snakes, active region
medical image segmentation

Paweł TRACZ[1], Piotr S. SZCZEPANIAK[1], Arkadiusz TOMCZYK[1]

APPLICATION OF ACTIVE REGION MODEL FOR DETECTION OF LIVER CANCER

Active region models are methods for automatic image segmentation. The models are able to detect shapes of irregular borders. In the present paper, the method is examined using medical images of liver changed locally by cancer cells.

1. INTRODUCTION

The most difficult procedure of image processing [3] is the task of image segmentation. The popular but well-motivated opinion is that medical images are particularly hard to analyze [1]. One of the most promising methods of image segmentation is the *active contour* approach [2,4,5,7-11]. Originally, *active contour* methods were developed as tools for low-level image segmentation but 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 a contour generated by the method. As shown in [8,10], contours are contextual classifiers of pixels (one part of the pixels belongs to the interior and the other part to the exterior of a given contour) and *active contours* are methods of optimal construction of classifiers. The concept of *active region* model is similar [4]. The difference lies in the evaluation of the quality of the segmentation result. While in the *active contour* methods, it is usually the shape of the contour that is examined, the *active region* models additionally evaluate the statistical parameters of the area inside the examined contour.

The paper is composed in the following way. First, the applied segmentation method, called *active regions,* is briefly presented. Then, the method is examined using liver cancer images. Because of its features, the method can be applied to automatic scanning of liver images. It must be emphasized that further the *active contour* term will be used as a synonym for *snakes* [5] method although the presented approach can be applied to other variants of *active contour* method.

2. ACTIVE REGION MODEL

For evaluation of the classic contour an objective function E, here called energy, is used. Its general form is as follows:

$$E = E_{\text{int}} + E_{img} + E_{\text{con}} = E_{\text{int}} + E_{\text{ext}}$$

(1)

where:

E_{int} - internal energy (e.g. evaluation of the shape),

E_{img} - image energy (e.g. evaluation of the position of the contour on the image),

E_{con} - constraint energy (e.g. additional medical knowledge),

E_{ext} - external energy.

The energy E may also be expressed as a weighted sum of its components.

In the *active region* models, the internal energy is identical to that used in the *active contour* approach [5]:

$$E_{int} = \int_0^1 \frac{\alpha(s)|v'(s)|^2 + \beta(s)|v''(s)|^2}{2} ds$$

(2)

where:

$s \in [0,1]$ - position of the point on the contour,

$v(s) = x(s), y(s)$ - coordinates of the considered point,

$\alpha \in [0,1]$ - elasticity parameter,

$\beta \in [0,1]$ - rigidity parameter.

The classic active contour acts as an edge detector while the active regions are considered as the so called region growers, whose evolution depends on the features of the area inside the contour. The statistical features of the examined area are computed and evaluated. The region energy (an element of external energy) is defined as follows [4]:

$$E_{region} = -\rho \iint_R G(I(x,y)) dx dy$$

(3)

where:

ρ – the parameter which determines the influence of region energy,

R – the region inside the contour are calculated,

$I(x,y)$ – the intensity of a given pixel,

$G(I(x,y))$ – the function that evaluates the goodness of the image data defined as:

$$G(I(x,y)) = 1 - \frac{|I(x,y) - \mu|}{k\sigma}$$

(4)

Region energy forces the contour to circumscribe the region with the expected mean intensity μ and standard deviation σ. The expected parameters can be earlier calculated on the basis of a given seed region, which can be the region inside the initial contour. However, this does not need to be a rule. The k parameter influences the value of G. Its value is problematic and it is chosen experimentally – preferably with the aid of a human expert. Note that G values ranges from minimum value of 0 to maximum value of 1.

Discrete approximation of a region energy (double integral over a region R) can be thought of as the sum of G values for all pixels in the region R. Usually the initial region is located inside the searched object (Fig. 1). However, the method can be successful even in the case where R is located partially outside the object (Fig. 2).
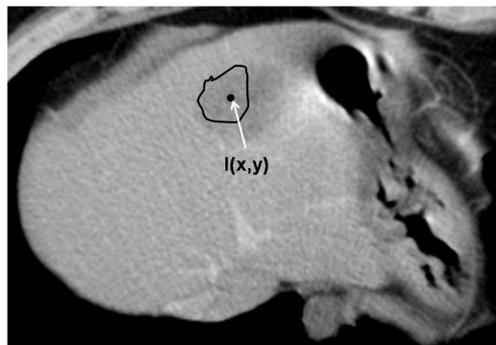

Fig. 1. CT image of the liver with sample examined region R. I denotes pixel intensity which is an argument of the function G.
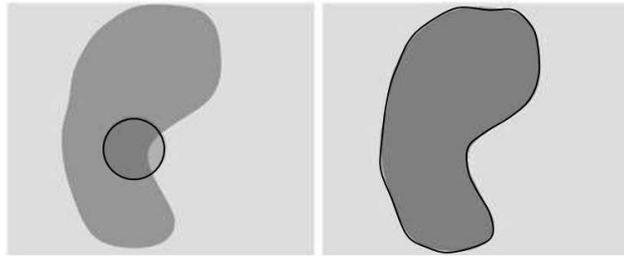
Fig. 2. Initialization – seed region R (circle on the left) and the result of segmentation (on the right).

Roughly speaking, the shape of the region is modified in the directions minimizing the value of the energy. A force that results from the region energy term is always perpendicular to the contour in a given point (Fig. 3). The direction of the force is determined by the influence that the resulting move exerts on the region's assessment (in the sense of statistical properties of the image). This force is called statistical pressure force.
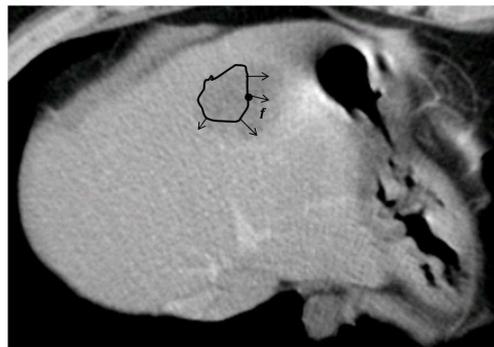

Fig. 3. Illustration of the active region model. The evolution of the contour is illustrated schematically. Black arrows indicate pressure forces.

Resampling of the contour allows it to change the number of its points dynamically during the evolution. It can be necessary for cases where initial contour has too few points to reflect the boundaries (e.g. corners and concavities) of the searched object accurately.

3. AUTOMATIC DETECTION OF LIVER CANCER

The procedure of automatic detection of local heterogeneity of the examined object can consist of the following basic steps:
- removal of the background,
- initialization of the method which is moved systematically or randomly in the area of the object, with the goal to investigate the whole image,
- the use of expert knowledge to decide which of the local heterogeneities detected must be accepted and considered for further investigation.

Fig. 4 and Fig. 5 show exemplary results of application of the *active region* method to segmentation of the area which can be considered as possible liver cancer. In Fig. 6 different stages of contour evolution are presented.
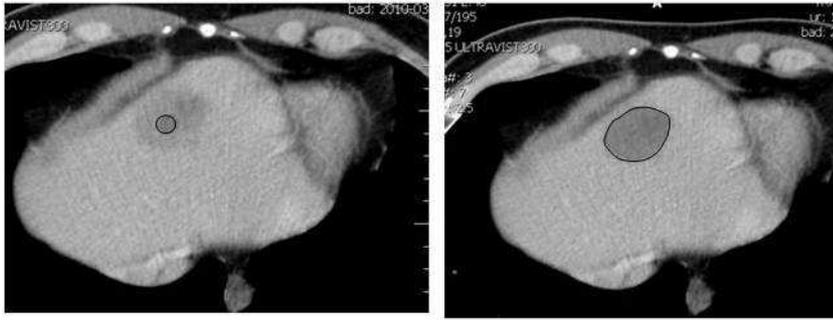
Fig. 4. Seed region R (small circle on the left) and the result – detected area of the liver cancer (on the right).
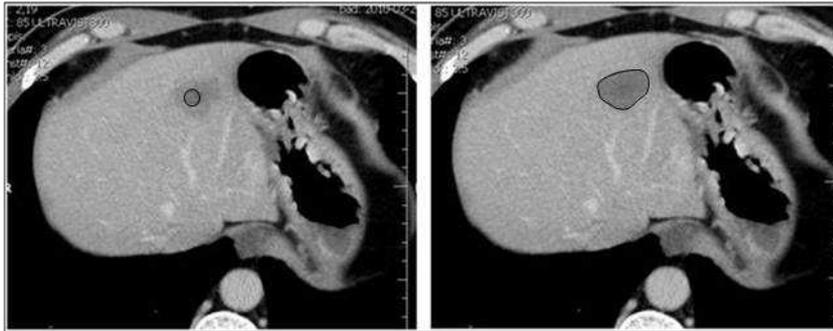

Fig. 5. Seed region R (small circle on the left) and the result – detected area of the liver cancer (on the right).

The quality of the segmentation can only be determined if a set of reference images exists. In the considered case, one needs a number of liver images where the area of liver cancer has

Fig. 6. Different stages of evolution of an *active region* model - starting from a circle (in the top left corner) and leading towards the segmentation result (in the bottom right corner). Seed region presented in Fig. 5 was considered in this case.

been exactly marked by a human expert. Assuming that such a collection exists, the following measure of segmentation quality can be applied [6]:

$$F_\beta = \left(1 + \beta^2\right) \frac{precision \cdot recall}{\beta^2 \, precision + recall}$$

(5)

where β is a non-negative number. Frequently, $\beta = 1$ is used and the measure is called F_1-score or F_1-measure. The *precision* and *recall* are well-known measures which can be defined as follows:

$$precision = \frac{t_p}{t_p + f_p} \quad recall = \frac{t_p}{t_p + f_n}$$

(6)

where:

t_p – *true positive*; the number of image pixels that were classified as belonging to the searched object and in reality do belong to it,

f_p – *false positive*; the number of image pixels that were classified as belonging to the searched object, but in fact do not belong to it,

f_n – *false negative*; the number of image pixels that were wrongly classified as not belonging to the searched object but in reality do belong to it .

In the reported investigations, the reference regions were not available.

4. SUMMARY

The *active region* method is suitable for the task of image segmentation because it carries the information about statistical properties of pixel group inside an examined region. Moreover, similar to other *active contours*, during contour evaluation it can also take into account different features of the contour shape. All this gives the method an advantage over the classical ones. With additional contour resampling, this method can be successfully used for detection of concave and irregular borders.

The practical evaluation performed using a collection of liver images allows one to expect that the method performs well. The investigated medical images of computer tomography have been taken in different conditions and are of different quality. Moreover, the stadium of the diagnosed cancer was different in each case.

Further developments of this method should be directed at enriching shape energy (internal energy) with additional mechanisms and geometric parameters of shapes, which would enable the method to describe different types of shapes and make it less sensitive to the noise.

BIBLIOGRAPHY

[1] BANKMAN I.N., (Ed.), Handbook of Medical Imaging. Processing and Analysis. Academic Press, San Diego, 2000.

[2] CASELLES V, KIMMEL R., SAPIRO G., Geodesic Active Contours. Int. Journal of Computer Vision, Vol. 22, No. 1, 2000, pp. 61-79.

[3] GONZALES R.C., WOODS R.E., Digital Image Processing. Prentice-Hall, Inc., 2002.

[4] IVINS J., PORRILL J., Active Region Models for Segmenting Medical Images. Artificial Intelligence Vision Research Unit, University of Shefield, 1994.

[5] KASS M., WITKIN W., TERZOPOULOS S., Snakes: Active Contour Models. Int. Journal of Computer Vision, Vol. 1, No. 4, 1988, pp. 321-333.

[6] MAKHOUL J., FRANCIS K., SCHWARTZ R., WIESCHEDEL R., Performance measures for information extraction, in: Proceedings of DARPA Broadcast News Workshop, Herndon, VA, 1999.

[7] TOMCZYK A., Image Segmentation using Adaptive Potential Active Contours. in: KURZYŃSKI M., et al. (Eds.), Computer Recognition Systems, Springer-Verlag, Berlin, Heidelberg, 2007, pp. 148-155.

[8] TOMCZYK A., Active Hypercontours and Contextual Classification. Proceedings of the 5th International Conference on Intelligent Systems Design and Applications – ISDA'2005, IEEE Computer Society Press, Wroclaw, Poland, 2005, pp. 256-261.

[9] TOMCZYK A., PIETA L., SZCZEPANIAK P.S., Potential Active Contours – Basic Concepts, Mechanisms and Features, in: PIETKA E., KAWA J., (Eds.), Information Technologies in Biomedicine, ASC 47, Springer-Verlag, Berlin, Heidelberg, 2008, pp. 74-84.

[10] TOMCZYK A., SZCZEPANIAK P.S., On the Relationship between Active Contours and Contextual Classification, in: KURZYŃSKI M., et al. (Eds.), Computer Recognition Systems, Proceedings of the 4th Int. Conference on Computer Recognition Systems – CORES'05, Springer-Verlag, Berlin, Heidelberg, New York, 2005, pp. 303-310.

[11] TOMCZYK A., SZCZEPANIAK P.S., Adaptive Potential Active Hypercontours, Proceedings of the 8th International Conference on Artificial Intelligence and Soft Computing – ICAISC'2006, Zakopane, Poland, Springer-Verlag, Berlin, Heidelberg, 2006, pp. 692-701.