A Novel Breakthrough Neural Network Uses Raw Electromyography Signals to Control Prosthetic Hands

Running title: EMG-based sophisticated prosthetic hands

According to recent World Health Organization reports, there are about 40 million amputees in the world and as the life expectancy and associated ageing-related diseases like diabetes are on the rise, the number of people affected by amputations is expected to increase. The quality of life for upper-limb amputees can be markedly improved by high-performance prosthetic hands. Recent advances over the past several decades, led to the development of the currently available prosthetic hands, which are able to support performing certain level of activities. However, the key issue is effectively controlling these prosthetic hands, without the use of complicated mechanics and yet providing the necessary functionality for such device, using the naturally generated electric signals from the muscles.

A group of engineering scientists at the University of Texas, Dallas, have now reported a novel artificial intelligence assisted approach to control prosthetic hands employing a newly developed deep convolutional neural network, which makes use of raw electromyography signals. Mohsen Jafarzadeh and associates from the University of Texas emphasized that among the various ways of controlling prosthetic hands electromyography (EMG), is the most convenient for amputees. The principle behind this approach is the ability of a non-invasive surface EMG electrode to read and measure the electric potential generated in muscle fibers, when they contract in response to neuronal stimulation.

In the new EMG based control system described by Jafarzadeh and associates, the raw EMG signals without preprocessing, feature extraction or spectrogram, obtained from 8 dry linearly and evenly spaced EMG surface electrodes, are used by the deep convolutional neural network. This type of architecture is an advanced form of artificial intelligence using deep neural networks and is a step closer to achieving the goal of fully end-to-end (E2E) optimization of EMG controlled prosthetic hands.

Unlike the conventional approaches which consist of four subsystems of preprocessing, feature extraction, dimension reduction (feature description), and a classifier, the present system employs only a novel convolutional neural network that uses raw EMG data as input, a FIFO memory, an aggregation unit, and a look-up table. Additionally, in this new convolutional neural network, 1D convolutional layers are used instead of 2D convolutional layers, and also the filter sizes consistently decrease in deeper layers (not fixed).

Due to the limited number of available datasets, which restricts the ability to train very deep neural networks of greater than 10 layers, the presently proposed networks consisted of 6 convolutional layers and 2 dense layers, and the input of the networks is 8 vectors, with each vector consisting of 200 elements. For the present device, Jafarzadeh's group employed NVIDIA Tesla V100 GPGPU using V100 compute nodes in the Maverick2 at the Texas Advanced Computing Center (TACC), and Python 3.5 with TensorFlow library for implementing the convolutional neural network.

Jafarzadeh's group used data from two subjects for testing and the other six subjects for training and validation. They found that the eight-layer network (six convolutional layers and two dense layers) gives a validation accuracy of 91.26% and training accuracy of 99.98%, with the test accuracy reaching to 48.40%.

The proposed convolutional neural networks are found to run in real-time, with the ability to transmit the signal to the prosthetic hand low-level controller, with the error probability of zero, thus making the final product error-free and functional.

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