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ACCURATE IMAGES' CO-REGISTRATION TECHNIQUE FOR FINE GEO-LOCATION IN THE FUEGO/FFEW PROJECT
UNA TECNICA DE CO-REGISTRACION DE IMAGENES PARA LA GEOLOCALIZACIÓN FINA. PROYECTO FUEGO/FFEW

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ABSTRACT: This work is aimed on the development of the automatic technique for accurate co-registration of multi temporal images, taken by the FUEGO/FFEW s/c in order to provide fine geo-location. The technique is based on selection and matching of control points and uses correlation and LST moving window algorithms for recognition of similar image fragments. Additional sub-pixel LST based control points adjustment insures very high accuracy. An iterative control points verification makes it possible to avoid wrong matches. This technique could be applied in automatical, semi-automatical or manual way. Provided experiments shows quite high accuracy and reliability of the proposed technique.

Key words: Image co-registration, Least Square Technique, FUEGO/FFEW, SPOT, Landsat-TM.

RESUMEN: El objetivo de este trabajo es el desarrollo de una técnica para co-registrar imágenes multitemporales del sistema FUEGO automáticamente con una alta precisión. La técnica se basa en la selección y emparejamiento de puntos de control y usa algoritmos de correlación y LST de ventana móvil para el reconocimiento de fragmentos similares. Un ajuste adicional LST sub-pixel asegura una altísima precisión. Un análisis iterativo de los puntos de control elimina los emparejamientos erróneos. La técnica puede utilizarse en modo manual, semiautomático o automático. Los experimentos demuestran la alta fiabilidad del método.

Palabras clave: Co-registración, FUEGO/FFEW, SPOT, Landsat-TM; Ajuste por mínimos cuadrados.

INTRODUCTION

The FUEGO/FFEW system is designed to provide operative detection and monitoring of forest fires. The system concept requires real time imagery processing to provide results to users with the same rate of image reception every 25 min.

The fine geo-location of obtained images is one of the steps of FUEGO/FFEW image on ground processing. The main requirements to this process given by the project statements state, that it must be provided automatically in real time and with a very high accuracy to insure the exact location of detected fires. The RMS error value must not exceed 0.5 of pixel size. Navigational information is processed by the preliminary geo-location software to obtain some estimation of ground coordinates of received images. The accuracy of such preliminary estimation is ±10 pixels and is limited first of all by errors of navigational instruments.

Different geo-location strategies have been studied by the Alcatel team in 1999. It was shown that the indirect method of co-registration of new obtained image with the previously fine geo-located image provides the best results. Application of such approach transforms the problem of fine geo-location to the problem of co-registration of the new (called *registered*) image with some preliminary accurately geo-located (called *base*) image from the same sensor.

The problem of images co-registration is aimed on establishment of the unique correspondence of all pixels of the registered image to the pixels of base image that represent the same areas on the ground surface.

IMAGE CO-REGISTRATION ALGORITHM

The images' co-registration problem is quite well studied by previous researches and a lot of various techniques exist for its solution for some specific cases [2,3]. Most of the approaches are based on detection and establishment of correspondence between some distinguishable features and objects on the ground surface. The usual *control points* (CP) concept was chosen to be basic in this work.

The common CP-oriented algorithm was chosen for images co-registration that can be subdivided into the listed below steps:

- Preprocessing of registered and base images to represent them in the most convenient form for subsequent co-registration. This step includes some spatial filtration and re-sampling of one of the images to the same scale and rotation angle.
- Selection of control points over base image at locations of some distinguishable features with prediction of their location at the registered image. At this step the preliminary geo-location results are involved to provide the best possible prediction.
- Control points matching. At this step selected control points are adjusted to insure, that they are locating the corresponding features at both registered and base images.
- Verification of the obtained CP set. This step assumes excluding of wrong matched control points that really correspond to different features at registered and base images to increase reliability and accuracy of co-registration.
- Fine adjustment of the remaining CP pairs with the sub-pixel accuracy.
- Estimation of transformation function that describes the geometrical relations between the registered and base images. This estimation is made on the base of obtained CP set.
- Transformation of the registered image to the projection of base image by re-sampling.

The presented above algorithm description is quite schematic. Different techniques have been tasted and selected to be applied at every step. The final transformation step is well studied, described in literature and implemented in most of remote sensing image processing commercially available software packages. Therefore, this step is not considered in this work.

Point features detection over images by means of selection of centers of fragments providing the best values of some interest operator have been used for initial selection of control points acceptable for subsequent matching. Entropy [4] and Moravec [5] interest operators have been studied and compared. Moravec interest operator have shown better results with acceptable reliability of subsequent matching.

Local technique have been proposed as an addition to the polinom-based forecasting of CP location. It makes it possible to take into account local distortions on images during forecasting, so decreasing the necessary size of search area for subsequent matching.

Various image pre-processing techniques have been studied in application for subsequent control points selection and matching. Edge detection by a Laplacian filter with the subsequent selection of fragments by means of the Moravec Interest operator have shown the best results.

Moving window concept have been selected for the core step of control points matching. *Least Square Technique* (LST) [1] has been chosen as an alternative to the ususal correlation. The correlation technique provides quite good reliability, but its accuracy in sub-pixel estimation is limited. Also its application is disputable in a case of images with quite different radiometric characteristics. LST is able to provide very high accuracy and can be applied to images with different spectral characteristics. The drawback of the LST is that even for image shifts estimation it requires the solution of non-linear system of equations, iterative approach for its solution and thus intensive computations.

The proposed approach splits the process of LST estimation into two stages, providing pixel and sub-pixel accuracy correspondingly. At the first stage, assuming the linear dependence between brightness of pixels of the base and registered image, we estimate coefficients of this linear equation inside a fixed size window moving pixel by pixel and find the best position. This stage gives the reliable estimation with accuracy of one pixel. The second stage involves the sub-pixel adjustment around the estimated at the previous stage location. At this stage, instead of iterative process we use four approaches from different starting points. This leads to reliable and quite accurate estimation of the true CP position in fixed time.

The estimation of shifts between different channels of multi-channel sensors was carried out as a test of the proposed technique [6]. Inter-channel shift values in images, received from the Landsat-TM instrument were estimated with the accuracy of about 0.02 pixel. The mean error at a separate CP was 0.1 pixel, proving very high accuracy of the proposed sub-pixel LST adjustment technique.

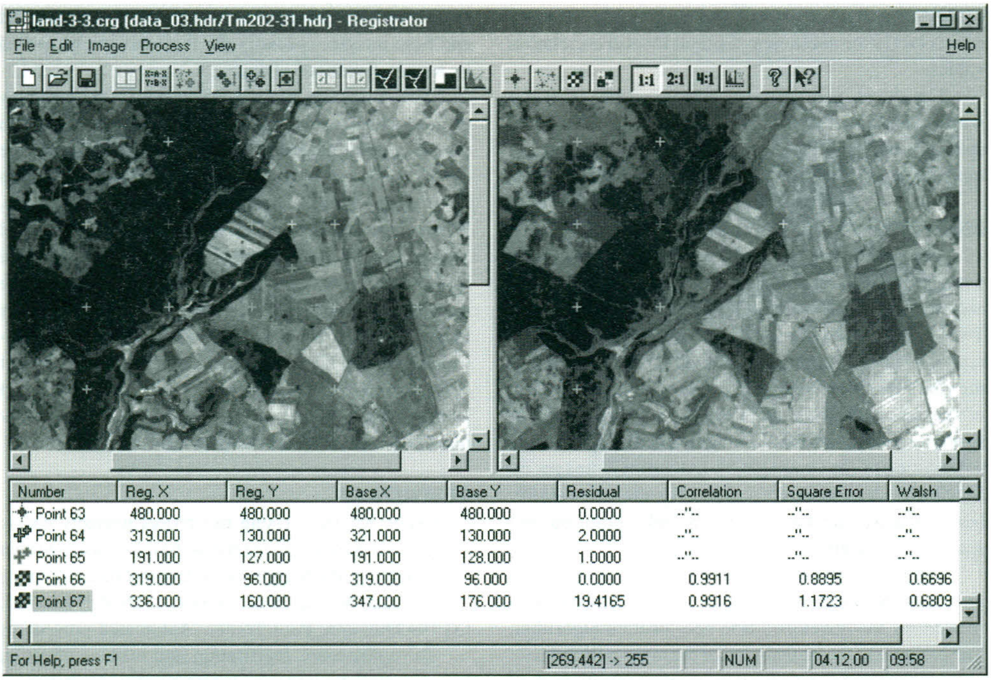

Figure 1. Main working screen of the "Registrator" program.

Different control point verification techniques have been studied. The combined iterative straightening verification algorithm by residual errors and fragments similarity measure have been proposed. The correlation coefficient was used for the measurement of fragments similarity by Walsh transformation analysis of their texture. Only medium frequency coefficients of the Walsh transformation were used to characterize the fragment texture. Such approach leads to reliable exclusion of the wrong matched CP.

The regression to the selection of additional control points may be needed after the verification step to provide quite homogeneous coverage of the image by control points and provide better overall accuracy.

SOFTWARE

The described image co-registration technology have been implemented in a specialized software developed in a framework of FUEGO/FFEW project. The "Registrator" program was designed as multi-purpose image co-registration tool. It is aimed on co-registration of two images on the base of the control points and the moving window main concepts.

The program can operate in one of three modes of *manual*, *semi-automated* and *automatic* co-registration. The manual co-registration mode allows traditional manual selection and adjustment of control points. In this mode the operator is armed by some useful tools that help to provide accurate co-registration easily and quickly. Semi-automated mode assumes providing of all co-registration process steps automatically with manual adjustment of some parameters. The common automatic co-registration algorithm is implemented in the fully automatic operation mode, where processing steps are carried out automatically according to the pre-selected sequence and parameters.

The comfortable representation of information by the user-friendly interface makes it possible to analyze results of any processing step and so adjust if necessary algorithm parameters for better performance. Main working screen of the "Registrator" program is shown at Fig. 1. Three main program windows contain the registered image (left), base image (right) and CP list (bottom). All control points are shown in images windows by crosses. Window of control points table contains at every line description of one control point:

cordinates at both registered and base image, residual error, correlation coefficient, LSE and Walsh correlation values.

The developed software is compatible with the widely distributed ENVI commercial image processing software package by the images and control points representation formats.

EXPERIMENT

The final test on images co-registration was carried out to prove the acceptability of the proposed algorithm and developed software for the FUEGO/FFEW project. Two SPOT-XS images of the same "Castilla y Leon" region obtained at time interval of about 2 months in the year 2000 have been used for the test. First channels of the selected SPOT-XS images have been used to simulate FUEGO/FFEW images. Such approach of substitution of the simulated FUEGO/FFEW images by SPOT-XS channel is not critical for the test validity because quite similar images ground resolution and spectral characteristics.

Manual rough co-registration was used to simulate results of the preliminary geo-location processing step needed for the developed fine geo-location algorithm. The preliminary co-registration of the registered and base images have been carried out by manual selection of 10 control points homogeneously distributed over the images with low accuracy (the mean error value of 2 pixels).

The developed images co-registration algorithm have been carried out by means of the "Registrator" software in the automatic mode with the pre-selected parameters. Totally 151 control points have been selected by the Moravec interest operator after the Laplacian edge enhancement pre-processing. Control points matching have been performed by Correlation. Discrimination by the Walsh correlation and subsequent two-step strighting discrimination by residual error have been used for control points verification. After the sub-pixel LST control points adjustment the residual error of the remaining 76 control points had the mean value of 0.995 pixels. The obtained spatial distribution of control points was far from homogeneous.

Additional control points selection have been performed over free of control points image areas by Moravec interest operator without image pre-processing. Matching of these control points by LST and similar to previous verification led to the resulting set of 160 control points with the mean value of residual errors equal to 0.975 pixels.

It is necessary to note that the used linear transformation function is not able to accurately describe all mutual geometrical deformations of the registered and base images, specially the local deviations caused by terrain elevations change.

The following indirect approach to the accuracy estimation has been used. Registered image have been transformed to geometrically fit the base image by the ENVI package feature of geometrical correction according to the obtained control points set. Triangulation mode have been used because the assumed high reliability and accuracy of control points. Visual inspection have proved the high accuracy of the transformed image relative to the base image. In order to numerically estimate the overall accuracy of the control points matching and transformation process 30 test control points have been manually selected and matched at transformed and base images. The mean residual error indicated was 0.3 pixel (RMS=0.56).

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