A NEW CONCEPT IN THE EVALUATION OF CYBERNETIC ACTUATORS CONTROL USING VIRTUAL REALITY

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ABSTRACT

In order to control the movement of a cybernetic actuator the EMG signal is generally used as a source of command. This signal has to be processed in order to extract relevant features, which are then classified. Many schemes exist today in both feature extraction and classification, each one claiming to reduce the error rate and there has been some approaches in order to assess the input-output characteristics of prostheses. This paper will introduce a new concept in developing a unique platform using virtual reality (VR) tools for evaluating both the different schemes of EMG signal processing and cybernetic control. The design follows a modular approach allowing for the change of each module (analog signal conditionning, data acquisition, signal processing, actuator control, VR aspects) accordingly to the specific needs of an application. The foreseen applications of this work are performance evaluation of EMG signal processing algorithms for prosthesis control in real conditions, performance evaluation of the motor control schemes by executing real tasks, selection of the optimum scheme for a particular application (spatial, medical surgery, underwater, etc....) and training of amputees or future users of the system in real conditions where "real conditions" means the VR simulated environment.

INTRODUCTION

With the price reduction of new technologies, it is now possible to apply these technologies to rehabilitation engineering. This field has unfortunately not benefited from the results of advances in such growing fields as VLSI electronics compared to other ones although simple robotic devices have been used for physical therapy and rehabilitation [1]. One of these new technologies is virtual reality (VR): two years ago, only an organisation could afford such a system (with prices from around $100 000 US for an acceptable system), but it is now possible even for the individual to purchase his own PC based VR sytem for less than a thousand $ US. On the other hand, with the tremendous advances in micro-electronics, it is also possible to design smart myo-electric prostheses. This new generation of artificial devices will be fitted personally to each patient, taking into account both mechanical (e.g. socket fitting to the stump) and electrical aspects. As the electromyogram (EMG) signal is generally the best candidate and used by many researchers [2]-[4], the latter aspects consist essentially of EMG signal processing in order to determine which feature to extract keeping in mind that the requested characteristics for these features are good controlabilty by the subject, ease of training and real-time implementation. The requested characteristics for the cybernetic actuator itself are: anthropomorphism, low-weight, low-cost.

There is obviously a need to evaluate the effectiveness of EMG signal processing and cybernetic control schemes in order to choose the most appropriate one for a particular case of rehabilitation. Although there has been some research in this field [5], unfortunately there has been no harmonizing work in order to compare in the same real conditions the performance of these algorithms when they are used in their respective environment.

In the following sections, the design concept of a rehabilitation device using VR tools will be described. The basic idea is to prototype a modular system leading to a single platform allowing to implement and test different schemes of EMG signal processing and cybernetic control. Each module may consist of hardware and/or software, but all parameters should be software programmable. The modules are: analog signal conditionning, data acquisition, EMG signal processing, actuator control, VR environment generator and display. These modules are selected accordingly to the specific needs of an application-patient combination. Both common daily and professional activities are considered. This idea is in fact the extension of previously observations of the effectiveness of using computer graphics in order to automate the learning of an artificial arm [6]-[7]. It is thought that this new approach can offer the following advantages over the classical one:

- selection of the best scheme (signal processing and actuator control) for a specific user profile by the definition of an objective performance index,
- easy and attractive training of amputees by allowing for self-paced, self-selected environment (especially for children) and
- objective follow-up of the amputee.

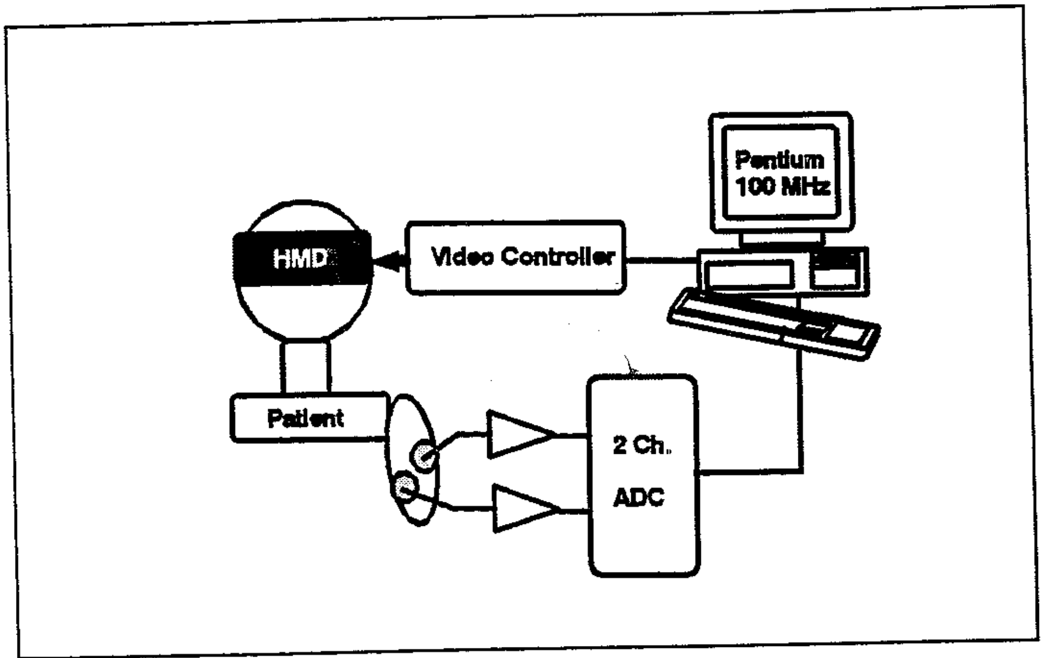

Fig. 1: The set-up.

METHODS

The set-up is schematized in figure 1. EMG signals are picked-up by surface electrodes. The number and position of these electrodes are determined by the type of EMG signal processing. In this specific example they are to be positionned at the bulk of the biceps-brachii and triceps-brachii muscles respectively [8].

These signals are then amplified and filtered and the output is fed to a Pentium 100 MHz microcomputer via a 12 bits resolution analog to digital (A/D) converter running at a frequency of 5 KHz. The microcomputer has two different tasks:

-performing the computations needed to classify EMG signals in order to activate corresponding (virtual) motors and

-creating and displaying a 3-D VR environment in which the artificial arm is moving.

The VGA signal of the display controller of the PC is fed back to the head-mounted-device (HMD) via a video converter. The amputee can immediately assess the effect of the contraction of his muscles, easing the selection of the state of contraction in a more natural manner than by computation [9].

The following parameters are software selectable:

- number of input channels of EMG.
- gain and filter characteristics for each input channel.
- A/D resolution and sampling rate.
- EMG signal processing scheme.
- motor actuating scheme.
- environment generator.

PROTOCOLS

The following procedure is proposed:

1- User's profile.

In order to be able to compare the acceptance of this method versus the traditional approach, the following groups of subjects are needed:

I: Amputees trained only by classical approach (witness group).

II: Amputees trained by new VR tools.

- Group II-A: with prior myo-electric prosthesis experience. - Group II-B: without any prior training of myo-electric protheses.

III: Healthy subjects. In this case the idea of the amputation simulator [2] could be used.

2- VR acquaintance.

The use of standard environments and devices is recommended. Each session should last about 10 minutes, repeated twice in two separate days before the experiment.

3- Task selection.

Three kinds of tasks should be defined: - common daily tasks (e.g. holding a glass of water). - professional tasks (directly related to the profession exerced now or in the future by the user e.g. hammering). - specific tasks (not directly related to any daily or professional task such as washing a window's glass).

The performance obtained in each of these tasks is not going to be the same: obviously the amputee is going to put much more efforts to improve the skills he needs daily or in his work in order to assure his independence rather than some extra-task he will not often have to do.

CONCLUSIONS AND FUTURE DIRECTIONS

Although like every new idea, this concept has to be put at work in order to evaluate objectively its success, one can foresee the cost-effectiveness of this new approach to rehabilitation considering the following:

- the training is done in a more natural manner, without the risk of breaking or droping objects.

This will alleviate the amputee from being stressed about the result of what he or she is intending to do, thus easing the learning process. - the training is self-paced, with the attendant presence only on necessity.

- a good training will reduce the rejection rate of prosthesis which is generally due to a bad fitting where the mechanical and myo-electrical aspects are weakly taken into account.
- it is easily possible to follow the amputee's performance periodically by assigning specific and objective tasks.

As future directions we propose:

- definition of more tasks/environments.
- implementation of sensory feedbacks to the amputee (electrical, vibrotactile) and evaluation of their effectiveness.
- operator presence in the VR field of view by amputee request.
- amputee intervention for changing the EMG signal processing scheme or any other parameter in order to fine-tune the algorithm to its own profile (advanced users).
- definition of standards for the application of VR to this field.
- definition of bimanual tasks for the cases in which both hands are required to play a role. In this case, depending on whether the other hand is healthy or not, one has to consider the use of Data Gloves (for the healthy hand case) or a duplicated set-up for the other amputated hand.

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