Foot Postures Classification using sEMG Signals

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Abstract—The paper proposes an approach to classify three target foot postures from sEMG (surface electromyography) signals measured around the right lower leg. A band-type fabric sensor is utilized to acquire sEMG signals for training and real-time testing, respectively. To implement a classifier of target foot postures, a machine learning algorithm using multi-layer perceptron (known as an artificial neural network) is utilized for the sEMG signals. Experimental result shows that the proposed scheme is effective with an overall accuracy 96%.

I. INTRODUCTION

Surface electromyography (sEMG) has been used in various fields such as health care, sports and wearable robots, which is an efficient way to detect the human intents and to transmit the information regarding human behavior to outside devices or equipments. Especially, the sEMG signal has been treated as one of the research topics for a robotic hand control because it is able to offer user’s intents directly through non-invasive electrodes located in the sEMG sensor [1]. In recent years, real-time pattern recognition methods for robotic arms have been applied to wrist or finger movements by attaching sensors to the forearm. Chu et al. [2] have used a four-channel sensor at the forearm for multi-functional control, and multi-layer perceptron was applied to classify several hand motions. On the other hand, electromotive force signals of eight channels at the forearm were captured for six hand motions classification, ultimately, for exoskeleton robot hand control [3].

Robotic prosthetic hands are being developed for upper limb amputees, for instance, Touch Bionic Hand, i-Limb Hand, and Michelangelo Hand have been now commercially available. To classify the more hand postures, the more EMG signals measured from different muscles are required, but higher level amputees such as trans-humeral, shoulder disarticulation, and forequarter amputation, do not have enough muscular parts to acquire EMG signals. This study proposes a method to control the prostheses in real-time with foot postures recognition from the sEMG signals. To do this, a fabric band sensor is used to measure EMG signals, and three postures are classified using multi-layer perceptron (known as an artificial neural network, in short ANN). In addition, real-time posture classification experiments are conducted using 16-channel sEMG data obtained from the fabric band sensor.

This work was supported by the Convergence Technology Development Program for Bionic Arm through the National Research Foundation of Korea funded by the Ministry of Science and ICT (NRF-2015M3C1B2052811), Republic of Korea.

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II. METHODS

This study was approved by the Institutional Review Board (IRB) on Human Subjects Research and Ethics Committee at Hanyang University Hospital, Seoul, Korea (2018 July, HYI-16-055-3).

As shown in Fig. 1, three target foot postures are chosen such as resting posture, adduction, and flexion for experimental training and real-time testing. The participant is required to perform the three target foot postures for approximately 10 seconds by five times with respect to one posture. The sampling time was set to 1000Hz using INTAN RHS200 chip for high-speed analog-to-digital conversion. The acquired sEMG data were filtered and collected as training data to classify the foot postures using the multi-layer perceptron model. For the training data, root-mean-squaring (RMS) was conducted as a preprocessing.

Fig. 3 illustrates an entire procedure in performing the
real-time classification. First, as shown in Fig. 2, a multi-layer perceptron (ANN) model is constructed using an input layer having 16 nodes corresponding to 16-channel sEMG signals, a hidden layer having 200 nodes, and an output layer having 3 nodes corresponding to different foot postures as one hot-vector. Rectified Linear Unit (ReLU) was applied to the nodes of hidden layer as activation functions, and finally, softmax function was applied to the output nodes. After learning process with training data set, the foot postures were predicted using real-time sEMG signals obtained through the fabric band sensor worn on the right lower leg. Second, the fabric band sensor was used to acquire 16-channel sEMG signals. The conductive fabric is made of silver-coated yarns as suggested in [4]. The specifications of fabric electrodes were determined based on the SENIAM (Surface Electromyography for the Non-Invasive Assessment of Muscle), for instance, the size of electrode was set to be 12mm × 12mm and the distance between adjacent electrodes was designed to be 20mm. The fabric band sensor has in total 32 bipolar electrodes for 16 channels, and also, it was fabricated as the band type to wrap user’s lower leg.

III. RESULT

To verify the classification performance of real-time foot postures recognition, several experiments were conducted. The RMS-filtered 16-channel sEMG signals were plotted in Fig. 4. Especially, it is noted that sEMG signals of channels 1 through 5 have large amplitudes compared to the other channels located around the front lower leg. Through experiments, overall classification accuracy for three target postures arrived at 96%. Moreover, the overall statistics tell us that the average value of the adduction posture is highest as shown in Table I.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>AVERAGES AND STANDARD DEVIATIONS OF RMS VALUES OF sEMG SIGNALS CORRESPONDING TO THREE TARGET POSTURES, WHERE SD IMPLIES A STANDARD DEVIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>resting</td>
</tr>
<tr>
<td>average</td>
<td>12.5331 µV</td>
</tr>
<tr>
<td>SD</td>
<td>2.5574 µV</td>
</tr>
</tbody>
</table>

IV. FUTURE WORKS

This paper presents an approach to classify three target foot postures in real-time using 16-channel sEMG signals acquired from 32 electrodes located at lower leg. The real-time implementation based on multi-layer perceptron model and fabric band sensor does not any restrictions such as place and time. Also, this method makes myoelectric prosthetic control to be inexpensive and more intuitive. In near future, how to classify a variety of foot postures will be studied and experimented for multiple degrees-of-freedom electric prosthetic hand control.
REFERENCES


