Abstract:

Despite great advances in many areas of medical technology over the past 20 years, very little has changed for the prosthetic limbs used by amputees. Improvements in materials have made them lighter and stronger, but little headway has been made in giving amputees more functionality and easier control. Recently, this problem has been addressed on a number of fronts, including electrical control from the muscles of the stump, or nervous system and surgical techniques involving multi-contact nerve arrays and muscular reinnervation. While these techniques represent important future directions for the field, they have not been shown to provide the robust and intuitive control signals required to take full advantage of a dexterous hand prosthesis.

Nerve cuff electrodes represent a less invasive alternative to penetrating array electrodes. Individual neurons in peripheral nerves are separated into fascicles, which are loosely spatially organized based on the location they innervate. This thesis leverages the spatial organization in order to separate and recover fascicular signals. Simulations of a human femoral nerve finite element model were used to validate the approach, and demonstrate source localization to $180 \pm 170$ m. The electrode and recording system built to implement in vivo experiments provided a 2 Vrms noise floor on 16-channels, allowing the reconstruction accuracy to be measured at $R^2 = 0.81 \pm 0.08$ for large synchronized neural responses in an in-vivo Rabbit sciatic nerve model. Smaller, pseudo-spontaneous signals generated with high-frequency sinusoidal stimulation were separated with crosstalk of $23 \pm 13\%$, and found to transmit $4 \pm 2$ bits-second-per-source. These recovered fascicular sources correlate to individual muscle activities (even if the muscles have been amputated) and their activity may be used to drive corresponding motors in limb prosthesis. Beyond prosthetic limbs, this same technique is applicable for recording and localizing sources within any large nerve trunk and may be useful for many other artificial sensors and organs.