

# Automatic Segmentation of MRI Images in Dynamic Programming Mode

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## Abstract

**Objective:** Purpose of this work was to develop methods contour and volume of areas of interest definition in tomographic images of the breast. **Methods:** The study included images of the breast of 13 patients obtained on an open electronic resource The Breast-MRI-NACT-Pilot image collection. Statistical processing of the data was carried out, the reliability of the results of calculating the volumes of the breast areas was estimated, a visual evaluation of the obtained numerical values was provided – a linear graph. **Result:** A program for automatic determination of breast volume and volume of pathology has been developed and tested. For segmenting areas of the breast, a threshold segmentation and a managed watershed method programs were written in Matlab package. The developed programs allowed to obtain reliable data when processing MRI images of the breast of 13 patients. Results of using Hurst exponent show that in the case of a pathology, the exponent is less than 0.4, and for the tissue without pathology the Hurst index is greater than 0.4. This method is implemented in dynamic programming mode, which allows to adjust the algorithm for a task of examining images. **Conclusion:** The developed methods of definition of contours and calculating volumes allow an automatic quantitative evaluation of the ratio of the volumes of different identified areas of interest in the postprocessing of MRI images. Also, the results have established that it is possible to use the Hurst exponent as an additional tool for identifying pathologies in areas of interest.

**Keywords:** Segmentation- MRI- postprocessing

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## Introduction

The development of universal automatic methods of segmentation of MRI images is an important task of radiation diagnostics. In free access to date, the global network contains much software for image segmentation: AMIDE, Synedra View, UniPACS DICOM viewer, Mango, XmedCon, DICOM Viewer, OsiriX, openDICOM, NET, K-PACS, Aeskulap-DICOM, software package 3Dview (Russia). All these methods are distinguished by the quality of image segmentation and the degree of detail of the allocated zones. Now there is no universal method suitable for solving various segmentation tasks - each of the methods has its advantages and disadvantages (Khaimov and Efimtsev, 2011; Pavlidis, 1982; Suvorov et al., 2013).

For postprocessing processing of MRI images, the manual segmentation method is most often used, in which the operator in manual mode designates the boundaries of each image. This is a time-consuming process that requires considerable time. This approach is used to segment the most important parts of the image and may contain errors caused by subjective errors (Soifer, 1996).

Semi-automatic segmentation is states that the operator denotes objects and, possibly, the boundaries of objects in

one image, and then the segmentation algorithm refines the boundaries of objects.

Automatic segmentation is based on an algorithm that performs segmentation of medical images without human intervention, based on spatial characteristics such as sides and edges, for example.

The most popular methods of image processing for this method are based on calculating the gradient module over the entire area of the digital image by the approximate first derivative. Approximate gradient components are computed with a sliding mask that moves around the entire image. In this case, the image pixels falling into this mask are firstly multiplied with the corresponding mask coefficients, and then summed.

There are several types of masks: Roberts, Prewitt, Sobel, Kirsch, etc. Each mask has its own characteristics. The most convenient mask is the mask of Prewitt, the Roberts mask has a size of 2x2 elements, and the Sobel mask gives the greatest weight to the central finite differences (Khaimov and Efimtsev, 2011).

One method of separating outlines on halftone raster images is the threshold segmentation method, based on the calculation of the norm or the square of the norm of the gradient of the brightness variation of the pixels. If the value of the norm or the square of the norm of the gradient

is greater than the threshold value, then all the elements are selected on the new black and white monochrome matrix. The associated configurations of elements of black color are accepted as the outlines of objects on a monochrome matrix (Zubov and Senyukova, 2015; Magonov and Trofimova, 2012).

Another method of isolating image contours is segmentation is by the controlled watershed method, which consists in representing the image as a certain terrain map, the brightness values are defined as the heights relative to a certain level (Marusina et al., 2015; Bucha and Ablameiko, 2006).

## Materials and Methods

To study various segmentation algorithms were used programs written by authors with Matlab package. For the segmentation were selected 13 breast images (Table 1) scanned with MRI. MRI images were obtained on the open electronic resource The Breast-MRI-NACT-Pilot image collection (The Breast-MRI-NACT-Pilot image collection; Anodina-Andrievskaya et al., 2011).

Software products were analyzed using different algorithms and methods of segmentation to determine the optimal and most universal method of breast segmentation (Marusina et al., 2013; Marusina et al., 2014).

This paper, also, examine fractal analysis using Hurst exponent for identification pathologies, fractal dimension for regular fractals describes the repeatability of geometry, and for irregular it describes repeatability of statistical characteristics when zooming, so it can be another proof of pathology if area (Magonov and Trofimova, 2012; Kuklin, 2008).

## Results

The results of the comparison of software systems are given in Table 2. The results of the segmentation of images with written software systems are given in Figure 1.

The STL-models (Stereolithography-model are files in STL format with a resolution of .stl, obtained by restoring segmented MRI images) were obtained with the managed watershed method and the threshold segmentation method in Matlab package.

The STL model is obtained by the controlled watershed method visually doesn't reliable to contour images of the breast (Table 3). Because of fuzzy boundaries, the capture of nearby tissues occurred in the initial images during segmentation (Suvorov et al., 2013; Tolkovich et al., 2013).

Based on the results of the calculations, a table of MRI images of the breast for 13 patients was generated using

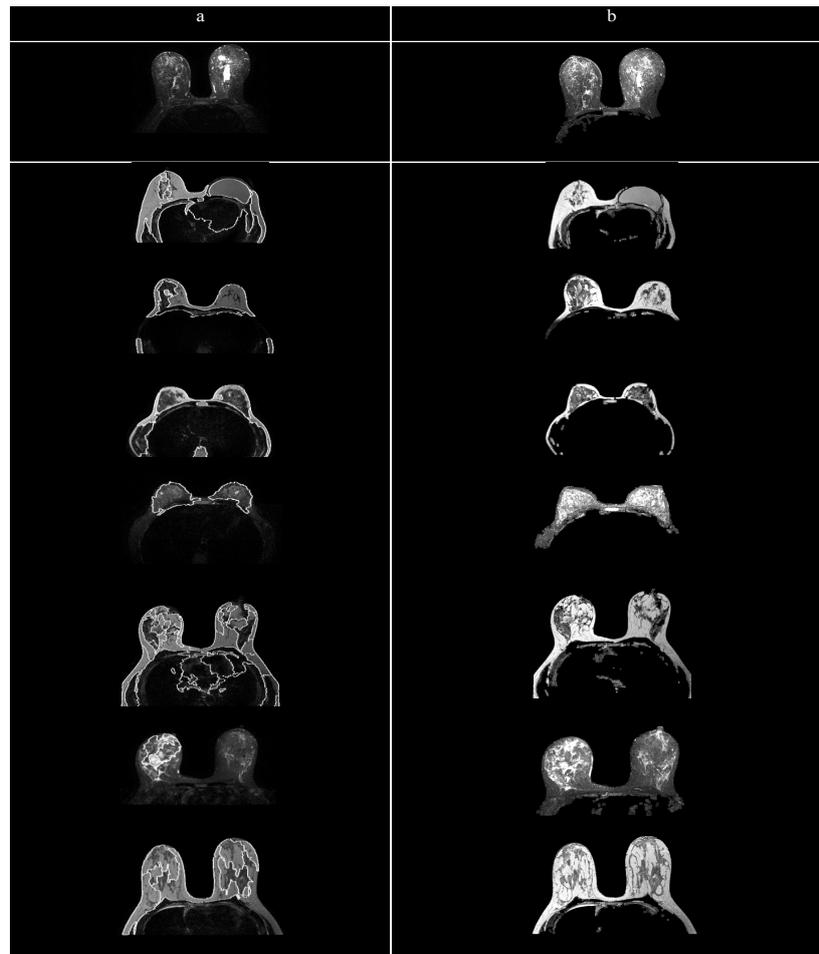


Figure 1. Examples of Segmentation of Images. a) Images that passed automatic segmentation using the managed watershed, which was written in the Matlab software package; b) Images passed automatic segmentation by the threshold segmentation method, which was written in the Matlab software package

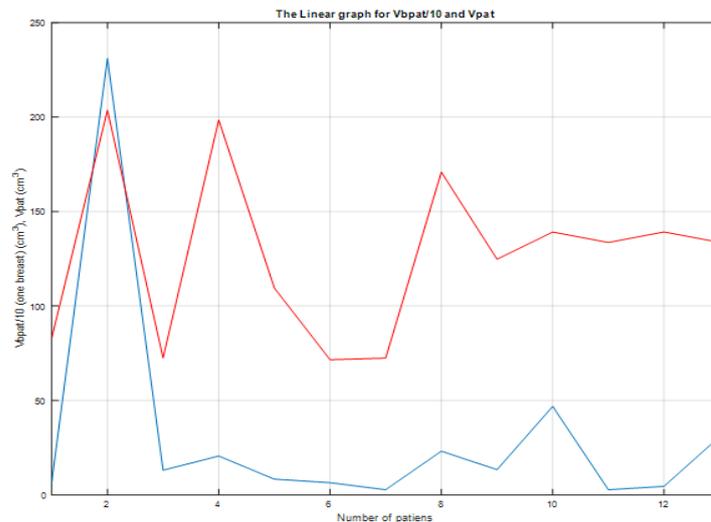


Figure 2. Linear Graph for the Variables Vbpat/10 (One Breast) (cm<sup>3</sup>) and Vpat (cm<sup>3</sup>)

Table 1. Characteristics and Depth of the Pathology

Number of patient	Anatomic localization	Depth of occurrence (cm)	The volume of pathology. (cm <sup>3</sup> )	The presence of metastases
1	Right breast. central quadrant	6.8	7.066	-
2	Left breast. left lower quadrant	5.8	231.114	+
3	Left breast. right lower quadrant	7.4	13.058	-
4	Left breast. right upper quadrant	2.2 (granular formations throughout the breast)	20.593	+
5	Right breast. central quadrant	5.4	8.33	-
6	Right breast. central quadrant	5.8	6.437	-
7	Left breast. right upper quadrant	4.2	2.761	-
8	Right breast. central quadrant	4.0	23.143	+
9	Right breast. right upper quadrant	3.2	13.358	+
10	Right breast. central quadrant	6.9 (3 voxel/slice)	46.887	+
11	Right breast. central quadrant	6.8	2.767	-
12	Both in central quadrants	5.6 (right) 2.6 (left)	4.532 (right) 3.764 (left)	+
13	Left breast. left lower quadrant	5.8	30.86	+

the developed threshold segmentation program. Data for three patients are given in Table 4.

The fractal dimension of the image (D) and the Hurst exponent (H) were chosen as diagnostic features for tomographic imaging. Fractal dimension for regular fractals describes the repeatability of geometry, and for irregular it describes repeatability of statistical characteristics when zooming. The Hurst exponent is a measure of self-similarity. The value of this parameter for most signals in the range  $0 < H < 1$  and for the two-dimensional signal defined by the ratio

$$D = 2 - H \quad (1)$$

The closer the Hurst exponent to 1, the more pronounced the fractal properties. Thus, the value of the Hurst exponent, which lies within the  $0.7 < H < 0.9$  indicates

self-similar process with the long-term dependence, while at  $H < 0.5$  process is unstable (antipersistent), and at  $H = 0.5$  – random process (Marusina et al., 2014).

Results show that in the case of a pathology, the exponent is less than 0.4, and for the tissue without pathology the Hurst index is greater than 0.4 (Table 5). Thus, the indicator of the Hurst exponent makes it possible to identify changes in the zone of interest as a pathology.

#### Estimation of reliability of results

The reliability of static indicators should be understood as the degree to which they correspond to the displayed reality. To evaluate the reliability of the indicators means to determine with what probability it is possible to transfer the results obtained on a sample basis to the entire population.

The data obtained can be used to monitor the dynamics

Table 2. The Results of the Comparison of Software Systems

Functionality and UI Software system	software package written with the Matlab- segmentation by the managed watershed method	software package written with the Matlab - threshold segmentation method
Universality of methods of visualization and processing, absence of narrow specialization on certain systems of the human body	+	+
Image Segmentation	+	+
3D-visualization of data (voxel or polygonal)	+	+
Interactive visualization of data in three projections - axial, coronal and sagittal	-	-
Average image segmentation time	0.5 min.	0.2 min.
Support for the traditional user interface of radiological stations	-	-
Editing of the contour	No	No
The possibility of constructing a model of a segmented section	+	+
Ability to calculate volume	Yes	Yes
Ability to connect software libraries with closed source code	+	+
The ability to be used as a platform for developing programs with closed source code	+	+

Table 3. Results Obtained after Segmentation by the Method of Controlled Watershed and Threshold Segmentation

Method and Threshold Segmentation (Breast)



of changes in pathologies in patients during treatment. The process of processing MRI data presented in the article takes about a minute, which greatly reduces the time of postprocessing image processing. In Figure 2 graphically shows the obtained data on the V<sub>bp</sub> (volume of the breast of the patients) and the V<sub>p</sub> (volume of pathology). The graph shows that the volume of pathologies is from 2.7614 to 231.1136 cm<sup>3</sup>. The linear graph shows that there are categories of volume of breast, so there is a recommendation for image pre-processing: it is necessary to determine the patient's texture size for setting treatment parameters, then cut the breast area so that solid parts of the body do not enter the treatment zone, and artificial implants do not fall through the processing of a series of images without contrast fluid.

This this graph can be useful in the study of subsequent

Table 4. The Results of Calculating the Volumes of the Breast by the Method of Threshold Segmentation

Patient №	1	2	3	4	5	6
Volume						
Breast (two/ one) (cm <sup>3</sup> )	1665 832.5	1450 725	2190 1095	1431 715.5	2784 1391.5	2673 1336.5
Pathology	7.066	13.058	8.33	6.437	46.887	2.767

Table 5. The Comparison of the Fractal Dimension and the Hurst Exponent for Each Patient

N	Fractal dimension (Db)		Domains of physical activity (H)	
	pathology	norm	pathology	norm
1	1.702	1.13	0.298	0.87
2	1.737	1.008	0.263	0.492
3	1.726	1.418	0.274	0.582
4	1.697	1.337	0.303	0.663
5	1.753	1.271	0.247	0.729
6	1.628	1.014	0.372	0.986
7	1.679	1.36	0.321	0.64
8	1.885	1.107	0.115	0.893
9	1.604	1.202	0.396	0.798
10	1.753	1.423	0.247	0.577
11	1.791	1.089	0.209	0.911
12	1.733	1.475	0.267	0.525
13	1.725	1.215	0.275	0.785

patients who have similar parameters, it can be trace in which cell will get numerical values of breast volumes and pathologies. The entry into the same cell can indicate the presence of similar signs of the disease.

### Discussion

Based on the results of the testing of software systems for visualization and processing of medical images, it is proved that the developed program of automatic

determination of volumes allows obtaining reliable results. The statistical analysis of MRI images of 13 patients was carried out with the developed programs. The developed automatic methods for determining contours and volumes allow to obtain quantitative data on the volumes of zones of interest quickly and can be useful in fast postprocessing of medical images.

The study examined the possibility of creating a fractal rapid analysis for the presence of focal lesions. Results of the study indicate significant differences of the fractal dimension and the Hurst exponent. It is established, that the Hurst exponent can be used as an important diagnostic feature.

These methods are implemented in dynamic programming mode, which allows you to adjust the algorithm for a task when examining images, this will save time for medical staff inspecting the pictures manually, as well as improve the effectiveness of screening programs, which will cover a larger number of people. To provide this opportunity it is necessary to test these methods on the bigger sample of patients and compare to traditional methods of diagnosis.

The scientific novelty of the method considered in this article is that the use of new software, as well as the existing one with the Hurst index, as well as the non-standard method for determining fractal dimension, is suggested.

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