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GEOMETRIC CHARACTERISTICS OF IRAQ'S RASTER TOPOGRAPHIC MAPS USED FOR AUTOMATIC UPDATING THE ROAD NETWORK

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Summary

This paper is devoted to the problem of road network extraction from raster image. The task of road network extraction is formulated in common view. The approach to the road map extraction has been proposed which can be applied for topographic map updating and is based on image clustering by k-means method and on application of scanning algorithm for extraction of road network fragments. Road map description is formed as set of linear fragments with knowing parameters. These linear fragments are created by merging of smaller parts. Experimental researches were implemented for maps of 10 Iraq cities. Experimental results show in average the extraction precision of 86% (in comparison with human expert).

Keywords

maps update • road networks segmentation • topographic raster map • tracking algorithms • scanning algorithms • methods of image binarization • k-means method

1. Introduction

Extraction of road networks from raster images is one of several stages of topographic map updating. Topographic map updating is actual problem for many terrains due a continuous change in the area infrastructure. Today because of digitizing of existing topographic maps and availability of satellite images there is a need for automatic maps updating.

Digital topographic maps can be represented in vector or raster view. For these two cases the solutions of the problem are different.

In case of raster topographic maps it is necessarily to distinguish the objects of terrain. Traditionally at first place the features (e.g. line segments) are distinguished, then typical objects (e.g. road network, vegetation area, building sites) are recognized.

In this paper author describes an extraction of road network elements on the raster topographic maps.

2. Related work

There is no unified method for automatic road network extraction from raster images. All researches consider local image features and have moderate success in automatic road extraction from high-resolution multispectral images.

Several methods of road network extraction are described in literature. In most of researches the segmentation of original image is a first step of the process. A. Grote [2011] uses aerial images of Grangemouth (Scotland) and Vaihingen (Germany). For image segmentation author uses normalized cuts algorithm. Road fragments are extracted from segmented images and then are merged for road network forming. Anil and Natarajan [2010] proposed statistical area merging for image segmentation. Road network is extracted as a skeleton by pruning method based on contour partitioning, where the partitions are obtained by Discrete Curve Evolution. In Dal Poz et al. [2010] road extraction method based on dynamic programming in object space (instead image space) is proposed. Moreover, some methods are discussed in Grote [2011], Qiaoping Zhang [2006], Ziems et al. [2012], Ziems et al. [2010]. An interested approach is presented in Callier and Saito [2011]. There are many researches dealing with road extraction from aerial and satellite images, e.g. Beyen et al. [2012]. Road extraction from raster maps is described in Chiang Yao-Yi and Knoblock [2009, 2010]. All approaches have one common feature – semi-automatic image segmentation. It means that initial points for road extraction are selected by human operator.

Based on the published results analysis we can say that methods and tools from different science fields should be used in order to solve the problem of road network extraction. These fields are digital image processing (in particular, filtration, segmentation or clustering methods), pattern recognition theory, linear algebra, mathematical statistics. For points classification (i.e., road points separating from other points), the statistical methods, methods of cluster analysis and methods of the images binarization are used [Gonzalez and Woods 2008, Forsyth and Ponce 2012].

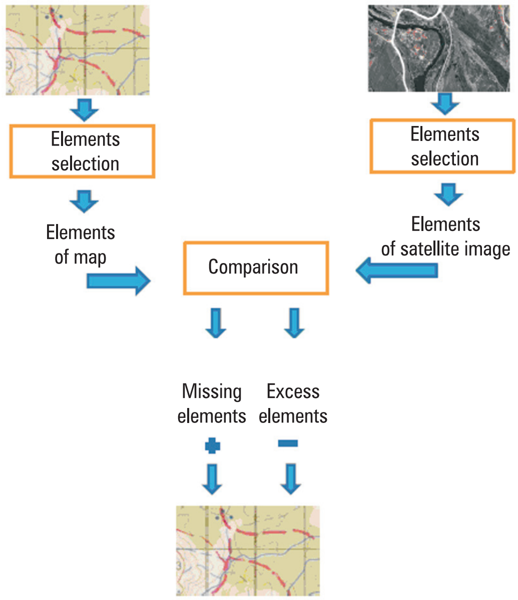
The result of extraction is a set of metrical and attributive data that describe road fragments.

The problem of road extraction is solving after image binarization. There are used two extraction approaches: tracking and scanning. Tracking algorithms assume that one point of object detected whereupon contour is tracked and vectorized [Shapiro and Stockman 2001]. Simplicity is advantage of these algorithms. Disadvantages contain slowness of step-by-step realization and some complexity of internal contour searching and processing. Scanning algorithms are based on entire image scanning and boundary points extraction without tracking of object contours [Forsyth and Ponce 2012, Zheltov and Vizilter 2004, Oneshko et al. 2010].

Scanning algorithm [Zheltov and Vizilter 2004] is based on storage of image band in computer memory and on extraction of cross points and line ends in the process of band moving across the whole image.

Topographic map updating using data of satellite images is performed as follows. There are raster map and raster image, taken later than map was created and the procedures for selection of elements from map and image are known. Problem of map updating using data of satellite images can be solved via finding of two sets of elements. First set contains the elements that are present on image but are absent on map (i.e. new objects that are appear afield after map creating); these elements must be added to the map. Second set contains elements that are present on map but are absent on image (i.e. old objects that are disappear afield after map creating); these elements must be deleted from the map.

So, automatic map updating by satellite image can be described by scheme at Figure 1.



Source: author's study

Fig. 1. Common scheme of map updating using satellite image

In this paper author reviews stage of automatic road extraction from raster maps.

3. Problem of road network elements separation on raster image

Initial data for road network extraction is raster map. Results of extraction are geometrical parameters of road network elements. During road network elements separation initial raster image must be transformed into binary image. As a rule, information about colour of each point in raster images presented as triple R, G, B, corresponding to intensity of red, green and blue colour components. After binarization image should contain the points of two different colours, corresponding to studied elements and background. Further, geometrical structures extraction algorithms may be applied to the binary image.

Raster maps obtained by scanning of old paper sources may contain many colours. As a rule, they are undistinguished for human: often the colours formally described by different values of colour components R, G and B are perceived by human as similar. Considering this fact as well as limited number of colours on topographic maps, the first stage of processing of raster topography map shall be the clustering of the initial image. The aim of clustering is partition of initial colours so that colours included in one cluster will be more similar to each other than colours included in different clusters. Further, image binarization and road network elements extraction are performed.

Set of linear fragments is a result of the extraction. For each of fragment the position (start and end coordinates) and line thickness are known.

In general the process of road network extraction from raster map is shown on Figure 2.

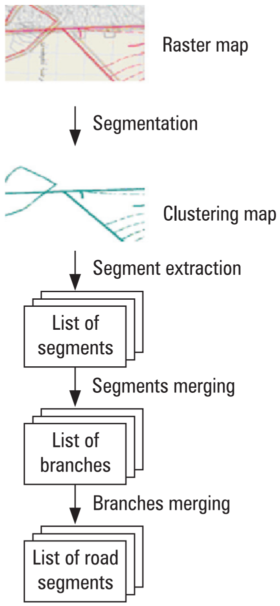


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Fig. 2. Stages of road network extraction

In this paper author uses for clustering method k-means [Zheltov S. and Vizilter 2004], for additional processing – methods mathematical morphology and image filtering [Gonzalez and Woods 2008], for linear segments extraction – scanning algorithm [Forsyth and Ponce 2012]. These operations are outlined below more detail.

4. An algorithm for raster image clustering

The large amount of papers are devoted to the problem of aerial and satellite images segmentation, e.g. Burshtynska et al. [2014], Grote [2011], Anil and Natarajan [2010], Dal Poz et al. [2010]. For clustering the author applied k-means method. K-means clustering aims to separate *m* observations (from space R^n) into *k* clusters. As a result each observation is included into nearest cluster [Shapiro and Stockman 2001]. For colour raster image the algorithm can be described as follows.

Let *Im* be a raster image represented as matrix with *Xmax* columns and *Ymax* rows. Each element of the matrix $Im[i, j]$, $0 <= j < Xmax$, $0 <= i < Ymax$, storages a color value of corresponding map point as triple R, G, B, corresponding to intensity of red, green and blue colour component. Then, assume that K_1 is total number of different triples (R, G, B) in initial image *Im*, and K_2 is number of different colours on topographic map, $K_2 << K_1$.

On the first step it is established the number of clusters K_2. The colours of the initial image are uniformly divided between the clusters. For each cluster average colour value (separate for each colour component) $\overline{R}, \overline{G}, \overline{B}$ is calculated according to the formulas:

$$\overline{R}_i^1 = \frac{1}{n_i}\sum_{j=1}^{n_i} R_j,$$
$$\overline{G}_i^1 = \frac{1}{n_i}\sum_{j=1}^{n_i} G_j, \qquad (1)$$
$$\overline{B}_i^1 = \frac{1}{n_i}\sum_{j=1}^{n_i} B_j,$$

where:

i – cluster number, $i \le K_2$,
n_i – number of points in i^{th} cluster.

On the second step each initial colour shall be included into cluster which centre is the nearest to this colour. Each colour is included only into one cluster even it can be included into two or more clusters. The Euclidean distance is used for the "nearest" measuring:

$$\rho_i = \sqrt{(R_{k,p} - \overline{R}_i^1)^2 + (G_{k,p} - \overline{G}_i^1)^2 + (B_{k,p} - \overline{B}_i^1)^2}, \qquad (2)$$

where:

ρ_i – distance from the centre of the i^{th} cluster,
$R_{k,p}, G_{k,p}, B_{k,p}$ – colour components for point $Im[k,p]$,
$\overline{R}_i^1, \overline{G}_i^1, \overline{B}_i^1$ – average values for i^{th} cluster, calculated within the first stage.

Further the centre of each i^{th} cluster shall be recalculated according to the formulas (1).

The second stage shall be repeated until the centre values will have no longer change:

$$\bar{R}_i^q, \bar{G}_i^q, \bar{B}_i^q = \bar{R}_i^{q+1}, \bar{G}_i^{q+1}, \bar{B}_i^{q+1},$$

where:

q – is the number of stage.

As a result new clustering image are created. In clustering image points colours are the centres of selected clusters.

5. Scanning algorithm for separation of linear road network fragments

Scanning algorithm [Zheltov and Vizilter 2004] is built upon the storage of the band of image pixels in computer memory and detecting of contour points during band moving across the whole image. There are two cases for data processing: situation detecting and situation resolving. Two image rows, current and previous, are kept in band simultaneously. X-coordinates of black series are analyzed in order of coordinates increasing, from left to right. There are revealed five situations and they are processed separately: "origin" (Figure 3a), "extension" (Figure 3b), "branching" (Figure 3c), "merging" (Figure 3d) and "end" (Figure 3e).

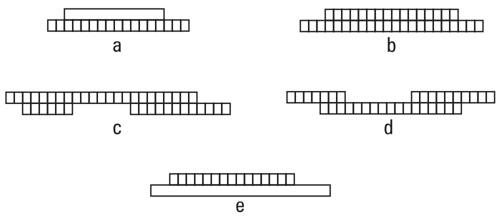

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Fig. 3. Five situations for scanning algorithm

Processed rows are presented as arrays of structures. Each structure contains x-coordinate of black series origin/end and address of buffer. The buffer kept information about one branch which crossed processed row.

Author has modernized the algorithm for the case when road and scanned row has the same direction. The essence of changes is that length of black series is analyzed and if this length is more than maximal width of selected roads then horizontal fragment is created. Width of this fragment is depicted by the analyze of adjacent black rows number.

List of fragments and list of branches are results of fragments separation procedure. Both of lists are array, which elements are depicted selected fragments and branches. For each fragment some features are calculated: *X* and *Y* coordinates of origin and end, line width, number of points, branch number. Each branch is depicted by branch number, count of constituent fragments, numbers of start and end fragments.

The count of separated fragments is sufficiently large at this stage. List may contain short isolated fragments that are not a parts of road network and fragments of the same line. Therefore the list of fragments requires of further processing. The first step of this processing is merging of fragments pair if their end and start points are closely-spaced. Next step is branches merging. Also short isolated fragments are deleted.

6. Experimental results

Author has developed the program for road network extraction from raster topographic maps and satellite images.

For experiments author used map of 10 Iraq cities. Map scale is 1 : 100000 for all studied maps. Scanning resolutions are from 80 to 120 dpi, land areas are from 300 km^2 to 400 km^2. The maps contain main, secondary, highland, and rural roads. Quality of paper maps is quite good.

Clustering was performed by selection of 8 clusters and subsequent rejection of excess clusters. For road painting there was used colour that different from average colour of corresponding cluster (for better visual perception). For points that depicted as "non-road" white colour was used.

As a result two-colour images were obtained, as shown on Figures 4 and 5. Further for such image it can be applied scanning algorithm and parameters of linear road network segments can be calculated.

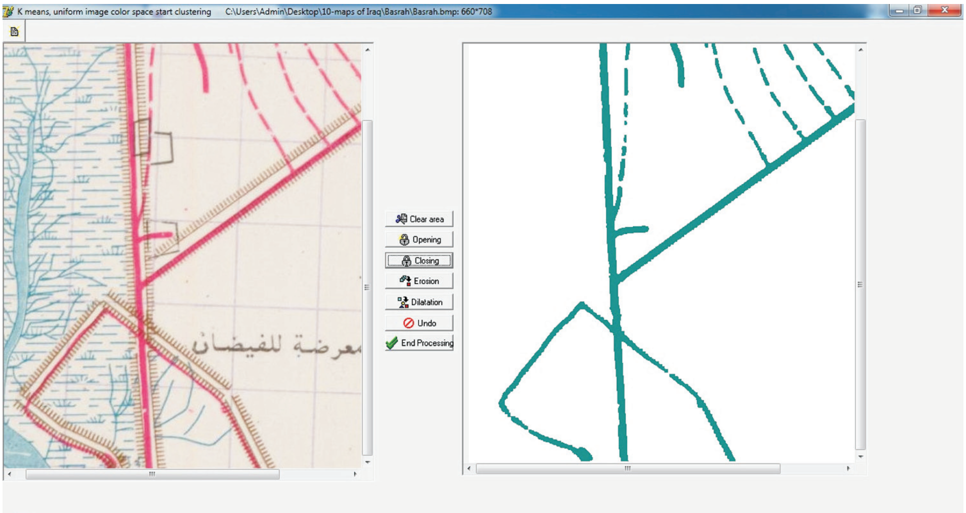

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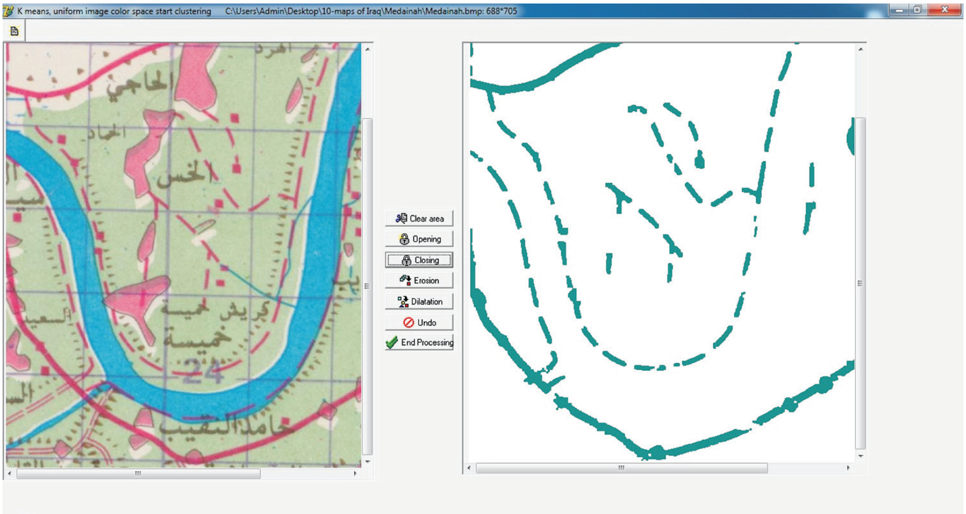
Fig. 4. Result of binarization of Basrah (Iraq) map fragment



Source: author's study

Fig. 5. Result of binarization of Medaynah (Iraq) map fragment

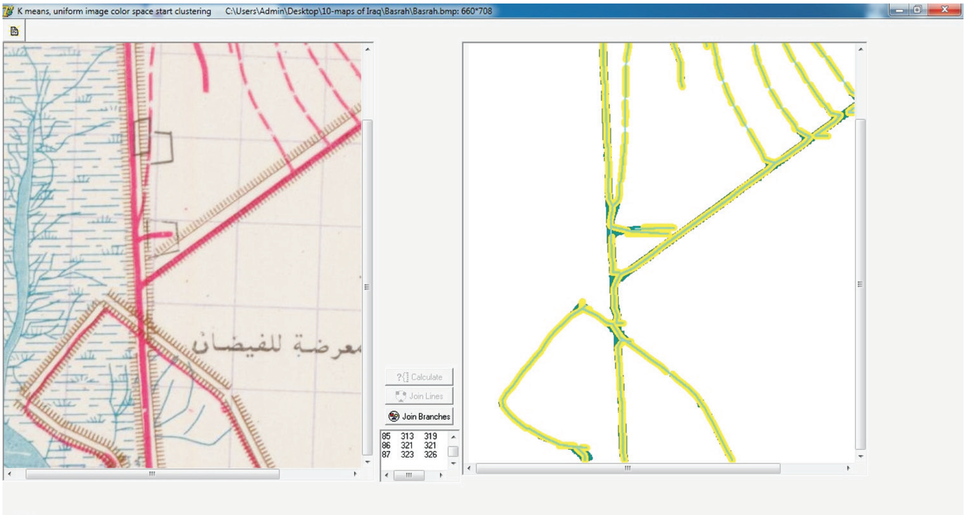
Clustering results show that some road network elements have been not determined. The reason is defects of their plotting. Furthermore, for representation of non-road objects the same colour as for road can be used. As a segmentation result these objects also will be selected. This situation is regular and fairly common. Therefore program must contain tools for manual image correction.

For selection of linear road network fragments author applies modified scanning algorithm that described above.

Results of this stage are displayed as a set of line fragments. Fragment width is taken as average value that calculated in process of scanning algorithm.

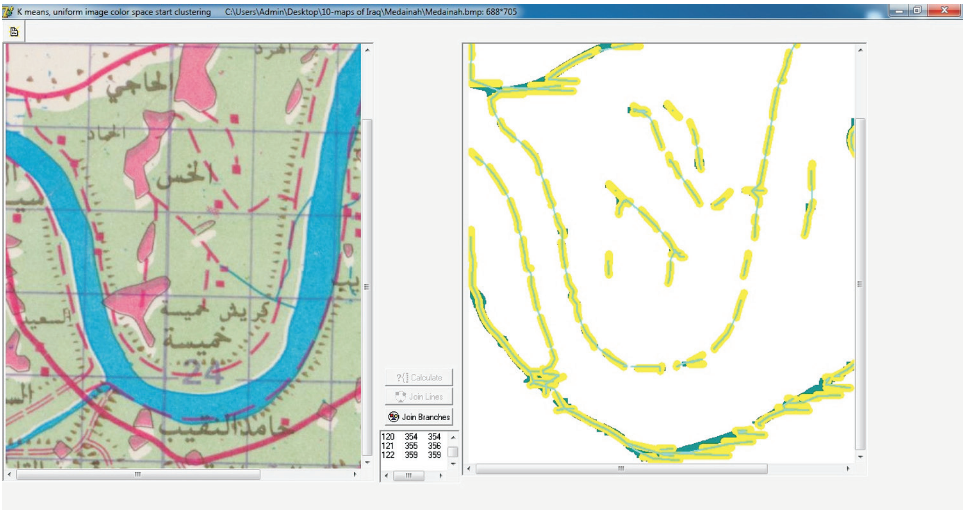
Then branches merging are performed. Result of this stage (Figures 6 and 7) is depicted as centrelines of fragments that was obtained at previous stage. For visibility reasons the line widths were not displayed.

For results estimation author compared obtained road network with results of manual human expert extraction. Two characteristics are used for extraction quantity estimation: *P* (precision) and *R* (residue). Precision shows the proportion of correctly selected road network fragments relating to all selected fragments. Residue defines the proportion of non-correctly selected road network fragments to all selected fragments. Also density of road network was estimated for investigation areas. Table 1 shows data of estimation for 10 maps of Iraq cities. Average precision value is 0.86, minimal precision value is 0.7, maximal precision value is 0.95. These characteristics show that for city maps (particularly Nasiriya, Medaynah) average precision value is 0.725. Average precision value obtained for rest of rural area maps is 0.894.



Source: author's study

Fig. 6. Result of road network extraction for Basrah map fragment (left – map fragment, right – extraction result: yellow lines – after linear fragments extraction, cyan lines – after merging of branches)



Source: author's study

Fig. 7. Result of road network extraction for Medaynah map fragment (left – map fragment, right – extraction result: yellow lines – after linear fragments extraction, cyan lines – after merging of branches)

Common analyze shows that for maps with high density of road network extraction results are worse then for maps with road network with low density. Increasing of scanning resolution from 80 to 120 dpi not may have a perceptible effect on extraction results.

Because all road network elements can not extracted automatically, further it's necessary to provide possibility of manual results correcting.

Table 1. Experimental results.

No.	City	Land area [km²]	Distance between investigation area and city and direction	Scanning resolution [dpi]	Kind of roads	Density of road network	Precision	Residue
1	Sulaimaniya	300	21 km north-west	120	Secondary, mountain, rural	0.53	0.95	0.05
2	Um – Rehel	350	11 km north-west	120	Secondary, rural	0.66	0.90	0.10
3	Thari	400	10 km North	80	Main, secondary	0.73	0.95	0.05
4	Shuaib – Farach	400	12 km south-east	80	Rural	0.70	0.95	0.05
5	Rumaila	300	15 km south- west	120	Main	0.68	0.90	0.10
6	Chamchamal	300	7 km north-east	120	Secondary, mountain, rural	0.90	0.80	0.20
7	Basrah	400	16 km south-east	120	Secondary, mountain, rural	0.72	0.90	0.10
8	Samawa	400	5 km south-west	80	Secondary, mountain, rural	1.10	0.80	0.20
9	Nasiriya	350	0 km (city area)	80	Secondary, mountain, rural	1.40	0.75	0.25
10	Medaynah	400	0 km (city area)	120	Secondary, mountain, rural	1.30	0.0	0.30

7. Conclusion

In this paper the author introduces an approach to road network extraction from raster topographic map. This approach combines k-means clustering and selection of linear fragments by scanning algorithm. Experiments show acceptable results: average precision value is 86% (in comparison with human expert). In the future, author is going to assess the accuracy of road network extraction from satellite images and to increase precision of extraction through algorithm improvement, e.g. considering the value of width for different roads when fragment and branches merging.

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