Electrode Interfaces for Peripheral Nerve Prosthesis

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***Abstract* - An ideal prosthesis system is one that is directly interfaced with the peripheral nerve stump of a patient, enabling him to use it naturally and control it. The motivation to study the reliability of the neural interfaces arises from the requirement of neural interfaces to sense the nerve signals from peripheral nerves, as these recordings provide information that can be used to control the limb muscles. The current focus is to study how much useful information can be extracted from the peripheral nerves. This promotes a direct interest in the design of neural interfaces and subsequently prosthetics that can restore the lost limb functions. We review the use of nerve interfaces to pick up peripheral nerve signals in the framework of a peripheral nerve prosthesis, and propose critical requirements for the next generation neural probes.**

I. Introduction

There has been a significant amount of interest in designing neural prosthetics to mimic the basic functionality of the underlying peripheral nerve circuitry. However, the current prosthetics provide a small portion of functionality of the natural limb. The technologies used in the neural interface (NI) for prosthetics are in two major areas: Central NI and Peripheral NI. Central NI is marked by significant amount of invasiveness arising from the need to insert the electrodes into the brain. Peripheral NI is comparatively less invasive and offers an advantage in recording nerve signals that are required for muscle activation. This is because decoding is taken care of, to a large extent by the existing nerve circuitry from brain to the peripheral nerves.

Conventional recording approaches include the use of cuff electrodes that wrap around the nerve. This type offers minimal damage to the nerves and long term stability, relatively to intra-neural types. This comes at the cost of reduced specificity in recording and stimulating nerves as this is carried out at extra-fascicular level. Intra-neural types like UTAH Slanted electrode array, Longitudinal and Transverse intra-fascicular electrodes (LIFE & TIME), are penetrating electrodes and offer direct contact with the axons. Increased recording specificity comes with increased risk of nerve damage, inflammation and scar tissue formation, impeding the nerve signal acquisition. The current work involved recording of nerve signals from the nerve bundles corresponding to different muscle groups using thin film LIFE (tf-LIFE) electrodes implanted in a non-human primate (NHP). Corresponding muscle activity was simultaneously recorded with intra-muscular electrodes.

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II. Review

Reliable chronic application in recording and stimulation of nerve fibers has been the focus of electrode development over the latter half of the previous decade. Efforts to improve the electrode biology interfaces have been mainly focused on using new substrate materials, creating a low impedance bio-compatible contact with the nerve tissue and reducing the form factor of electrodes to make them thin and flexible.

Fabrication of low impedance electrode arrays has been reported where the recording surface is modified with nano-flake structures or nano-porous metal deposits. Carbon fiber array for long term neural recording have been developed[1]. Recent work has also seen a significant shift from bulky electrode structures to thin flexible forms. Silicon electronics on a silk base have paved the way for implantable devices with a dissolving base[2]. The capability to create thin circuits has primarily aided the drive to achieve ultrathin tissue interfaces. The use of new substrate materials, interface mechanisms and advancements in fabrication techniques can further promote high-quality interfaces that can integrate conformably with the soft, curvilinear nerve surfaces. These capabilities create promising opportunities for chronic, reliable nerve signal recording.

III. Future Work

On-going work is being performed in the project "*Peripheral Nerve Prostheses – A paradigm Shift in Restoring Dexterous Limb Function*", aimed at developing an implantable peripheral nerve prosthesis for the treatment of proximal nerve injuries. The current work focuses on developing neural interfaces using bio-materials.

References

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