UPPER LIMB MULTIFUNCTIONAL PROSTHESIS CONTROL SYSTEM VIA ANALOG SIGNAL MICROPROCESSOR

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ABSTRACT

An increase in prosthesis operation range depends on the amount of active movements controlled by physiologically adequate command sources minimizing patients' mental efforts. The main problem in developing myoelectric control systems is the necessity to envolve maximum information from the signals generated by the phantom limb contractions applied for initiating corresponding prosthetic movements and the limited amount of real myoelectic signals due to the lack or insufficiency of the physiologically active muscles participating in lost movements.

The proposed control system incorporates optimal combination in control of signals of typical and non-typical movements. Considering patients' capacity for mental control of myoelectric signal duration and strength in performing non-typical movements dual model of control myoelectric signals is proposed. This model represents them simultaneously as both quasistationary sto'chastic process and random train of pulses varying in amplitude and duration.

Practical realization of the proposed method is possible through the use of analog signal microprocessors united into the finished calculating system for digital signal processing and analog control.

Key words: myoelectric control, adequate movements, dual model, analog signal microprocessor.

In upper limb amputees effectiveness of prosthetic fitting largely depends on functional performance of prostheses. An increase of their performance is related to the number of active functions controlled by physiologically adequate sources of commands while reducing to the minimum wearers' psychophysiological efforts when using prostheses.

One of the possible ways to solve such problems is the use of myoelectric signals as basic control commands and control systems for prosthesis permitting to organize various functional levels of prosthesis control meeting individual demands of amputees.

The control making use of myoelectric signals from the stump muscles performing phantom limb movements associated with corresponding prosthesis movements is physiologically considered to be the optimal method of myoelectric multifunctional control of prostheses.

The use of natural motor cinergy in control of prostheses permits to reduce patients' psychophysiological efforts and to achieve highly effective application of prostheses.

When developing myoelectric control systems for prostheses the key problem is to reach potentially high functional response through the use of signals from phantom limb muscle contractions for initiating adequate prosthesis movements because the means for such control are limited due to the lack of muscle partici - pating in the lost limb movements and retaining the required level of physiological functions. The proposed approach to the problem aims at such a control system which would employ full potential of patient's control of prosthesis via phantom limb activity of corresponding muscles while the absent sources of control are compensated with the signals generated by other non-typical though physiologically similar and easily trained muscle contractions. Realization of such an approach suggests the control system capable to recognize typical and non-typical signals of movements and to select their proper use in control of terminal devices.

Many studies refer the signals generated by phantom muscle contractions in performing typical movements to quasistationary stochastic processes and for their description successfully employ parameter models of power spectrum (1). Estimated parameters of this model obtained through arm EMG signals even from single site make it possible to recognize reliably such movements as elbow flexion and extension, pronation and slightly worse wrist supination. The characteristic feature of parameter models is high sensitivity of signal spectrum parameters to changes in type of movement and invariance to the signal intensity in a wide muscle force range permitting to use such models for proportional control.

Evaluation of spectrum model parameters and classification of motions in real time is a complicated scientific and technical problem. Scientifically this problem results from the lack of statistical data in the monitored signals which are necessa - ry to solve the task of reliable recognition, while the techno - logic problem is related to the large amount of calculations for signal processing. There are various approaches to this problem. One of them is based on error prediction value analysis of signals made up of a set of autoregressive (AR) filters whose coefficients correspond to different types of movements. Another approach comprises direct calculation of correlation matrix of signals, calculation of spectrum parameters and their application for classification of movements. The intermediate position is reserved for the approach making use of adaptive prediction filter to evaluate signal spectrum parameters and to classify movements.

Spectrum characteristics of signals generated by phantom limb muscle contractions are determined physiologically and can not be volotarily controlled by patients. This feature serves as a basis for reliable operation of control systems using phantom limb contractions but it does not limit application of parameter models of power spectrum in control of the lost limb movements.

Considering the fact that the basic characteristics of EMG signals which can be controlled consciously by patients in performing non-typical movements are their time and intensity, dual model of control signals is proposed. This dual model interprets the signals as both a quasistationary stochastic process and as a random train of pulses variable in amplitude and duration.

The control system based on time-amplitude analysis of signal characteristics enables trained patients to perform six movements (2). A more informative variant of this model is the representation of the signal as a sequence of specifically related events which are the peak values of RMS of EMG. This model makes it possible to realize control system as a descrete automation with several terminal states associated with different states of terminal devices. Transfer from one state to another is caused by a sequence of peak signal values with predetermined characteristics. This approach permits to use changes in signal characteristics which do not bring about changes in the state of the automation to control pulling forces of terminal devices. The analysis of the functional range of such a system for a certain group of patients is presented in the table. In the upper part of the table are listed the EMG signal characteristics controlling typical movements via the signals generated by the phantom limb contractions. Excess of information in them permits to determine the requirements for non-typical contractions which can be basically utilized to control the rest prosthetic movements. Physiologically adequate level for "grasp" and "hand open" functions is achieved through reliably recognized simultaneous contraction of the biceps and triceps which is presented in the bottom of the table. In patient groups with different functional ranges or different specific demands distribution of control resources between various terminal devices may differ from the distribution listed in the table.

Analog signal microprocessors which are the completed calculating system for digital signal processing and analog control fully meet the demands for practical realization of the proposed control method. To achieve the required effectiveness prosthetic control system structure can apply modular concept according to which the calculations to be performed are distributed among several microprocessors each performing its part of general processing in real time. Application of such concept for control systems enables to create both simple and sophisticated multifunctional prostheses basing on one technical development.

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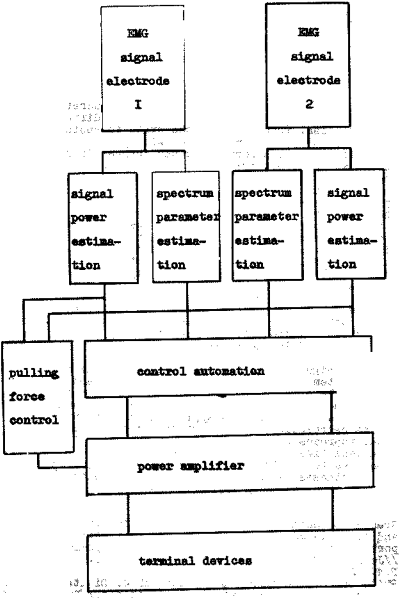

Block diagram of the combination prosthetic control system

Table

Functions performed by the combined prosthetic control system

Movement	EMG instant power		Spectrum signal parameters		Potential control characteristics
	biceps EMG	triceps EMG	biceps EMG	triceps EMG	
1. Elbow flexion	Change in proportion to force	-	classify flexion	-	proportional control
2. Elbow extention	-	Change in proportion to force	-	classify extension	- " -
3. Wrist pronation	-	-	classify pronation	classify pronation	relay control
4. Wrist supination	-	-	classify supination	classify supination	- " -
5. Grasp	continuous train of RMS high-level peaks		classify flexion	classify extension	- " -
6. Hand	continuous train of RMS low-level peaks		classify flexion	classify extension	- " -