VOL.4, NO.1, APRIL 2013

elektrorevue
ISSN 1213 - 1539

Pathological Area Detection in MR Images of Brain

Pavel Dvořák[1,2], Walter G. Kropatsch[3], Karel Bartušek[2]

[1]Dept. of Telecommunications, Faculty of Electrical Engineering and Communication, Brno University of Technology, Technicka 12, 612 00 Brno, Czech Republic
Email: pavel.dvorak@phd.feec.vutbr.cz

[2]Institute of Scientific Instruments of the ASCR, v.v.i., Kralovopolska 147, 612 64 Brno, Czech Republic
Email: {pdvorak, bar}@isibrno.cz

[3]Pattern Recognition and Image Processing Group, Institute of Computer Graphics and Algorithms, Faculty of Informatics, Vienna University of Technology, Favoritenstr. 9/186-3, A-1040 Vienna, Austria
Email: krw@prip.tuwien.ac.at

Abstract *– This paper focuses on automatic locating of pathological areas in brain and its extraction. The knowledge of properties of healthy brains are used for locating the approximate position of a pathological area. These areas are found as parts of the brain breaking the left-right symmetry. This method works for axial and coronal slices and it was tested on T2-weighted images and FLAIR images in both planes.*

1 Introduction

The detection of brain tumors is generally a more complex task than the detection of any other image object. Pattern recognition usually relies on the shape of the required objects. But the tumor shape varies in each case so other properties have to be used. The general properties of healthy brain are widely used as a prior-knowledge. One of them is the probability of tissues locations using probability brain atlas, which is used e.g. in [1]. Another widely used knowledge, which is used in this article, is the approximate left-right symmetry of healthy brain. This approach is also used e.g. in [2] [3] [4]. Areas that break this symmetry are most likely parts of a tumor.

There are also many other methods used for tumor extraction, but they usually rely on machine learning algorithms such as SVM used e.g. in [5]. For this purpose, many algorithms need to have patient-specific training dataset. This makes the method more demanding for the experts. These methods usually rely on other contrast images, such as T1-weighted contrast enhanced images [6]. Fully automatic exact segmentation of the tumor is still an unsolved problem, as the accurate image segmentation itself.

The method proposed in this work is fully automatic and it is used only for the detection of the brain tumor location for subsequent segmentation, which will be the aim of future work.

The big advantage of the symmetry approach is that the process does not need any intensity normalization, human work etc. The only step that needs to be done is the symmetry axis detection. Another advantage is its independence on the type of the tumor. It can correctly detect anomalies in images containing a tumor, a tumor with edema or only an edema, which is an abnormal accumulation of the fluid around the tumor and is present only with particular types of tumors.

2 Proposed method

The proposed method is based on our previous work [8]. The input of the whole process is a stand-alone 2D magnetic resonance image containing a tumor. It means that no neighbor slices are considered. This method works for both axial and coronal planes, where the approximate symmetry for healthy brains exist. At first, the image is filtered by Wiener filter [7], which suppresses the noise. This causes the particular tissues to be more compact.

The tumor extraction process consists of several steps. The first step is the extraction of skull followed by cutting the image. In this cut image, the asymmetric parts are detected and then the decision which half contains the tumor is made. The detection of the symmetry axis is skipped because the input data were aligned in previous processing. The only assumption of proposed method is a vertically aligned head. For the purpose of detecting the symmetry axis, the method described in [9] or [10] could be used. Addition of this or similar method as a preprocessing step will be one of the aims of the future work.

2.1 Skull Extraction

Since it was demonstrated in previous work [8] that the accuracy of comparing the mean of detected regions reach slightly better results that comparing them to the rest of the brain, the first way of tumor locating is used in this work. This simplifies the brain extraction process into the skull extraction process.

The extraction of skull is based on technique mentioned in [11] and is done by the well-known method called Active

elektrorevue
ISSN 1213 - 1539

contour, or Snakes [12]. At first, the points of background are filtered out. T2-weighted medical images in many cases do not contain noise in background. In these cases, the background could be filtered out by simple thresholding, where the threshold would be set to the value of the top-left pixel. In case of noise presence, the threshold has to be computed. Since the level of noise is much lower than the signal of tissues, the computation is not complicated. The threshold is computed as an average value from the region multiplied by two, where no tissue is present. Since the tissues cannot be present in top corners of the image, the threshold is computed from these parts. The image is than thresholded and the segmentation algorithm is executed with this initial mask. Even though some points of background could remain in the initial mask, they are eliminated by segmentation.

The results of the segmentation algorithm is not only the border of the skull, but also the border of the brain and in some cases of coronal slices, some parts of the neck can be extracted as separated regions. For this reason, holes of all regions are filled and only the largest region is extracted. The smallest rectangle surrounding the head is then extracted. Assuming that the head is approximately symmetric, the symmetry axes is set to be parallel to the vertical axis and to divide the detected rectangle into two parts of the same size. The operation of logical conjunction is performed with this segment and its symmetric flipped image. This causes that points that are not on one side will not be considered also on the other side.

The resulting mask is then applied to this filtered image followed by cutting the image because in parts outside the mask, the symmetry does not need to be checked.

Even if the mask is not so precise, the future results are not so influenced because the asymmetries caused by tumors are much higher.

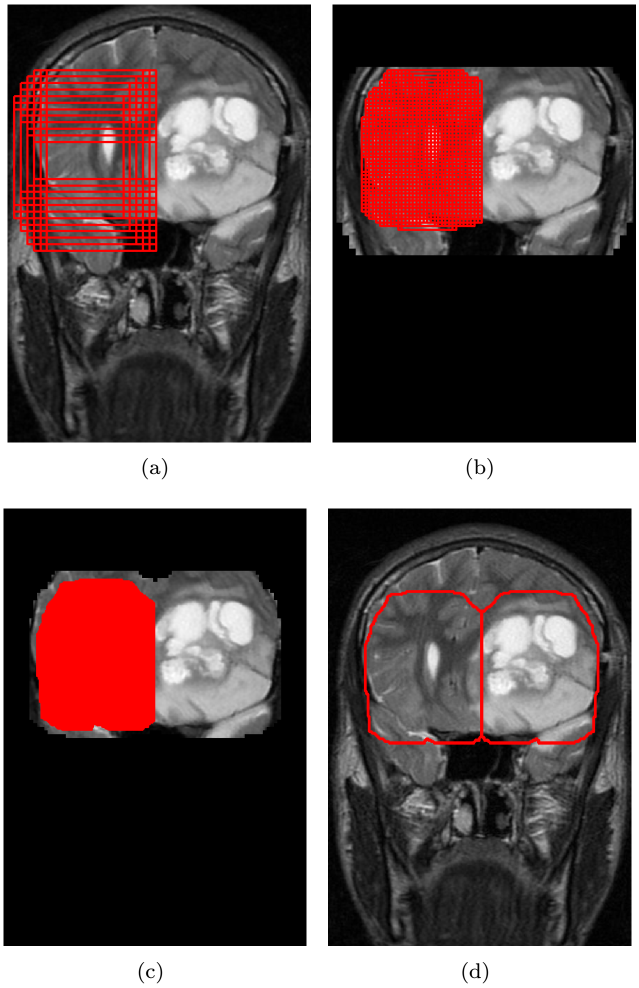

Figure 1: Asymmetry detection: (a) the first step, (b) the second step, (c) the third step, (d) the result of the asymmetry detection.

2.2 Asymmetry detection

The process of asymmetry detection remains the same as in previous work [8] and is based on multi resolution image analysis [13]. At first, the input image is divided into two approximately symmetric halves. Assuming that the head is not rotated and the skull is approximately symmetric, the symmetry axis is parallel to vertical axis and divide the image of detected brain into two parts of the same size.

The algorithm goes through both halves symmetrically by a square block. The size of the block is computed from the size of the image. The step size is smaller than the block size to ensure the overlapping of particular areas. These areas are compared with its opposite symmetric part. Normalized histograms with the same range are computed from both parts and the Bhattacharya coefficient (BC) [14], which expresses the similarity of two histograms, is computed from them. The asymmetry for particular blocks is computed as *1 - BC*. The most asymmetric block is detected. Since the tumor can be larger than the initial size of the block, the blocks with asymmetry bigger than $0.5 \cdot max(A)$, are also extracted. The whole cycle is repeated twice for this new extracted regions but with smaller block. Height and width of the block is iteratively reduced to the half of the previous value.

Since some asymmetry in health regions could cause that healthy parts far away from the tumor could be extracted, only the region with the most asymmetric block is labeled as pathological.

The results of particular steps for a T2-weighted coronal slice are shown in Figure 1. As can be seen, searching for asymmetric parts is done only in asymmetric areas provided by previous step.

2.3 Locating the tumor

The detection of asymmetric areas does not explicitly locate the position of the tumor. There are still two possible locations of the tumor - right or left side. The prior-knowledge of the physical properties of brain tissues and a tumor manifestation is used.

In T2-weighted and FLAIR images, tumors and edemas

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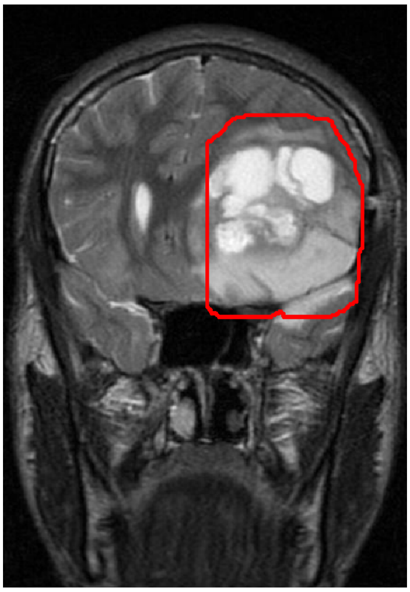

Figure 2: Located tumor.

Table 1: Results for axial plane.

Result	T2	FLAIR
Number of images	73	35
Incorrect anomaly detection	1	2
Detected main part of path. area	72	33
Correct half	66	28
Too large area	8	10
15-25% outside	9	5
Correct anomaly detection	55	18
Correct area extraction	52	17

Table 2: Results for coronal plane.

Result	T2	FLAIR
Number of images	7	18
Incorrect anomaly detection	0	1
Detected main part of path. area	7	17
Correct half	7	17
Too large area	2	1
15-25% outside	0	1
Correct anomaly detection	5	15
Correct area extraction	5	15

appear hyperintense [15]. This means that the produced signal is stronger than the signal of the white matter, in which tumors are located in most cases. This method is based on computation of the mean of the region. Tumors located near ventriculus could cause problems, because ventriculus produces even stronger signal. This could lead to misclassification.

The result of the tumor location for the input image from Figure 1(d) is shown in Figure 2. In this figure, the result image of the whole algorithm is demonstrated.

A problem occurs if the tumor appears in both halves of the brain. Since the tumor is not symmetric it is likely detected as asymmetric area even in this case. But the locating step relies on comparing both sides, therefore only one of them can be labeled as a pathological. In some cases, a tumor can be located almost symmetrically. In these particular cases, these method would fail. But this is not so common.

3 Results

The algorithm was tested on 73 T2-weighted and 35 FLAIR axial images and on 7 T2-weighted and 18 FLAIR coronal images. Some of these test images were acquired in The University Hospital Brno and some of them are from Radiopaedia database, the on-line collaborative radiology resource. Every image contained a tumor, a tumor with an edema or only an edema. Various shapes, locations, and sizes of these pathological areas and various image resolution were tested. Results for particular plane are shown in Table 1 and Table 2. Results are evaluated for particular types of scan separately.

In tables, the row *Incorrect anomaly detection* expresses cases, where the area, which was labeled as asymmetric, does not contain a tumor. These cases are not considered in any other evaluation. In all the other cases, the main part of the tumor was inside the labeled region. The decision, on which side the pathological area is, is summarized in the row *Correct half*. Next 3 rows consider all images where the main part of the pathological area was detected and express the accuracy of the detection. The last row means the correct final area extraction and it is intersection of correct anomaly detection and correct half decision.

The worst results occurred for axial FLAIR slices. In 3 cases of axial T2-weighted and all 3 cases of axial FLAIR slices, where the pathological area was found, but from 15% to 25% of it was situated outside the extracted area, the pathological area was located in both halves. In the most incorrect anomaly detection cases, only small edema was present.

The reason for too large extracted regions could be explained by influence of the tumor in the neighbor parts of the brain. Because the tumor is a tissue which is growing during the time, it presses the other parts of the brain. This creates the deformation and asymmetry not only in the tumor location but also in the adjacent parts and gradually in the whole brain.

A few results can be seen in Figure 3. The area of the tumor location is surrounded by a red line.

In general, since the method is based on asymmetry detection, the problem appears when the tumor is located in both halves or on the symmetry axis. In these cases, some parts of the tumor could be outside of the extracted area even if they are located in the half in which the tumor was

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ISSN 1213 - 1539

detected. The reason is that the tumor located in both sides causes symmetry in these parts, so for the algorithm it seems to be a healthy tissue. For these reason, to detect tumors located in both halves, another feature such as probabilistic atlas has to be used.

In comparison with the approach proposed in [11], our algorithm provides a region containing the most of the tumor area, which will be necessary in the next processing that is the aim of the future work. Moreover, the results of our method are not simple rectangles, but they can better capture the structure of the tumor.

4 Conclusion and future work

The aim of this work was not the precise segmentation of the brain tumor but the fully detection of approximate location of the tumor. This location could be then used for more precise tumor extraction and could make this task easier. The proposed method correctly extracted the pathological area in 52 of 73 T2-weighted axial slices, in 17 of 35 FLAIR axial slices, in 5 of 7 T2-weighted coronal slices, and in 15 of 18 FLAIR coronal slices. In other 31 cases, the main part of the pathological area was detected, but the result was not so precise.

The future work will consist of the automatic symmetry axis detection and the more precise extraction of the tumor based on current results.

The attention in the future work will also be paid on automatic detection of the image containing the brain tumor and searching for the relations between neighbor slices. The work will continue with extending the method to 3D MR images by combining both planes and neighbor slices.

Acknowledgements

This research work is funded by project SIX CZ.1.05/2.1.00/03.0072, EU ECOP EE.2.3.20.0094, CZ.1.07/2.2.00/28.0062, project GACR 102/12/1104, and project CZ.1.05/2.1.00/01.0017 (ED0017/01/01), Czech Republic.

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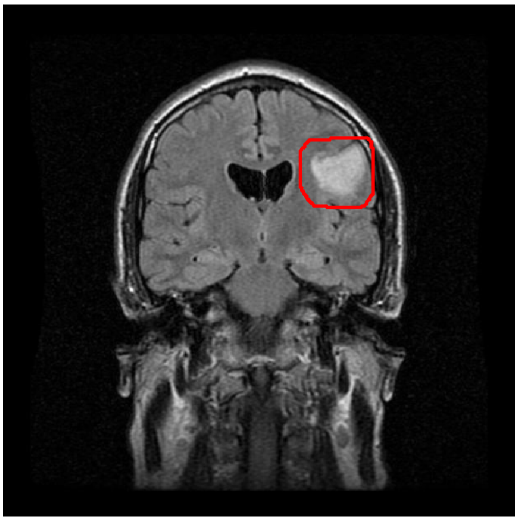
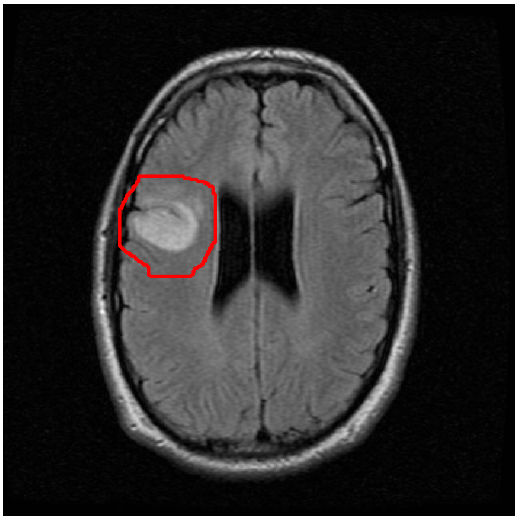
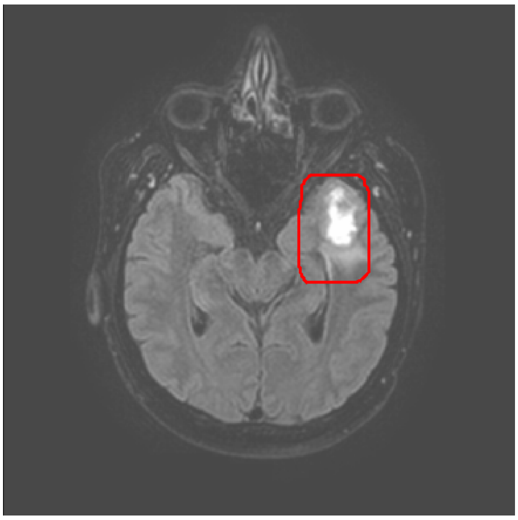


(a)



(b)



(c)

Figure 3: Examples of correct area extraction for (a) FLAIR coronal slice, (b) FLAIR axial slice and (c) T2-weighted axial slice.

elektrorevue
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