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APPLICATION OF REGION GROWING METHOD TO BRAIN TUMOR SEGMENTATION – PRELIMINARY RESULTS

In this article image have been subject to segmentation using Matlab software, i.e. T1 in normal conditions, perfusion images and images after administering a contrast agent. The tumor in images made in normal conditions was difficult to identify. The images obtained after administering the contrast agent confirmed that the homogeneity criterion has been appropriately selected. In perfusion images the pixels of the background were added to the tumor. When the parameters were changed i.e. pixel counter or neighborhood type the method became more efficient; the tumor boundaries were outlined more precisely. The region growing method enables precise tumor detection; however, the selection of an appropriate homogeneity criterion is a prerequisite for correct segmentation.

1. INTRODUCTION

Image processing is a significant tool used to examine anatomical structures. The images obtained during the examination are a valuable source of information for a physician and are divided i.a. into T1- and T2-dependent. These images display the brain structure in the best possible way. In T1-dependent images, the gray matter and tumors are shown in black, while the white matter is shown in gray. It is the other way round in T2-dependent images; the gray matter and tumors are gray, the white matter is black. However, it sometimes happens that the pathological structures are poorly visible or the boundaries of the tumor are difficult to define; this is when the obtained images require computer processing. In article [1], [10], [11] authors draw attention to the problem with precise assessment and localization of the tumor. Additionally in article [3], [11] authors suggest that perfusion images are helpful in diagnostics of tumors, so it is necessary to find a method which allows to display easily and with precision the pathological structures in the images.

Various methods and algorithms are used for image processing; segmentation is one of them. Segmentation is a process of dividing the image into coherent regions that are homogeneous in terms of a selected criterion and related to objects visible in the image. In articles [6], [8] authors point out that homogeneity criteria may be as follows: intensity, its gradients, color or characteristic textures. The outcome of segmentation is an image consisting of points assigned to the same object. In common opinion segmentation is still considered a challenging area for researchers.

In article [5], [9] authors presented Kernelised Weighted C-Means segmentation algorithm. This method was based on the minimisation of an objective function. The results of segmentation were promising but boundaries of the tumor weren't precisely marked. In the images the overflow of pixels

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outside the tumor region was visible. Authors in [7] using gradient methods and polynomial approximation to segmentation obtained satisfactory results but this method is too complicated for the medical practitioners. Articles describing region growing method [2], [4], [6] show that using this method for brain tumor detection is efficient. This method only needs one seed point inside the region of tumor. Segmentation is correct when the seed point is in the center of tumor but to find the center point is a difficult task. Comparing methods described in [5], [9] with [2], [4], [6] and [7] it is concluded that region growing method is the most accurate one and enables the most efficient brain tumor detection but to find a proper seed point and homogeneity criterion is still a problem.

The article describes a region growing method which allows to display easily and with precision the anatomical structures that are poorly visible in the images and pathological areas.

According to the region growing method, points that meet a specific homogeneity criterion are added to one another. The area grows until the homogeneity criterion is met. The most difficult part of the region growing method is to identify an appropriate homogeneity criterion. As soon as the criterion is properly defined, image pixels being elements of the tumor will be added to the pathological region.

In order to determine pixel intensity in the region growing method, it is also necessary to identify the localization of the point, hence the notion of neighborhood must be introduced. Mainly 4-neighborhood and 8-neighborhood are considered. The method requires the seed point to be selected, either manually or from previous processing. Initially, the region subject to growing consists of the seed point, next pixels neighboring with the seed point are picked and the homogeneity criterion is verified. After the pixels are included in the region, pixels adjacent to the pixel included in the region are checked. The region ceases to grow when the pixels no longer comply with the homogeneity criterion and cannot be included in the region. Visual presentation of 4-neighborhood is presented in Fig. 1.

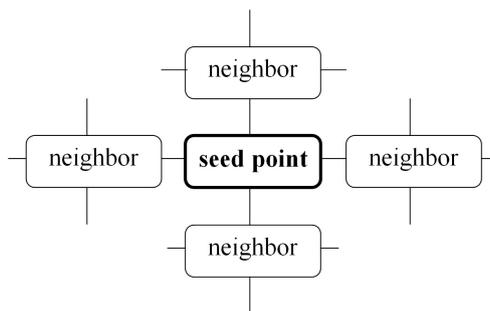


Fig. 1. Visual presentation of 4-neighborhood.

The paper has been divided into several sections: the method, results and conclusions. The section METHOD presents the general operation of the algorithm, as well as the segmentation procedure. The section RESULTS describes the results of the performed tests and compares them with results obtained for changed parameter values. The section CONCLUSIONS focuses on conclusions inferred from the conducted research, as well as elaborates on plans to improve the region growing method in the future.

2. METHOD

T1 images, obtained in various phases of the tests, were used in the analysis. The image series (images that are homogeneous by type in various cross-sections) consisted of T1 images obtained in normal conditions, perfusion images and images obtained after administering the contrast agent. T1 images made in normal conditions visualize the brain structure. The spot where the tumor is present has not been precisely marked. The tumor cannot be seen because the images have been made without the use of the contrast agent. The contrast agent, which permeates the blood-brain barrier, makes the tumor visible. On the other hand, perfusion images (obtained during blood passage examination) make it possible to evaluate brain disorders. As a result of the evaluation, it is possible to determine the level of the disorder, so in which region of the brain the changes are irreversible. After it was discovered that abnormal blood vessels with increased wall permeability appear around the tumor, perfusion tests

became an important tool to pinpoint the spot for biopsy [3], [11]. Additionally, as has been mentioned before, the contrast agent makes it possible to see brain structures with a very clear outline of the tumor in the images. T1 images in normal conditions (A), examination with a contrast agent (B) and during a perfusion examination (C) have been visualized in Fig. 2.

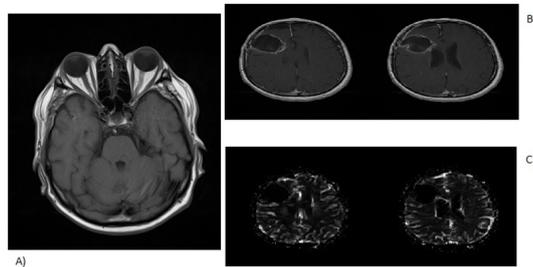


Fig. 2. T1 images in normal conditions (A), after administering the contrast agent (B), after a perfusion examination (C).

After administering the contrast agent, the image reveals the spot with the tumor, yet it is impossible to precisely define its boundaries. The boundaries of the tumor must be precisely visible for the neurosurgeon to remove it in whole, without interfering with the healthy brain structures and without leaving any part of the tumor inside the brain.

In order to define tumor boundaries, image segmentation with the use of the region growing method has been applied. The general algorithm has been shown in Fig. 3.

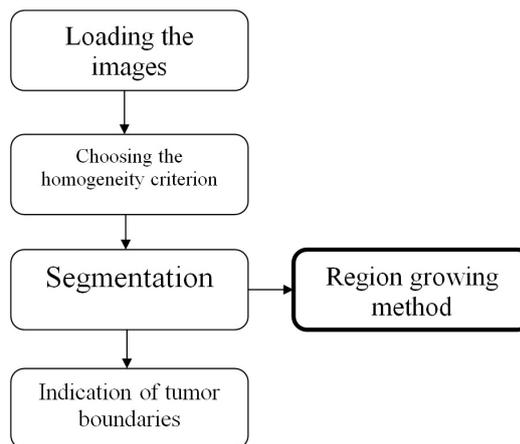


Fig. 3. The general algorithm applied during segmentation.

All image types have been subject to segmentation in the Matlab environment, i.e. T1 in normal conditions, perfusion images and images after administering a contrast agent. The homogeneity criterion was calculated based on seed points, previously provided by the user. The process of determining the homogeneity criterion and adding pixels that meet the criterion consists of several stages:

- selecting the image type and displaying a single cross-section;
- indicating the seed point with a marker, at the spot where the tumor is potentially present;
- displaying the next cross-sections and indicating the seed point with a marker, at the spot where the tumor is potentially present;
- defining the homogeneity criterion through the difference in intensity versus the seed point and versus the average intensity of the region;
- checking pixels with similar intensity and assigning them to the region of pixels complying with the homogeneity criterion.

The segmentation algorithm has been designed in such a way that the user may choose the type of images and cross-sections to undergo segmentation. Owing to the fact that the homogeneity criterion is selected on the basis of calculation of seed points, the user ought to choose images where the tumor is at

least partially visible. After the seed points are selected and the calculations are made by the algorithm, images with tumor boundaries are displayed. There is a frame along the boundaries; pixels that meet the homogeneity criteria are inside the frame. Fig. 4A exemplifies a correctly segmented tumor.

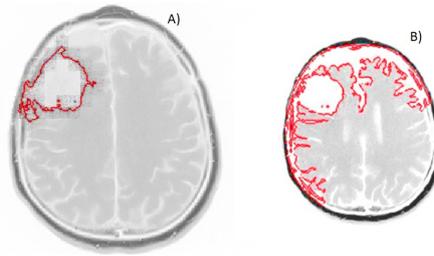


Fig. 4. A correctly segmented tumor (A), "Overflow" of pixels outside the tumor region (B).

As a result of an incorrectly selected homogeneity criterion, region growing passes the tumor boundaries and pixels of the healthy region merge with those of the anomalous region. This so-called "overflow phenomenon" is shown in Fig. 4B.

Fig. 5 demonstrates the block diagram illustrating the way in which the region growing method operates. After the image is loaded, the homogeneity criterion, the intensity difference and neighborhood type are defined. When the homogeneity *criterion* is defined, value "1" means the intensity difference versus the seed point, "2" stands for the intensity difference versus the average intensity of the region. The *intensity* difference is selected experimentally and the user may change the parameter values of the vector. 4-neighborhood has been used to define the neighborhood type (*type_neighborhood*).

Another stage of the algorithm's operation is to define the seed point and the number of images in a series to be segmented and then to identify the seed points and extreme intensity values, i.e. the minimum and maximum values. The *img* variable in the block diagram is the double representation of the image, which is needed for the calculations. Vector $[w, h]$ determines width and height of the image. *MinInt* and *MaxInt* parameters included in algorithm are minimum and maximum values of intensity in image *img*. *Average_intensity* is a vector of average intensity in loaded image. *Pixels* in algorithm is a counter of pixels in segmentation region. After initializing the parameters that are necessary for segmentation, such as the pixel counter or neighborhood type, the region growing method is put in operation. The method checks the point that is located closest to the seed point. A check is made if the point is analyzed for the first time and if it meets the homogeneity criterion. After the point is checked and it turns out that it has met the homogeneity criterion, it is added to the region of the verified object. The function $abs(criter(pkt) - intens)$ checks if the pixels comply with the homogeneity criterion. The next neighboring point is checked and, subject to positive verification, merged with the region complying with the criteria. The algorithm is performed until all neighboring points are checked, so all points in the neighborhood of the seed point are verified. The points failing to meet the homogeneity criterion are not added to the region. After the verification process is completed, the images are displayed with the marked segmented region.

3. RESULTS

All the described types of T1 images underwent segmentation. Varying results were obtained for each type, which is connected with the intensity of pixels in various cross-sections of the images. Cross-sections of images where only parts of the tumor could be seen, underwent segmentation several times in order to verify the correctness of the algorithm. After loading the images and initializing the program, images representing a given type were displayed one by one. Seed points were marked on the images. After selecting the seed points, the images underwent segmentation. Parameter values, such as intensity, pixel counter and neighborhood type were also changed within the framework of the tests (i.e. 4-neighborhood was switched to 8-neighborhood). Segmentation results for specific images are shown below.

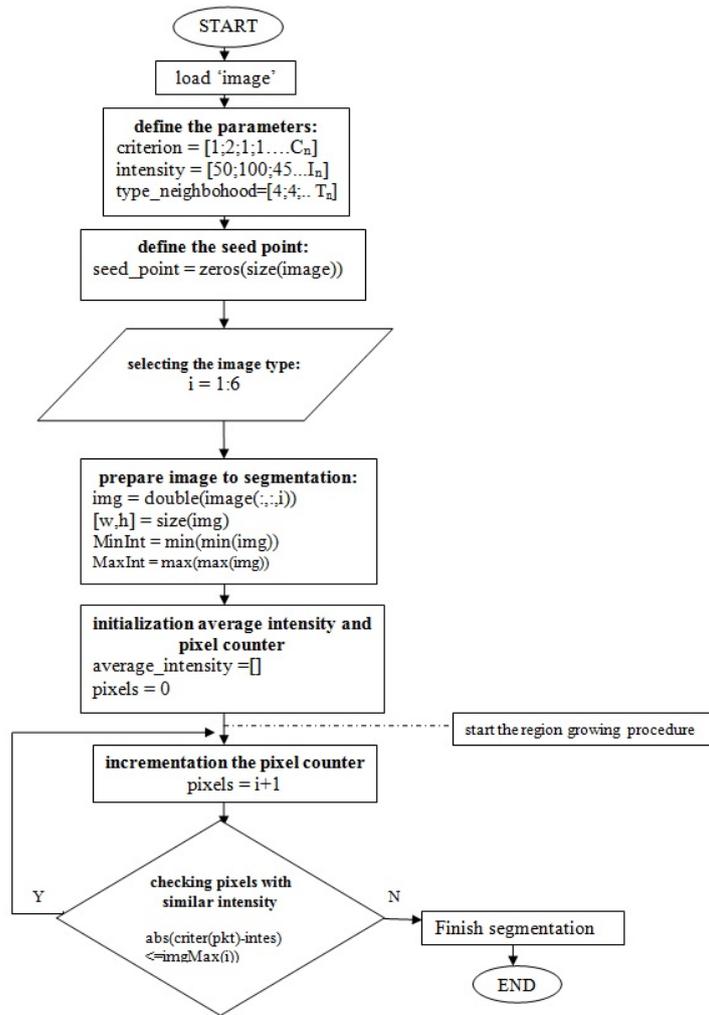


Fig. 5. Algorithm of the region growing method.

3.1. NORMAL IMAGES

Based on T1 images obtained in normal conditions, it is difficult to select the homogeneity criterion owing to similar levels of pixel intensity. Manual indication of the seed point with a marker is imprecise in this case. Pixels not meeting the homogeneity criterion were added to the tumor region during processing. The tumor in T1 images made in normal conditions was difficult to identify. The end result of the algorithm is the appearance of a frame with points that might be parts of the tumor, although without clear marking of the boundaries, Fig.6. Segmentation by means of the region growing method does not yield satisfactory results for these images. The appearance of a frame with points that might be elements of the tumor, may only indicate the potential region where the tumor is present, which hinders the analysis of the images.

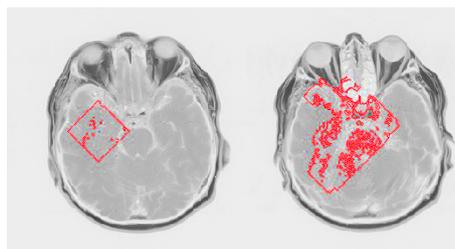


Fig. 6. Segmentation of normal T1 images.

Additionally was performed segmentation of images following a change in parameter values. After the neighborhood type was changed to 8-neighborhood and the criterion to the value of 2 and following the intensity change, similar results were obtained to results achieved during segmentation for standard values. Comparable results (Fig. 7) were obtained for various configurations, so for the change of neighborhood type and standard settings for the remaining parameters. The method becomes more efficient and the tumor boundaries are outlined more precisely when the parameters are individually tuned for each image

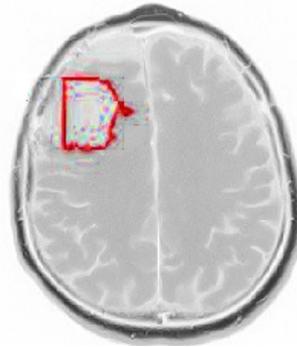


Fig. 7. Segmentation of normal T1 images following a change of the parameters.

3.2. AFTER ADMINISTERING THE CONTRAST AGENT

The images obtained after administering the contrast agent confirm that the homogeneity criterion has been appropriately selected. We can see the region where the tumor is present and the region growing method has made it possible to mark the boundaries of the tumor, Fig. 8. In order to verify the correctness of the method for images after administering the contract agent, segmentation was performed several times for this same images from series. Segmentation was successful for all test rounds. The tumor region was isolated and its boundaries were precisely marked.

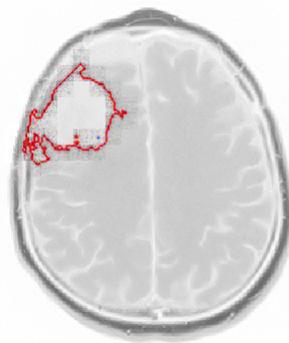


Fig. 8. Image segmentation after administering the contrast agent.

By changing parameter values for the images after administering the contrast agent, the tumor is outlined less precisely than in the case of segmentation for standard parameter values. The obtained result indicates that 4-neighborhood should be applied in segmentation of image after administering the contrast agent because the results are the most precise then, Fig. 9.

3.3. PERFUSION IMAGES

Structures through which blood does not pass cannot be seen in perfusion images and therefore the boundaries between the brain and the cranium are not marked in the images. Points outside the cranium

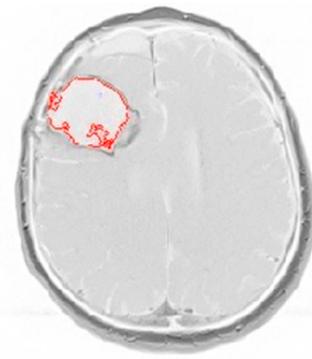


Fig. 9. Image segmentation after administering the contrast agent following a change of the parameters.

are also isolated during segmentation of perfusion images with the proposed algorithm; in such a case, the pixels of the background are added to the tumor, Fig. 10. This is the so-called "overflow"; perfusion images after segmentation by means of the region growing method proposed in this work fail to yield the desired results.

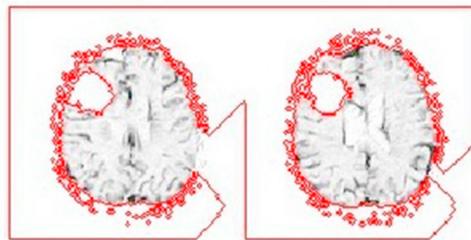


Fig. 10. Segmentation of perfusion images.

After changing the neighborhood type to 8-neighborhood, the pixel counter to the value of 2 and following the intensity change, similar results were obtained to those achieved during segmentation with standard values. The neighboring cross-sections are not joined like for standard values, yet "pixel overflow" outside the tumor region continues to occur, Fig. 11.

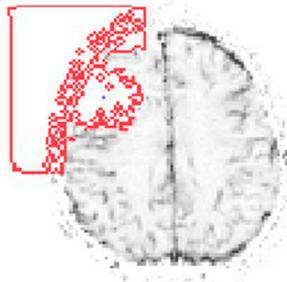


Fig. 11. Segmentation of perfusion images following a change of the parameters.

4. CONCLUSIONS

The region growing method enables precise tumor segmentation; however, the selection of an appropriate homogeneity criterion is a prerequisite for correct segmentation. It is rather complex to use the proposed algorithm to isolate specific regions from perfusion images. It is best to use images obtained immediately after administering the contrast agent for the applied segmentation algorithm. After administering the contrast agent, images are obtained with the marked tumor structure. Owing to the segmentation algorithm it is possible to mark tumor boundaries in the images. The algorithm

using the region growing method works relatively fast; the precision level of the method depends on the correctly chosen homogeneity criterion and on the quality of the images. Novelty of this method is that the seed point does not have to be placed inside the center of tumor region. It is enough that the seed point is chosen inside the edge of the tumor and the homogeneity criterion will be selected. Thanks to easier selection of seed point the correctly chosen homogeneity criterion is more effective than in cited articles. The region growing algorithm is a simple but modern method to the medical practitioners.

There are plans to improve the effectiveness of the method in the future, i.a. through automatic selection of the seed point. A manually marked seed point may be incorrectly indicated by the user, manual marking also requires a lot of precision. The planned software-assisted selection of the seed point may contribute to improved operation of the algorithm.

Moreover, it is possible to perform tests related to the analysis of the same cross-section of an image, but of a different type, for example a perfusion image may be put on top of an image obtained after administering the contrast agent. Following a simultaneous analysis of two different images, we can obtain the aggregate information contained in them and use the information as a point of departure to define the homogeneity criterion for a given area in two images at the same time. It is also necessary to put the images precisely one on top of the other (centering) so that cranium borders overlap in all images.

The obtained results are satisfactory, although further research must be conducted to increase the operational precision of the algorithm.

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