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Pixel based Symmetry Analysis of an Axial T2 Weighted Brain MRI

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ABSTRACT
In this paper, we have tried to encapsulate the recent developments in the field of Symmetry based approaches to detect tumor and then came up with a new parameter which plays a crucial role in proving that a high degree of Symmetry is present in an axial normal human brain MRI (Magnetic resonance Imaging) and this symmetry get affected or not present in abnormal cases highlighting the fact that tumor might be present. This paper also reveals one of the major technical flaw or loophole that is present in almost all Symmetry based approaches to detect tumor. As Symmetry is one of the most important properties of a human brain that can be utilized to detect the presence of tumor and other anomalies present in the human Brain. This paper tried to provide the proof of symmetry in human brain through a pixel based analysis using a number of neuro images cases. For the pixel based analysis T2 weighted MRI modality images are used. In this paper we are using T2 MRI images because in it an anomaly appears Hyper intense (brighter than the normal brain tissue).

Keywords
Symmetry, Tumor; Mean Pixel value, T2 weighted, Axial MRI, left hemisphere, Right hemisphere.

1. INTRODUCTION
The numerous developments over the last decade or so in the field of computer technologies and Image segmentation are simply catalyzing the development of modern computerized approaches for anomaly detection in radiological images. However many major issues came into existence because computers generally lack sufficient perceptibility and intelligence in terms of discovering pathological patterns, which ultimately hinders the decision making process. As the anatomical knowledge plays a pivotal or indispensable role in computer vision and artificial intelligence [1–3], integrating anatomical knowledge into the computer system holds great promise for facilitating decision making and improving patient care. Based on the assumption that the brain exhibits a high level of bi-fold symmetry (Fig. 1) and that this symmetry is violated in the presence of pathological anomalies conditions, many researchers have been motivated to construct a symmetry-based paradigm for automatic localization and segmentation of brain anomalies.

The general framework of this methodology is based on the hypothesis that the systematic correlation between asymmetry and pathologies can be a key to the improvement of existing detection algorithms. Integrating symmetry and asymmetry information as the prior knowledge or heuristics into a computer-aided diagnostic (CAD) [4–6] system, ought to enhance the system performance in the analysis of brain anomalies. To correctly quantify asymmetric patterns in brain images, however, the symmetry axis, or the symmetry plane, needs to be appropriately oriented in space. This enables the system to correct the possible misalignment of radiological scans and to evaluate hemisphere-wise asymmetry. Therefore, this paper has two main sections,

In the first section of this paper we tried to encapsulate the level of research already done in the field of Asymmetry and Symmetry based anomaly detection approaches while the second section contains a brief Pixel based symmetry analysis of a T2 MRI images highlighting or proving the fact that a high degree of symmetry is present in between the left and right hemisphere of a normal human brain, where as this symmetry is affected and not present in cases having tumor or any anomaly.

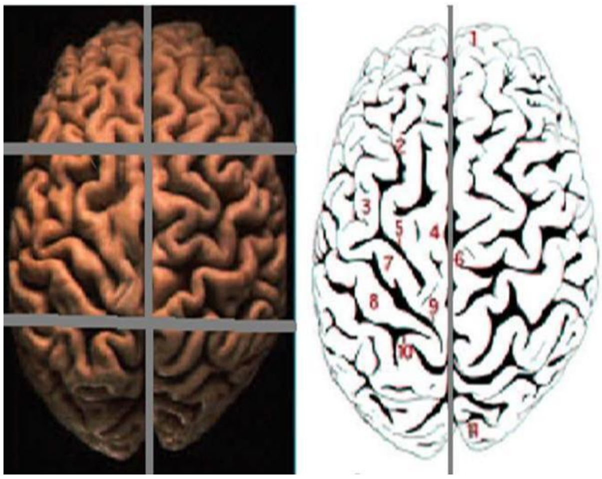


Fig. 1 The brain torque demonstrates that the brain is largely symmetrical, but not perfectly symmetrical: The right frontal lobe (1) is larger than the left one, and the left occipital lobe is larger than the right one (11). This illustration is adapted from [7]

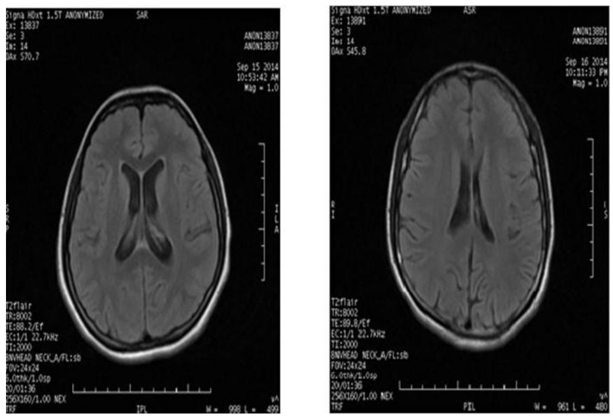


Fig. 2 Normal Human Brain T2 Axial MRI scans

2. THE MEDICAL PERSPECTIVE: MEANING OF SYMMETRY

A healthy human brain exhibits a extremely high level of bilateral symmetry, although it is not perfectly symmetrical [8]. Corresponding regions of two hemispheres have approximately same anatomical properties, and also have comparable, if not identical, physiologic (e.g., blood perfusion) properties. For instance, abnormal asymmetry in the brain indicates a wide range of pathologies, such as stroke, bleeding and tumor. Radiologists routinely use symmetry/asymmetry as one of the most discriminating features, in conjunction with other characters such as location, neighborhood relationship, and shape, to assess abnormalities in brain images.

As per functionally wise, the brain is functionally asymmetrical and each side of the brain assumes distinctive functions. For instance, in most individuals, the left hemisphere is more active in linguistic tasks, while the right hemisphere is specialized for non-verbal tasks such as visual perception [9]. The degree to which anatomical asymmetry correlates with functional asymmetry remains questionable, but it is evident that morphological differences between hemispheres, however slight, occur systematically in normal brains. One example would be that the right frontal lobe is expected to be bigger than its left counterpart [9]. In any case, however, one has to be aware of the existence of normal asymmetry might potentially confound the process of extracting abnormal asymmetry. Both the Symmetry as well as little Asymmetry phenomenon of human brain can be used to detect the tumor and other anomalies.

3. RESEARCH IN THE FIELD OF SYMMETRY BASED APPROACHES TO DETECT BRAIN TUMOR

The property of Symmetry is a well known means to discover the structure of objects and it was used in many domains. Most of the approaches based on using a priori knowledge on the image and the kind of symmetry that we are looking for (rotational or bilateral). The initial study was made by Atallah [10] and it required objects to be presented as points, lines or circles. Even some morphological methods as "grass fire" or thinning were tested but only on a set of binary images. Another good review paper written by Xia [11], which also showcased the sensitivity of these methods. Reisfeld [12] has proposed the first symmetry based detection approach which eventually does not need object recognition or segmentation. Then Kovesi [13] managed to compute symmetry without any a priori on the image by using the local phase. An algebraic approach based on the Fourrier transform was proposed by Keller [14]. In the field of medical imaging, symmetry was mainly applied to the brain were statistical measures and symmetry axis computation methods were proposed by Tuzikov [15]. A method for tumor detection using histograms was first proposed by Wang [16].
Nilanjan Ray, Baidya Nath Saha, and Matthew Robert Graham Brown in the year 2007 proposed a technique for computing bounding boxes around brain abnormality in standard MR images based on symmetry. This technique is based on a scoring function that provides a measure of the similarity or difference between two regions in terms of the Bhattacharya coefficient computed on those region intensity histograms. They also provide a mathematical basis of the behaviour of this scoring function that essentially locates the bounding box. This region-based and image feature histogram-based approach has opened new avenues of brain tumor boundary delineation [17].

In 2008, Nilanjan Ray, Russell Greiner and Albert Murtha come up with another technique based on Symmetry to detect anomaly in brain MRI [18]. In this approach they have simply proposed a real-time algorithm to locate the brain abnormality in an MR image by putting a bounding box around it. Their approach is based on left to right symmetry of the brain. In additional to being real-time, some advantages of the proposed algorithm are, It requires no registration of MR images, It needs no training image and It is independent of intensity variations across MR images. Their detection algorithm can play a useful role in indexing and storage of MRI data and as an initial step toward accurate tumor boundary delineation.

In the year 2010, Soniya Goyal [19] of IIT Delhi proposed a simple method based on symmetry to detect the brain tumor in the axial brain MRI. The approach simply based on the portioning of patient axial MRI image in module of fixed size and numbered them symmetrically and the compare these symmetrical modules present in left as well as in the right hemisphere. Although the approach was very simple but effective. She later on tests this approach on a number of test cases and proved to be very reliable.

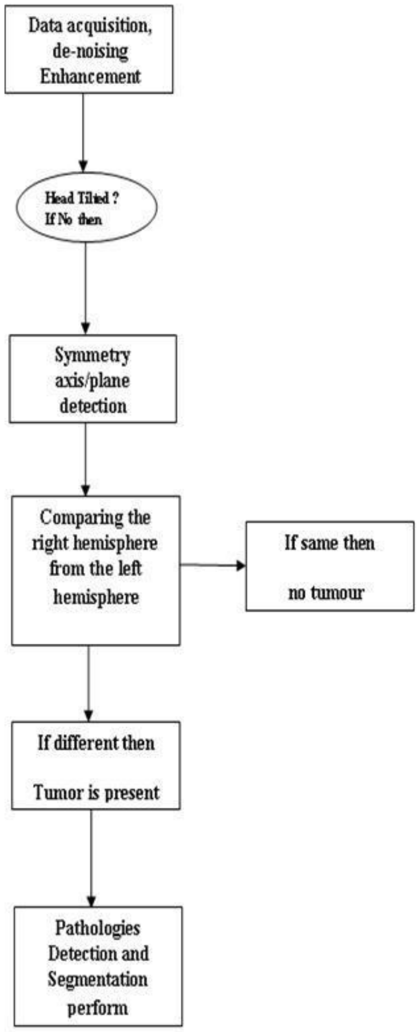


Fig. 3 A general Flow diagram depicting the primary stages involve in a general symmetry based approach

In 2013, Pavel Dvorak and Walter Kropatsch in the paper titled as Detection of Brain Tumors Based on Automatic Symmetry Analysis[20] proposed an automatic tumor detection method based on exploiting the symmetry property of the human brain.

In 2014, Mubbashar Saddique, Jawad Haider Kazmi and Kalim Qureshi, proposed a hybrid approach based on exploiting the symmetry property of brain [21]. In this paper first the MRI image of a patient is made to go through a number of morphological operations like erosion and dilation and then its mirror image is created. Then this mirror image is subtracted from the original image. This subtraction result in the highlighted ROI and hence tumor is detected.

However all symmetry based approaches unable to detect a certain class of tumors' specially which are present near or fall in the midline of the brain apart from that all symmetry based tumor detection approaches are fast and reliable when it comes to detect a tumor. The next section of this paper simply contains the pixel intensities values based analysis of MRI images showcasing the presence of high degree of symmetry in normal patient MRI and the cases in which symmetry property totally got compromised and unable to detect tumor.

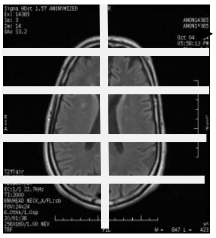
Table.1. Tabular Overview of Some of the Main Symmetry based Approaches in the Recent Years

Authors	Approach used	Advantages	Drawbacks
Nilanjan Ray, Baidya Nath Saha, and Matthew Robert Graham Brown, 2007	A symmetry based approach using a scoring function that provides a measure of the similarity or difference between two regions in terms of the Bhattacharya coefficient computed on those region intensity histograms.	It exploits approximate left-right symmetry of the brain. No pre processing, such as intensity standardization or noise removal is required. It requires no labelled image data, nor any training. It does not require image registration at all. Only two user defined parameters are used. It can be implemented in real-time.	Unable to detect the tumor on the midline and near the midline. Only able to detect tumor if it is present in either left hemisphere or right hemisphere.
Nilanjan Ray, Russell Greiner and Albert Murtha, 2008	An approach based on symmetry using a reference image in order to detect the tumor in MRIs by comparison.	Results are more encouraging and optimized with the application of Dice Coefficients. Provides an effective scoring function that helps locate anomalies in brain MR images. It uses only a single MR image, so there is no effect of variability in image intensity across MR images. This algorithm can also be applied in the area of video surveillance because of histogram-based score function.	Only able to detect Tumor either in Left or right hemisphere. Totally unable to detect the tumor near the midline or on the midline of the human brain.
Pavel Dvorak and Walter Kropatsch, 2013	A fully automated approach based on Symmetry and applying Bhattacharya coefficients to detect the anomalies in the brain MR image.	It is a fully automatic approach. The big advantage of the symmetry approach is that the process does not need any intensity normalization, human work etc. Another advantage of this approach is its independence on the type of the tumor.	The problem appears when the tumor is located in both halves or on the symmetry axis. In this case, 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 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.
Mubbashar Saddique, Jawad Haider Kazmi and Kalim Qureshi, 2014	In this paper two hybrid segmentation techniques are proposed. The first technique is a hybrid algorithm using symmetry and active contour (HASA). The second proposed	Proposed techniques can identify the tumour or abnormality present in either right or left sides and can also detect more than one tumour. Proposed techniques do not require any user interaction and are fully automatic. Since Mirror	One limitation of proposed techniques is that it will not give good results if the tumor is present near the symmetry line or on the symmetry line.

	technique is simply the extension of the HASA known as EHASA.	image is used for comparison so no need to detect the Symmetry axis and can deliver good results if head is titled.	

4. MATHEMATICALLY DEFINING MEAN PIXEL VALUE GRADIENT AS A NEW PARAMETER

The T2 Axial MRI image is decomposed into eight modules or sections. Since the MRI image is of 512*512 standard sizes so each constituent module is of size 128*256. The mean pixel value gradient of each module of T2 MRI image can be calculated as:



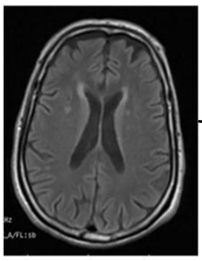
P1*1	P1*2	-	P1*256
P2*1	P2*2	-	P2*256
-	-	-	
P128*1	P128*2	-	P128*256

$$\text{Mean pixel value} = \frac{\sum P1*1+P1*2\text{----------}P128*256}{128*256} \quad (1)$$

5. PIXEL VALUES BASED SYMMETRY ANALYSIS OF AN AXIAL T2 WEIGHTED HUMAN BRAIN MRI

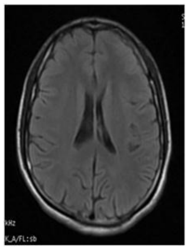
This pixel values based analysis is consist of three phases, the first phase is all about showcasing the symmetry quotient present in the Axial human brain MRI with the help of a new parameter as mean pixel value gradient. The mean pixel value gradient can be simply calculated with help of a matlab code that first convert a T2 MRI scan present in DICOM format (It is the standard used worldwide for the transmission of Medical images) into 512*512 standard grey level image.

Then the matlab code simply partition this standard size grey level image into eight constituent modules or sections. The four modules on the left simply represent the left hemisphere and the remaining four modules on the right represent the right hemisphere. The matlab code now computes the mean pixel values of each module or section which is presented below:



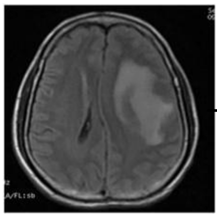
20.0742	21
44.31	45.20
51.02	52.90
36.8410	35.02

Fig. 4 T2 MRI Scan of a normal brain and its Corresponding Mean Pixel Value Table



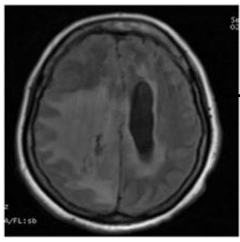
17.2034	17.1365
41.60	42.03
45.65	46.02
24.3618	21.3

Fig. 5 T2 MRI Scan of a Normal Human Brain and its Corresponding Mean Pixel Values



17.503	18.34
40.160	45.86
48.66	54.38
38.98	29.49

Fig. 6 T2 MRI Scan of a Patient having Anomaly in the Right Hemisphere



19.06	20.01
36.77	44.52
45.62	50.21
32.14	23.30

Fig. 7 T2 MRI Scan of a Patient Having Tumor in the Right Hemisphere and its Corresponding Mean Pixel Values

As from the above output, it is quite evident that high degree of symmetry does exist and can be very effectively represented with the help of mean pixel value parameter. However in cases having anomalies, the mean pixel values of both hemispheres deviated and are different by large margin. These different values or difference can be very effectively used to detect anomaly is present or not. Same or identical mean pixel values gradient of both right and left hemisphere will illustrate no anomaly and different values will represent presence of any anomaly. The only reason for using T2 weighted MRI images because in T2-weighted images, tumors and edemas appear hyper intense [22].

The third phase consists of a case in which symmetry based approaches failed or unable to detect anomaly. One of the biggest drawback of all symmetry based approaches lies in their ability to detect anomaly present near the midline and on the midline in an axial MRI scan. In these cases entire robustness of the symmetry based approach to detect anomaly got compromised or failed. As anomaly detection by symmetry based approach is based on harnessing the intensity difference in between the right and left hemisphere. If the tumor is present on the midline or near the midline then the difference in intensity comes out to be zero as the half portion of tumor present in left hemisphere and another half in right hemisphere. So when the left and right modules pixel values got subtracted then the result always comes to be zero or very small highlighting no anomaly. Some of the typical cases in which tumor either present near the midline or on the midline presented below:

101.99	105.23
116.12	118.02
120.35	122.65
131.25	134.25

Fig. 8 MRI scan of a patient having tumor in the midline just in between the right and left hemisphere

In the above case as the tumor is located just on the midline which separates the right and left hemisphere. In this case when we tend to apply the conventional symmetry based approach to detect the tumor by simply subtracting the left hemisphere from the right one in order to harness the difference in between the left and right hemisphere, the result always comes out to be zero or null. This happens because as the tumor is centrally located so half portion of it lies with the right hemisphere and exactly half portion with the left hemisphere which appears to be normal. In these cases symmetry remains present and solely symmetry based approach cannot be used to detect the tumor in the above case. Apart from this other MRI examples of midline tumor are given below:

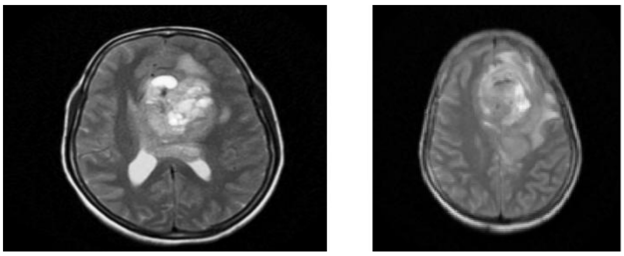


Fig. 9 T2 MRI scans of a patient having large tumor in the midline

6. CONCLUSION

All the symmetry based approaches are very popular because of its simple, effective and robust nature when it comes to detect anomaly in the MRI of a human brain. The new parameter i.e the mean pixel value gradient shows the high degree of symmetry is present in between the left and right hemisphere in normal human brain MRI and this symmetry is absent in abnormal human brain MRI. However it has been observed from our analysis that the symmetry property prove to be ineffective especially if the location of the tumor is near the Symmetry mid line or on the mid line. In such cases, the symmetry property alone cannot be used to detect tumor. It's a huge drawback present in all the approaches based on symmetry to detect the tumor. So there is an imperative need to improve the accuracy and robustness of all the symmetry based approaches. The main reason behind using T2-weighted image is the clear visibility of tumors in this type of MRI modality. In T2-weighted images, tumors and edemas appear hyper intense (brighter than the normal brain tissue) and hence easily detected.

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