ID de Contribution: **13** Type: **Non spécifié**

Multimodal analysis and inverse problems for brain imaging

mercredi 14 juin 2023 10:15 (30 minutes)

The deeper understanding of brain activity is a major challenge for clinical and mathematical research. In case of neurological disease, such as epilepsy, the main objective is to better understand and diagnose the origin of the crisis in order to propose a proper treatment for each patient. Among the non-invasive imaging methods used to study these pathologies, we are interested in the coupling of two of them : the electroencephalography (EEG) and the diffuse optical tomography (DOT). On one hand, the EEG measures the electrical potential generated by the neuronal activity. On the other hand, the DOT measures the absorption and diffusion of the light in the near-infrared spectrum by biological tissues, attesting of a change in the concentrations of oxyhemoglobin and deoxyhemoglobin.

EEG measures the electric potential difference between a reference electrode and electrodes placed on the scalp. There can be up to 128 electrods, arranged on a head cap placed on the head of the patient. Regarding the DOT, it is an imaging technique based on the absorption and diffusion of the light by the tissues. A head cap equiped with transmitters and receivers is placed on the head of the patient. A transmitter sends out light which is measured by the receptors after passing through the various layers of the head. Thanks to these measurements, it is then possible to reconstruct the optical parameters of the tissues in the head. Co-registration already exists for these two modalities, which represents a source of motivation for the mathematical modeling of this coupling.

In this communication, we present a time-dependent model for the acquisition of coupled measurements of these two modalities. Indeed, time is an important component of the neurovascular coupling. On the one hand, EEG measures the neural activity and on the other hand, the DOT highlights the change of optical parameters of brain tissues induced by the local increase in blood volume during cerebral activity. We will also present the inverse problems associated with these two imaging modalities, the inverse problem of the EEG being a source localization problem whearas the DOT problem is a parameter identification problem. Finally, we will explain how these modalities can be used together to improve the resolution of the inverse problems from a numerical point of view.

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