Integrative Visualization of Temporally Varying Medical Image Patterns

Jung Soh[1], Mei Xiao[1], Thao Do[1], Oscar Meruvia-Pastor[2] and Christoph W. Sensen[1]

[1]Sun Center of Excellence for Visual Genomics, Faculty of Medicine, University of Calgary, 3330 Hospital Drive NW, Calgary, AB, T2N 4N1, Canada

[2] Department of Computer Science, Faculty of Science, Memorial University of Newfoundland, St. John's, NL, A1B 3X5, Canada

Summary

We have developed a tool for visualizing temporal changes in medical image patterns. With this tool, a user can view 3D surface models of disease patterns generated from stacks of medical images. Changes over time in size, shape, and location of clinically significant patterns can be observed through animation of 3D models corresponding to different time points. Statistical measurements of the volume of the observed disease patterns can also be visualized simultaneously. Spatial data integration occurs to combine 2D slices of an image stack into a 3D surface model. Temporal integration then occurs in visualizing the 3D models from different time points together. Visual integration enables the tool to show 2D images, 3D models, and statistical data simultaneously. The tool has been used to visualize brain MRI scans of several multiple sclerosis patients. It has been developed in Java™, to ensure portability and platform independence, with a user-friendly interface.

1 Introduction

Tracking changes in disease patterns that appear in medical images is critical in analyzing the pathology of neurologic diseases. Conventional MRI has become the preferred imaging method for diagnosis of an autoimmune disease of the central nervous system, such as multiple sclerosis (MS). In MS patients, brain lesions form as the disease progresses, which are observable as distinctively bright areas in MRI images.

Several neuroimaging tools exist, which allow users to visualize multiple 3D images and reconstructed surface models simultaneously, volume render the resulting 3D images and overlay segmented anatomical structures on the original 3D images [1][2]. However, none of these tools makes provisions for visually exploring changes over time in 2D or 3D image representations of disease symptoms, such as the MS lesions that appear in MRI. For studying MS, time-varying changes in brain lesions have been studied before [3][4][5], but none of these was presented in a format that allows the user to visualize the changes in both 2D and 3D spaces.

In order to provide researchers with an efficient visualization tool to observe changing disease patterns manifesting in medical images, we have developed a software tool to visualize local and global changes in disease patterns, enabling the simultaneous display of 2D and 3D spaces. Our software package has been designed to be an integrative visualization tool which utilizes 2D images and 3D models generated from other software packages, in a platform-independent framework. It was developed using the Java™ programming language to maximize portability and platform independence, with a user-friendly graphical user interface that makes the use of software self-explanatory, requiring little learning time.

2 Methods

Figure 1 shows the flow of data in our visualization software as applied to observation of MS white matter pathology. We first need to preprocess a collection of MRI data obtained from a patient at different time points, to be able to visualize them properly in 3D. The required processing steps include: (i) brain extraction; (ii) registration of different scans; (iii) brain segmentation into different tissue types; and (iv) lesion segmentation. Brain extraction, registration, and tissue segmentation can be accomplished by using standard brain imaging tools, while segmentation of lesions needs to be done manually by clinical experts.

Once the preprocessing steps are completed for an MRI scan session, we have several masked stacks of MRI, each corresponding to one segementation of the original MRI scan. Usually, a brain would be segmented at least into cortical grey matter, sub-cortical tissues, and cerebrospinal fluid (CSF). We then create a 3D surface model from each stack of image slices, based on the marching cubes algorithm available from the Visualization Toolkit (VTK) [6]. These 3D models, when overlaid together, provide a cohesive anatomical context in which the lesions could be visualized.

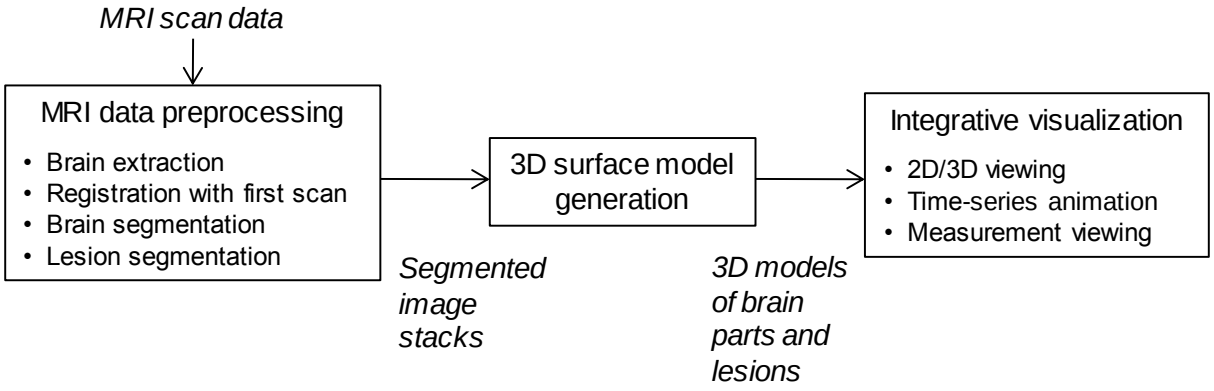

Figure 1: Data flow in integrative visualization of time-varying disease patterns. Multiple scans of the same patient are done at different time points to observe the changes over time through the time-series animation.

Figure 2 shows the main graphical user interface of the visualization software. Multiple 2D images stacks can be loaded onto the 2D display panel and multiple 3D models onto the 3D display panel. A 2D stack and a 3D model are visually linked side by side for easy referencing in either direction. Once multiple 3D models of the interesting disease pattern (e.g. brain lesions in MS patients) are loaded, they can be visualized in parallel or in succession to observe the changes in their shape, position, and size. The software also can measure the trend of changes in the pattern between scan sessions of a patient and plot it as a graph. This is done by counting the number of voxels comprising the 3D models of the disease pattern.

3 Results

To apply the visualization software to a clinical problem, we use T1, T2, and T2 FLAIR MRI images of MS patients as MRI data. The patients were recruited from the Dalhousie MS Research Unit. The subjects were each scanned six times, at monthly intervals.

Initial data analysis was completed using a combination of individual tools from two standard brain imaging software libraries: Analysis of Functional Neuroimages (AFNI, http://afni.nimh.nih.gov/afni) and Functional MRI of the Brain (FMRIB) Software Library (FSL, http://www.fmrib.ox.ac.uk/fsl/fsl/list.html). The processing pipeline consisted of brain extraction, registration, tissue segmentation and lesion tracing.

Figure 2: Main frame of the visualization software, which contains a 2D display panel (left), a 3D display panel (right), and a statistical chart display panel (bottom).

Once the segmentation procedures were completed, we reconstructed the corresponding 3D models from the stacks of masked images. We produced the 3D surface-based models for the cortex, sub-cortex, CSF and lesions for each MRI scan. After loading multiple lesion models of a patient, we observe the changes by visualizing the lesion models in several ways. Figure 3 shows a case where multiple lesion models from different time points were loaded and differentiated by distinct colors both in 2D and 3D panels. The 2D panel shows the overlay of lesion masks on the same numbered slice of a MRI scans of a patient. The 3D panel shows the 3D lesion models reconstructed from the corresponding scans. The changes in the lesions over time can also be shown sequentially as an animation instead of overlaying. To aid in the comprehension of the changes that occurred, the software can also compute the lesion volumes and display them as a chart. The measurement can be over all of the lesion models or only the selected portion of the models (as the white box in Figure 3 indicates).

4 Discussion

As temporal changes in medical image patterns are important indicators of pathology, there have been tools to automatically detect these changes [1]. Modelling of the changes by a mathematical time series has also been described [5]. However, these tools are essentially automated image analysis approaches that may not always correspond with decisions based on expert human observation. Advantages of the current software include the ability to load various types of preprocessed images, such as those in NIFTI format for image stacks or OBJ format for 3D models. While rendering of time-varying MS lesions has been done by some researchers, neither a graphical user interface nor animation capability was provided [7].

The focus of our software was the development of user-oriented visualization methods, rather than in the development of automated visual analysis. It is intended to be complementary to automatic change detection or curve fitting approaches and is designed to readily incorporate advances in these approaches into a format that allows expert researchers and clinicians to readily view and interpret such data. Future work will include analyzing temporal changes and generating qualitative/quantitative description of the observed global and local changes.

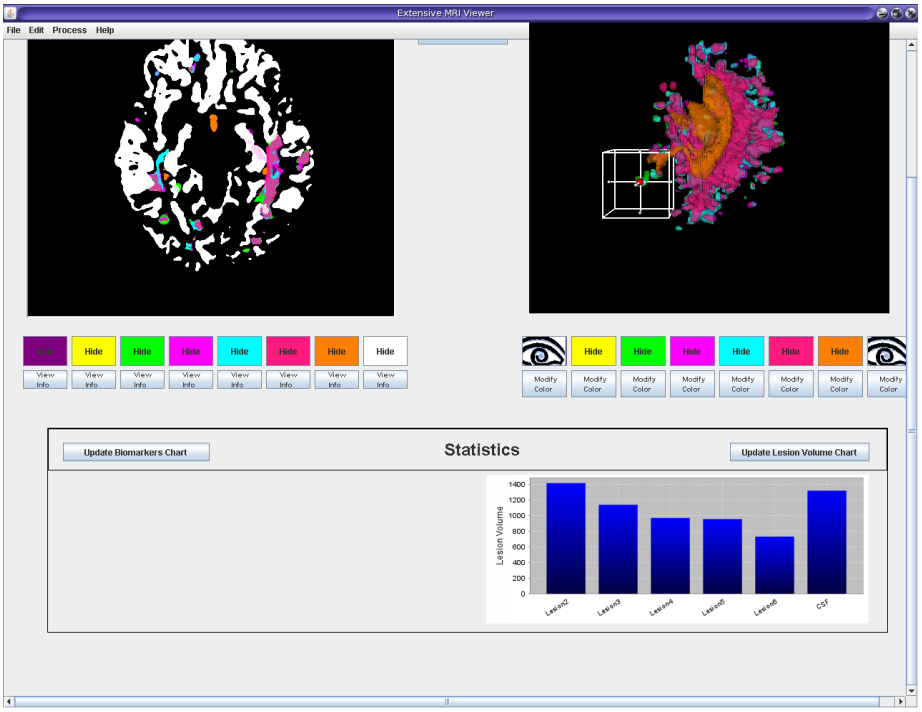

Figure 3: Visualizing lesions extracted from multiple scan sessions. 2D stacks of lesion masks and 3D lesion models are loaded and shown together, distinguished by unique colors.

Acknowledgements

This work was supported by Genome Canada/Genome Alberta, ASRA, WED, the Governments of Canada and of Alberta through WEPA, iCORE/Sun Microsystems Industrial Research Chair program, ANPI, and CFI. We thank Heather Angka, Carl Helmick, Jordan Fisk, John Fisk, and George Robertson for MRI data acquisition and processing.

References

[1] S. Huang, R. Baimouratov, P. Xiao, A. Ananthasubramaniam, and W.L. Nowinski. A Medical Imaging and Visualization Toolkit in Java. Journal of Digital Imaging, 19:17-29, 2006.

[2] R.B. Trelease and A. Rosset. Transforming Clinical Imaging Data for Virtual Reality Learning Objects. Anatomical Sciences Education, 1:50-55, 2008.

[3] M. Bosc, F. Heitz, J.P. Armspach, I. Namer, D. Gounot and L. Rumbachc. Automatic Change Detection in Multimodal Serial MRI: Application to Multiple Sclerosis Lesion Evolution. Neuroimage, 20:643-656, 2003.

[4] M. Filippi and R.I. Grossman. MRI techniques to monitor MS evolution: the present and the future. Neurology, 58:1147-1153, 2002.

[5] D.S. Meier and C.R.G. Guttmann. MRI Time Series Modeling of MS Lesion Development. Neuroimage, 32:536-537, 2006.

[6] W. Schroeder, K. Martin and B. Lorensen. The Visualization Toolkit. Prentice-Hall, 2006.

[7] M. Tory, T. Möller and M.S. Atkins. Visualization of Time-Varying MRI Data for MS Lesion Analysis. Proceedings of the SPIE, 4319:590-598, 2001.