256x256, Amazon, Brazil. Good registration with 128 points.

Figure 3: Aerial video sequence mosaic, 720x480, Amazon, Brazil.

4. References

[1] Fonseca, L.M.G, Manjunath, B.S., "Registration techniques for multisensor remotely sensed imagery". PE&RS, Vol. 62, No. 9, Sept. 1996, pp. 1049-1056.

[2] Fonseca, L M.G, Hewer, G., Kenney, C., and Manjunath, B.S., "Registration and Fusion of Multispectral Images Using a New Control Point Assessment Method Derived from Optical Flow Ideas", Proc. SPIE, Vol. 3717, pp.104-111, April 1999, Orlando, FLA.

[3] Fonseca, L M.G, Kenney, C., "Control Point Assessment for Image Registration", Proc. XII Brazilian Symposium on Computer Graphics and Image Processing, Campinas, Brazil, October 1999, pp. 125-132.

[4] Hartley R., Zisserman A., "Multiple View Geometry in Computer Vision", Cambridge University Press, 2000.

[5] Online registration demo, <http://nayana.ece.ucsb.edu/registration/>