Symmetry-based Method for Anomalies Detection on Morphological Neuroimages

Guilherme Cesar Soares Ruppert*†, Jorge Vicente Lopes da Silva† and Alexandre Xavier Falcão*
*Institute of Computing, University of Campinas, Campinas/SP, Brazil
Email: {ruppert,afalcao}@ic.unicamp.br
†Center for Information Technology Renato Archer, Campinas/SP, Brazil
Email: {guilherme.ruppert,jorge.silva}@cti.gov.br

***Abstract*—Many neurological pathologies are characterized by accentuated brain asymmetry and symmetry-based CAD (Computer Aided Diagnosis) tools are important for many purposes, such as: providing an earlier and more accurate diagnosis; serving as a first step for image segmentation methods; and to perform group studies. In this work, we present an automatic method for detecting asymmetries in neuroimages involving mid-sagittal plane detection, bilateral registration, and texture analysis using Kullback-Leibler's divergence. The method was evaluated on 20 MRI normal and pathological images and was able to quantify symmetry properly by highlighting clearly the asymmetric areas. The method takes less than three minutes to run, which qualifies it for use in emergency diagnosis cases, such as strokes and head injuries.**

***Keywords*-neuroimage analysis, symmetry analysis, kullback-leiber's divergence, texture symmetry, biomedical imaging**

I. Introduction

Human brains can be divided into two hemispheres and most structures in one side have a corresponding counterpart on the other side with similar shape and location. However, the human brain is not perfectly symmetric. Even healthy brains reveal some degree of asymmetry but this is accentuated in patients with certain pathologies such as schizophrenia, epilepsy and Alzheimer's disease, stroke, lesions and tumors.

The automatic detection of brain asymmetries can be very useful to assist radiologists to detect some of these pathologies that can be overlooked by visual inspection. If the computer points out regions with accentuated asymmetry, the radiologist will inspect more carefully those areas and the chances of missing something important are drastically reduced. This assistance is specially important when the radiologist available is less experienced or is under stress or overload. Furthermore, the detection of asymmetries in the image can be used to feed segmentation methods to delineate structures such as tumors and lesions. Traditional existing approaches [1], [2] use VBM (Voxel-based Morphometry) method which relies on an accurate image registration which is not always verified and can lead to unreliable results. Also, these methods takes several hour to run which hinders its use for emergency diagnosis.

In this paper we propose a new method for detecting brain asymmetries in 3D morphological neuroimages. The method is fast and provides quantification of symmetry that is visualized as a color overlay highlighting the regions with accentuated asymmetry to assist the radiologist diagnosis. The method was evaluated on 20 normal and pathological MR-T1 images and it successfully highlighted the asymmetric regions for all cases.

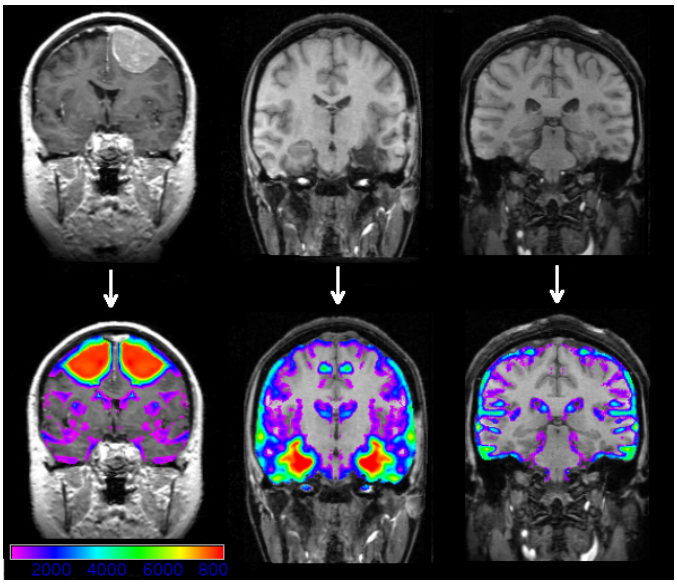

Fig. 1. The result of the method for a tumor patient (left), a post-surgery epilepsy patient (center) and a normal brain (right). The highlight of the asymmetries is very clear on the anomalies location.

II. Methods

The method consists in three main steps: (i) mid-sagittal plane detection, (ii) bilateral image registration and (iii) symmetry analysis, which are following described. The input images have to be interpolated to isotropic voxels, if necessary, so the original aspect ratio and symmetry properties are restored.

A. Mid-sagittal Plane Detection

The mid-sagittal plane (MSP) is the plane that divides the brain in two hemispheres and it is the main reference of bilateral symmetry. As the head position is unknown in the image, an automatic method to locate the MSP is necessary to realign the image (rigid transforms) so that the MSP is the central slice, and then the symmetry analysis can be performed.

In this work, we locate the MSP by applying a fast and accurate method [3] for MSP detection that is based on symmetry maximization. The method consists in two components: a symmetry measure, that evaluates a given candidate plane, and a search strategy, that searches for the best plane according to the defined measure. The symmetry measure is the cross-correlation between voxels from each side of the plane of the edges image. The method was compared against other three methods in the literature using a diverse dataset and provided the best accuracy and computational time.

B. Bilateral Image Registration

The symmetry alignment of the image based on the MSP detection already provides a very accurate symmetry reference for the analysis, however the bilateral correspondence can still be improved by using rigid-body image registration between the hemispheres. In order to register the hemispheres, we flip one of the hemispheres and apply a rigid-body registration method [4]. This method uses grayscale watershed transform and multi-scale parameter search to quickly find the transform to match the images. Experimental results reveal that this method provide a sub-voxel accuracy and takes less than 30 seconds to run.

C. Symmetry Analysis

The previous steps provide a very symmetrical realigned image, where the mid-sagital plane is located at the central plane $S_x/2$ (assuming axial orientation). Therefore, symmetrical voxels and regions are easily computed by reflecting the coordinates with respect to the central plane.

Although the brain present a good level of global symmetry, the brain is not perfectly symmetric, specially in the cortical area. Therefore, a simple voxel-wise symmetry comparison will not obtain good results.

In this work, we propose a texture descriptor based on histogram analysis between reflected regions. The method relies on the fact that symmetric regions present similar intensity distributions and is computed as follows. For every voxel in one hemisphere and for its reflected counterpart, we compute the normalized histogram within a spherical 3D neighbourhood of radius R mm. Then we compare these two histograms using the Kullback-Leibers's distance (KL-distance), which is a measure of divergence between two probability distributions. This measure is defined to be

$$D_{KL}(H_{left}||H_{right}) = \sum_i H_{left}(i) log(H_{left}(i)/H_{right}(i))$$

The distance D_{KL} tends to zero when the histograms are similar, meaning that those region is more symmetric. On the other hand, high values of this distance are found for asymmetric regions. The distance obtained is then assigned for both voxels in the left and right sides. The result of this procedure for the whole image is a new image with same dimensions where each voxel intensity corresponds to the KL-distance obtained between the region centered on that voxel and its counterpart. This resulting image is symmetric because reflected voxels are assigned with the same D_{KL}, and high asymmetric regions have higher values.

This symmetry descriptor can be computed for the whole image and the asymmetric regions of the skull and neck will be also revealed, but when the interest is only on the brain analysis, an automatic brain segmentation or skull stripping method can be used and then the symmetry computation is restricted to the brain mask. In this work we used the CLOUDS segmentation method [5].

We present this result to the radiologist by showing the results as an overlay over the aligned image. Voxels with symmetry values lower then the mean are not shown, and above this value we use a color spectrum map. The radiologist can also turn the overlay on and off to visualize which side of the brain present the anomaly.

III. Results

We evaluated the method for a dataset of 20 MRI images, with 10 control images (normal subjects) and 10 pathological images, using R=5mm. The pathological images included tumor and epilepsy patients with tissues removed by surgery. The evaluation by visual inspection showed that the method clearly highlighted the asymmetries (Figure 1) related to the pathology in all pathological cases, and presented significant lower values for the control images.

This method can also be used to feed segmentation methods to delineate asymmetric tissues, such as tumors. For instance, the method can be used to provide seeds to a markers-controlled watershed [6] by using the voxels with higher symmetry values as object seeds and the lower values as background seeds.

IV. Conclusion

In this paper, we present a method for detection of asymmetries in neuroimages. The method was evaluated on control and pathological images and showed to successfully highlight the asymmetries on the pathological regions. As future steps we intend to extend the method for group studying and also perform a deep quantitative evaluation of the method.

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