# Combined EEG & MEG Source Analysis coupled with a Two - Phase Spike Clustering Approach: A multifocal epilepsy case

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On the question of surgery planning for epilepsy cases that are characterized by resistance to anticonvulsive drugs, there are several directions introduced utilizing combination of neuroimaging modalities and advancements in computational techniques. Essentially, establishing the optimal resection strategy requires a multidisciplinary approach in order to avoid inflicting neurological deficits on the patients. An important aspect prior to the operative treatment exploits the combined use of Electroencephalography (EEG) and Magnetoencephalography (MEG), EMEG in source analysis. In order to estimate the spike onset within the irritative zone using the aforementioned method, an average across the annotated epileptic spikes is often used to improve the signal-to-noise-ratio (SNR). However, detecting the spike onset zone suffers from poor localization accuracy due to either unrealistic head modelling or because of hidden spike patterns.

This study addresses the source localization/reconstruction problem from interictal epileptic spikes to improve presurgical epilepsy diagnosis with the ultimate goal to design a process pipeline that can be used to guide epilepsy diagnosis and treatment. The patient studied in this case was a female suffering from pharmaco-resistant multifocal epilepsy with the seizure symptoms involving tingling feeling at the right anterior torso or hypermotor movement of right limbs, while the MRI scans revealed two focal cortical dysplasia (FCD) regions. Therefore the semiology of the seizures predisposes for sources located in the left fronto-central regions.

In this contribution, we propose a clustering scheme of two phases on interictal spikes with unsupervised learning methods, namely Self Organizing Maps (SOM) and K-means to construct spike patterns able to pinpoint the abnormal areas. Additionally, we suggest the use of an individualized (with regard to both geometry and conductivity) six-compartment finite element head model with calibrated skull conductivity and white matter conductivity anisotropy. Moreover we investigate the source reconstruction using a variety of inverse algorithms including Minimum Norm Estimate (MNE), sLORETA, eLORETA and beamforming but also combined EMEG source reconstruction.

The results demonstrate that SOM eliminates the random variations of K-means and stabilizes the clustering efficiency. In terms of source reconstruction accuracy, this study demonstrates that the combined use of modalities reveals activity around two focal cortical dysplasia regions (FCD), of the patient, one in the right frontal area and one smaller in the left premotor cortex. It is worth mentioning that only EMEG could localize the left premotor FCD, which was then also found in surgery to be the responsible for triggering the epilepsy. Last but not least, sLORETA functioned exceptionally in terms of goodness of fit since it achieved the localization of both FCDs in different clusters but also revealed propagation pathways.