Deciphering the Neural Code of Dexterous Hand Movements

By

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Abstract

The goal of this thesis was to understand the neural correlates of dexterous finger and wrist movements as well as to develop methods to decipher those movements using neural signals recorded from the cerebral cortex. The motivation arose from rapid advances in the field of brain-machine interfaces that have opened up the possibility of neurally controlled prosthetic limbs. We first developed linear models that explained the rate modulation of individual neurons in the primary motor cortex (M1) hand representation, during simultaneous movements of individual fingers and the wrist in trained rhesus monkeys. We also showed that the inverse of such models are predictive of the simultaneous kinematics of the fingers and the wrist, based on the activity of populations of neurons in M1. In order to decipher the kinematics of finger movements with a high degree of accuracy, we also developed non-linear dynamical systems using recurrent neural networks. These models were able to predict hand movements from neural activity at multiple spatio-temporal scales within M1. Next, we studied the practical limitations on neural decoding that might be imposed by the nature and geometry of neural interfaces (viz. implantable micro-electrode arrays- MEAs) that are commonly used to record activity from M1. We concluded that there are no differences in neural decoding of finger movements as a result of the site of implantation of the MEAs within the M1 hand area, as well as due to the type of MEA used for recording. We also explored the possibility of decoding finger movements using signals recorded from subdural electrodes, a.k.a. the electrocortigram (ECoG). In four human subjects with existing ECoG grids, implanted for epilepsy surgery, we observed that the amplitudes of the smoothed ECoG signals from the motor cortical areas were correlated with slow finger movements. A linear weighted sum of the low-pass filtered ECoG amplitudes was predictive of finger positions during slow grasping movements of the hand. This was robust to variations in hand and wrist position involving multiple recording sessions and days. This work lays the foundation for brain-machine interfaces for control of dexterous upper extremity prosthetics.

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