Statistical Validation of fMRI Data

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The Problem: Electrocorticography is the technique of recording the electrical activity of the cerebral cortex by means of electrodes placed directly on it. Electrocorticography is the established standard for functional testing of the nervous system during neurosurgery [3]. With the use of surface electrode arrays placed on the exposed brain surface, as well as peripheral electrodes for recording and stimulation, the motor and sensory systems of the cortex may be mapped. This mapping helps determine the location of eloquent brain matter, and therefore where the surgeons should not cut during surgery.

In an attempt to obtain a better mapping of the eloquent brain matter, fMRI techniques are being used for presurgical planning. It is necessary to validate that fMRI produces an accurate brain mapping of the eloquent brain matter. This validation is the topic of research being described here.

Motivation: Obtaining improved mappings of eloquent brain matter important to function would aid neurosurgeons in preparing for brain tumor removal. Current techniques are imprecise and pose some limitations.

Previous Work: With the increased use of fMRI for presurgical planning it is important to use electrocorticography to establish the utility of fMRI for accurate localization of eloquent brain regions, a current topic of research at several sites [3], [5], [8], [7], [2], [9], [10], [6], [4]. These cites have reported several problems and sources of error that arise in trying to evaluate the agreement of the two modalities.

Motion artifacts and registration of preoperative data to interoperative data account for a large portion of problems [3]. Deformation of the brain surface after the craniotomy can induce localization errors on the order of 10mm [3]. Being able to accurately map the stimulation sites to the fMRI scans is necessary in determining any agreement between electrocorticography and fMRI. This requires the use of a registration algorithm during surgery.

Another problem in evaluating the agreement of cortical stimulation and fMRI data is determining how to compare the voluntary movement performed during the fMRI scan to induced (either inhibitory or evoked) movement induced by stimulation [5]. These differing movements will undoubtedly invoke different, more or less neurons.

Currently all comparisons between these two modalities have been done by qualitative assesment. These methods compare activations of the two modalities as overlapped, some overlap, or contradictory. Typical methods would involve a preoperative scan, and interoperative stimulation mapping. During the interoperative stimulation the brain surface is marked with numbered tags indicating whether or not response to stimulation was detected. This mapping is then recorded with a photograph. Comparison analysis is performed by transferring the photograph to the rendered brain surface from the scan and measuring the distance between the activation epicenters [2], [9], [10], [6]. Krings et al recorded the stimulation mapping using a stereotactic system and then compared this to the rendered brain surface using similar measurements [5]. A quantitative measure is needed in determining localization accuracy.

Stimulation within the depth of a sulcus is not normally performed [5]. This means that a large portion of the brain can not be stimulated, resulting in an incomplete cortical mapping.

Approach: There are several problems with the current processing techniques used to validate fMRI with electrocorticography. As fMRI use increases it becomes necessary to solve these problems. My research will involve making improvements to the existing techniques.

I will use a non-rigid registration algorithm to correct for brain deformation and motion during surgery. I will develop a model of conductance and field propogation of the brain. In the work done by Bonovas, et al, a realistic and accurate volume conductor model of the brain is developed [1]. The purpose of their research is to
determine the best type and size of electrodes to be used in mapping brain abnormalities. We will use known tissue conductance values and propose the use of diffusion tensor imaging to determine tissue conductance direction.

Understanding the inverse model will allow us to predict the forward model and therefore provide a means for comparing involuntary movements with invoked movements.

The model will also allow us to understand the brain conductances and field propagation of stimulation currents. This will make depth stimulation possible. With the use of two more more electrodes on the brain surface we can focus the field potentials to achieve stimulation at sulcal depths.

Furthermore, in order to evaluate the agreement of of the two modalities, it will be necessary to generate spatial maps derived from both, and analyze them statistically for agreement. The conductance model will provide us with the means of mapping the surface stimulation results in such a way that comparisons will be more accurate.

**Impact:** Incorporating the conductance model into the 3D Slicer for use in the operating room could provide surgeons with a more accurate mapping of cortical stimulation. With stimulation electrodes connected to a stereotactic navigation system, this technology is possible.

The final goal is to validate the utility of fMRI for presurgical planning. The use of fMRI along with accurate stimulation models could lead to less injury of eloquent brain matter during surgery and a more ambitious approach to tumor removal.

**Future Work:** Future work will include more accurate brain conductance models. Additionally, the investigation of better field solvers will be explored.

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**References:**


