MediCAD: An Integrated Visualization System for DTI and fMRI Fusion with Anatomical MRI for Presurgical Planning

X. Guan[1,2], S. Lai[3], J. Lackey[3], J. Shi[3], U. Techavipoo[3], K. Mueller[2], A. Flanders[3], D. Andrews[1]

[1]Neurosurgery, Thomas Jefferson University, Philadelphia, PA, United States, [2]Computer Science, Stony Brook University, Stony Brook, NY, United States, [3]Radiology, Thomas Jefferson University, Philadelphia, PA, United States

Abstract

To obtain insight to the massive data that modern MRI technology provides, neurosurgeons and research scientists require an integrated system that reads multiple modalities of data, visualizes the information in an intuitive fashion, and offers instant user feedback. Similar systems have been designed and used in practice but require large-scale workstations. To relieve budget concerned hospitals and research labs from this requirement, we designed *MediCAD*, a software package that runs on personal computers with interactive frame rate. This software not only adds to user convenience, but offers information that is otherwise not intuitive.

Introduction

Neuro-oncological surgery is strongly dependent on image guidance. Interest in incorporating diffusion tensor imaging (DTI) and fMRI into presurgical planning is rapidly growing because these newly emerging techniques allow for mapping eloquent brain structures that neurosurgeons strive to avoid damaging during surgery. Visualization of each model has received extensive research interest [1] [2] [3]. However, more useful inferences for both clinical settings and research fields can only be drawn when all the data models are integrated into one environment. On the other hand, typically the day before a brain surgery, a patient is scanned to obtain the most up-to-date imaging data. Due to the time constraint between the scanning and the actual surgery, neurosurgeons desire a tool that can provide detailed integrated information as quickly as possible. Existing literature has reported such systems [4] [5] that, however, require expensive multiple workstations to do parallel computing in order to offer real-time response. To deliver a fast, affordable, and integrated environment that combines all the important information and offers instant feedback during navigation, a software system, *MediCAD* (Medical Computer-Aided-Diagnose), was developed in this work.

Method

The program was implemented entirely in C++ with OpenGL as the graphics API. A two-pass algorithm was applied to render transparent surfaces. In the first pass, we disable writing to the color buffer and write only depth value. In the second pass, we disable writing depth buffer and only write to color buffer, with depth test and blending enabled. On a PC with Intel Pentium(R) 4 3.2GHz CPU, 2G RAM and nVidia Quadro FX 4400 graphics card with PCI Express, the program runs at more than 20 fps (Frame Per Second) on a typical setting, and 5 fps with the heaviest load (8M vertices and 3M triangles, with lighting and transparency enabled).

Two male subjects with brain tumors (aged 39 and 42, respectively) were scanned with a clinical 1.5T scanner using a circularly polarized head coil (Vision, Magnetom, Siemens Medical Systems). For DTI data, a single-shot spin echo, echo planar imaging sequence was used (with a nominal TR/TE = 5000/99 ms, 90^o flip angle, 128x128 matrix size, 2x2x4 mm voxel size, one T2WI, 6 DWI with b = 1,000 s/mm2). T1-weighted anatomical images were collected as 100 axial slices with 1x1x2 voxel size using a 3D MR-RAGE sequence. Brain activation scanning was carried out to detect visual and auditory activation using BOLD imaging (TR/TE = 1.5s/40ms, 64x64 matrix size, voxel size 4x4x6 mm^3, paradigm 20s on and 20s off). Tumor and fiducial markers were manually segmented. The surfaces of anatomical T1WI, gray matter, white matter, tumor, and activation volume, were extracted with marching cube algorithm [6]. Gray matter and white matter surfaces were color-coded based on the activation data. White matter fibers were tracked using a weighted least square linear algorithm [7], pre-classified into bundles, and stored as line segments.

Results

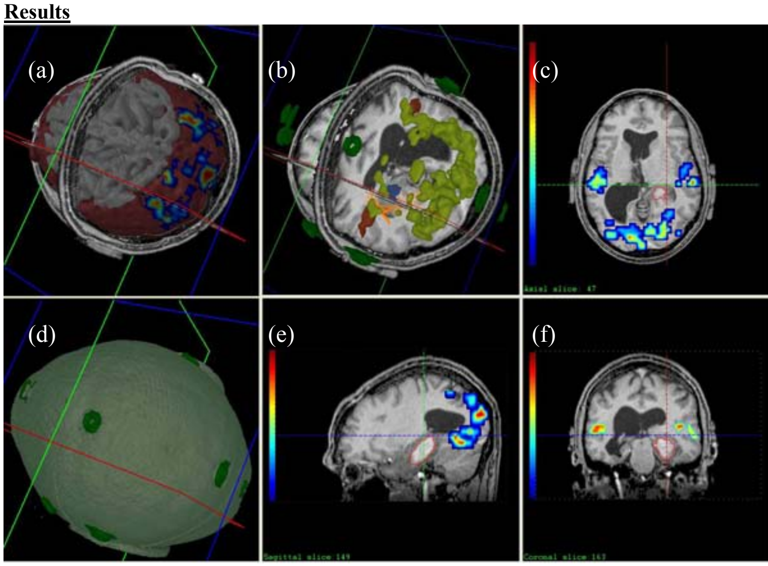

Figure 1. MediCAD program interface. (a), (b), and (d): 3D panels synchronized to the same view angle. User can zoom in/out, rotate, or translate to explore the scene. Panel (a) renders gray matter surface with color-coded activation field. Panel (b) shows fiducial markers (dark green), visual activation field (light green), auditory activation (brown), WM fibers (orange), and tumor (blue). Panel (d) shows the skull with fiducial markers. Three 2D panels show axial (c), sagittal (e), and coronal (f) slices that reveal locations of the lesion and activation areas. These slices are synchronized with those in the 3D panels. Users can navigate through orthogonal planes in all slices, allowing neurosurgeons to obtain comprehensive perspective regarding the spatial relationships among structures of concern. Data is from subject #2.

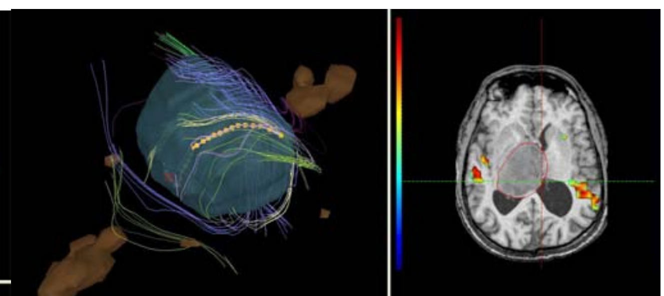

Figure 2. Left: 3D tumor volume (light blue, transparent), auditory activation volume (brown), and white matter fibers that may be affected by the tumor. Some fibers go inside the tumor, indicating that this is an infiltrative tumor (Subject #1). Right: showing auditory activation areas and the lesion.

Conclusion

MediCAD allows for integrated visualization of DTI and fMRI data together with anatomical images. It is capable of delivering real-time user interaction at low system cost.

Reference

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