

# Development of a Visualization and Manipulation Toolkit for 3D Medical Image

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**Abstract** – In this work, we present a CAS (*Computer Assisted Surgery*) system with customizable tools for visualizing and interacting with DICOM images. Providing the curvilinear reformatting [13] that allows peeling off tissues of human body, this system may support the neurosurgeons in the diagnosis and pre-surgical planning.

**Keywords** – medical imaging, DICOM, direct volumetric rendering, interactive visualization

## 1. Introduction

Focal cortical dysplasia (FCD) is a malformation of cerebral cortex consisting of a localized disruption of the normal cortical lamination associated with an excess of large, aberrant neurons, an increase in cortical thickness, and, often, abnormal neuroglial elements in the underlying white matter [1]. It believes that dysplastic neurons contribute to seizures in patients with refractory epilepsy, i.e., one which is resistant to anti-epileptic drugs.

Outcome data from epilepsy surgery suggest that medically resistant epilepsy patients become seizure-free after complete resection of the lesion. So advances in neuro-imaging have allowed better identification of these lesions, and thus more patients have become surgical candidates[11]. Surgical planning is, therefore, decisively influenced by the detection and delineation of individual patient's cortical lesions [4].

The main purpose of this work is to develop a computer-based tool that aids in detecting cortical lesions and in planning surgery of removal or disconnection of the abnormal cortical tissue from the rest of brain. Our main concern is appropriate 3D interaction techniques that allow a neurosurgeon quickly and intuitively evaluate, from ray-casting volume-rendered images, the critical brain structures around a pathologic anatomy and plan less invasive surgical resection.

## 2. Related work

Over the past two decades neurosurgeons have been benefited from images acquired with MRI for both diagnosing lesions and improving preoperative surgical planning. A variety of imaging modalities and

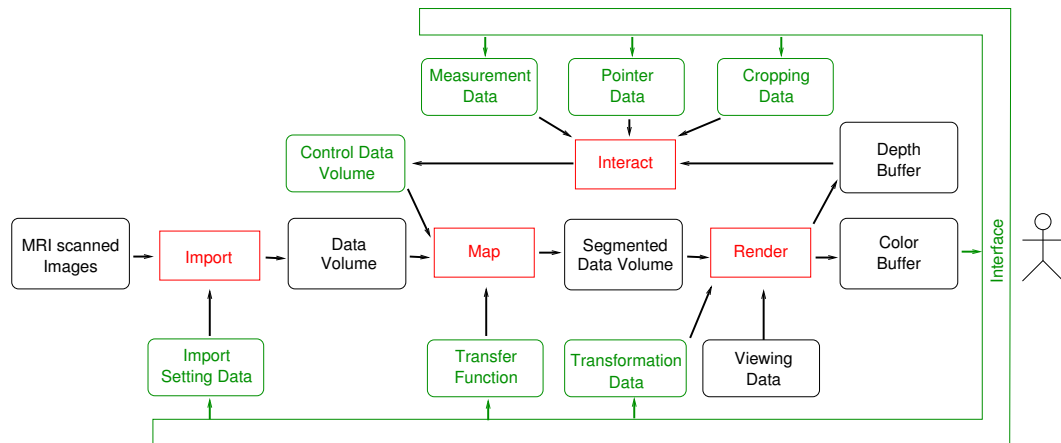
image processing algorithms are available for assisting them in visualizing, on a slice-by-slice base, the complex structures in the brain and understanding the consequences of a proposed surgical intervention to both the pathology (the “target”) and the surrounding tissues.

Depending upon the patient population and clinical problem, some are more appropriate than others. Much research effort has been focused on the multimodal volume visualization [10, 2, 7]. Instead of mentally fusing images from distinct acquisition sources, computer-assisted registration is applied to get a unique data volume. Furthermore, several clipping algorithms have been developed to selectively remove parts of volume data for revealing and exploring internal structures, such as axis-aligned cuts [8], cuts at oblique angles [6] and in pre-specified arbitrary geometry [12]. This may provide a physician more precise spatial relationships among the vascular structures, nerve fibers, physiologic function and anatomic structure, when the features of interest are “colored” distinguishably with help of an appropriate transfer function. The curvilinear reformatting via painting mode has been, however, reported recently [13]. This novel interaction technique allows the neuro-surgeons visualize the brain structures from a view-point close to the one they have during surgical interventions.

## 3. Architecture

An overview of the tool is shown on the workflow illustrated in Figure 1, comprising the tasks:

1. Data acquisition
2. Data visualization and exploration
3. Planning of the skin incision and bone removal area



**Figure 1. Architecture of proposed surgical planning system.**

4. Measuring of the location and the extent of resection

It is required that the images are in compliance with DICOM standard. We use the library GDCM to import them [5]. After the medical images being imported into the system, the sliced 2D images are ordered and grouped to compound a full 3D volume. Thereafter, a DVR (*Direct Volume Rendering*) technique is applied in order to display a 2D projection of a 3D discrete data set, without imposing any geometric structure on it [3].

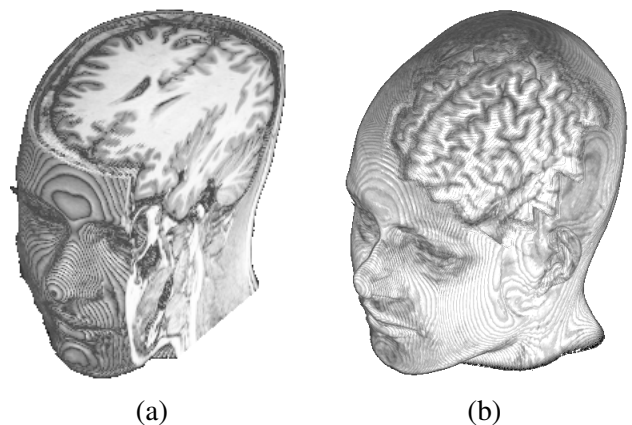
In medical imaging, the 3D scalar data volumes can represent different natures of data – mostly, radiation and resonance. Currently, the medical imaging acquired is performed by CT (Computerized Tomography), MRI (Magnetic Resonance Imaging), NM (Nuclear Medicine) and US (Ultrasound). Thus, to obtain a visualization that facilitates visual identification of features like cortical lamination and bone fractures, specific transfer functions are pre-defined.

Once displayed a 3D image, one of the following three interaction states may be selected: visual inspection (default state), exploration, and surgical planning. Figure 2 presents the user interface of our proposed system.

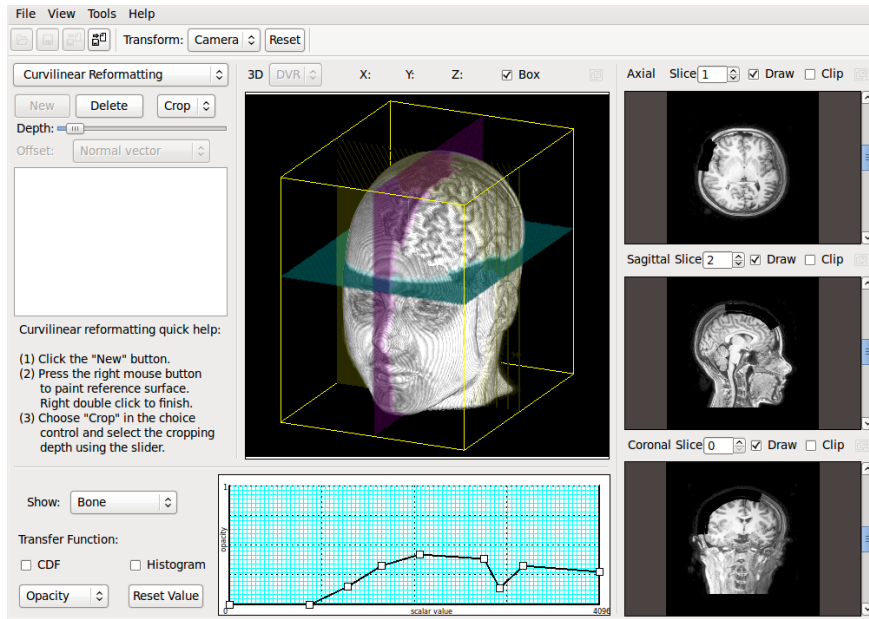
Visual inspection requires that different structures are displayed in the expected way. Manual control is given to a neurosurgeon for adjusting the transfer function parameter values in accordance with her/his need. The inspection itself may be performed either with one of three standard 2D views - sagittal, coronal and axial - or with the volume-

rendered 3D image. In a 2D view, the physician may evaluate a stack of images slice-by-slice in one of three mutually orthogonal directions, while in the 3D view, the data volume may be displaced, rotated, or zoomed.

In the exploration context, a neurosurgeon may explore the brain internal structure by slicing it, as shown in Figure 3.(a), or curvilinearly cropping it, as illustrates Figure 3.(b). For curvilinear reformatting, a user should paint a region of interest on the scalp and, automatically the cortical area underneath is layered and becomes possible to be peeled off from the scalp according to the selected peeling depth. In this context, detected lesional areas may be delineated and stored for further processing. We remark that Figure 2 presents different views of a data volume with curvilinear cropping. Observe its difference with respect to a planar cropping.



**Figure 3. Exploration by: (a) planar slicing or (b) curvilinear cropping.**



**Figure 2. User interface: the center view is the 3D volume with reference planes, the right lateral views are the axial, sagittal and coronal views, and the graph at bottom is the editable transfer function.**

A medical doctor can switch to the surgical planning state if there exists at least one stored lesional area. In this case, one or more fiducial marks on the visible structure may be defined by pointing the mouse on them and the distance measurements between them and the pathologic anatomy may be carried out. In addition, a neurosurgeon may enable the contours of the identified lesion area for planning skin incision and bone removal.

#### 4. Results

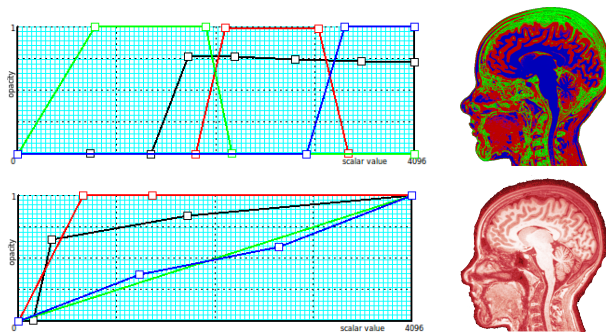
There are several problems underlying our proposed architecture. First, we should devise an efficient way to integrate the volume data acquired from distinct sources for multimodal visualization. In the current version of our system only MRI volume data are supported. Second, we should design an appropriate transfer function for highlighting features of interest in the volume data. On the actual stage of development a linear 1D transfer function, mapping the 3D scalar-field to RGBA color values, is implemented. The user can edit it via the inserted control points. Figure 4 exemplifies how a transfer function impacts on the rendered images. Third, how can a neurosurgeon interact with the surface of a volume data without its extraction [9]. We develop a novel interaction technique with use of the depth buffer. The procedure consists in writing in the depth buffer the depth of the visible voxel projected onto

each fragment, whenever a fragment shader is processed. Fourth, how to construct the control data volume shown in Figure 1 that can provide appropriate visual feedback to the user's actions. In our implementation, the control data volume has the same resolution of the data volume and each of its voxels contains a visibility state: either it is visible or it is not. If it is visible, the visibility state specifies the optical property to be assigned to the voxel. Whenever a voxel is manipulated, its visibility state is updated and, before the volume data is sent to GPU, its scalar values may be modified in accordance with the voxel visibility state. Fifth, we would like to have a smooth cropping even when the data are noisy. This has been achieved by integrating the algorithm presented by Wu et al. [13] in our system. In the actual state, only one curvilinear cropping is allowed per working session. Finally, we should decide how to make measurements on the visible data volume. This module still remains in its infancy.

#### 5. Conclusions

Although we get satisfactory results, several tasks should be carried out in order to make our system a useful tool in practice, i.e. a tool that better backs up neurosurgeons in their clinical routine.

In the short term we would like to conclude the implementation of the measurement tools and



**Figure 4. Transfer functions.**

to overcome the limitation that only one curvilinear cropping is allowed per working session. In the mid term we expect to improve the way that a transfer function is designed for visualizing the structures of interest. This is because that a transfer function is also fundamental for discarding irrelevant features. This facilitates the restriction of interaction domain into a meaningful one. And in the long term we would like to integrate into a unique data volume the 3D images from distinct acquisition sources. This is because that each has a specific scope of application. For example, angiography allows specific evaluation of brain's vascular structure, computed tomography (CT) provides excellent soft tissue contrast and discrimination, presenting bony details, magnetic resonance (MR) has shown to be more sensitive than CT for assessing brain injury, functional magnetic resonance (fMR) is appropriate for identifying the neural activity, and diffusion magnetic resonance (DT) is suitable for revealing fibers of cranial nerves.

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