Computer-Aided Tracking of MS lesions

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ABSTRACT

Multiple Sclerosis (MS) lesions are known to change over time. The location, size and shape characteristics of lesions are often used to diagnose and to track disease progression. We have improved our lesion-browsing tool that allows users to automatically locate successive significant lesions in a MRI stack. In addition, an automatic alignment feature was implemented to facilitate comparisons across stacks. A lesion stack is formed that can be browsed independently or in tandem with the image windows. Lesions of interest can then be measured, rendered and rotated. Multiple windows allow the viewer to compare the size and shape of lesions from the MRI images of the same patient taken at different time intervals.

Keywords: Computer-aided diagnosis/tracking, Lesion Visualization, Multiple Sclerosis

INTRODUCTION

Diagnosing and tracking Multiple Sclerosis (MS) is challenging as the lesions do not necessarily increase in size over time. Instead the location, size and shape of Multiple Sclerosis (MS) lesions can change during disease progression. In addition, tracking of lesions can document disease activity which can guide treatment planning and help to measure the efficacy of medications.

The MRI images were segmented using an automatic segmentation and quantification algorithm that considers partial volume (PV) effects, and noise artifacts simultaneously. The resulting segmented image is mapped into grey matter (GM), white matter (WM), cerebral spinal fluid (CSF), and lesions. This classification of brain tissues provides clinicians with an objective measurement of Multiple Sclerosis.

In this study we focus on automatically aligning the stacks and then locating and viewing successive lesions from the segmented MRI stacks. During the alignment phase, we minimize interpolation errors by limiting rotations. The lesion browsing tool aids users in locating and viewing lesions in depth order in multiple MRI stacks.

Several groups have worked on visualizing and tracking MS lesions. The Multiple Sclerosis (MS) Project at Brigham and Women's records multiple scans of patients over several years. From this, they produce animations showing how the MS lesions change location, size and shape and size over time. Another group at the Technion has developed image processing algorithms to characterize MS lesions and analyze changes in lesion shape. They showed that some lesions go through significant geometrical changes over time and do not necessarily change in volume and size. This shows that a quantified measure of lesion load alone is not sufficient and that three-dimensional viewing tools are necessary as well. The Simon Fraser University group uses glyphs to emphasize changes in lesions over time. There are also commercial products, such as the Lesion Finder which has a user directed interface to select regions of interest and to then visualize lesions.

Our lesion tracking tool is written in Java as an open-source real-time ImageJ plugin. It can process images of any type including raw images.

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2. METHODS

2.1 Alignment

Existing ImageJ alignment tools such as TurboReg, StackReg, MultiStackReg align two images, a stack of images and several stacks, respectively [14]. All use interpolation that modifies the image pixels. The method described here, rotates the stack without interpolation using a single rotation. The alignment procedure calculates the angle of rotation between the normal line and the midline of the brain. To find the midline we scan the canvas to find the largest possible diagonal line that intersects brain image pixels. This process finds the max line of the image which is the local maximum within our scanning range. We assume that the max line of the brain image is very close to the brain’s midline.

We translate all open images to the canvas center and align to the vertical. We calculate the angle by which to rotate the image relative to the brain midline by considering lines that go through the center of the canvas. Potential rotation angles are considered by generating lines within a range of the canvas diagonal that intersect the center. By recording all the local minima of the number of intersecting pixels and then finding the smallest one, we find the brain midline. All the open MRI stacks are rotated by the resulting angle to the upright position. Figure 1 shows the steps in the alignment process.

Although this procedure allows for a maximum rotation of 45 degrees, realistically, the angle of rotation will be much smaller and is typically only a few degrees off-center. Thus, although the maximum theoretical error (we considered the lesion areas before and after the rotation) is approximately 7%, the actual error is closer to 3%.

![Diagram of alignment procedure]

Figure 1. Alignment Procedure

2.2 Lesion Dialog

Once the MRI stacks are aligned, the user can view the stacks and lesions in tandem. An efficient procedure was developed to reduce the search time for successive lesions. By approximating the brain region as an oblate spheroid, we isolated the brain region from the surrounding background. Only areas within this region are considered during the lesion search process. A brain mask, computed using a modified Sobel edge finder, is displayed to give reference points without other distracting details.

To enable clinicians to compare recent MRIs to previous baseline ones, the browser was designed to work with several open images at once. Initially, if no images are open, the user is prompted to open one primary MRI (either by importing a raw image or by opening a standard image file. The user has the option of opening multiple additional MRI images for
comparison. Once the images are opened, the browsing controls on the GUI allow the user to navigate all open stacks simultaneously.

The lesion stack button invokes the lesion finder on the primary MRI, finds the brain mask, and combines the image stacks as described above. To enable users to navigate the lesions smoothly, a button is provided to navigate to the next lesion (on all open stacks and on the brain mask). Another allows the user to select a lesion by number, and prepares the lesion for rendering through an ImageJ plugin for volume rendering.

3. RESULTS

Figure 2a shows the middle slice of an original image. The red dot shows the center of the bounding box about the brain, while the blue dot is the canvas center. In Figure 2b the red line shows a scan line through the diagonal of the canvas. The scan line moves from pixel to pixel until it reaches the top right of the canvas. This represents a total arc of 90 degrees (assuming a square canvas).

![Figure 2. a. Center the image. Translate center of bounding box to canvas center. b. Generate potential midlines.](image)

Each red dot in figure 3a represents the number of brain pixels each line intercepts. The absolute dip represents the brain midline. The MRI stacks are rotated to the upright by the angle between the midline and the vertical.

![Figure 3. a. Finding the relative minima and absolute minimum. b. Rotate by computed angle.](image)
Figure 4 shows the graphical user interface (GUI) that allows the user to view a MRI stack and then browse through the lesions with the option to render lesions of interest. The lesion depth (slice number) and lesion volume are displayed for each browsed lesion. When the user enters the patient ID and selects the “Segmented Image” button the segmented images are displayed with the first significant lesions highlighted (Figure 5). When the user selects “Next Lesion,” the lesion is displayed. The user has the option to volume render lesions or to browse to the next lesion. The lesion stack combines all the found lesions into one stack. The scroll control allows the user navigate sequentially through all open stacks in tandem.

![Lesion Dialog](image1)

Figure 4. Graphical User Interface.

A baseline and six month visit MRI are displayed in figure 5. A lesion is present in the more recent scan (red arrow) and can be compared with the same location in other open stacks. The clinician can then browse locally to view adjacent slices to determine the extent of the lesion and whether it has moved over time.

![Multiple windows displayed in parallel](image2)

Figure 5. a.b. Multiple windows displayed in parallel.

The result of selecting the Lesion Stack button from the Lesion Dialog is shown in figure 6a. The brain mask is displayed for reference. Figure 6b. shows rendered lesions from the lesion stack that can be rotated to examine each orientation.
4. CONCLUSIONS

A lesion-browsing tool may serve as a useful aid to diagnose and monitoring MS lesion activity for a single MRI stack and for the study of patterns of MS lesion progression at different time intervals. Automatic alignment of the successive stacks allows for effective comparisons. This should aid in the diagnosis and monitoring of MS lesion activity for a single MRI stack and for the study of patterns of MS lesion progression at different time intervals. Future work will focus on providing additional anatomical references in the lesion stack.

REFERENCES


