Tomasz RYMARCZYK[1], Paweł TCHÓRZEWSKI[1]

Netrix S.A., Research and Development Center (1)

doi:10.15199/48.2017.01.48

e-Medicus System to Segmentation and Analysis Medical Images

***Abstract**. In this work, there was presented authoring system to exam the medical images by using statistical methods, topological algorithms and computational intelligence methods. These methods are used to identify the properties for the images. There was prepared a special e-Medicus system to machine learning, analysis and compare data and pictures. The solution shows the architecture of the system collecting and analysing data. There was tried to develop an algorithm for level set method (LSM) applied to piecewise constant image segmentation. These algorithms are needed to identify arbitrary number of phases for the segmentation problem. The image segmentation refers to the process of partitioning a digital image into multiple regions. There is typically used to locate objects and boundaries in images.*

***Streszczenie.** W artykule, został przedstawiony autorski system do badania obrazów medycznych przy użyciu metod statystycznych, algorytmów inteligencji obliczeniowej i metod topologicznych. Metody te stosuje się w celu identyfikowania właściwości obrazów. Przygotowano specjalny system e-Medicus do uczenia maszynowego, analizy i porównywania danych i obrazów. Rozwiązanie przedstawia architekturę systemu do gromadzenia i analizy danych. Opracowano algorytmy oparte na metodzie zbiorów poziomicowych (MZP) jako odcinkowo stałej segmentacji obrazu. Algorytmy te są potrzebne do identyfikacji dowolnej liczby faz dla problemu segmentacji, która odnosi się do procesu dzielenia cyfrowego obrazu w różnych regionach. Używana jest zwykle do lokalizacji obiektów i brzegów w obrazach. (**System e-Medicus do segmentacji i analizy obrazów medycznych**).*

Keywords: Electrical Impedance Tomography, Image Analysis, Level Set Method
Słowa kluczowe: tomografia impedancyjna, analiza obrazów, metoda zbiorów poziomicowych

Introduction

In medical clinical research and practice, imaging has become an essential part to diagnose and to study anatomy and function of the human body. The image understanding is the process of actually interpreting regions to figure out what's actually happening in the image [1-9, 19]. It may also include ultimately making some decision for further actions. This paper presents the applications for the medical image segmentations. They are not sensitive to light factor, but very important for them is a patient motion, because it makes many noises and artefacts. Digital X-ray images are represented as two-dimensional matrix. The value of each pixel determines the amount of X-ray radiations. Despite of many advantages of digital radiography (among which reduction X-ray on patient, archiving medical results and enabling the pre-processing by removing noises or improve contrast should be mentioned), no chance remains the fact, that recognizing anomalies in tissue is still the responsibility of the physician. Segmentation presented in this paper is an attempt of such a classification pixel in the image to the appropriate groups to receive separate areas as a result and thus to locate the disease states of soft tissue [13-16].

E-Medicus system consists:

- artificial intelligence algorithms,
- segmentation algorithms
- the framework,
- agents,
- topological algorithms
- databases,
- visualization systems,
- the user interface.

The application can use the following data sources:

- Electrical Impedance Tomography
- DICOM
- Images
- Databases

Electrical impedance tomography

Electrical tomography is an extremely ill-posed inverse problem and high resolution imaging would require unpractically accurate current injection, voltage measurement, low noise levels, and large number of electrodes attached to the boundary of the object [17]. In electrical impedance tomography electrical currents are injected into an object using a set of electrodes attached on the boundary of the object and the resulting electrode potentials are measured. The conductivity of the object is reconstructed as a spatially distributed parameter based on the known currents and measured potentials. Electrical tomography is an imaging technology in which the electrical conductivity of a body is estimated as a spatially distributed parameter based on measurements of electrical currents and potentials at the boundary of the body. In absolute imaging, the conductivity distribution is estimated using a single set of potential measurements, during which the conductivity is modeled. Applications of EIT include monitoring the heart and lungs. Several medical solutions have been proposed including lung function monitoring of intensive care patients. In medicine, the injected currents are small and harmless to the patient. Almost real-time imaging with tens of frames per second can be achieved with devices small enough to reside by the bedside. This makes electrical impedance tomography attractive especially for constant monitoring. Figure 1 presents the idea of the electrical tomography measurement system.

Fig. 1. The idea of the measurement system

Image analysis

The proposed algorithms have been used to real pictures with promising results in the medical images segmentation. The level set methods have natural flexibility to create various shapes. The segmentation gives good results, because the region borders accurately locating the object edges. An increasing numbers of iteration the quantitative results are better but it is not the principle [10-12,18,20]. Although, this algorithm as an example of supervised classification has a learning set, it does not have a classical learning stage, but only a recognition stage, which relies on calculating the distance between classified point and all the points in training set. Then, the smallest distance is selected e.g. there are selected k points which lie closed to the classified point. Finally, this point is included to the group, to which most of its neighbours were included. Authors present also a proposition of application for screening of melanocytic lesions based on level set methods, k-means clustering, canny based edge detection.

The formulation for geometric active contour forces the level set function to be close to a signed distance function. This idea was used to minimization problem in image processing. This topological method tracks the motion of an interface by embedding the interface as the zero level set of the signed distance function. The motion of the interface is matched with the zero level set, and the resulting initial value partial differential equation for the evolution of the level set function. The Bayesian algorithm based on Bayesian's Theorem is another method used to classify objects. Also in this case, the number of classes M is known in advance and is usually fixed by specialist from the area. In turn, the allocating of objects X to classes takes place in an unambiguous manner. Because they can be described with plenty of features, before the applying the algorithm. It must be first selected only those that are significant in terms of the classification. This algorithm, for $j = 1,...,M$, is determined by the formula:

(1) $$P(J = j \mid X = x) = \frac{P(X = x \mid J = j)P(J = j)}{P(X = x)},$$

where: $P(J = j)$ is the probability distribution of classes, $P(X = x \mid J = j)$ is the probability distribution features in these classes and $P(X = x)$ is the probability distribution all features.

The decision function has the form:

$\Psi(x) = i$

(2) $$\Leftrightarrow P(J = i \mid X = x) = \max_{j=1,2,\ldots,M} \frac{1}{N\sqrt{2\pi}} \sum_{i=1}^{N_j} h_j \exp\left\{-\frac{(x - x_{j,i})^2}{2}\right\}$$

for $i = 1,2,\ldots,M$.

Another algorithm is neural networks MLP (Multi Layer Perceptron) to detect changes periapical on digital dental images. There were used a collection of 160 images. In order to recognize changes on periapical dental digital image there was created neural network MLP with eight inputs and one output. Number of inputs describes the number of descriptors, while the number of outputs is determined by obtaining one of two responses: find or not find a change of the apical. The network has one hidden layer. As a result of learning there was achieved 98% effectiveness. The object was described by coefficients: surface area, ratio Feret, sphericity factor, compactness, the beads and shredding. In addition, two other factors: the coefficient of compactness and circularity convex there were used to describe the isolated areas, based upon the convex shells of these areas. The convex hull algorithm there was recovered by Graham. Designated descriptors were subjected to a process of normalization.

Results

Figure 2 shows the original image and the segmentation result on 4 clusters using k-nearest neighbour with euclidean distance. Figure 3 presents the image segmentation by using the level set numerical algorithm (looking for areas with specific characteristics). Figure 4 shows the medical image analysis – Neural Networks: (a) original picture, (b) searched object, (c) segmentation – Bayes algorithm. Hybrid algorithm (the level set method with the fuzzy clustering) was presented in Figure 5.

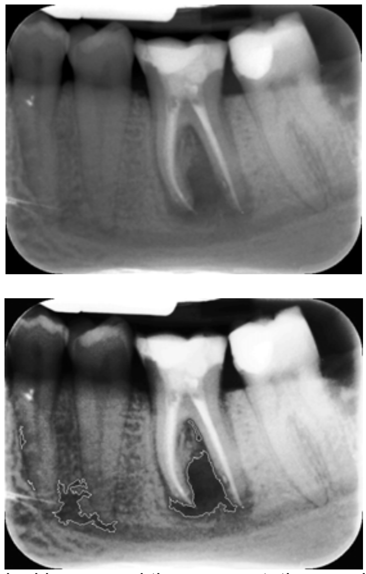


Fig.2. The original image and the segmentation result on 4 clusters using k-nearest neighbour with euclidean distance

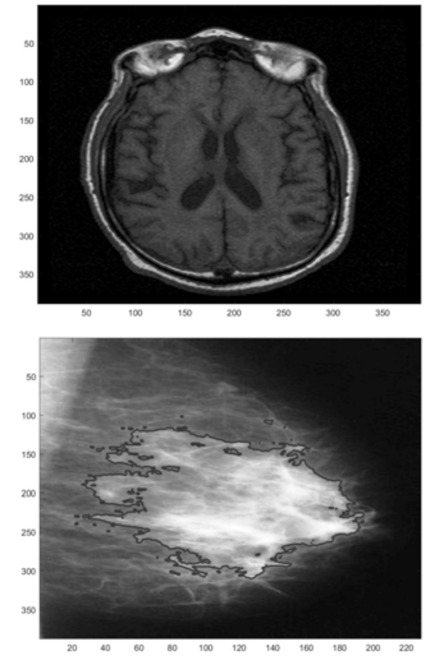


Fig.3. The medical image analysis by the level set method (looking for areas with specific characteristics)

Examples below show lung imaging without a change of the thorax shape. This test case was done to produce a reference case of lung imaging comparing the image reconstruction between the Gauss-Newton method and the level set method. Figure 6, 8 and 10 present the geometrical model lungs and heart with 16 electrodes, where (a) the initial model, (b) reconstructed by Gauss-Newton method, (c) zero level set function, (d) differences between the initial object and the final solution, (e) reconstructed by the level set method. Figure 7, 9 and 11 present the objective function for the tested models.

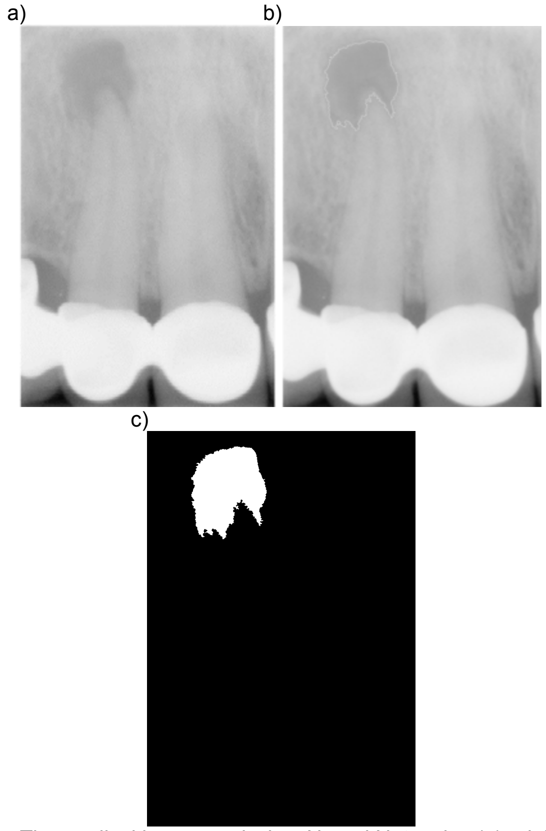


Fig.4. The medical image analysis – Neural Networks: (a) original picture, (b) searched object, (c) segmentation – Bayes algorithm

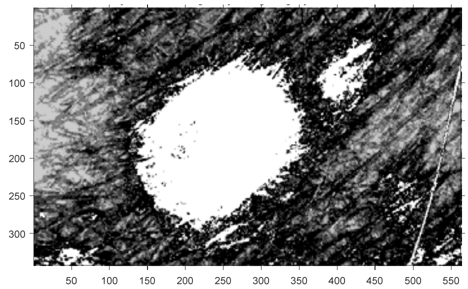
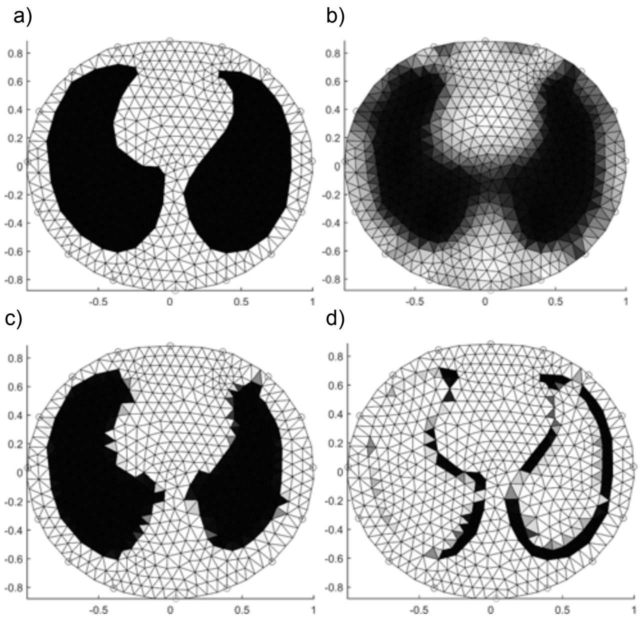


Fig. 5. Hybrid algorithm – LSM and Fuzzy Clustering



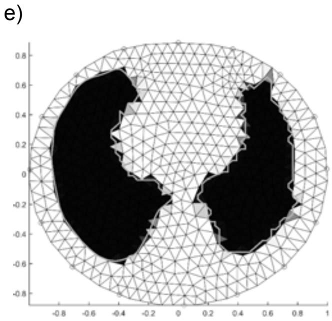


Fig. 6. The geometrical model lungs with 16 electrodes: a) the initial model, b) the image reconstruction by Gauss-Newton method, c) zero level set function, d) differences between the initial object and the final solution, e) the image reconstruction by the level set

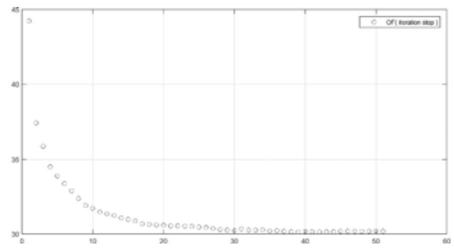


Fig. 7. The objective function for the model in Figure 6

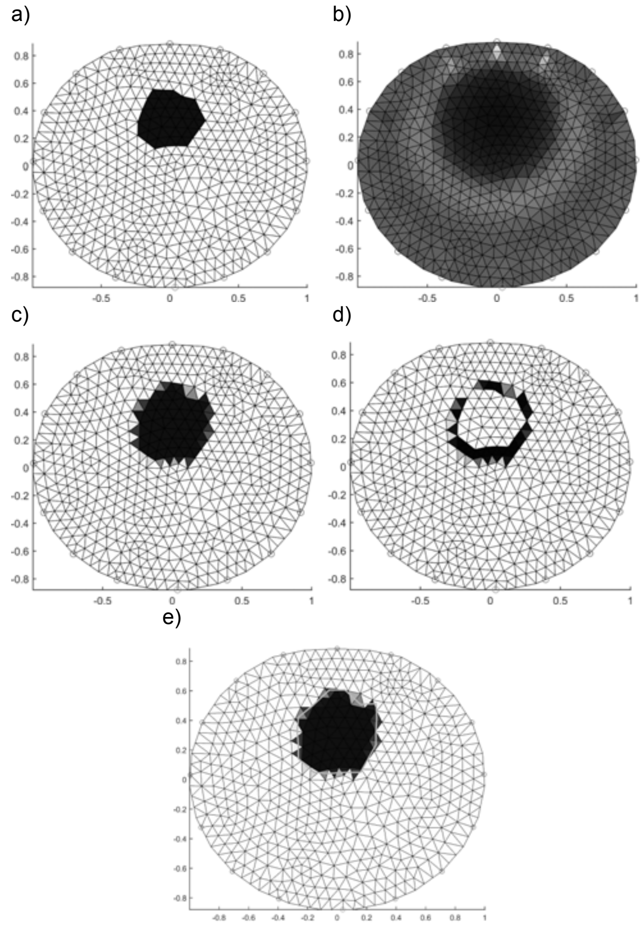


Fig. 8. The geometrical model heart with 16 electrodes: a) the initial model, b) the image reconstruction by Gauss-Newton method, c) zero level set function, d) differences between the initial object and the final solution, e) the image reconstruction by the level set

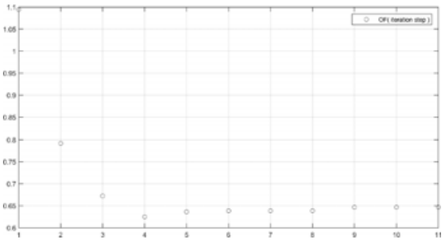


Fig. 9. The objective function for the model in Figure 8

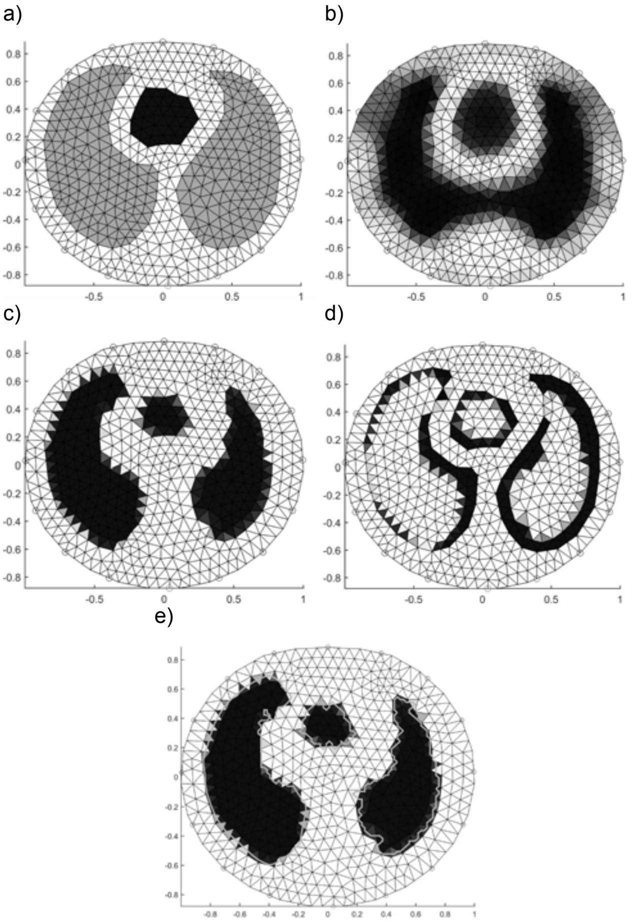


Fig. 10. The geometrical model lungs and heart with 16 electrodes: a) the initial model, b) the image reconstruction by Gauss-Newton method, c) zero level set function, d) differences between the initial object and the final solution, e) the image reconstruction by the level set method

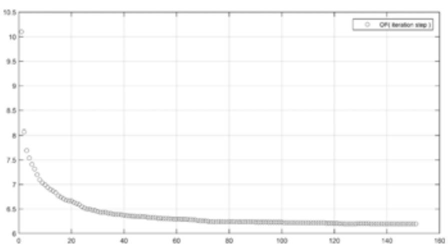


Fig. 11. The objective function for the model in Figure 10

Summary

In medical clinical research and practice, imaging has become an essential part to diagnose and to study anatomy and function of the human body. The proposed algorithms have been used to real pictures with promising results in the medical images segmentation. The level set methods and the artificial algorithms have natural flexibility to create various shapes. The segmentation gives good results, because the region borders accurately locating the object edges. There was proposed also an approach to EIT image reconstruction in cases where the Gauss-Newton and the level set methods were implemented. In the proposed approach, the conductivity after the change is represented as a linear object.

Acknowledgments:

Projekt współfinansowany przez Unię Europejską z Europejskiego Funduszu Regionalnego. Działanie 1.4 – wsparcie projektów celowych. Umowa nr UDA-POIG.01.04.00-06-022/11-00. Nazwa Beneficjenta - Netrix S.A. dawniej Net-Art Paweł Rymarczyk. Tytuł projektu „Stworzenie prototypu aplikacji e-Medicus opartej na funkcjach zbiorów poziomicowych oraz algorytmach inteligencji obliczeniowej" (2012-2015).

***Authors**: dr inż. Tomasz Rymarczyk, Netrix S.A., Research and Development Center, Związkowa 26, 20-148 Lublin, e-mail: tomasz.rymarczyk@netrix.com.pl, mgr. Paweł Tchórzewski, Netrix S.A., Research and Development Center, Związkowa 26, 20-148 Lublin*

REFERENCES

[1] Argenziano G., Soyer P.H., De Giorgi V., Piccolo D.: Interactive atlas of dermatoscopy, EDRA (2000)
[2] Balla-Arabe S., Gao X.: A Fast and Robust Level Set Method for Image Segmentation Using Fuzzy Clustering and Lattice Boltzmann Method, IEEE Trans Cybern. (2013), Jun;43 (3)
[3] Braun R. P., Rabinovitz H. S.: Dermoscopy of pigmented skin lesions, J Am Acad Dermatol (2005); 52:109-21
[4] Gdula A., Rymarczyk T.: Application Computational Algorithms for Analysis of Dental Image (2015), WD 2015
[5] Jajuga K.: Statystyczna teoria rozpoznawania obrazów, PWN, Warszawa (1990)
[6] Johr R.H. Dermoscopy: Alternative melanocytic algorithms-the ABCD rule of dermatoscopy, Menzies scoring method, and 7-point checklist. Clin. DermC.atol. (2002), 05
[7] Kamińska J., Winciorek G.: Dermatologia cyfrowa, Cornetis (2008)
[8] Kurzyński M.: Rozpoznawanie obiektów. Metody statystyczne, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław (1997)
[9] Li C., Kao C., Gore J. C., Ding Z.: Minimization of Region-Scalable Fitting Energy for Image Segmentation, IEEE Trans. Image Processing (2008), vol. 17 (10), pp. 1940-1949
[10] Mumford D., Shah J.: Optimal approximation by piecewise smooth functions and associated variational problems. Comm. Pure Appl. Math. (1989), (42):577–685
[11] Osher S., Fedkiw R.: Level Set Methods and Dynamic Implicit Surfaces, Springer, New York, (2003)
[12] Osher S., Sethian J.A.: Fronts Propagating with Curvature Dependent Speed: Algorithms Based on Hamilton-Jacobi Formulations. Journal of Computational Physics, (1988), 79, 12-49
[13] Ossowski S.: Sieci neuronowe do przetwarzania informacji, Politechnika Warszawska, Warszawa (2006)
[14] Osowski S., Markiewicz T., Kruk M., Kozłowski W.: Metody sztucznej inteligencji do wspomagania diagnostyki patologii tkanek, WAT, Warszawa, (2011)
[15] Rymarczyk T.: Characterization of the shape of unknown objects by inverse numerical methods, Electrical Review (2012), 5/2012/7b
[16] Rymarczyk T., Osior K.: E-Medicus System for Analysis and Images Segmentation (2013), IIPhWD 2013
[17] Rymarczyk T.: New Methods to Determine Moisture Areas by Electrical Impedance Tomography, International Journal of Applied Electromagnetics and Mechanics (2016), vol. 08, 1-9, DOI:10.3233/JAE-16207
[18] Sadowski T, Rymarczyk T.: Method for Segmentation Medical Images of Thorax and Detecting Anomalies (2014), WD2014
[19] Stolz W., Braun-Falco O.: Color atlas of dermatoscopy, Blackwell Science (1994)
[20] Vese L. Chan T.: A new multiphase level set framework for image segmentation via the Mumford and Shah model (2001), CAM Report 01-25, UCLA Math. Dept.