image segmentation,
potential active contours

Łukasz PIĘTA[*], Arkadiusz TOMCZYK[*],
Piotr S. SZCZEPANIAK[*]

ACTIVE CONTOUR SEGMENTATION OF DISJOINT OBJECTS APPLIED TO MEDICAL IMAGES

Potential contours are methods for automatic image analysis. In the present paper, potential contours adapted in the supervised way are used for segmentation of disjoint objects and examined using medical images.

1. INTRODUCTION

Image segmentation is one of the most difficult procedures of image processing [1], and medical images are frequently particularly hard to analyse [2]. In general, there are two approaches to image segmentation, namely exploiting the supposed homogeneity of intensity values within image components and finding borders between image components – exploiting the image inhomogeneities. One of the most promising methods of image segmentation is the active contour approach [3,6-11]. Originally, active contour methods were developed as tools for a low-level image segmentation with the ability to use high-level information. The high-level information is hidden in the given objective function, called energy, which is used for evaluation of the quality of contour generated by the method. The search for optimal contour is performed in an evolution process (optimisation). As shown in [8,9], contours are contextual classifiers of pixels (one part of pixels belongs to the interior and the other one – to the exterior of given contour), and active contours are methods of optimal construction of classifiers.

The paper is composed in the following way. First, the applied segmentation method called potential active contours is briefly presented. Then, the method is examined using artificial images to show its ability for finding many disjoints objects simultaneously. Finally, it is shown how the method can be applied to detection of objects on a cross-section of human skull.

2. POTENTIAL ACTIVE CONTOURS

Potential active contours are based on the well-known potential function method of classification, where the label (class) assigned to the object depends on the distribution of the objects already known and classified [3,10,11]. The contour occurs in points of equal electrostatic field potentials; in other words, the contour is determined by a certain number of control points, which behave like electrically charged objects (field sources). The sources with positive charge can be taken as sources of the object, while the sources of negative charge can be assigned to the background of the image.

Potential active contour possesses the ability to *evolve* with the change of the location of control points, and with modification of parameters of potential functions. The search of optimal contour is performed by optimisation of the performance index *E,* called *energy* in the theory of active contours. In *E,* almost any type of information can be used assuming that we are able to implement this information in the computer-oriented form.

Flexibility of the potential active contours can be improved if one allows the number of control points to change during the optimisation procedure. For example, we can start with a small number of those points and add new ones, if necessary. The rate of misclassification in some area can be the reason for introducing a few new control points. This additional mechanism of changing the contour is called *adaptation* [10].

The search for the optimal contour may be driven in many ways, e.g. by the use of simulated annealing, introduced in [12] or genetic algorithm, which perform global search and do not use gradient. In our work, we apply the former method.

[*] Institute of Computer Science, Technical University of Lodz, ul. Wolczanska 215, 90-924 Lodz, Poland

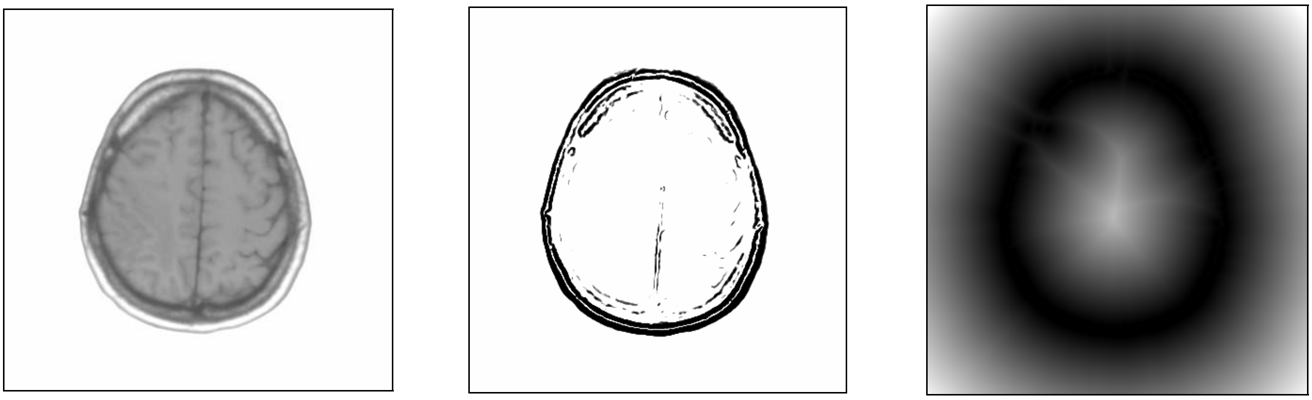


Fig.1. Images of human skull (from left to right): real medical image, detected edges, image after blurring

In the case of greyscale images, the value of the external energy (and consequently of the whole contour energy) depends on the intensity of pixels. The black pixels give the lowest energy, while the white ones – the highest energy value. Therefore, the annealing mechanism which is driven by the external energy, tends to move the contour towards dark pixels. This is the reason why preprocessing of input images is recommended. Within this process the colour of pixels is scaled so that their shades change continuously from white (the colour of background) to black (object). Each pixel obtains a value in a greyscale depending on the distance between the pixel and the nearest black point. The formula is:

$$i(x, y) = 255 \cdot \delta(x, y) / \delta_{\max} \quad (1)$$

where $i(x,y)$ denotes the intensity of light at a pixel specified by coordinates x and y, $\delta(x,y)$ – Euclidean distance between the point (x,y) to the nearest black point of the considered object, δ_{max} – the longest distance $\delta(x,y)$. The blurring of contours obtained in this way enhances the method's efficiency. During segmentation, the analysed image does not change. Thus, it is useful to blur the image during the preparation process and then to use the image prepared in this way, cf. Fig.1.

3. DETECTION OF MANY OBJECTS ON ARTFICIAL AND MEDICAL IMAGES

Let us show a simple disjoint object that consists of two oval shapes (Fig.2). The contour has a constant number of sources, which is big enough for the contour to be adjusted to black part of the image and which consists of two sources located inside the objects.

Table 1. Adjustment of the contour to the disjoint object – the parameters

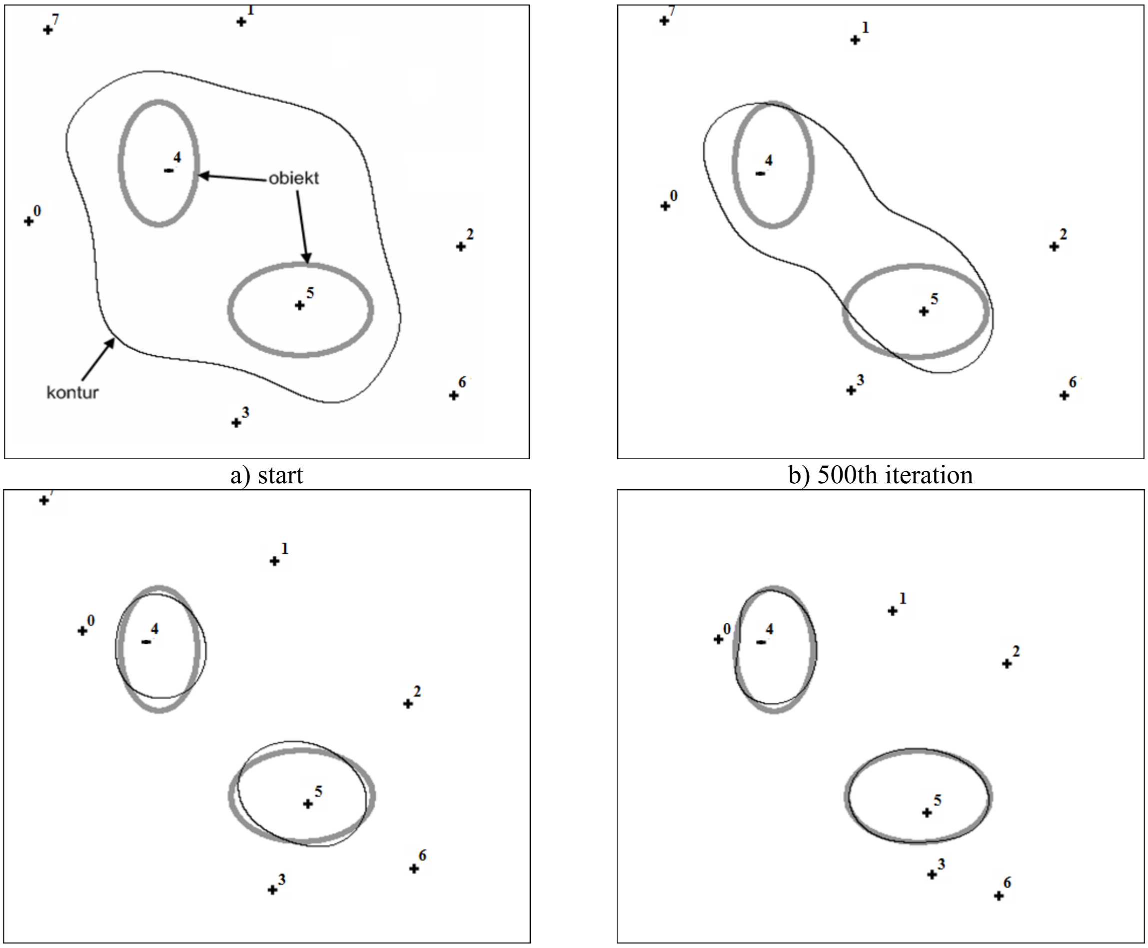
Simulated annealing	
Initial temperature	-
The calculation of initial temperature	YES
The number of iterations needed to calculate the initial temperature	100
Maximal number of iterations	5000
Temperature range	10
Annealing scheme index	0.95
Normalisation	YES
Markov process	YES
Best contour retrieval range	30
Movement generator	
Position disturbance radius	3.0
The force of charge disturbance	0.02
The probability of the change of number of sources	0
Equalisation of chances of the sources	NO

The method turned out to be successful, with no need to add new source. It was not difficult, because the sources of the image had been situated inside the desired objects from the start.

For the next experiment, the same image was used. Only the initial configuration of the contour was changed (Fig.3). This time, one of the sources is situated outside the object. Moreover, the initial contour is bigger. Annealing parameters are the same as in the previous case.

The contour consists of 8 sources, two of which being the sources of the image. Not all sources are visible, as there is not enough space for them in the image. Although the initial configuration is changed, the contour detects the desired objects.

As shown in fig. 4, the initial contour encompasses all objects. Without source no. 8 it would be difficult to adjust the contour to all objects. The source must be situated in the right place before starting the contour's modification, or one must implement a mechanism which enables a new source to be added automatically.



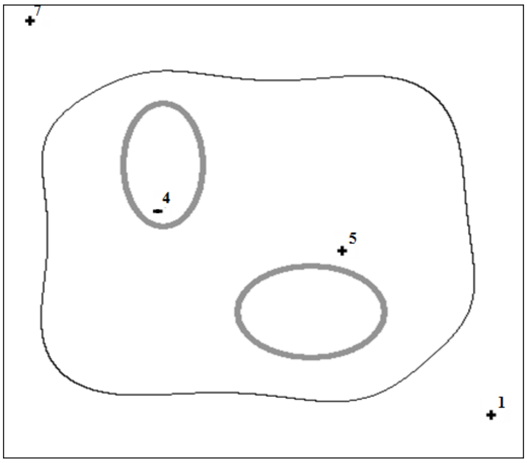
a) start   b) 500th iteration

c) 2000th iteration   d) 5000th iteration, energy = 161,25

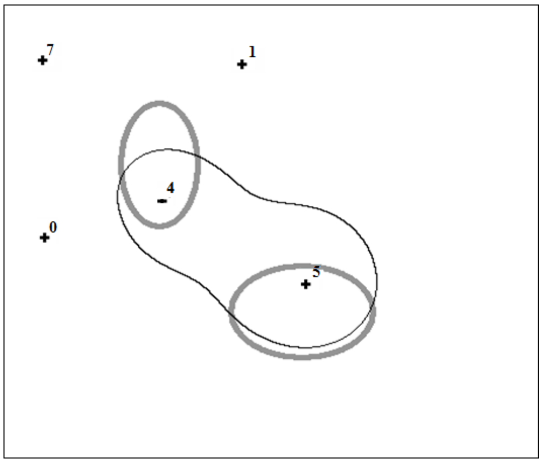
Fig.2. Adjustment of the contour to two disjoint objects

Potential contour can detect a class of shapes that is undetectable by the standard snake or Brownian strings method. Starting with a uniform shape, the contour can be split into smaller ones, all of which, independently of each other, are able to search for a given object in the image. However, the results depend on the choice of initial contour and appropriate experimental matching of parameters. The contour has to be determined by many sources, the number of which has to be at least equal to the number of objects recognisable in the image. The best results are obtained when the movement generator induces slight disturbances (the radius of position disturbance is 2.0 or 3.0, and the force of charge disturbance is not bigger than 0.02), which last long enough, i.e. for at least 3000-5000 steps.

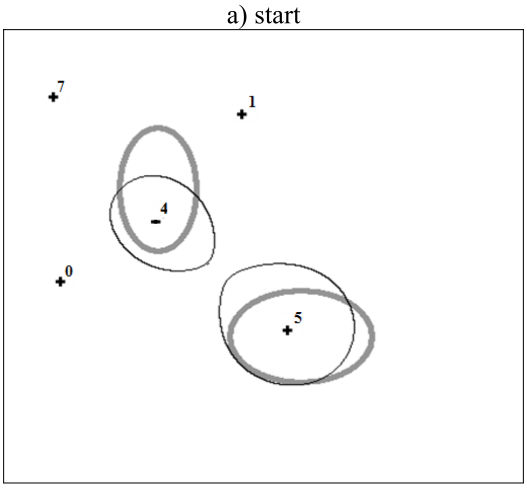
The test was performed using the image that contained three disjoined circles (Fig.4).



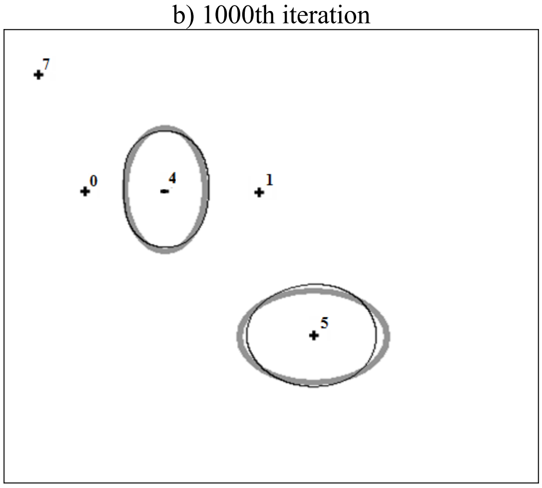
a) start



b) 1000th iteration



c) 1300th iteration



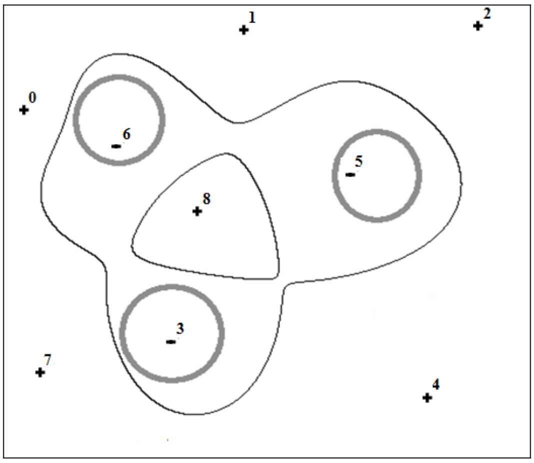
d) 5000th iteration – the end
(Energy = 313,93)

Fig.3. Detection of two disjoint objects

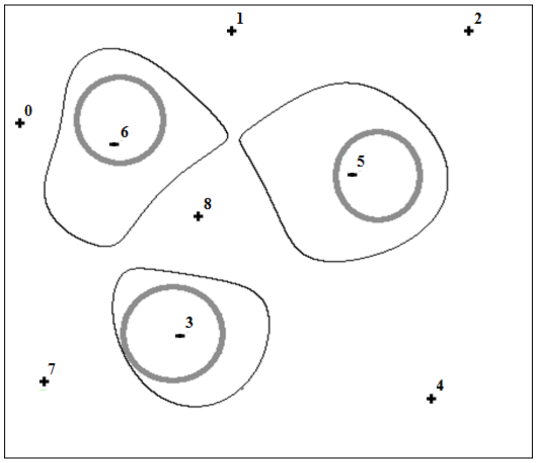
Table 2. Adjustment of the contour to three disjoint circles – the parameters

Simulated annealing	
Initial temperature	-
Calculation of initial temperature	YES
The number of iterations needed to calculate initial temperature	100
Maximal number of iterations	5000
Temperature range	15
Annealing scheme index	0.95
Normalisation	YES
Markov process	YES
Best contour retrieval range	50
Movement generator	
Position disturbance radius	2.0
Force of charge disturbance	0.02
Probability of the change of number of sources	0
Equalisation of chances of the sources	NO

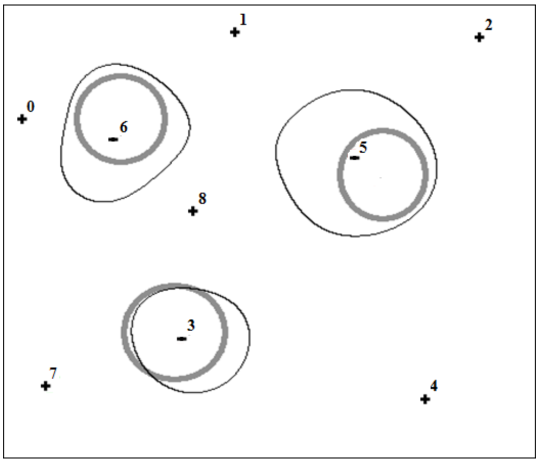
Simultaneous detection of a few real objects can be exemplified by the detection of the eyeballs on a cross-section of human skull. Of course, sequential detection of each eyeball separately is also possible. However, a different mechanism should be applied then - at the start we choose initial contour whose task is to detect a single object with selected features. As shown in Fig.5, the method is able to find many real objects simultaneously.



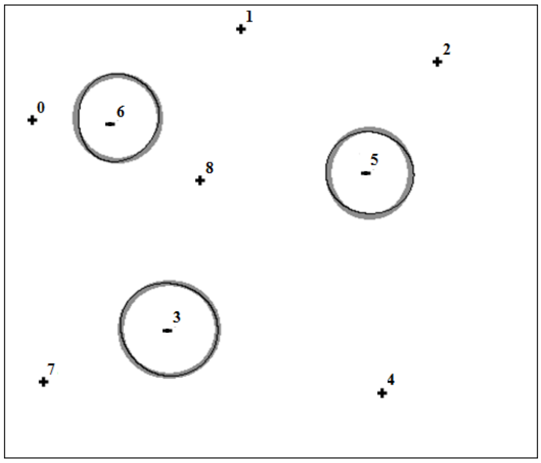
a) Start – contour with a gap near source no. 8



b) Iteration no. 110



c) Iteration no. 300



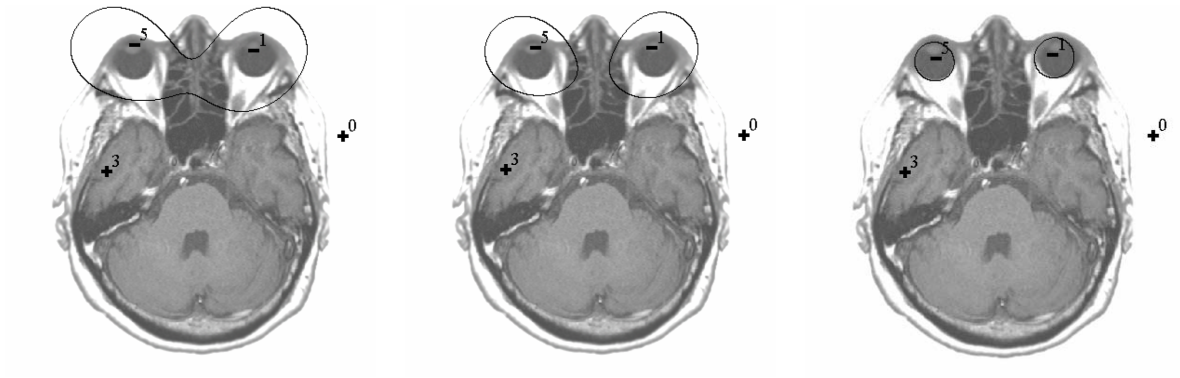
d) The end - iteration no. 5000 (Energy = 109,39)

Fig.4. Simultaneous detection of three disjoint objects

4. SUMMARY

The experiments (a few of which were presented in this paper) prove the usefulness of the potential active contour method in the segmentation of images which contain objects that need to be automatically detected. By means of this method, one is able to successfully perform segmentation and detect a few objects at the same time, starting with only one contour. Moreover, the experiments are characterised by high repeatability of results. It is worth mentioning that potential contour is based on a probabilistic optimisation algorithm. Therefore, the results depend to a large extent on a random factor. The algorithm has to be reiterated a few (or many) times, so that the best solution could be selected. The method is most efficient if preceded by a preparation phase during which the contours are detected and the medical image is blurred.

The active contour methods are a very useful segmentation tool, outrunning the classic methods, because they take into account the information about the brightness of a group of pixels, as well as other characteristics. The potential active contour enables the detection of objects that consist of many parts or those that have gaps, i.e. groups of pixels which do not belong to the object. The contour can also detect concave or open shapes. Moreover, it is possible to detects objects the area or circumference of which has been set. In addition, we can determine the roundness of a given object by means of a roundness coefficient.



a) E=3902 b) E=2916 c) E=562

Fig.5. Simultaneous detection of both eyeballs (a) – Initial contour. (b) – Result obtained after 100 iterations. (c) – Result obtained after 2000 iterations.

Further research on the method in question should focus on enriching the energy of shape (internal energy) with additional mechanisms and geometric coefficients of shape that would allow one to describe different classes of shapes.

ACKNOWLEDGEMENT

This work has been supported by the Ministry of Science and Higher Education, Republic of Poland, under project number N 519007 32/0978; decision no.0978/T02/2007/32.

BIBLIOGRAPHY

[1] GONZALES R. C., WOODS R. E. (2002): Digital Image Processing. Prentice-Hall, Inc.
[2] BANKMAN I. N. (Ed.) (2000): Handbook of Medical Imaging. Processing and Analysis. Academic Press, San Diego.
[3] TOMCZYK A. (2007): Image Segmentation using Adaptive Potential Active Contours. In: Kurzyński, et al. (Eds.): Computer Recognition Systems. Springer-Verlag, Berlin, Heidelberg; 148-155.
[4] SONKA M., HLAVEC V., BOYLE R. (1994): Image Processing. Analysis and Machine Vision. Chapman and Hall, Cambridge.
[5] YONG Y., CHONGXUN Z., PAN L. (2005): A novel Statistical Approach for Segmentation of Single-Channel Brain MRIusing an Improved EM Algorithm. Journal of Appled Computer Science, 13(1), 113-125.
[6] CASELLES V, KIMMEL R., SAPIRO G. (2000): Geodesic Active Contours. Int. Journal of Computer Vision, vol. 22, no. 1, pp. 61-79.
[7] KASS M, WITKIN W., TERZOPOULOS S. (1988): Snakes: Active Contour Models. Int. Journal of Computer Vision, vol. 1, no. 4, pp. 321-333.
[8] TOMCZYK A., SZCZEPANIAK P. S. (2005): On the Relationship between Active Contours and Contextual Classification. In: M.Kurzyński, et al. (Eds.): Computer Recognition Systems. Proceedings of the 4th Int. Conference on Computer Recognition Systems – CORES'05. Springer, Berlin, Heidelberg, New York, pp. 303-310.
[9] TOMCZYK A. (2005): Active Hypercontours and Contextual Classification. Proceedings of the 5th International Conference on Intelligent Systems Design and Applications – ISDA'2005. Wroclaw, Poland, IEEE Computer Society Press, pp.256-261.
[10] TOMCZYK A., SZCZEPANIAK P. S. (2006): Adaptive Potential Active Hypercontours. Proceedings of the 8th International Conference on Artificial Intelligence and Soft Computing – ICAISC'2006. Zakopane, Poland. Springer-Verlag, Berlin, Heidelberg; pp. 692-701.
[11] TOMCZYK A., PIĘTA L., SZCZEPANIAK P. S. (2008): Potential Active Contours – Basic Concepts, Mechanisms and Features. In: E.Pietka, J.Kawa (Eds.): Information Technologies in Biomedicine. ASC 47, Springer-Verlag, Berlin, Heidelberg, 2008; 74-84.
[12] KIRKPATRICK S., GELATT C. D. (1983): Optimization by Simulated Annealing. Science, 220(4598); 671-680.