Trends in EMG based Prosthetic Hand Development: A Review

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Abstract

In this paper we have discussed the trends undergoing in all the various steps involved in EMG (Electromyogram) based prosthetic hand development. In order to overcome some limitations of current prosthetic hands mainly related to the proper functionality and controllability, the prosthetic hand has been designed following a biomechatronic approach based on biologically inspired design solutions. The majority of electrically powered prosthetic hands are based on a simple design that limits motion to one degree of freedom. Designs of multi-articulated prosthetic hands have had limited success due to their complexity and number of mechanical components. Classical EMG (myoelectric) controllers have failed in the past, since they were based on only determining existence or nonexistence of an EMG signal. Recent work has approached this multifunctional control problem using a large number of electrodes, though still considering only a limited part of the EMG spectrum.

Keywords: Emg (Electromyogram), ANN (Artificial Neural Network), SVM (Support Vector Machine)

1. Introduction

One of the major challenges for prostheses development is to produce devices to mimic their natural counterparts. No research has been identified that investigates the control of prostheses directly from the body’s neural network, which gives a more natural control. The most challenging field in prosthetic hand is to feed the information from the sensor to the brain neurons directly so that the control command may come directly from the brain not from the controller so that the amputee gets a natural feeling. The development of a prosthetic hand comprises of the following components. These are: 1.Electrode Placement; 2.Signal Conditioning (Hardware Part); 3.Feature extraction; 4.Feature Evaluation; 5.Classification Technique; 6.Mechanical Design; 7.Sensor Performance.

1.1 Electrode Placement

Human Arm Anatomy: In the upper arm, two groups of muscles have to function in opposing pairs (flexor groups and extensor groups) to move the elbow joint [1]. Working on the theory that the use of the three types of electrodes that are used for the EMG recording will allow all hand and wrist functions to be controlled simultaneously the following muscles were chosen: Supinator and pronator teres to give wrist rotation, flexor carpi ulnaris to give wrist flexion and extension, flexor pollicis longus and extensor pollicis to control a thumb, and flexor digitorum sublimas and digitorum communicus for finger opening and closing [2].
In order to obtain meaningful EMG signals for eight kinds of prehensile posture [3], the placement of EMG surface electrodes is important. Recent advancements in the prosthetic hand show that the earlier ways of placing the surface electrodes did not provide data with greater accuracy. The muscles that are targeted are the extensor carpi radialis (ECR), extensor carpi ulnaris (ECU), extensor digitorum communis (EDC), extensor pollicis longus (EPL), flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), flexor digitorum superficialis (FDS), flexor pollicis longus (FPL), pronator teres (PRON), and supinator (SUP). In addition, six surface electrodes are placed in an equally spaced array around the circumference of the forearm. This placement of electrodes generated some good results with minimum error and greater accuracies up to 92.8% [4].

1.2 EMG Conditioning (Hardware part)

The main problem in the process of detecting an EMG signal is that this signal is easily affected by impure signals that come from different sources of noise such as 50/60 Hz electromagnetic induction from power lines. The next step is to remove the unwanted components of the EMG signal, which can be achieved by means of a band pass filter. This filter should remove low frequencies (below 20Hz), related to artifact movements and some instabilities in the EMG signal, as well as high frequencies, associated with RF interference. As the power spectrum of EMG signals is concentrated in the 20-500Hz range, the authors designed a hardware using a second order band pass Butterworth filter with cut-off frequencies of 20Hz (low) and 5 kHz. Further filtering can be applied with digital filters implemented in the software [5]. It is worth noting that in a simple on-off device a notch filter at 50 or 60Hz (depending on the frequency of the electric power supply) filter could also eliminate some important information present in the EMG signal and should not be used for multifunctional hand [6].

1.3 Feature Extraction

Since late 1970s the EMG signal was modeled as amplitude modulated Gaussian noise whose variance was related to the force developed by the muscle and as a consequence, most commercial microprocessors used in prosthetic control are now based only on one dimension of the EMG signal—the variance or mean absolute value [7], the Otto Bock SUVA (Schweizerische Unfall Versicherungs Anstalt –Swiss Insurance Agency) Hand [8], is designed so that the grip force was controlled by the intensity of the muscle signal. In the 1990s, researchers found that there is useful information in the transient burst of myoelectric signal. Hudgins and colleagues [9] showed that there is a considerable structure in the myoelectric signal during the onset of a contraction. For this reason several features are extracted.

**Time Domain Features:** Integrated EMG (IEMG, Variance, Bias Zero Crossings (BZC), Slope-Sign Change, Waveform Length, Willison Amplitude (WAMP), AR Model Coefficients (ARC), Cepstrum Analysis, Time Series Modeling of EMG, Signals EMG Histogram.

**Time Frequency Representation:** Time-frequency representation can localize the energy of the signal both in time and in frequency, thus allowing a more accurate description of the physical phenomenon [10]. Among all different types of TFR, discrete, linear TFRs short – time Fourier transform (STFT), wavelet transform (WT), and wavelet packet transform (WPT)– are preferably to quadratic TFRs, which are too computationally intense for real-time application.
1.4 Feature Evaluation: The three main parameters that evaluate the performance of a feature are: Maximum Class Separability, Robustness, and Complexity. EMG Histogram feature performs best and is evaluated excellent among all the features on the basis of above three criterions [11]. Here, we compare the effectiveness of a variety of EMG features commonly used for movement control of cybernetic prostheses. We see that all the features extraction techniques that have already been mentioned are used but only some of them provide good results [12].

1.5 Classification Techniques
There are several possible classification techniques [13]. Among them, the most used are Bayesian pattern classifiers and artificial neural networks. Recently, some authors have tried to use a neuro-fuzzy classifier and support vector machines (SVM).

1.6 Mechanical Design
Mechanical design deals with the two points generally 1. Grasping Capabilities and 2. Movement of fingers during grasping. Commercial prostheses have been designed to be simple, robust and low cost; at the expense of their grasping ability [14]. Hands such as the All Electric Prosthetic Hand utilize a series of gears to transmit the motion of motors housed in the forearm to the relevant fingers. The initial design consisted of four fingers and a thumb attached to a palm. Actuation was to be provided using a servo motor driving a belt, through a series of pulleys to the joint requiring motions. This design was altered as it became overly complicated to create a relative motion between the joints in one finger when only one motor was being used to drive three degrees of freedom in the finger [15]. Another important issue is the selection of the most appropriate material, among the different commercial types of polymers, for matching the guidelines required for industrial production (taking a suitable shore, the CE93/42, concerning the fire proof requirement and the bio compatibility) [16]. During the last two decades several robotics and anthropomorphic hands have been developed. All these hands have a high number of DOFs (up to 16) and dexterity comparable to that of the human hand. Some examples of robotic hands are the Utah/MIT (Massachusetts of Technology) hand, The Stanford/JPL (Jet Propulsion Laboratory, US) hand, the DLR hand (developed by DLR Institute of Robotics and Mechatronics) and the Robonaut hand. Unfortunately, some of these hands can be used as prostheses, because their actuation and control system are quite heavy and bulky, and thus they can’t be embedded within the hand [6].

1.7 Sensor Performance
Intuitive myoelectric prosthesis control is difficult to achieve due to the absence of proprioceptive feedback, which forces the user to monitor grip pressure by visual information leading to fatigue and handling errors. Myoelectric sensors measure electric muscle activity and these sensors detect the level of muscle construction and therefore give amputees the possibility to control mechanical prostheses by muscle activity. Sensory feedback can be integrated using feedback actuators to give the amputee more detailed information about the gripping process beyond a pure visual feedback. In a forearm stump a maximum of two different muscles signals (tensors and extensors of the forearm) can be contracted independently [17]. The motion of body-powered prostheses enables the wearer to sense device actuation through cable tension and harness position. Thus, direct feedback and potential control of the position, velocity and prehensile force of the device can be maintained in a manner known as extended physiological proprioception. This is crucial to the minimization to the lead length between the analogue and
sensor and signal processing components as well as eliminating the need for externally mounted devices, which are susceptible to reliability problems. The output of the current sensors are amplified and filtered in order to eliminate high transient effects that are particularly noticeable at motor start-up. The processed signals are then may input to the ADCs on board the micro processor for controlling action [18].

Conclusion

This paper covers the details of the steps followed in designing prosthetic hand. The work proposed and implemented by many researchers has been discussed. The effect and role of every step in designing prosthetic hand has been explored. The advances in computation techniques have allowed discrimination of motion very precisely. Several techniques have been developed to control multifunctional prosthetic devices, and many of them showed promising result. Moreover, these techniques could be also applied in other fields, not only in the control of myoelectric prosthesis. The work can be extended to provide the feedback from the sensors to brain, which will allow the amputee to provide better natural feelings.

References

5. Adriano de Oliveira Andrade and Alcimar Barbosa Soares, EMG Pattern Recognition for Prosthesis Control.
7. Bashamajian JV, De Luca CJ. Muscles Alive Baltimore, MD Williams & Wilkins, 1985
15. David Harvey and Benjamin Longstaff, The Development Of A Prosthetic Arm.
18. C. M. Lighty, P. H. Chappell, B. Hudginz and K. Engelhartz, Intelligent Multifunction Myoelectric control of hand prostheses; Journal of Medical Engineering & Technology, Volume 26, Number 4, (July/August 2002), pages 139-146