Case Western Reserve University EST. 1826

Biomedical Engineering

Ph.D. Dissertation Defense

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“Extracting Voluntary Activity of Fascicular Sources within Peripheral Nerves with Cuff Electrodes”

By

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Summary:

The advancement of multi-degree of freedom prosthetic limbs designed for amputees and the recent work on restoring sensation through functional neural stimulation have allowed for the possibility of an intuitive, bi-directional integration of bionic limbs. However, extracting signals with which to command these devices did not evolve to an equal level and represent the technology sector where further improvement is needed.
This thesis had proposed the hypothesis that fascicular-level physiological signals can be recovered with the flat interface cuff electrode (FINE) recordings, from which the movement intent can be predicted, and this recovery can be maintained under chronic preparations. This hypothesis was tested in three parts.

First, physiological neural activity was recorded with 16-channel FINE from the sciatic nerve of dogs under chronic conditions. The results showed consistent recording quality with SNR range of 3.65-7.59dB and recording baseline noise of 0.62-1.00 μVRMS. The results also showed that the electrode interface was stable, represented by contact impedances of 2.04-4.32 kΩ and >80% of the contacts remained functional during the implant duration.

Second, the possibility of extracting the activity of fascicular groups was demonstrated. The information needed to separate activities at different locations within the nerve was contained in the combination of the pre-determined contacts' locations and the recordings at these contacts. These results are novel in showing that multiple command signals that reflect voluntary movement intent can be extracted from a single nerve with the FINE.

Finally, the extraction of fascicular activity was maintained at high accuracy when compared with the actual movement outcome from up to 9 months implanted FINEs. ROC analysis showed that the predicted neural commands match the observed muscle movement outcomes, quantified by AUROC of > 0.85. This accuracy was consistent and did not show significant variation during the study duration. Also, the predicted location of the fascicular sources remained within 15% of the cuff width from the initial estimation that was made at the training phase, which validated the assumption that these estimated source locations are stable and hence a single training phase at early recording sessions is sufficient to yield long-term high accuracy in movement intent prediction.