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Thesis title: **A CORRECTIVE MOVEMENT-BASED APPROACH TO THE ONLINE ADAPTATION OF NEURAL DECODERS FOR PROSTHESIS CONTROL**

Abstract:

A subset of neurons in the primary motor cortex of primates has been shown to encode information about the ongoing movement of the limb. Through multi-electrode **brain-machine interfaces**, it becomes possible to simultaneously record the activity of a large number of these neurons. Furthermore, it has been shown that one can construct a model that translates the neural activity into a prediction of arm movement. If the model is accurate, the predictions that it produces can be used to drive the motion of a robotic prosthesis that takes the place of the original limb.

A key issue is therefore to determine a model for interpreting these signals and recover the “intended” arm movement, in order to control a prosthesis. The model can be constructed using a supervised learning approach that uses tuples of cell activity and arm motion. Using classic approaches, firing patterns and movements are associated during a calibration period that consists of performing specific movements related to the normal use of an arm, such as reaching to an object for instance. Once neural activity has been mapped to movements, the model can be used to control the arm. Live neural activity is monitored and neuron firing patterns are identified using the model. Then, the motor commands of the prosthetic arm corresponding to these firing patterns are activated, which allow the arm to move.

The main issue with brain implants is that with time, the true behavior of the system will drift with respect to the model, due to changes in neuron behavior or in signal extraction. The subject will need to go through a new calibration phase every time a drift occurs. To avoid such a recalibration process, we would like to use the behavior of the patient to recalibrate the arm continuously, allowing an **automatic calibration**.

While reaching to an object, a subject produces a sequence of submovements. Some of these submovements are corrections to the ones that precede them. These **corrective movements** can be considered as estimates of vectorial errors in the motor commands produced by the model, and used to drive the descent process of a quasi-gradient search. In this study, we propose a **learning approach** that continuously tunes the model to the patient, based on the corrective movements produced by the subject.

We demonstrate the utility of our approach using a **non-invasive cursor control task** performed by a set of human subjects. This task is an abstraction for the control of a prosthetic arm using neural signals. In this task, a human subject reaches targets with a cursor on a computer screen, using a sensor attached to his hand. The model translates sensor movements into cursor movements. This model is tuned using the corrective movements within the patient's behavior.

In experiments using this task, subjects are presented with previously unknown models, simulating sudden drifts in the set of neurons that serve as inputs to the models. Our learning algorithm has shown a significant advantage over the control case by allowing the subjects to quickly learn to perform well with new models. This result has important implications for the possibility of continuously calibrating decoders and for achieving a highly functional prosthesis.