AN AUTOMATIC CONTOUR BASED DETECTION OF TERRESTRIAL OBJECTS FROM AERIAL IMAGERY DATA

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ABSTRACT:

The original approach to image matching is proposed. The method itself can be classified as contour matching, based on boundary pattern analysis technique. Contours extraction technique is reinforced by combined information from independent contours and boundaries of segmented regions. In this process some general assumptions and simple rules are effectively used. Boundaries of the regions under investigation are extracted from digital images. Then 1-D representation of contours is constructed for further analysis. Features of 1-D representation are used for contour matching. For robust extraction of contour features the special procedure, based on dynamic resampling is used. In order to avoid ambiguities the dynamic programming technique for curves matching was elaborated. All calculation procedures are invariant to images rotation. Finally, the developed approach is applied to the problem of automatic image registration for aerial images.

1. INTRODUCTION

Image matching or image fragment localization is the actual and important problems, aroused in many different applications of machine vision. Ecological monitoring, forestry, monitoring of urban areas, automatic search of remote sensing data in vast geospatial databases - to mention just a few applications leading to the problem of image matching as a problem of patch identification inside large images. At the same time, the situations when accurate information on scale an orientation of images is not available and distortions are not known a priory are not uncommon. The authors, based on various ideas, proposed many approaches to such matching problem but up to present day, this problem is far from final decision. On the other hand, the task under consideration should be of interest for wide range of specialists.

In general, image can be represented as a set of spatially distributed features. Each feature is described by set of digital parameters to be unique. In all feature based methods (FBM) matching is done on extracted features as points, edges, or regions (Zitova, B., Flusser, J., 2003). In contrast to the area-based methods, the feature-based matching works with image information of higher level. This property makes feature-based methods suitable for situations when illumination conditions or image geometry changes are expected.

Feature based matching procedures consist of three steps:

- extracting distinct features (points, edges or regions) in the images separately,
- building up a preliminary list of candidate pairs of corresponding features based on a chosen similarity measure,
- deriving a final list of feature pairs satisfying the set of criteria.
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Considerable efforts was done by the investigators in this branch, many interesting results was obtained (Heipke, C., 1996, Woozug, C., 1996), each optimal to use in its specific domain. Here we try to develop some special type of contour based matching invariant to image rotation and some distortions. This method was elaborated mainly for automatic monitoring of large areas from aerial images. The characteristic property of the method under investigation is that dynamic programming (DP) technique is used for proper curves matching. All intermediate steps of the method are illustrated on two pairs of images, one demonstrating natural objects and one demonstrating artificial objects.

2. FEATURES EXTRACTION

2.1 Outline of the Registration Method

Among the features used for matching edges (or contours) are of special interest mainly because of two reasons: contours are highly stable with respect to various kinds of geometric distortions and they are natural visible features for most type of objects in images. In view of difficulties arising in extraction of contours from real images, the authors tried to develop approach, combining primary information from both types of features, edges and regions.

The *line features* can be the representations of object contours, coastal lines, rivers and roads in aerial imagery. Standard edge detection methods, like Canny detector and detector based on the Laplacian of Gaussian (Nadernejad, E., Sharifzadeh, S., Hassanpour, H., 2008) are employed for the line feature detection. However, these techniques usually do not give contours of required quality for real images because of presence of discontinuities and considerable dependence on illumination conditions.

The *region features* can be the projections of general high contrast closed-boundary regions of an appropriate size, ponds and lakes, buildings, forests, car parks or shadows. The general criterion of closed boundary regions is prevalent. The regions are often represented by their centers of gravity, which are invariant with respect to rotation, scaling, and skewing and stable under random noise and gray level variation. Region features are detected by means of segmentation methods (Pal, N., Pal, S., 1993). The accuracy of the segmentation can significantly influence the resulting registration. The researchers took much efforts to develop segmentation technique robust to various changes in shooting conditions (Zitova, B., Flusser, J., 2003).

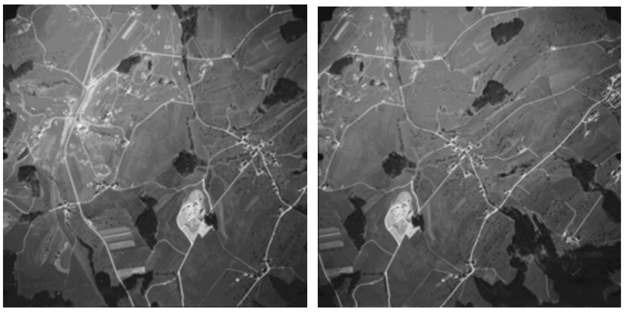

Figure 1. Rural area

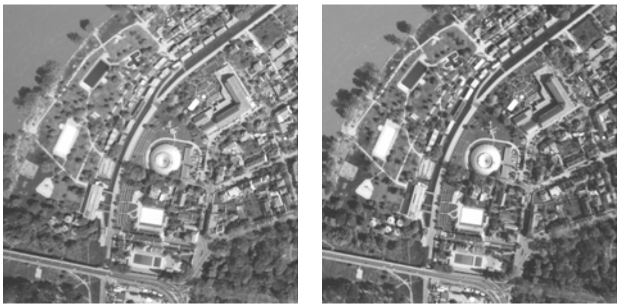

Figure 2. Urban area

Combining merits from two groups of algorithms, developed for lines and regions separately one can try to construct the improved technique for extracting contours of desired quality. In this paper two control pairs of images are used (see Figure 1, Figure 2) to demonstrate the main steps and the results of the samples recognition technique.

2.2 Extraction of contours

For edges extraction Sobel filter and Canny detector was used as basic technique. Then morphological algorithms was followed for pruning the tales from contour lines. The results of independent contour extraction are shown in the Figures 3 and 4. This technique produced a large number of edges, but the result is still too noisy and spotty.

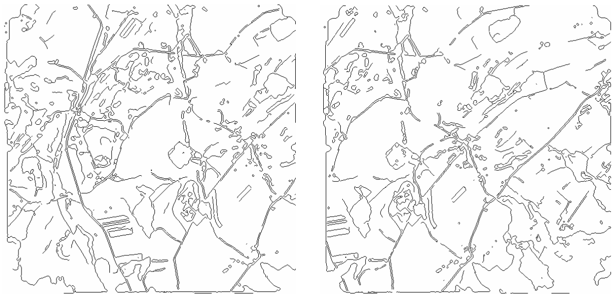

Figure 3. Rural area, edges

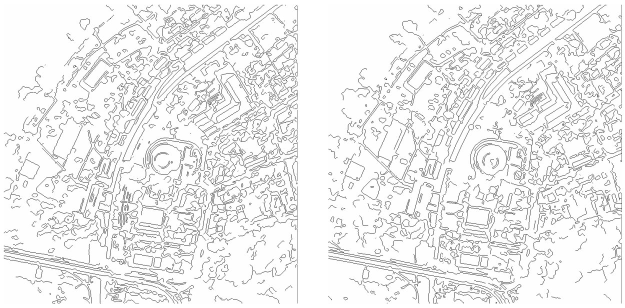

Figure 4. Urban area, edges

2.3 Image segmentation

Image segmentation was performed by watershed algorithm, which is known to produce many small areas at the preliminary stage (Shafarenko, L., Petrov, M., Kittler, J., 1997). Then closest areas joined according to some criteria. For images under consideration, fusion was performed according to mean gradient difference along the borders. Second rule for fusion was characteristic object size, which amounts 200 pixels for images under consideration. Pre-processing of images with truncated median filter produces the resulted segmentation of better quality.

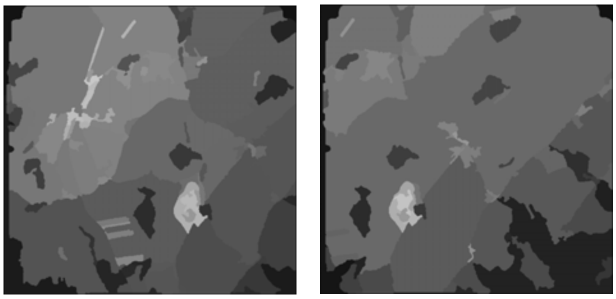

Figure 5. Rural area, regions

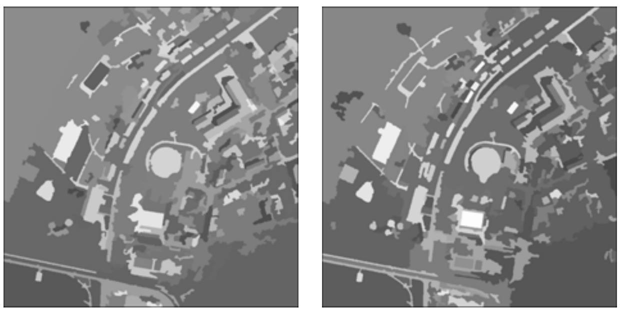

Figure 6. Urban area, regions

The results of image segmentation are shown in the Figures 5 and 6. Although the areas obtained are very close to the outlines of real objects in the source scene we sure, these results could be still more distinct. One of the disadvantages of watershed algorithm is that it finds region border biased due to morphological dilatation used for regions growing.

2.4 Contours versus regions

Next step is contours refinement with taking into consideration aggregated data from both areas with their borders and independent contours. For further images processing let us use three additional rules:

- delete all closed contours which are fully contained inside some region,
- merge all regions inside closed contours into one region,
- make more accurate borders of regions, taking the nearest independent contours as precise position of the border.

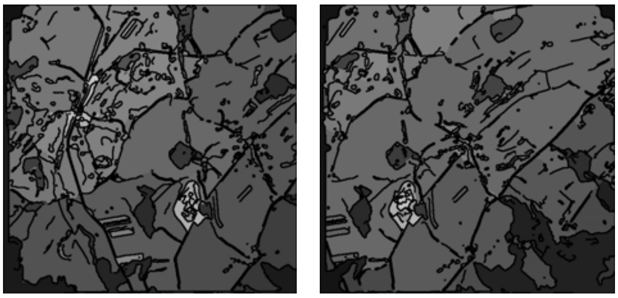

Figure 7. Rural area, contours versus regions

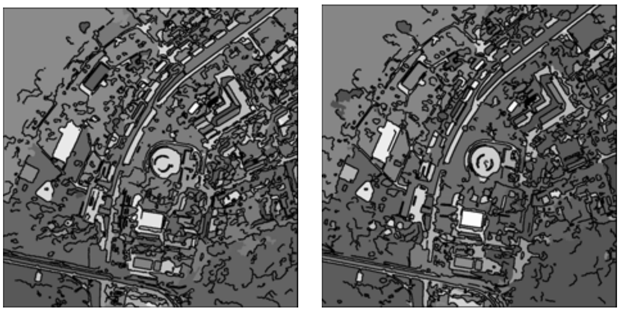

Figure 8. Urban area, contours versus regions

From successive implementing of these rules the final set of contours showing in the Figures 7 and 8 (together with regions), and in the Figures 9 and 10 (together with source images) arises.

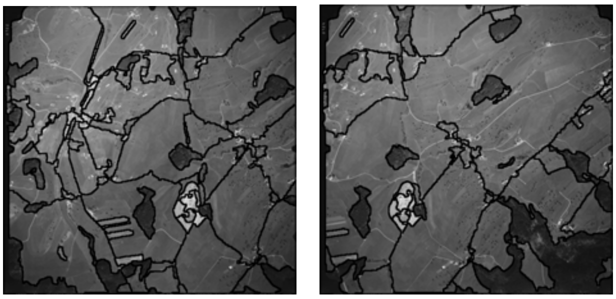

Figure 9. Rural area, borders versus source image

Analysis of Figures 7-10 shows that implementing of combined technique for every image from the presented ones gives a distinct set of closed contours, near to what we could expect from human operator. Now one should try to match the appropriate pairs of contours.

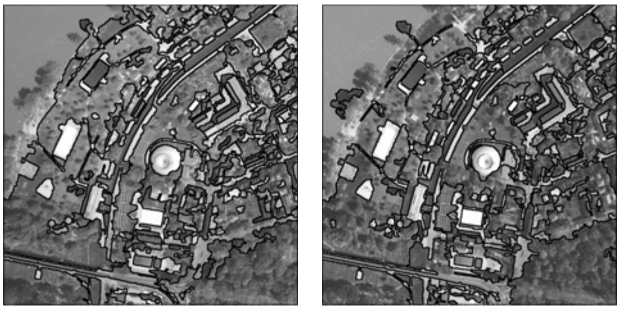

Figure 10. Urban area, borders versus source image

3. CONTOURS MATCHING

3.1 Contour presentation

As a result of extraction and refinement procedures in previous section a set of contours in the form of simple chain codes for every image was obtained. In further investigation, the means of contours presentation plays an important role for success of their digital comparison by any way. We have chosen for this purpose rational splines (Zavjalov, Y., Kvasov, B., Miroshnichenko, B., 1980), which shows very good behaviour in situations when shape of curve is not known a priori. A preliminary step in spline approximation is to find any valuable set of nodes by means of some regular procedure. A simple and natural way to obtain the set of nodes required is to build up a piecewise linear approximation for chain code. A widely known algorithm described in Prett, W., 1978 was used for this purpose. A set of polygon vertices obtained is taken as a set of spline nodes.

On the basis of rational spline one then build up 1-D curve representation, curvature versus arc length (Davis E.R., 2005, Schenk, T., 1999). The form of curvature function for 2 contours from 2 images are presented in Figures 11-14. The initial point of every curve is arbitrary and proper length shift is estimated during feature matching.

Figure 11. Curve representation A1

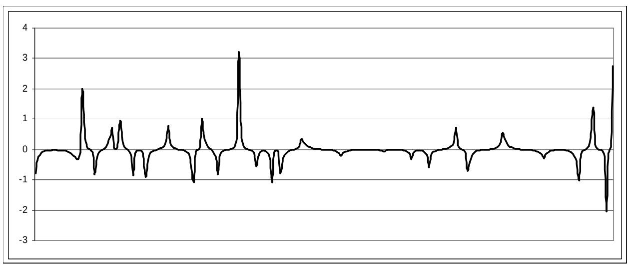

Figure 12. Curve representation B2

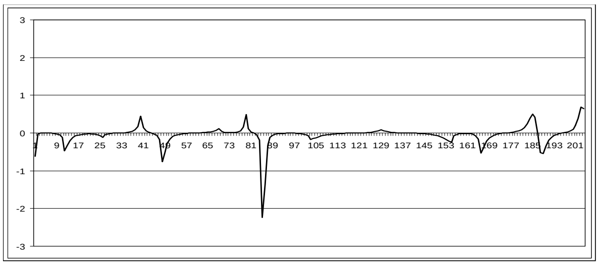

Figure 13. Curve representation A2

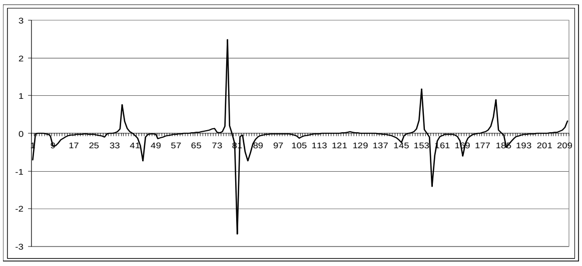

Figure 14. Curve representation B2

Next step in contours identification is to construct matching procedure for contours, presented in the form "curvature versus arc length".

3.2 Matching with dynamic programming

The contours under investigation should be prepared for matching procedure beforehand (Ohta, Y., Kanade, T., 1985). In 1-D contour representation one finds all local extrema with absolute value more than threshold T, Figure 15. All these points present the most distinguished ones of function and hence they are taken further as features for matching.

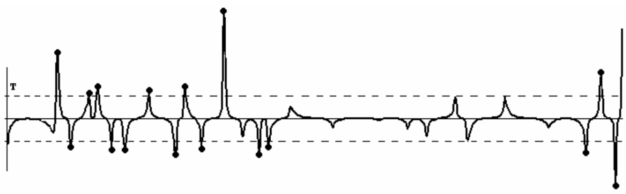

Figure 15

For each pair of contours A and B from first and second images respectively one should calculate the DP matrix and find optimal way minimizing the cost function. Dimensions of matrix depend on the numbers of extrema in two contours. Extrema of contour A define the number of columns M while extrema of contour B define the number of rows N in DP matrix.

The cost D(A,B) of matching of contour A with contour B is defined as:

$$D(A,B) = \max(C(m,n)),$$

where $C(m,n)$, the cost of partial path from first point to node (m,n) is given by

$$C(m,n) = \max_{i,j}\{c[(m,n),(i,j)] + C(i,j)\},$$

where $1 \le i \le m$, $1 \le j \le n$, $i + j < m + n$ and $c[(m,n),(i,j)]$ is the cost of primitive path between nodes (m,n) and (i,j):

$$c[(m,n),(i,j)] = \frac{\alpha(m,n)\cdot K(m,n)}{\max\{length\_of\_A, length\_of\_B\}},$$

where

$$\alpha(m,n) = \frac{\min\{|Pos_A(m) - Pos_A(m-1)|, |Pos_B(n) - Pos_B(n-1)|\}}{\max\{|Pos_A(m) - Pos_A(m-1)|, |Pos_B(n) - Pos_B(n-1)|\}},$$

$Pos_A(m)$ is the position of m-th extremum in the curvature function of contour A;
$Pos_B(n)$ is the position of n-th extremum in the curvature function of contour B;
$K(m,n)$ is the normalized cross-correlation value between local neighbourhood of m-th extremum in the curvature function of contour A and local neighbourhood of n-th extremum in the curvature function of contour B.

The performance of DP-algorithm in finding the optimal matching solution for two contours, presented by their curvature functions, is shown in Figure 16, the typical size of DP matrix is of the order 20. The optimal way is underlined by bold line.

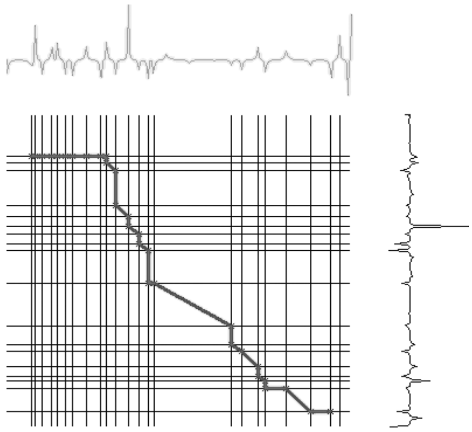

Figure 16

As a result, DP algorithm has found 9 matched contours for rural images and 7 for urban ones, shown in the Figures 17 and 18 respectively together with source images. Therefore, we can identify these pairs of images with high degree of confidence as images of the same 3D site.

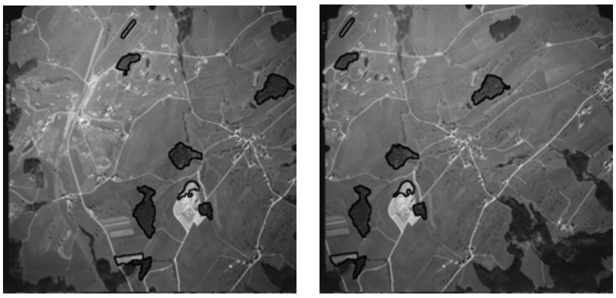

Figure 17

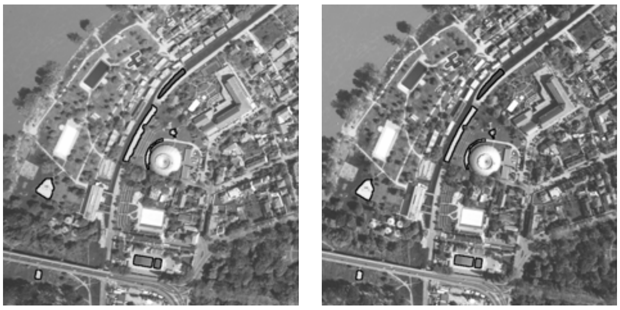

Figure 18

4. CONCLUSION

In the presented paper, the original approach to image matching under unknown geometrical and photometrical distortions is proposed. For robust matching procedure, both contours and significant regions are taken into consideration. A set of rules for effective selection of most valuable data from contours and regions results in stable and distinct set of final features. Feature matching is based on dynamic programming technique which enables to find the best correspondence of type many-to-many. The algorithms proposed have shown effective performance on aerial imagery of various content even in case of considerable rotation and scaling. Authors plan to extend the results of this work for cases with more complicated distortions types.

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