DIRECT COLOR OBJECTS PROCESSING IN CARTOGRAPHIC IMAGES

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Abstract. An approach for direct map processing and interpretation in color cartographic image and charts is proposed which directly works on the original color images without global binarisation or color separation. It consists of four stages: adaptive color separation using point's proximity in HSV color space, local thinning and object tracing. The proposed approach allows getting the correct solution of object extraction even in very difficult situations (when original images contain a lot of noise) without extra image improvements.

1. Introduction

The scanned cartographical data should be vectorized and represented in a GIS format. In most of the systems, the process of scanned map digitizing can be divided into three main stages: global color separation, raster-to-vector transformation with the aim of obtaining a structural representation, and automatic/interactive recognition of cartographic objects to obtain the required final map representation [2, 6, 9,12, 14]. This way is not always optimal because after global color separation and binarisation some information is already lost and can not be reconstructed and used.

Often objects cannot be extracted using gray scale information but can be extracted using color information. Compared to gray scale, color provides additional information to intensity. People realize that color is useful or even necessary for pattern recognition and computer vision. Also the acquisition and processing hardware for color image become more and more available for dealing with the problem of computation complexity caused by the high-dimensional color space. Hence, color image processing becomes increasingly prevalent nowadays.

Color gives its own specifics and additional information that should be used during digitizing. Most of line-drawing interpretation systems use an approach that allows getting several binary layers from an original color image. Procedures of color separation allow to allocate in a separate binary layer points with identical or similar colors.

However, often the global color separation is used. Therefore, objects, which change their color or background locally, can be lost or selected in binary layer with the holes or other redundant parts of the map image. The vector model obtained after global color separation demand more time for hand correction and editing.

As a result, the existing procedures for cartographic images can work well only with grayscale and binary images or global color separation/binarisation procedure for color images is used. In that way, the development of approach for direct processing of the color maps is necessary. In this paper, we combine interactive object tracing with adaptive color separation procedure and proposed algorithm directly works on the original color images without global methods. It is processed for each object user wants to digitize, adapting to the background, color distribution and shape of the object.

The offered approach of direct color objects processing permits to use the full self-descriptiveness of the color image with better outcomes. Due to interactivity and adaptive color separation, there is a possibility to find the exact solution even in very difficult situations, which the classical approach does not cope with.

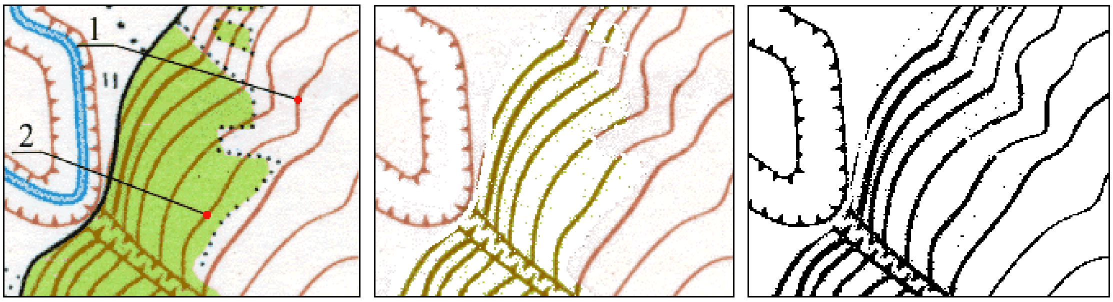
2. The proposed approach

Automatic vectorization achieves good results in map processing when quality of input images enough well for used algorithms or steps for images restoration or improvement took place. However, the procedures of image restoration and improvement demand more time and each image distortion or noise demand special filter or procedure to reduce its harmful effect. The choice of the optimal filters set for image improvement is not trivial and for each family of documents new filters set should be determined. Therefore it's useful to have such universal methods of vectorization and recognition which can work without extra image improvement procedures and global color separation.

It's very difficult to determine the term quality in cartographic images. Therefore let us to examine the cases which result to recognition complication and ambiguities. First of all examine case when object changes its color or background locally. At *Fig. 1(a)* a line cartographic object be situated on white (point 1) and green (point 2) backgrounds. The mean color features deviation between points on the white and on the green background in HSV color space are H-7%, S-49%, V-29%. It is clear that it's one object and input layer for automatic vectorization should be constructed with it. Often some kind of automatic or interactive color separation algorithm is used [3-5, 10, 11].

Automatic color separation algorithms have to be trained or optimal parameters for cartographic images family have to be chosen. The parameters tuning depends from human and color separation algorithm in use and demand more time. Result is not often optimal and resulting layers can contain superfluous part, holes or even cannot be used in vectorization process.

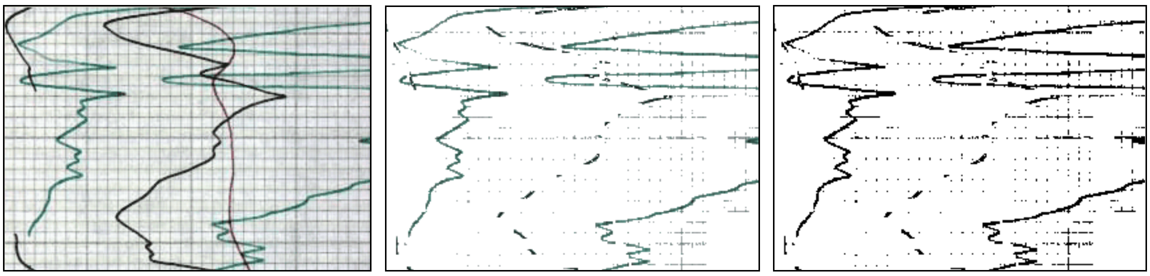
In such cases interactive color separation should be used. Often in such approach human selects base color point, area for selection and tunes deviations in some color spaces to select homogeneous regions. Combining layers the well results can be achieved (*Fig. 1(b)*). At *Fig. 1 (c)* the binary layer for vectorization is shown.



a) b) c)

Fig. 1 A color map image (a) and result of interactive color separation (b) and binarisation (c)

In *Fig. 2* even fine tuning of deviations in interactive color separation algorithm produce results which can not be practically used in green line recognition process or hand editing and correction stages is necessary. Due to rapid changes of object color and background the global separation procedure cannot achieve results useful for recognition. The homogeneity properties vary in wide range and thresholding procedures are non-applicable. Therefore when an extra time is necessary for correction stages or difficult to use the global properties of homogeneity we suggest to combine color separation and vectorization/recognition stages in one to reduce time of processing and improving the quality of recognition.



a) b) c)

Fig. 2 A color chart image (a) and result of interactive color separation (b) and binarisation (c)

In most of the existing color image segmentation approaches, the definition of a region is based on similar color or on homogeneity [3,5]. The pixels similarity is defined in any color representation. Each color representation has its own advantages and disadvantages. There is still no color representation that can dominate the others for all kinds of color images yet.

There are linear or nonlinear transformations of color spaces. The major problem of linear color spaces is the high correlations of the three color features, which makes components dependent upon each other and associate strongly with intensity [3]. Also the color features do not express such useful terms as hue, saturation and intensity. The problems described above can be overcome by using HSV color space.

It was noticed that in cartographic images the stable homogeneity regions with minor deviations in HSV color space can be determined. It is the basis of proposed interactive approach for connection such regions together. It's like a blind digitizing but more intellectual. Fewer points are necessary for getting right vector model. The proposed approach is useful when other approaches can't achieve satisfying result and there is choice between blind digitizing and interactive vectorization.

The pixels homogeneity determines in HSV color space later. We use thresholds which can be fixed for wide family of documents or can be selected from the experiments with the particular image document. The initial points from which a homogeneity region will be constructed have to be chosen by the human. The merging procedures have been included in vectorization stage to merge nearby regions avoiding color object intersection.

Two types of object can be extracted from color image: area and line objects. In each case information about type of object being picked supplied by the human. The vectorization stage occurs when two regions have been selected. The problem of objects overlapping and intersection also discussed and threshold method is proposed to process such cases. We use the following main stages in vectorization process.

Start and terminal points input.

The user indicates start and terminal points as the supplementary information, permitting to control process of selecting and merging homogeneity regions in one and determination of the vectorisation direction. Each inputted point produce one homogeneity region.

Homogeneity regions creation.

After the any point was inputted, the color separation algorithm performed. All pixels around inputted which satisfy pixels proximity definition (section 3) are selected in single homogeneity region.

Region thinning or contour detection

Depending on the type of object in question the procedure of local thinning or contour detection performed. The local nature is the main difference from algorithms used in the classical vectorization.

Object tracing algorithm

The tracing algorithm has to find the path from initial and terminal inputted points using selected homogeneity regions or computes a new contour if possible for the area object.

Automatic vectorisation and approximation.

The path of points is the outcome of object tracing algorithm. Path can be considered like a marked raster since each point related to one of the pixel groups described below. Classical vectorization and approximation is used to produce the desirable vector representation. In addition, information (color, thickness,) about object can be stored.

3. Pixels proximity definition

HSV space (Hue, Saturation, Value) is constructed on the basis of subjective perception of color by a person. The cylindrical coordinate system is used, and a subspace, in which model is determined, is the hexahedral pyramid. The Hue is measured by an angle around of a vertical axis, and red, green and blue colors corresponds to H, which is equal 0 °, 120 ° and 240 °. Intensity (V) lengthwise axis at the top increases from 0 up to 1 at the supremum where it becomes maximum for all colors. Saturation (S) is determined by an interval from an axis. On a vertical axis there are achromatic, gray colors.

The similarity measure for points P1(H1, S1, V1) and P2 (H2, S2, V2) in system HSV can be determined by using following statement:

Point P1 (H1, S1, V1) is similar to point P2 (H2, S2, V2), if

$$\left\{ \begin{array}{l} \min(|H1 - H2|, |360 - H1 - H2|) \le c1 \\ |S1 - S2| \le c2 \\ |V1 - V2| \le c3 \end{array} \right\}$$

where *c1, c2, c3* – are some thresholds. And $0 \le c1 \le 360$, $0 \le c2 \le 1$, $0 \le c3 \le 1$.

4. Homogeneity regions creation

The main goal of the homogeneity region creation is to construct a homogeneity region, which contains pixels with the similar colors. Algorithm scans an image around inputted point P(x,y) and groups pixels into region based on pixel connectivity, *i.e.* all pixels in a connected component share similar pixel proximity condition and are in some way connected with each other.

Pixels which satisfy pixel's proximity condition are object pixels or points, other points we call background. The pixel's connection we interpret like object point connectedness with other object pixels in the eight nearest neighbors (8nn). We suggest the following algorithm for selection connected pixels (*Fig. 3*). This algorithm uses a stack or queue for storing and analyzing pixels.

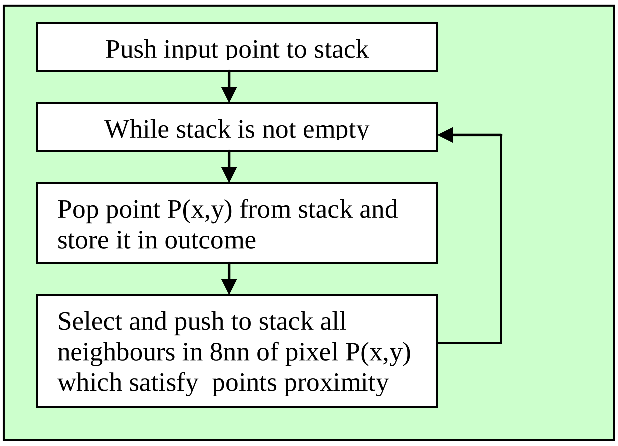
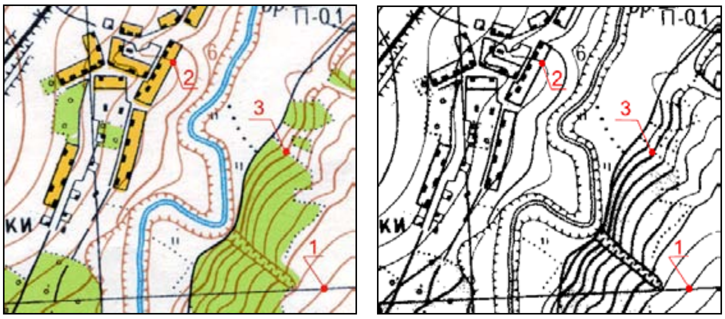


Fig. 3 Homogeneity region creation algorithm

5. The region merging approach

It is known that objects overlapping and intersection at maps leads to ambiguity (points 1, 2, 3 in *Fig. 4(a)*). Automatic vectorization of binarised color image (*Fig. 4(b)*) will produce a vector model that can not be practically used for object recognition, since considerable effort is essential to further vector representation fragmentation to semantic layers and vector objects editing.

To process such situations, we suggest to use interactive management of vectorization process and color parameters to separate objects and to solve ambiguity of color objects intersection and overlapping.



a) *(b)*

Fig. 4 A color (a) and binary map (b) with objects overlapping and intersection

Let us to consider situation when two cartographic objects intersect and overlap (*Fig. 4*). Assume that user entered initial pixel P1(x1,y1) and terminal pixel P2(x2,y2) (*Fig. 5(a)*). Then, homogeneity region creation algorithm performed. Two entered points produce two homogeneity regions (*Fig. 5(b)*). Sometimes two points can produce two identical regions. Such situation is possible when initial and terminal pixels belong to the same region.

Some of these regions may contain very few pixels and should not be considered as proper regions. Also there might be some regions that are very close to each other and they may need to be combined. We use the region merging approach included in vectorization process to solve this problem.

6 The region merging criterion

One problem with region merging is how to define merging criteria. Generally, region merging is based on both feature space and the spatial relation between pixels simultaneously. Hence, we take into account color similarity and distance between feature pixels when deciding if two regions are to be merged.

The outcome of region creation algorithm is used as an input for thinning algorithm or contour detection. The choice of algorithm and merging criterion depends from the type of extracting object.

6.1. Line object

Each thinned region has feature pixels. We define the following groups of feature pixels:

- begin/end pixels group
- node pixels group
- connected pixels group

Pixels P1, P4, P5, P6 and P8 are begin/end pixels (*Fig.5 (b)*). P7 is a node pixel. For taking decision about pixels belonging to one of the group, algorithm computes characteristics numbers [1]. Pixel belongs to begin/end group if $\{A_8, N_{c8}, C_n\} = 1$, to node group - if $\{N_c, C_n\} \geq 3$. In addition, pixel is a connected pixel if $\{N_c, C_n\} = 2$ [1].

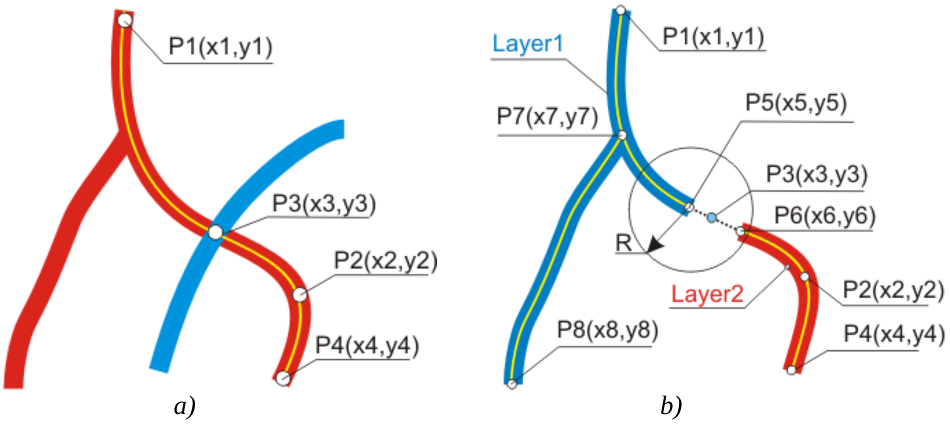


Fig. 5. Intersection of two objects (a) and two homogeneity layers with feature pixels (b)

After finding feature pixels, we combine two region layers in common layer and find path connecting initial and terminal points. Path is a set of pixels bounded by key pixels. If path in a common layer between entered initial and terminal point exists, it is stored in necessary vector format Otherwise, we find nearest begin/end points belonging to different binary layers. There are points P5 and P6 (*Fig. 5(b)*). If distance between such founded points less than selected threshold R, approximation procedure begins and junction point P3 is calculated. Else, user has to decide to create line between initial and terminal points without founded path or try to enter another begin/end point.

When inputted terminal point P2(x2,y2) can be related to connected pixels group (*Fig. 5(b)*) founded path should be extended to nearest point from begin, end or node group from the same region. Terminal point in such situations is interpreted like direction of path extension.

Terminal point becomes an initial point at the last stage of tracing algorithm. Now an operator has to give a new terminal point or finish to create current vector segment. After finishing tracing one object, a new object is processed.

6.2. Area object

Hence, we take into account distances between all the pixels belonged to the region contours. The well-known operations from mathematical morphology are used to merge area regions together. The size of the 2D structural element regulates the allowable holes radius between regions. When necessary region have been selected the procedure of contour detection and vectorization performed.

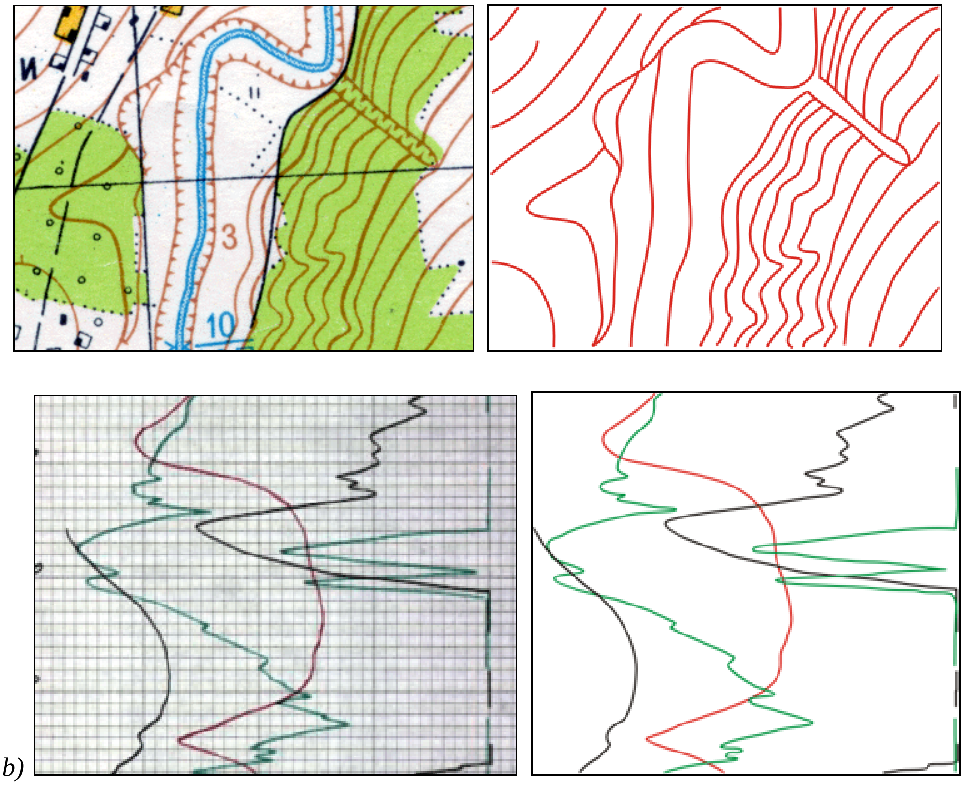
7. The conclusion

The proposed approach has been tested to digitize topographic maps and color charts. Example of map and chart part is shown in *Fig. 6*.

The difference between the proposed approach and automatic vectorization is that in each moment of time algorithm work only with the part of the image the user works with. This approach allows to proceed from global methods and algorithms to local, which are operated better and faster.

The offered approach of interactive vectorization of the color image permits to use to the full self-descriptiveness of the color image with better outcomes. Due to interactivity, there is a possibility to find the exact solution even in very difficult situations, which the automatic vectorization does not cope with.

The right vector model was found even in images, which contain a lot of noise and improvement of original image was not taken (*Fig. 6*).



a) b)

Fig. 6 Result of object vectorisation for map (a) and chart (b).

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