Semi-automatic detection of cartographic objects in digital images

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Abstract. A computer system for semi-automatic detection of specific 2-D objects in digital images of cartographic maps is presented. The system design combines image analysis methods with computer graphics and data base technologies. The purpose of this application system is to speed up the work of a cartographician, to increase its efficiency and to transform cartograhpic maps into a symbolic, vektor-based shape, i.e. to represent them in a general purpose data base. Thus, three main system modules are described: image analysis, graphic editor and data base administration. Up to now the object types being detected are: roads, cities, textured areas and some characteristic signs.

1. Introduction

One of recently new techniques of map acquisition is the automatic interpretation of aerial or satellite images from given territory [1]. Nevertheless still the most popular techniques for creation of a new map is the drawing of objects and names made by the editor, either "made-by-hand" or with the help of a computerized graphic editor. This requires a heavy workload, frequently renewable if some changes have to be included.

The field of automatic image analysis offers standard algorithms [3] suitable for: image segmentation, contour detection, texture detection and sign recognition, as well as the line approximation by polygons. From the point of view of image analysis similar problems arise in line drawing analysis, OCR and document analysis [4]. As far as graphic editors are concernd, the existing universal programs like *Corel* [2] or *Paintbrush* [5] can not access data bases with symbolic cartographic data. A more specialized editor, satisfying this condition, is required. A solution for the optimal storage of of cartographical objects should also be given, filling into the framework of geographical information systems *GIS* [6].

The most severe drawback of universal graphic systems as applied for cartography is the lack of a data base for cartographic objects and no handling of geographical coordinates. For example during a map preparation in *Corel* the visualization parameters like position coordinates, shape, size, colour and texture, of a common topological unit can be defined only, but not the kartographical object itself. In this way the additional, relevant information of such object can not be linked automatically in the map preparation process. For example, an object representing a town, could hold following information: town's name, geographical coordinates, number of inhabitants, administrative status, etc.

The net of geographical coordinates is simply a set of straight or curved line segments, orineted horizontally or vertically. No concrete values about geographical width or height are linked to them, as such information is represented by text entities, implicitely only related (located in the neighborhood) to these line segments. In order to avoid problems with redefinition and rescaling of maps for each object its geometrical position coordinates should be provided, instead of the cartesian coordinates of the drawing.

Several existing cartography-oriented specialised graphic editors, also have some drawbacks, like: the manual obiect vectorzation process, the data base containes no topology information. For example the system *AVISO* [7] works with a data base of three elementary object types: point, line, surface. In *AVISO* geographical coordinates are used. There is no explicite topological information given (i.e. no relations between objects), but for topological queries could be compuited, whenever necessary. The data base in *AVISO* is filled manually, i.e. after scanning the map into a digital image, the objects should be drawn on top of the background image. The last version of *AVISO*, containes some semi-automatic vectorization method. After pointing two terminal vertices of a line, its line segments are generated. Similar functionality like *AVISO* posess other specialized cartographic systems: *MapInfo*, *InterGraph*, *MapLook* [8].

In existing document analysis systems, one tries automatically to detect, localize and classify differenet objects in the image [9]. For this purpose image processing and pattern recognition methods are applied. Explicite topological information should be provided in the data base, if the cartographic data system interactively has to answer topological queries. For example the search for a connection between two cities can be realized as path search in the graph representation of roads. Road crossings correspond to graph nodes, while road segments are graph edges. By pattern recognition methods one can segment a digital image into edges, regions, etc. and one can also extract their geometrical relations. For the detection of roads and towns in the image it is convenient to apply the homogenity criteria, whereas for specific regions and map symbols a criteria related to prespecified texture may be applied. The segmentation process could be guided by user-defined parameters, like color interval and size interval of searched objects.

Hence the goals of a specialized map processing system are specified as follows:

(1) automatic detection of cartographic objects in the digital image, (2) storage of detected objects in the data base (symbolic map description), (3) interactive correction of data base objects by the user in a specialised graphic editor mode, (4) automatic map generation (visualization of objects) from the data base and (5) exporting the symbolic map description into different file formats.

The paper consists of following six sections. In section 2 the overall structure of proposed system is described. Section 3 containes details of the realized data base. The most important module for automatic object detection is scope of section 4, whereas the specialized graphic editor for interactive correction of the image analysis results is described in section 5. Examples of test results are shown in sections 2-5. The paper ends with a summary section.

2. System structure

The general system structure is given in **Figure 1**. Three main modules can be distinguished: (1) the image analysis module, (2) the graphic object editor and (3) the data base administrator, as well as two additional functional units: (4) user interaction (for parameter definition, on-screen visualization) and (5) visualization and export into other data formats.

After the user has defined the analysis parameters (i.e. object type with its color and size interval), the image analysis module performs automatic object detection and stores the objects in the data base. After the image analysis is finished, the user has the possibility of object correction by using a specialised graphic editor. This editor enables a fast and easy correction of the localization, shape and relations of all object types. Hence, a probably difficult work in the text mode directly on the data base records can be avoided.

The objects in the data base can allways be viewed by the graphic editor, but additionally they can be exported outside the system in different visual formats (for example in *Postscript*) or system specific symbolic files (for example in *Corel* standard) by using the visualization module. An example of a working session of the system is given in **Figure 2.**

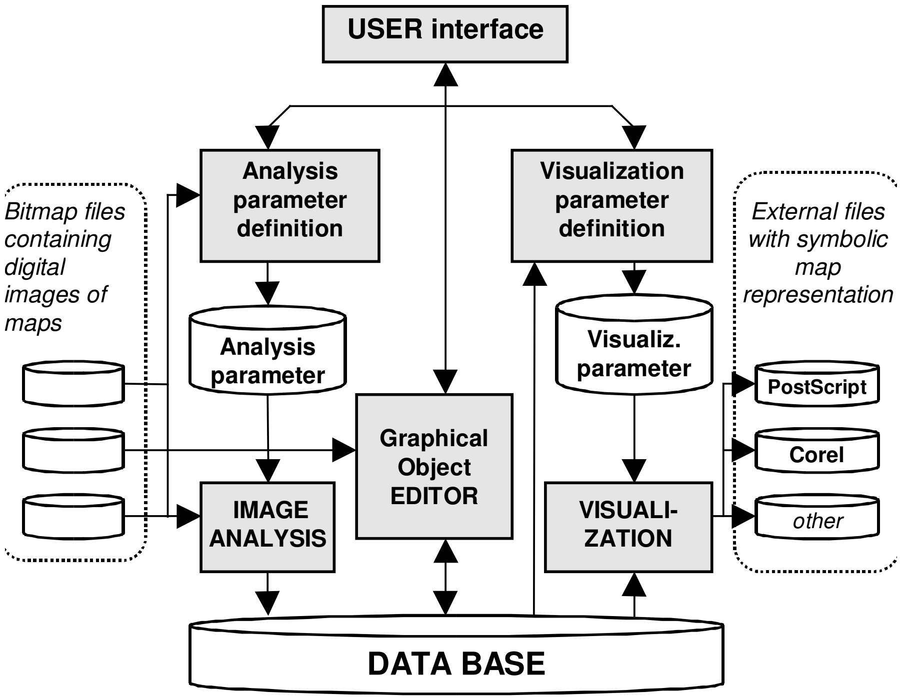
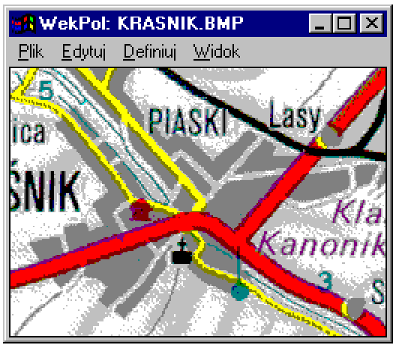
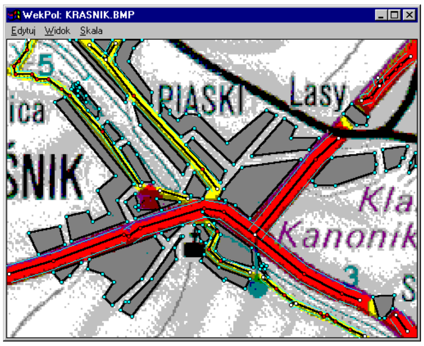


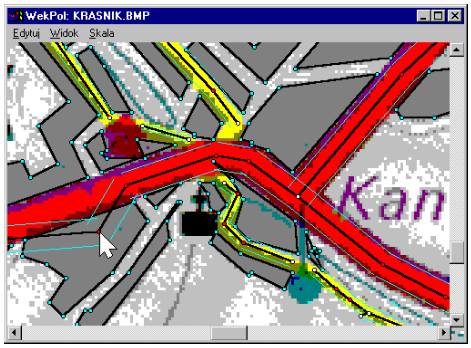
Fig. 1 The system structure for semi-automatic cartographic object detection.



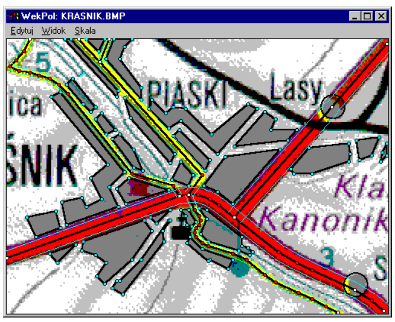
(a) The selected input image.



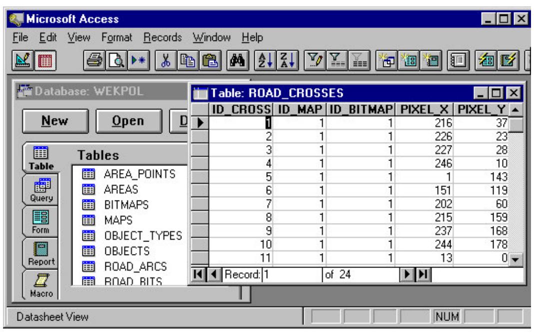
(b) After road and town detection (for roads its center and border lines are drawn, for towns - its polygonal border).



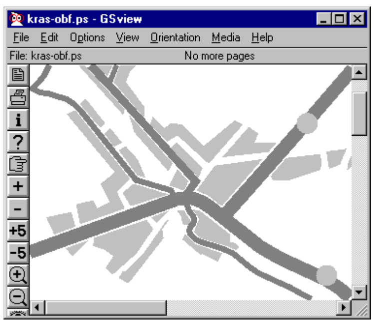
(c) Interactive correction in the graphic editor (more detailed view can be selected, a vertex can be shifted, deleted or added).



(d) The final objects after interactive correction.



(e) The symbolic information about detected objects is stored in the data base.



(f) Exporting visual data (postscript) of detected objects.

Fig. 2. Example of a working session of the system.

3. The data base for cartographic objects.

The road network is represented in the data base as a non-directed graph, with nodes representing road crossings and edges representing connections between crossings or terminal points of the road (**Figure 3**).

Towns are represented either by a set of polygonal borders (for large towns with specified urban areas) or circular points (small towns) (**Figure 4**). Map areas with specific texture are represented by polygonal border (like urban region), additionally their texture patterns are stored. For characteristic graphic signs their positions and pattern indices are stored.

Fig. 3. The road network.

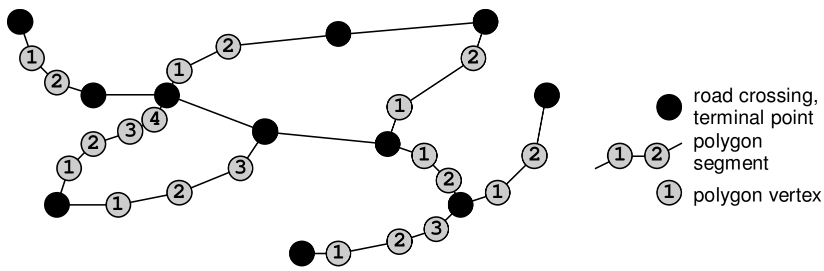
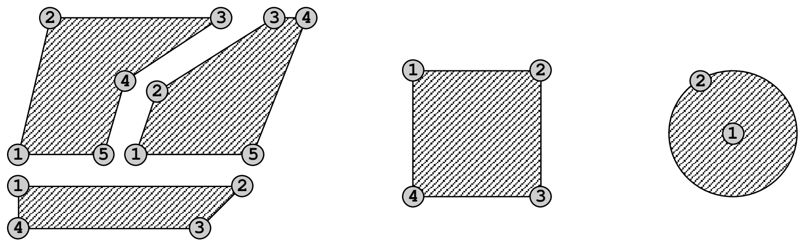


Fig. 4. Urban area (by polygon sets) and smaller town (by circular ponts) representations.



3. The image analysis module.

In the first step of road detection a segmentation procedure for contour detection is applied (**Figure 5**). The detected contours are processed further by a skeletonization procedure. In the obtained skeletons are vertex points are detected, defined as the common points of more than one sekeleton segment. The edges between vertices are approximated by polygons. Finally the positions of vertices and polygons are stored in the data base (see an example in **Figure 6)**. Similarly, the detection of urban areas also starts with the contour segmentation process. Each contour is approximated by a closed polygon. Finally the positions of polygons are stored in the data base (see **Figure 7**).

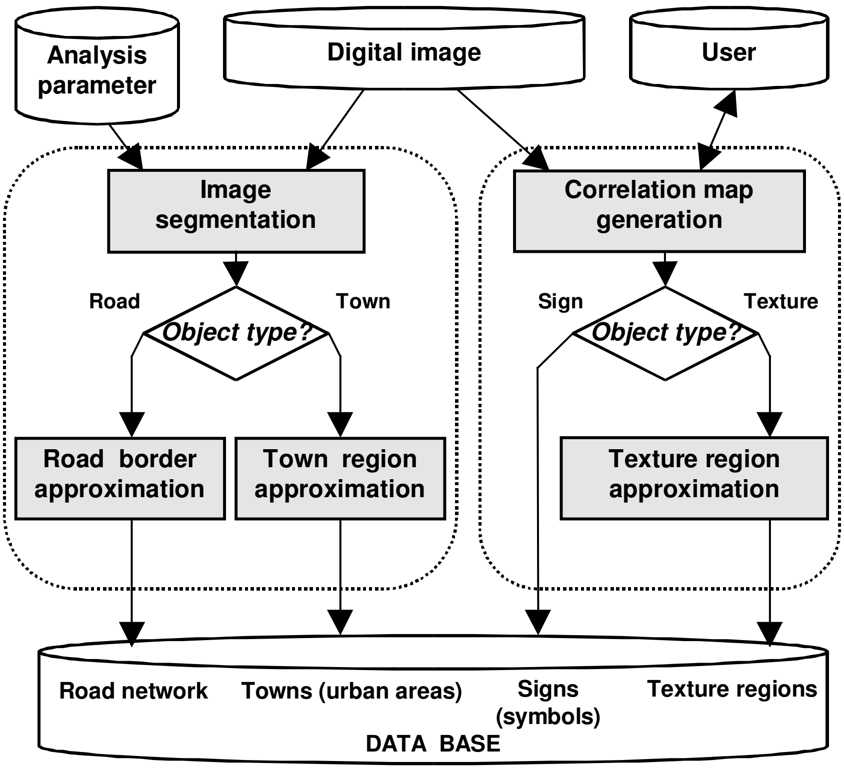
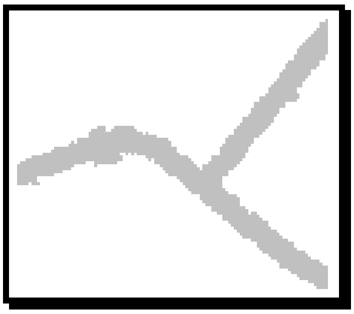
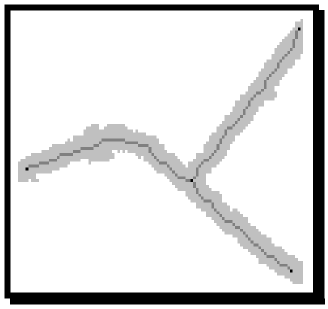


Fig. 5. Processing flow of the image analysis module.

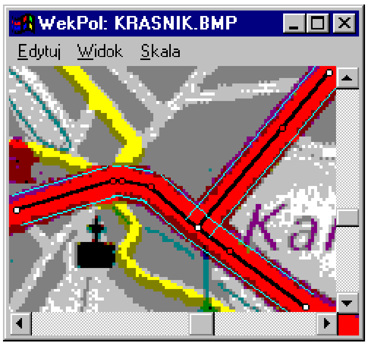
(a) Input image with a road



(b) Road segmentation results

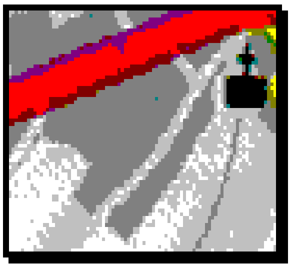


(c) Skeleton- and vertex detection

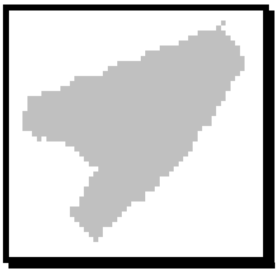


(d) Line segment approximation of road's center and border lines.

Fig. 6 Example of road detection.



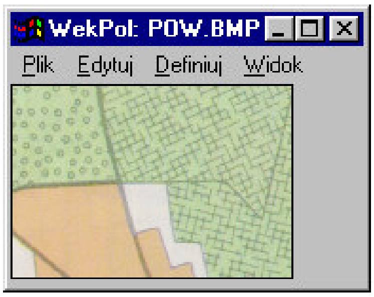
(a) Input image with an urban area



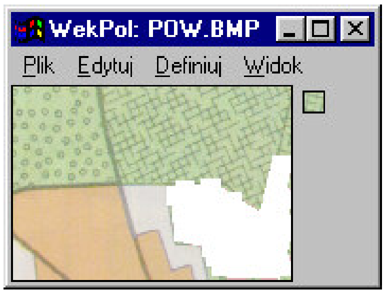
(b) A region after segmentation

(c) Polygonal border approximation

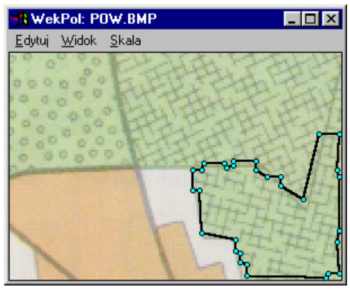
Fig. 7 Example of urban area detection.



(a) Input image with three different texture regions.

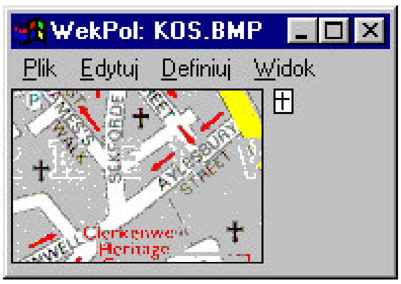


(b) Detected region (white pixles) of given texture.

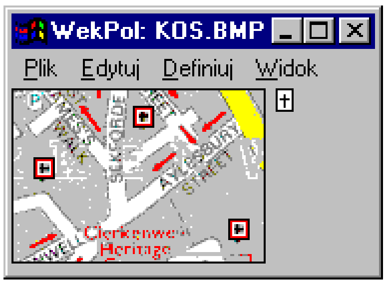


(c) Region border approximation

Fig. 8. Example of texture region detection



(a) City map with church signs.



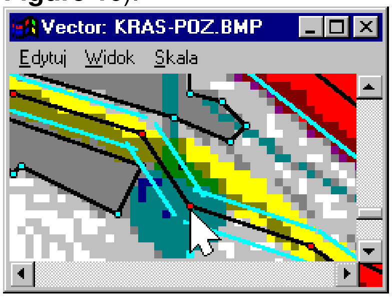
(b) Three detected church signs.

Fig. 9. Example of sign (symbol) detection

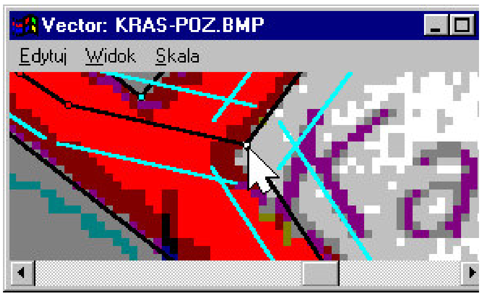
For both processes of texture region and sign detection the user has to define a rectangular texture pattern, for example by simply pointing one reference pattern in the analysed image. Then two different correlation procedures are applied for the detection of these two object types (**Figure 8,9**).

4. Interactive object correction.

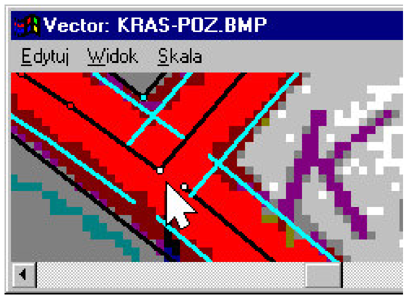
A complete set of correction operators on the cartographic objects is available in the graphic editor in an interactive user mode, like change of object parameters, deletion or addition of new object points (see **Figure 10**).



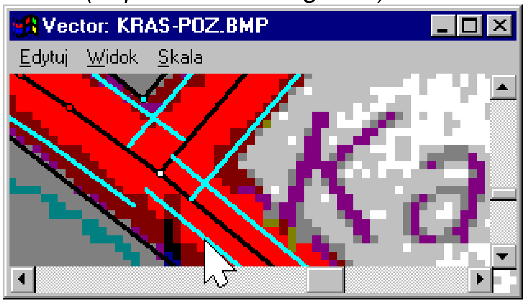
(a) Correction of a polygon vertex (repres. a road segment)



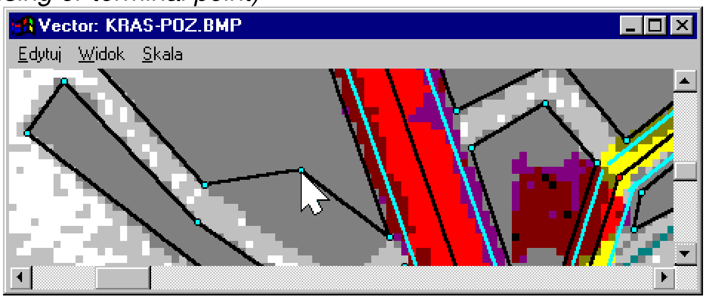
(b) Correction of a road net node (road crossing or terminal point)



(c) Addition of a road net node



(d) Changing the road width



(e) Changing the position of a polygon vertex (urban area)

Fig. 10. Examples of editor operations on cartographic objects.

5. Summary

With this work we have successfully applied image analysis methods for the detection of cartographic objects in digital images of cartographic maps. Particularly four object types are detected: road network, urban areas (towns), textured areas and specific signs. A suitable graphic editor for interactive correction of detected objects has also been developed. The obtained symboli information can be efficiently used for the design of new maps of given territory. By using this system the work of a cartographician on new map preparation is more convenient, easier and faster. In the future the system may be extended in different ways:

(1) by procedures for the automatic detection of new objects (for example a two lane road object), (2) by using pre-defined texture and sign patterns, (3) including more compact curve representations (for example Bezier curves) and (4) by extending the available procedures for export data formats.

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