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Source Localization of Activated Motor Units Towards Advanced Muscle-controlled Prostheses

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ABSTRACT

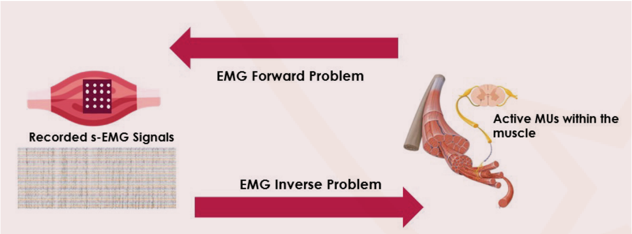
Electromyography (EMG) is recognized as a distinctive diagnostic technique in the medical field. It measures the surface electrical activity of muscles in response to a nerve's stimulation and provides information about the anatomical and physiological status of the neuromuscular system. In this paper, we investigate the identification of position of underlying activated motor units from the surface potential map that those motor units had produced. This challenging inverse problem can be used to help detect and diagnose neuromuscular diseases and control prosthetics more accurately

Myoelectric controlled interfaces have become a research interest for applications in exoskeletons, prostheses, and robot teleoperation. They detect and recognize the patient's motion intent based on electromyography (EMG) signals, and then helps the user to accomplish upper or lower extremity motions in real time.

Electromyography (EMG) is a measurement tool for the recording and analysis of the muscular electrical activity. EMG recordings can reveal nerve and muscle dysfunction, or problems related to nerve-to-muscle signal transmission. At the same time, valuable data can be extracted from the recoded electrical activity such as the spatial positioning of the activated motor units within the muscle [1-3]. This is known as source localization and plays an important role in more accurate and precise prosthetic control and rehabilitation guidance with biofeedback. Source localization represents the core of our research which was conducted in collaboration with the University of Technology of Compiegne, France, and published in the 2021 International Conference on Advances in Biomedical Engineering (ICABME), IEEE [4].

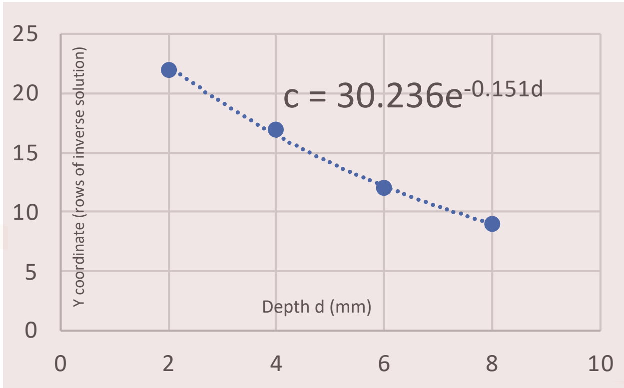
Invasive and non-invasive techniques can be used to measure the electrical activity of the muscles. Intramuscular EMG (imEMG), an invasive technique, includes the insertion of needle electrode into the muscle and thus allowing reading of the action potentials produced from only the very close regions surrounding the needle. Despite its high selectivity, imEMG suffers from important limitations such invasiveness, pain and discomfort for the patient, and in certain cases interference with muscle contraction. Surface EMG (sEMG), in contrast, uses surface electrodes for the measurement of the superimposed action potentials generated by many motor units located under the surface on which the electrodes are placed. sEMG is limited in terms of low spatial resolution but is usually attractive and desirable for being non-invasive.

Source localization in sEMG is achieved using a mathematical approach, illustrated in the following figure, known as the forward and inverse modelling. It is applied to multi-channel sEMG signals allowing the non-invasive exploration of the spatial positioning of the motor units within the muscles.



This approach requires the presence of a mathematical muscle model known as the volume conductor model. Incorporated in this model are the anatomical and geometric characteristics of the muscle as well as its conductivity properties. The forward problem is used to find the surface potentials generated due to the underlying current sources and the inverse problem is seen as the estimation of the distribution of those current sources given the surface electrode measurements. Currently available techniques for source localization suffer from high computational cost since most of them are based on complex numerical models thus disabling them from being used in real-time applications such as prosthetic control. Our research uses an analytical simulation model with a real-time source estimation algorithm which is specially tailored for muscles.

In our research, the information produced by the inverse solution of a pre-determined set of motor units (MUs) is used to create a fitting curve with a fitting equation. The purpose of this curve to predict the depth of a definite MU with an unknown location within the muscle geometry, solely by using the surface signal this MU produced to compute its inverse solution. Specific information extracted from this inverse solution (the Y coordinate of the maximum amplitude) is then fitted within the formulated fitting equation to predict the depth of this MU. A test MU located at a depth of 5mm was used to test this fitting curve. The Y-coordinate for the maximum amplitude was yielded from the inverse solution of this test MU and was substituted in the equation and turned to be 4.21 mm was retrieved. This validates the efficiency of the proposed methodology.



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BIOGRAPHY

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Dr. Hassan obtained his PhD degree in Electrical and Computer Engineering from McGill University, Canada, in 2010 and his specific research interests are focused on of Biological Microsystems (BioMEMS), Brain Machine Interfaces, Artificial Intelligence for Medical Applications, and Engineering Education. Dr. Hassan is holder of one USA patent and has a number of refereed journal and conference papers. He also served as reviewer for different journals and conferences.