Pseudo-distance map transformation for interactive object tracing

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Abstract: *In this paper, the algorithms for interactive objects tracing on grey-scale images are proposed that is based on a pseudo-distance map (PDM). The PDM is a simplified distance map of gray-scale image and uses only that features of image and objects that are necessary to build a optimal contour. The algorithms wors fast for large gray-scale images and allows constructing a high quality contour as well as central line.*

Keywords**:** Interactive object extraction, distance map, thinning, gray image processing.

1. INTRODUCTION

Many researchers concentrate their efforts on automatic objects extraction with subsequent hand correction of results [1, 2]. In fact, fully automatic approaches often provide the medical, GIS and engineering application with unsatisfactory imperfect data and correction time can be comparable with semi-automatic image investigation. Therefore interactive recognition approaches are developed to take upon oneself the routine work of operator while keeping the possibility of full user control of segmentation/recognition process.

Interactive segmentation techniques can be either region-based or boundary-based [3, 4]. The magic wand tool [5] belongs to the first group and enables user to interactively select a seed point to grow a region by adding adjacent neighboring homogeneous pixels[6]. Active contour (also called snake) is a well-known boundary based technique which allows setting an initial curve to be modified by the external and internal forces [1]. The final boundary is estimated while minimizing energy functional.

Another well-known boundary-based technique is live-wire [3] which uses a global graph search. The pixels are considered like graph nodes, and a cost based on boundary features is assigned to graph arcs. A minimum cost path from the seed to every image pixel is calculated. User gets the desired segmentation result by interactively moving a cursor near object's boundary.

Such approaches, however, can extract only the area objects while many research applications need a center line for elongated objects. In addition, it's very difficult for the magic wand and snake approaches to provide user with the interactive visual feedback.

In this paper, we consider approaches for interactive objects extraction: one based on connected components accumulation and one based on live-wire paradigm.

In contrast to known interactive segmentation techniques, the proposed approach based on live-wire paradigm allows extraction of object's centerline rather than boundary.

The centerlines are extracted using a novel image representation scheme as a generalization of a pseudo-distance transformation (PDT) [7] for grayscale images using only distance with a glance features of flat and gradient regions. The skeleton features representing a centerline of elongated objects (fibers, vessels, roads, rivers, etc.) are highlighted by PDT transformation and used by live-wire technique for objects extraction from remote sensing images.

For interactive live-wire reconstruction one of the most significant operations in such processing is thinning, which is transformation of original "thick" object into lines of one-pixel thickness, that has the following basic properties:

- •It preserves a topology of an original object;
- •It is located in an object area and desirably in an object center;
- •All pixels of a skeleton are connected with each other;
- •Isotropy – skeleton is preserved after image rotation (at least for an angle that is divisible by $\pi/2$;
- •It has a width that is equal to 1 pixel.

Generally, interactive countering by distance transform includes the following steps:

- •construction of distance map;
- •detecting pixels of contour;
- •postprocessing (pruning).

The proposed algorithm is based on pseudo-distance map (PDM), which is a simplified distance map of gray-scale image and uses only that features of image and objects that are necessary to build a skeleton. These lines can be basis for line or area contour reconstruction.

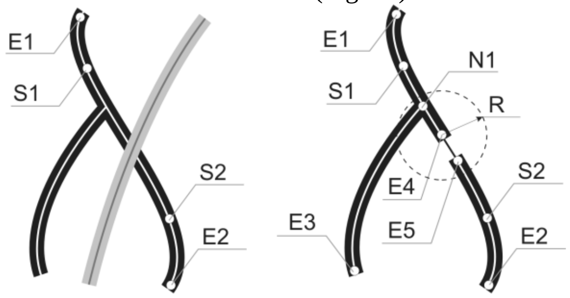
2. TRACING LINE OBJECTS

Consider the situation in which two line objects overlap (Fig. 1a). Suppose the operator's goal is a vector representation of a line linking pixels E1 and E2 (Fig. 1a). Two seed pixels, S1 and S2, are specified (Fig. 1a), and two connected components are extracted (Fig. 1b). If a connected path can be achieved between S1 and S2 then vectorisation can be done automatically without further user intervention. Overlaps and intersections are, however, common. Additional path reconstruction processes will often be required.

First, thinning applied and the skeleton of each component is estimated (marked as a thin white line in figures 3 and 4). Next, feature pixels are found. We define the following types of feature pixel:

- end pixels
- node pixels
- connected pixels

When feature pixels have been marked, the path between seed points can be found. We examine the neighborhood of each end point to find places where a line approximation should take place. For each end pixel belonging to one connected component the distance to the nearest pixel on the skeleton of another component is computed. A line then connects the pair of pixels with shortest distance between them (Fig. 1b).



a) b)

Fig.1 – Interaction of two objects (a) and extracted components (b).

An upper limit R is placed on the length of these connecting lines At any time the user can decide if and how to create a line between pixels: to select the most appropriate path, to vary R or to switch to manual approximation mode. The results of applying this process to the examples are shown in figure 2b.

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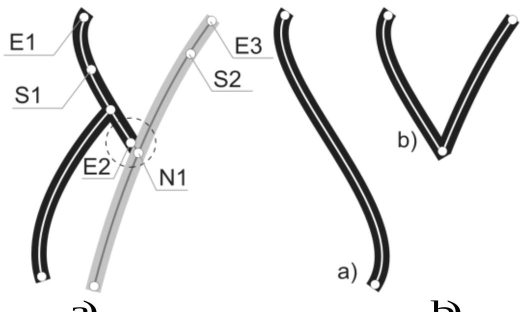


a) b)

Fig.2 – Tracing a line object(a) and result of digitisation(b).

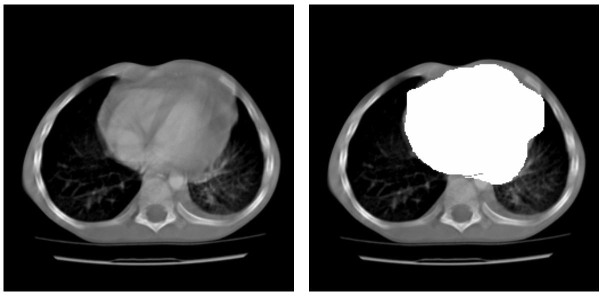
3. TRACING AREA OBJECTS

Given area objects the goal is to combine regions. Suppose the operator wishes to define area contour. Contours are constructed around connected components.

There are two classes of contour construction methods:

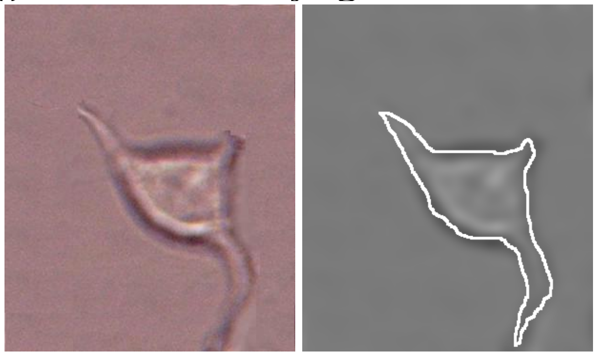
- by selection regions with rather like features (fig. 3),
- by common object borders (fig 4.).

Object-oriented morphological operators are executed only when pixels arising from different connected components are under consideration. In other words, the morphological operators do not affect pixels of the same component. This prevents the corruption of external and internal boundaries of components.



a) b)

Fig.3 – CT image of tumor with common brightness features (a) and result area definition by brightness features extraction.



a) b)

Fig.4 – cytology image with common border features (a) and result area definition by border extraction. (b).

Comparisons of processing times and boundary accuracy achieved have been made between the proposed approach and a standard manual tracing method. Using the proposed approach the same extraction took at most half times needed for manual digitization. The accuracy of the boundary and skeletons extracted by the proposed approach was also better in each case. When properly targeted, automatic thinning, contouring and entity extraction are more stable than manual tracing.

4. PSEUDO-DISTANCE MAP CONSTRUCTION

4.1 Principles of PDM building

Distance transform (DT) is defined as replica of the region of image where pixels are labeled with their distance from a reference pixels set of object [7,8]. For gray-scale image, reference set for such region is constituted by different gray-scale. The union of DTs of regions of all gray-scale is the DT of gray-scale image. When computing the DT of a region with gray-scale k, adjacent regions with the levels greater than k are obstacles for the propagation of distance information. Thus, distance transform of a region with value k may require more than one pair of forward and backward scans of the image [9].

The result of thinning operation is a skeleton. For gray thinning algorithm, it is necessary to build special distance map, which includes all necessary properties of a skeleton. Skeleton reflects the following topological properties of an object:

•Skeleton must cross pixels of local maximum. These pixels have no neighbors with greater gray-scale in their neighborhood.

•Skeleton must cross node pixels. These pixels connect more then three neighbors with higher value by a sole way.

•Skeleton must finish at the end pixels. These pixels have only one pixel with greater or equal value.

•Skeleton should not cross pixels of local minimum. These pixels have no pixel with lower level.

Let us build a PDM that preserves all these proper-ties and can be built in a more effective and easier way.

For construction of a PDM, a gray-scale image is described as a collection of binary layers where every lower layer includes pixels from a higher layer [10]. Distance map of one binary layer is constructed by increasing pixels depth for reflecting distance proper-ties of pixels. Mostly gray-scale image has 256 levels. In this way, if every binary layer is raised to 256 levels (with zero level), then we will have enough depth of gray value for construction of a distance map for every binary layer (fig. 5).

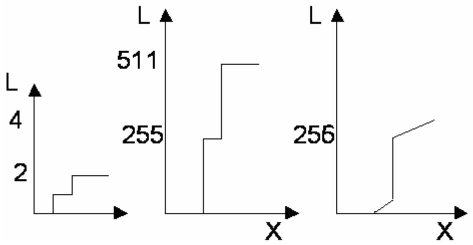


Fig.5 – Profile (L – pixels value, x – pixels coordi-nate) of a) gray values in an original gray-scale image b) gray values multiplied by 256, and c) a pseudo-distance map.

On the base of obtained image with increased pixels value, distance map is built for every layer. The set of PDMs of all binary layers results to a pseudo-distance map with topological properties. In the result, we have a set of 256 image layers with 256 gray values for each layer.

4.2 PDM building algorithm

The PDM building algorithm contains two-scans.

The first scan is realized in the direction from top to bottom and from left to right. For constructing PDM in this direction, every pixel is changed by the following condition:

$$p=\begin{cases}(p_i+f_i), & \text{if } L(p_i+f_i)=L(p) \\ p_i, & \text{if } L(p_i+f_i) \neq L(p),\ i=1..n \\ p, & \text{in other case}\end{cases}$$

where:
p - is a pixel value,
L(p) – level of binary layer in image,
pi – value of pixels from a neighborhood,
fi – value of corresponding point from mask-table for Chamfer metrics (fig. 6),
i – index of element in mask-table,
n - number of elements in mask-table.

	11		11	
11	7	5	7	11
	5	0	5	
11	7	5	7	11
	11		11	

Fig.6 – Chamfer metrics mask

The Chamfer metrics is employed above for the best compromise between computational complexity and quality.

The second scan is realized by the similar condition with direction from bottom to top and from right to left and it finalizes constructing PDM. This results to a pseudo-distance map with basic topological properties of an image (fig. 7). In this case, PDM corresponds to sets of layers of distance maps. Every layer starts from value, which multiples by 256. In the result, pixel value of PDM includes properties of gray-value and distance (fig. 8).

0	0	0	0	0	0	0	0
0	255	255	255	255	255	255	0
0	255	255	255	511	511	255	0
0	255	255	255	511	511	255	0
0	255	255	255	511	511	255	0
0	255	255	255	511	511	255	0
0	255	255	255	255	255	255	0
0	0	0	0	0	0	0	0

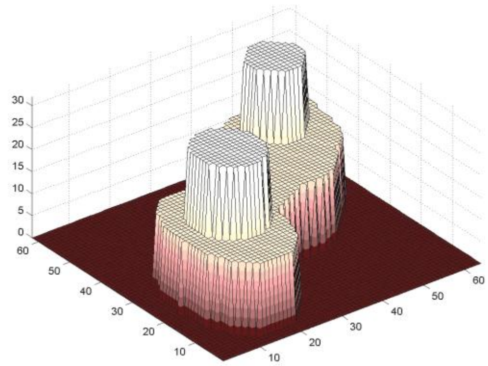
a)

0	0	0	0	0	0	0	0
0	1	1	1	1	1	1	0
0	1	2	2	256	256	1	0
0	1	2	3	256	256	1	0
0	1	2	3	256	256	1	0
0	1	2	2	256	256	1	0
0	1	1	1	1	1	1	0
0	0	0	0	0	0	0	0

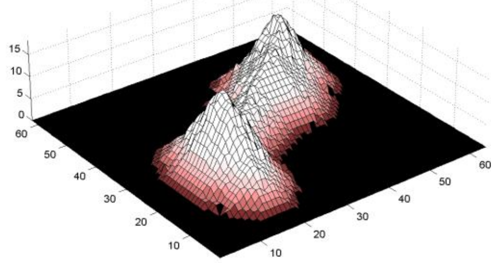
b)

Fig.7 – Stages of pseudo-distance map construction a) A gray-scale image multiplied by 256, and b) its pseudo-distance map.

Example of pseudo-distance map is shown in fig.4.



a)



b)

Fig.8 – An original gray-scale surface (a) and its pseudo-distance map (b).

5. OBJECTS EXTRACTION APPROACH BASED ON LIVE-WIRE PARADIGM

There are a number of interactive approaches of interactive objects extraction. Among those approaches, we inspired on segmentation paradigm live-wire [3] and develop a semi-automatic road extraction technique at remote sensing images based on direction of pseudo-distance maps pixels.

In the proposed method, a user firstly specifies a start point and an end point of the target road on a bitmap image. This is the only step manually performed by the user. The remaining steps will be done by automatically. Then a regular-mesh graph is prepared on a bitmap image by treating every pixel as a node and putting an edge between every pair of adjacent nodes w_{pipj} (fig. 9).

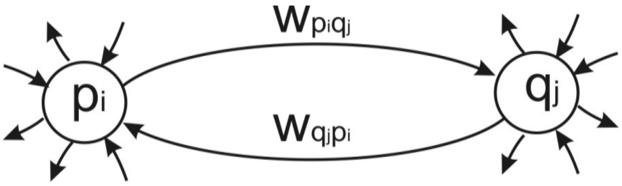


Fig.9 – Graph model.

Now, the elongated object extraction problem can be considered an optimal path problem between the start and the end nodes. Thus, for every edge of the graph, a weight is assigned and total weight accumulated along the path is to be minimized.

The weight is assigned with the proposed pixel value on pseudo-distance map. The simplest definition of the criterion is the magnitude of the topology vector at each pixel on pseudo-distance map surface, because the this vector often becomes small around the skeleton (fig. 10).

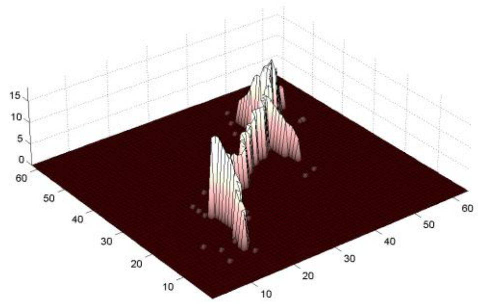


Fig.10 – Gray scale skeleton

Thus, under this criterion, the elongated object extraction task is similar to the foregoing thinning task (i.e., skeletonization task), although road extraction task is organized in an optimization framework and provides connected path as a road. The graph weights w_{pipj} are assigned with following equation:

$$w_{p_i,p_j} = \left|F_{p_i}\right|,$$

Using a dynamic programming (DP)-based algorithm [3], we can obtain the minimum weight path between the start point and the end point efficiently. It is noteworthy that the DP algorithm can provide the minimum weight paths between a fixed start pixel and any other pixels at once.

In other words, by only specifying a start pixel manually, the user can obtain the minimum weight path to any end pixel. In this sense, we refer to the start pixel as “seed point” and refer to the end pixel as “free point”. Figure 11 shows an example of the result of road extraction from a remote sensing image.

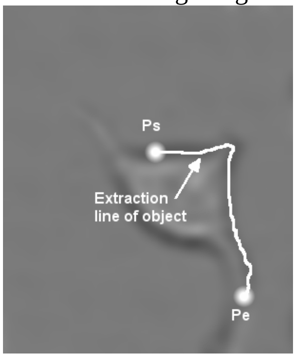


Fig.11 – Result of road extraction. (Ps: seed point. Pe: free point.).

The optimization procedure discussed above can be utilized for boundary detection from color images. The modification from the elongated object extraction task is done only in the criterion. Specifically, if we evaluate “boundariness” at each edge of the mesh-graph, we can obtain the boundary of the image under an optimization framework.

Topology direction of pseudo-distance map pixel can be used for the evaluation of boundariness. The boundariness of the pixel can be evaluated by finding minimum weight paths between a fixed start pixel and any other pixels. The graph weights w_{pipj} are assigned with following equation:

$$w_{p_i,p_j} = -\left|F_{p_i}\right|,$$

Figure 12 shows an experimental result of central line detection of the road from remote sensing image. After the seed and the free points were specified, the boundary between the forest area and the surrounding field area was detected accurately.

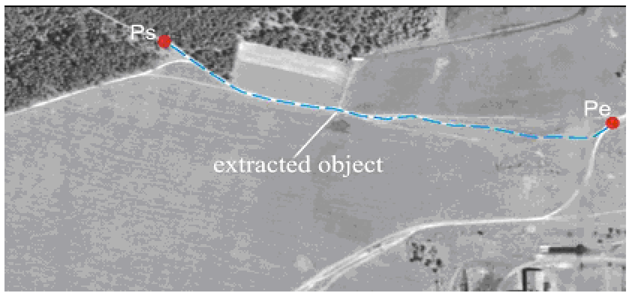


Fig.11 – Gray scale line skeleton on satellite image

6. CONCLUSION

The proposed approaches provide accurate and efficient interactive tools for the extraction of objects from grayscale images. The enhanced interactivity provided by approaches, supports high-quality digitization even in very difficult situations, when automatic systems fail.

This algorithm is based on building a pseudo-distance map and produces a high quality skeleton and topology surface for detection of short path between pixels and is faster that ordinary raster-based algorithms. The algorithm has been wide

The developed approaches are implemented into experimental software and allow to improve the level of automation and efficiency of digital map creation and update. As a result the cost for map and remote sensing images interpretation is also reduced.

7. ACKNOWLEDGEMENT

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