QUALITY CONTROL AND REFINEMENT OF THE COREGISTRATION OF MULTIRESOLUTION REFLECTANCE AND LAND COVER DATA

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ABSTRACT

The quality of the rectification of a satellite image to a map coordinate system, or a reference data, is usually defined by the residuals and the RMSE of a transformation using a limited number of control points. A RMSE of 1 to 2 pixels is often regarded satisfactory.

The RMSE of a global transformation can hide periodic errors or shifts, which can be visualised or checked only by a large number of control points. For instance the periodic shifts resulting from nearest neighbour sampling are not detected from the RMSE of a global transformation with a limited number of control points.

If the reference data is available in digital form, the geometrical consistency between the datasets can be checked by local cross correlation matching over the image area. The visualization of the local shifts extracted from the correlation coefficient surfaces emphasize existing periodic or other systematic shifts between the datasets. It can also act as a quality certificate with the diagram of the size distribution of the shifts.

Results from cross correlation matching for geometrical quality analysis are presented. Although the datasets to be compared are often reflectance or radiance data, and land cover data or other thematic data on the other side, the classification, or the derivation of a common layer enables the cross correlation matching between them.

1 INTRODUCTION

The rectification of satellite images to a map coordinate system is based on orbit information, ground control points and, when necessary, to the DTM. The quality of the geocoding, or the positional accuracy of the rectified image, is usually quantified by the residuals and the RMSE of the transformation using a limited number of control points.

In optimal cases, the RMSE is from 0.5 to 2.0 pixels with Landsat TM (pixel of 30 m) or SPOT (10-20 m) imagery. This accuracy is usually regarded satisfactory. When the rectified satellite image is compared to data from other sources, the effect of the geometrical differences is minimized by using only pure pixels apart from the boundaries of different land covers.

In some cases, the homogeneous areas are not the relevant ones, and a more accurate coregistration is needed. The mixed pixel analysis, change detection analysis, and the analysis of textured regions do profit of a more accurate registration. The geometrical correspondence between two datasets has been improved by the transect method, like in Van Kootwijk et all (1995) and Bajjouk et all (1998), where the location of a ground transect in the image is optimized by the regression technique. Torlegård (1986) reached the accuracy of 0.3 pixel in image matching by digital image correlation. This accuracy can be improved to 0.1 pixel for ground control points, if the other dataset can be resampled for each correlation surface by the point spread function (PSF) of the imaging device, like in Cracknell (1998).

However, the RMSE of a global transformation can hide periodic errors or shifts, which can be visualized or checked only by a large number of control points. For instance the periodic shifts resulting from nearest neighbour sampling are not detected from the RMSE of a global transformation with a limited number of control points.

The local positional shifts between two datasets can be calculated by cross correlation matching, and checked for periodic or other systematic differences. In the following examples, the cross correlation coefficient is used to derive the local positional shifts between radiance or reflectance images and thematic layers. In the case of periodic or other systematic differences, their elimination is justified, while the correction of random shifts do need for instance a more accurate DTM.

2 VISUALISATION OF MISREGISTRATIONS BETWEEN DATASETS

2.1 Modeling of the geometry of the satellite image

Figure 1 shows the residuals of the transformation between control points from a Landsat TM image and the national base map 1: 20000. The large number of control points results from the automatic control point measurement method presented by Holm et all (1995). The method uses feature based matching of lakes and islands extracted from the digital base map and the satellite image.

A first order polynomial transformation was used to detect periodic or other systematic errors. The RMSE of the transformation was 20 m (0.7 pixels). The maximum residual was 34 m (1.1 pixels) The residuals show rotation between the northern and southern part of the image. The location and direction of the residuals imply a line of inflexion between the geometry of the satellite image and the reference map, and the need of a separate transformation of the two parts of the image.

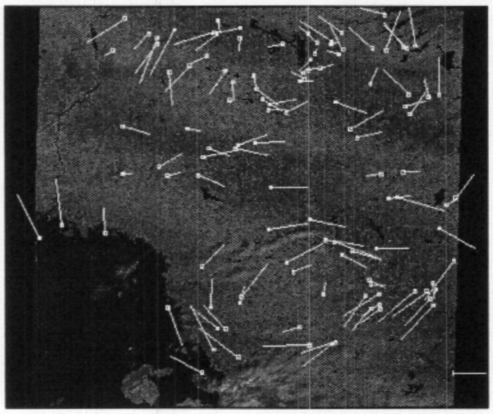

Figure 1. Residuals of control points between Landsat TM image and national base map.

2.2 The nearest neighbour artefact

Nearest neighbour rectification implies that any pixel may be in error by up to +- 0.5 pixel in E-W and N-S directions. These errors have a uniform distribution with mean =0 and are in principle independent in the two directions. Adamson et all (1988) conclude that when images are rectified by means of nearest neighbour approximation, there is an irreducible minimum relative (slot-to-slot) RMS error of almost 0.6 pixel. The existence of doubled lines and columns in the satellite image (Figure 2 imply the use of nearest neighbour sampling in the system processing phase, and occur when the image is resampled to a smaller pixel size than the original pixel size.

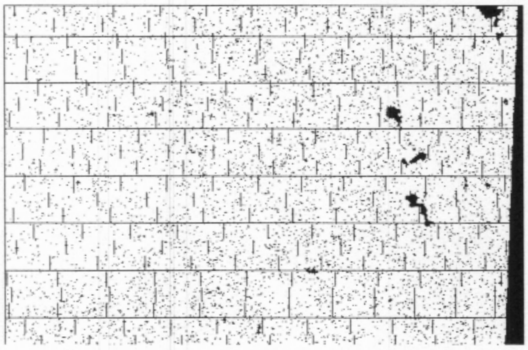

Figure 2. The location of doubled lines (horizontal lines) and doubled columns (vertical segments) from nearest neighbour sampling.

In the EC shared cost FLIERS project methodology was developed for the estimation of land cover proportions or class memberships of Landsat TM satellite image pixels using higher resolution (0.3x0.3 m2) land cover map as reference and training data. Figure 3 shows the local shifts, ranging from -0.5 pixel to +0.5 pixel (15 m), from the image correlation between the nearest neighbour sampled and cubic convolution sampled Landsat TM image. Local misregistrations of the training areas affect the performance of the class membership classification, especially in a high textured urban test area, where most of the pixels are mixed pixels.

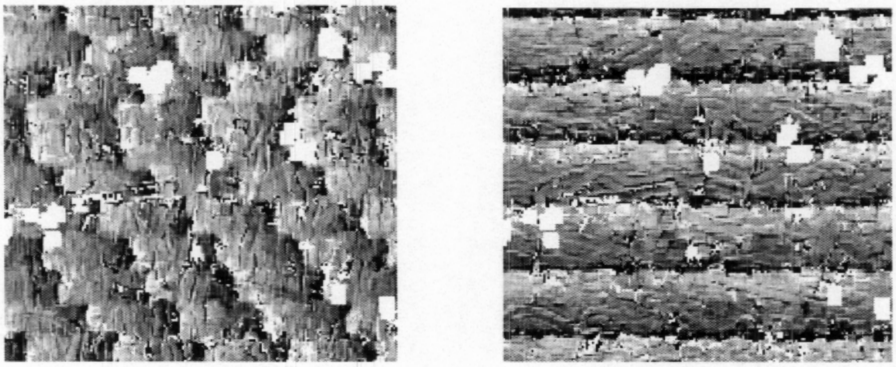

Figure 3. Positional shifts between nearest neighbour sampled and cubic convolution sampled imagery in west-east (left) and north-south (right) directions .

To reduce the uncertainty in the classification training, the geometry of the TM image was analysed by cross correlation matching on a pixel by pixel basis with the reference data, to extract the local shifts between the two images. In this case, the other dataset was radiance data and the other dataset was classified land cover data, so that the spatial correlation could not be calculated directly between them. However, by integrating the vegetation related classes from the high resolution reference data to a vegetation map, and by deriving the NDVI image from TM channels 3 and 4 to represent the vegetation layer from TM data, the cross correlation matching did succeed.

In the correlation matching between the vegetation map and the NDVI image, image chips of 5 x 10 pixels (150 m x 300 m) were used. Longitudinal chip windows were used to minimize the effect of the doubled lines to the correlation results: longitudinal in x-direction for y-shifts and longitudinal in y-direction for x-shifts. Hence the doubled lines should have minimum effect to the shift values, because at the doubled lines, the shift changes abruptly from -0.5 to +0.5, and do disturb the correlation more than in the smoother shift change areas.

The validity of the correlation results was checked by comparing the resulting shift images to simulated shift images, that represent the theoretical local shifts resulting from nearest neighbour resampling. The shifts were simulated from the nearest neighbour behaviour, using the location of doubled lines and columns to derive the shifts. The simulated shifts are based on the principle, that the shift range from -0.5 to +0.5 when traversing from one doubled line, or column, to the second doubled line, or column. The shifts were interpolated linearly for the pixels between the doubled lines.

The simulated shifts, which corresponded to the periodic components of the shifts from the cross correlation matching, could then be used to locate the footprint of the TM pixels in the original higher resolution reference data. New membership values were integrated for the TM pixels, by using the PSF of the Landsat TM scanner presented in Markham (1985).

2.3 Comparison of a high resolution digital image mosaic and orthophotos

The aerial digital image mosaic used in the study was produced by EnsoMOSAIC imaging and image processing system presented in Holm et all (1999). The mosaic is composed of 494 digital camera pictures of the resolution of 1528 (H) x 1146 (V) pixels taken in the year 1998. The ground resolution of the images is about 0.6 metres. The image overlap along the strip was 10 per cent and between the strips about 50 per cent. The mosaic covered an area of 10,000 hectares in the south-east Finland. The georeferencing of the mosaic was derived from the Real-time Differential Global Positioning System (RDGPS) to which the exposures had been synchronised. The coordinates of these locations have been entered to the photogrammetric bundle adjustment to get the orientation parameters of the individual images for mosaic resampling. The greatest residual error of the observations derived from the least squares adjustment was 2.8 metres and the standard error of the unit weight was 0.85 metres, both in the ground scale. The mosaic was corrected for the terrain elevation differences using the digital terrain model provided by the National Land Survey. The final mosaic was resampled to the pixel size of one metre to the national map projection.

The geometric accuracy of the mosaic was studied by comparing it digital orthorectified photographs provided by the National Land Survey. This digital data were produced from two black and white aerial photographs exposed to the scale of 1:60,000 in the year 1993. The photographs have been digitised to the pixel size of one metre on the ground.

The geometrical coincidence between the ortho-images and the aerial image mosaic was checked by cross correlation matching. The resulting positional shifts and their distributions can be seen in Figure 2 and Figure 3. The greyvalue scale represents shifts from 0 meters (white) to +-10 meters or more (black, including also areas where cross correlation has failed). A considerable amount of the shifts are in the class of less than ten metres. However, Figure 2 shows a constant shift of 3 meters in the area of the left ortho-photo, which indicate an erroneous origo coordinate in the orthophoto.

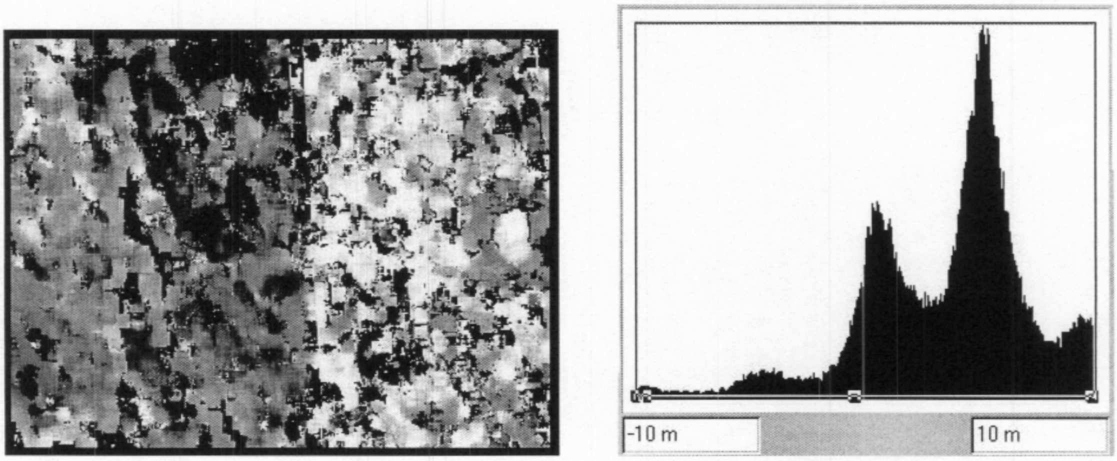

Figure 2. Left: the positional shifts in east-west-direction between the digital camera mosaic image and the orthophoto. Right: the distribution of the shifts in east-west direction.

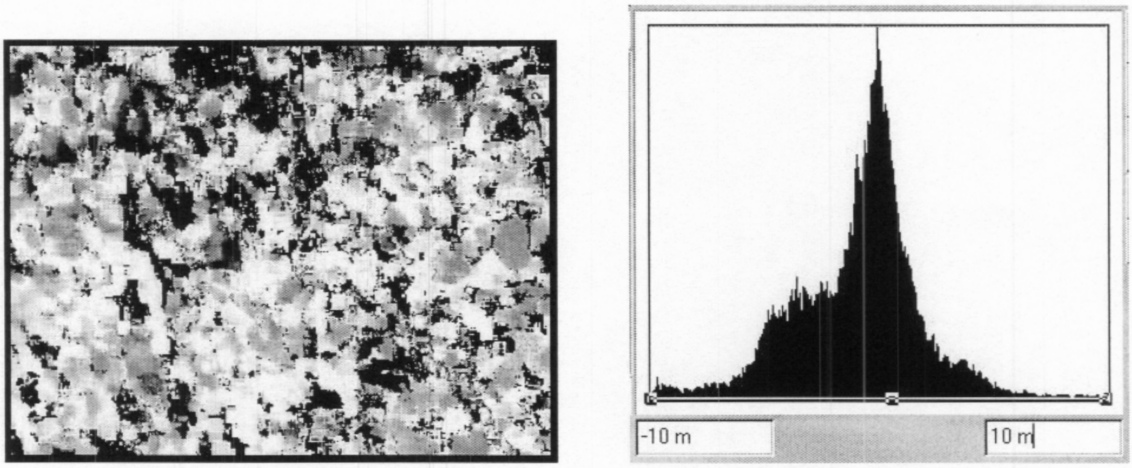

Figure 3. Left: the positional shifts in north-south-direction between the digital camera mosaic image and the orthophoto. Right: the distribution of the shifts in north-south direction.

3 CONCLUSIONS

Although the RMSE of a global transformation of a satellite image into a reference data shows good positional accuracy, there may exist periodic misregistrations between the image and the reference data. These can be checked and revealed by local cross correlation matching of the images.

Often the reference data is land cover data or other thematic data. The cross correlation can succeed between them, if common physical layers are first extracted from the two datasets. Water areas are extracted reliably from satellite images and can be matched with the water element of the base map. NDVI images calculated from Landsat TM images can be matched with the synthesis image of vegetation classes from land cover data.

The image of the local shifts resulting from cross correlation matching, and the diagram of their size distribution can be used as a quality certificate of a rectified satellite image.

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