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Master's Degree in Biomedical Engineering

A Shift Correction Algorithm to Improve Wearability of an Event-driven Hand Gesture Recognition Armband

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Abstract

Hand Gesture Recognition (HGR) systems represent a powerful method for creating Human-Machine Interfaces (HMIs) with natural control. Armbands based on surface ElectroMyoGraphic (sEMG) sensors are currently the most popular technologies among HGR systems because of the characteristics of the sEMG signal, which is non-invasive and highly correlated with the gesture performed. Gesture recognition systems based on sEMG work well when the armband is placed in the same configuration used for classifier training. However, when the orientation of the wearable device changes, which is quite common in practice, the classification accuracy is drastically reduced.
In this thesis, an algorithm is proposed to correct the rotation of the sEMG sensors to allow a more comfortable and immediate wearing phase for the subject using the device, without necessarily requiring the same positioning configuration used during the training phase. The algorithm was implemented on an HGR armband developed by the researchers of the Micro and Nano Electronic System (MiNES) group at the Department of Electronics and Telecommunications (DET) of the Politecnico di Torino. The system comprises seven sEMG channels and is equipped with an Artificial Neural Network (ANN) to classify eight active hand gestures plus the inactive state in real-time. Moreover, the analog front-end of the device exploits the Average Threshold Crossing (ATC) technique. This bio-inspired approach reduces the information the sEMG signal carries to decrease power consumption for computations and wireless (i.e., Bluetooth Low Energy (BLE)) data transmission while maintaining correlation with the exerted force. Before this work, the armband required its seven component boards to be placed on predefined muscles. As soon as they were moved from the optimal position, even by a few degrees, the correct classification of hand gesture was no longer guaranteed. The proposed shift compensation algorithm is directly implemented on the armband and allows reconstructing the muscle activity by interpolating the ATC profile (i.e., the 7 ATC values related to each acquisition board). It relies on two calibration gestures (i.e., wrist extension and ulnar deviation) to be executed at the beginning of each session to determine the wearing direction and the shift w.r.t. the standard configuration. The results were evaluated by a test campaign involving 25 healthy subjects who

independently chose the armband placement. The obtained classification accuracies have shown that the recognition system, improved by the correction algorithm, allows the user to wear the armband in different orientations for training and testing, with a mean accuracy of 93.38%. Furthermore, the microcontroller performs gesture prediction with a latency of 1.75 ms. Considering also the ATC window length of 130 ms and a maximum latency of 50 ms adducible to BLE communication, a total latency of 181.75 ms is obtained, well below the 300 ms threshold usually considered for real-time control of robots and prosthetics. Finally, with 2.90 mA of current consumption during prediction mode, this optimized version of the armband firmware confirms its suitability for long-term medical and consumer applications.