

Epilepsy is one of the most common disorders of the brain affecting worldwide around 50 million people with estimated costs around 1% of the global burden of disease. Despite a steady development of pharmacological treatments, 3 out of 10 epileptic patients are not sufficiently receptive to such therapy requiring other treatment. In many cases surgical removal of the epileptogenic zone is the recommended solution. One of the barriers in wider adoption of surgical treatment of epilepsy at present is insufficient precision of localization of these sources of epileptic activity.

We have recently developed several tools which place us as at a unique position to improve this situation. First, we have developed a novel approach to reconstruction current sources from depth electrodes or from microelectrode arrays with arbitrarily distributed contacts (kernel Current Source Density method, kCSD). Secondly, we have mastered the use of finite element method to model physical and geometrical properties of the tissue and their influence on the propagation of electric field. Finally, we have developed tool for processing three-dimensional and multimodal data neuroanatomical data.

Our goal is to combine these advancements to develop and implement a new technique of source localization of specific events in neural activity, such as a seizure, from multimodal imaging data, including ECoG (strip and grid electrodes), depth electrophysiological recordings, and MRI data from humans. The method will be validated with ground truth model data and tested on clinical data obtained from epilepsy patients of Johns Hopkins University School of Medicine.

Our plan consists of three parts. First, we will extend our previous method obtained for analysis of depth recordings in animals (kCSD) to take into account realistic brain morphology and spatial variations in brain conductivity. The core of the method is construction of so-called kernel functions, mathematical objects, which starts with computation of the potential generated in the brain by numerous basis functions covering the probed volume. This will be achieved using finite element models, a computational technique for solving equations for propagation of electric field in complicated systems. Our preliminary results in simplified scenarios indicate that this approach is feasible and can provide estimates of source location from both surface and depth electrodes incorporated in a uniform fashion, but we need to investigate how to best use available information, and how to perform these complex computations efficiently.

Secondly, we need to take into account realistic geometry of the human head and its conductive properties. This will call for a different expertise of constructing simplified models of head structure, so called 'meshes', on which the relation between the neural activity and evoked potential must be found. Finally, the obtained method will be adapted for analysis of human data obtained in a clinical setting from epilepsy patients with medically resistant partial onset seizures, who required implantation of intracranial electrodes for epilepsy surgery planning. We will analyze data from patients with a broad spectrum of seizure patterns with different numbers of available seizure recordings, different types of arrays (ECoG or depth) and configurations of implanted electrodes, and different underlying pathologies.