EXPERIENCE WITH HIERARCHICALLY CONTROLLED HAND PROSTHESIS

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INTRODUCTION

The principles of hierarchical control of hand prostheses have been described in previous MEC meetings [1]. Simply put: It is possible to achieve easy use of a multi-axial artificial hand if the detailed control of the hand's grip posture and force is devolved to a microprocessor controller. Thus the controller is given simple instructions to open and close the hand and the controller decides on the grip posture based on the contact between hand and object and then adjusts the grip force depending on any motion of the object relative to the hand. Thus if the object slips the hand automatically grips tighter.

This idea has been considered for many years [2,3]. Now it is sufficiently well taken that similar methods are being applied by prosthesis producers [4]. The detection of the slip is achieved using an acoustic method [5], where the sound of the start of the slide is detected. Although this may not mean that the entire object is moving relative to the hand, but only parts of the object, so called *partial* slip [6]. A second method is that of measuring the change in the contact forces and inferring slip from those changes, [4,7]. This method can be confused by a change in orientation of the object or hand that occurs *without* slip.

The concept has been realised by a number of designs of prostheses in the past. They can be used with different numbers of degrees of freedom, from one through to four (and most recently six) [3,7,8,9,10]. The basic control remains the same, the only difference is the number of different types of basic grip form can be achieved. For example: In the two degree of freedom hand, the controller can select from precision or power type prehension. Additional degrees of motion allow the controller to add, two or three jaw precision, lateral prehension and a more compact form of the power grip [7,11]. The trigger between the different grips is the point of first contact between the hand and the target object during the reaching phase of a manipulation.

The current generation of device that has been produced at the Oxford Orthopaedic Engineering Centre has been designed in order to be produced in small numbers and to be used extensively in the field. To that end a lightweight, robust, device was designed an tested and is now undergoing field assessment at Oxford [12].

PROSTHESIS CONTROL

To make it possible to construct and use the device the design choices centred on the ability to produce a hand light enough to be worn conventionally. Thus lightweight materials were used and a three finger, two degree of freedom format was chosen. More details of the basic device are in [1,12].

Some of the significant mechanical design features are: The digits curl continuously from straight to fully flexed. The thumb abducts with flexion. The mechanism is reversible. The thumb can be braked or released easily when the hand is deactivated

The electronics are in a separate package which includes a microprocessor. The input electronics (such as amplification or filtering) are separated so that it can take a verity of different input forms: EMG, switch, FSR. The essential difference with the control of the hand to the more conventional schemes is that the degree of flexion is proportional to the level of input (such as EMG tension). It is thus more akin to a body powered device, voluntary opening/involuntary closing. It uses a second control input (such as the opposing muscle) to be used for the control of the hand in the HOLD mode (where the automatic slip/grip reflex is used). Application of the tension switches into HOLD. If the operator then wishes to override this reflex they reapply the second EMG channel. Any further tightening of the hand will only be proportional to the tension in the second muscle.

This makes the control of the hand progressive and logical. The hand is always opened with one muscle and hold switching and squeezing is with the second. As the hand places the lightest possible force on the object the operator only has to let the hand close on its own, without close supervision.

Microprocessor control makes the device more readily adaptable and allows the information about the hand, controller and user to be made available, this telemetry line can be used in training and diagnostics. Monitoring of the input channel and its use in training is a well established technique, both in the experimental [9] and the commercial [13]. It is the logical extension of the use of analogue meters used as a training aid. These, however, do not exploit the full potential of the system. It is possible to provide the telemetry link that informs of the inner state of the hand and this can drive a computer display [12]. This display can drive a simulation of the hand or drive a game to make training more interesting [14]. The link can also output data on the controller states and the sensory inputs. When this link is run over a wireless connection the user can undertake standard tasks while the therapist can observe their progress.

While the control is different to that of a conventional device it is designed to be easily learned and progressive in nature. Extensive use of computer interfaces are used in the training and assessment of the device. In addition the Southampton Hand Assessment Protocol (SHAP) [15], is used to monitor the subjects' progress.

The control of the hand is quite simple but it does have differences to the conventional myo-electric hands. As observed the control is single sided, more akin to body power than myoelectric. The prehension control is proportional, the opening hand proportional to tension. A relaxed extensor means that the hand closes. The slip-grip control is turned on by tension in the opposing muscle. The reflex is also turned off and over-ridden by re-application of the same muscle. Thus a delicate object can be held or extra tension voluntarily placed on the target. The releasing of an object can be made more deliberate as the threshold tension is greater to open the hand when it is in the hold state.

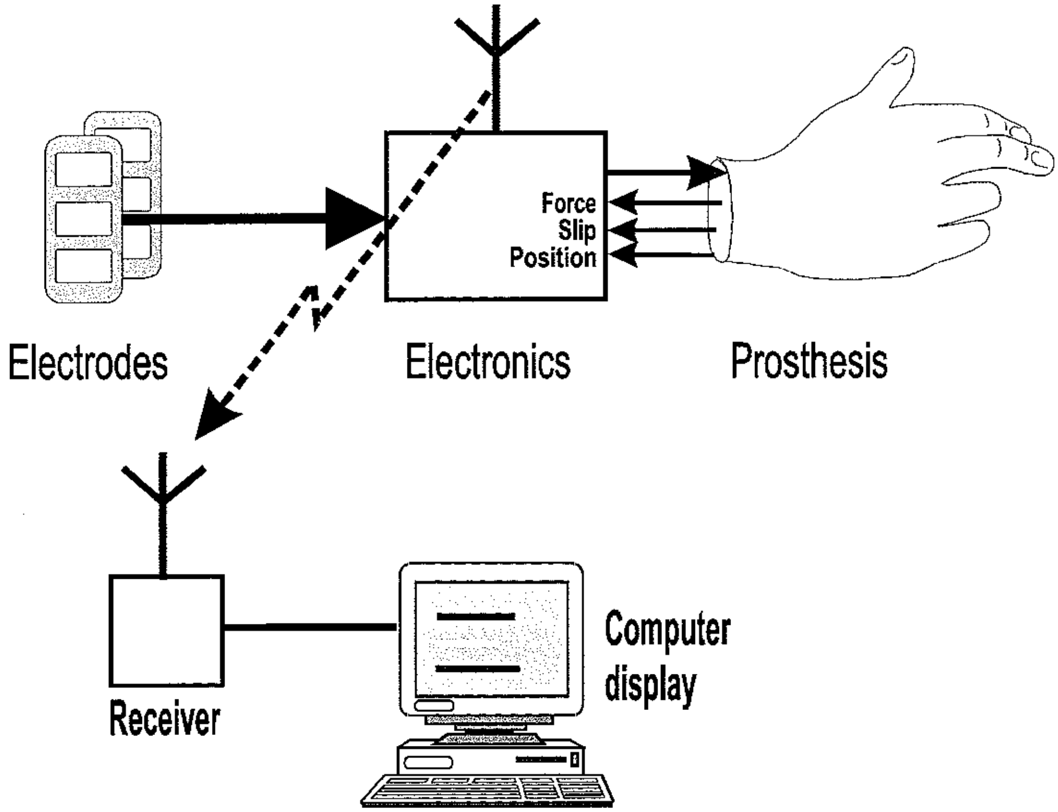

Figure 1 - Telemetry system for the LO/SH Hand

This difference means that some experienced myoelectric hand users can take time to adjust to the difference. Assuming that the user employs the conventional extensor/flexor opposing muscle pairs, then using the telemetry display, experienced myo-users can be observed to driving the hand closed like a standard voluntary opening voluntary closing hand in vain. This has no effect on the hand controller. As the commanding extensor muscle is relaxed the hand will close irrespective of the state of the flexor muscle. However, before the operator is allowed to switch the hand into the hold with their flexor mode they must relax it first. The apply the tension so that it cannot slide into a holding state accidentally.

So seen from the outside it does not make any difference to the motion of the hand. However it has been observed that with the slow voluntary opening and voluntary closing method employed by conventional hands the operator opens the hand wide and early in a reach phase of the manipulation [16]. Natural hands are opened much later in the reach, and then only about 10% greater than the minimum required. Once it is appreciated that the hand can be opened quickly and precisely and much later in the operation and without the detailed conscious control of the conventional system.

Even so those who have no preconceptions about myo-electric control because they have no experience prior to their exposure to the hand they have little difficulty in grasping the concepts.

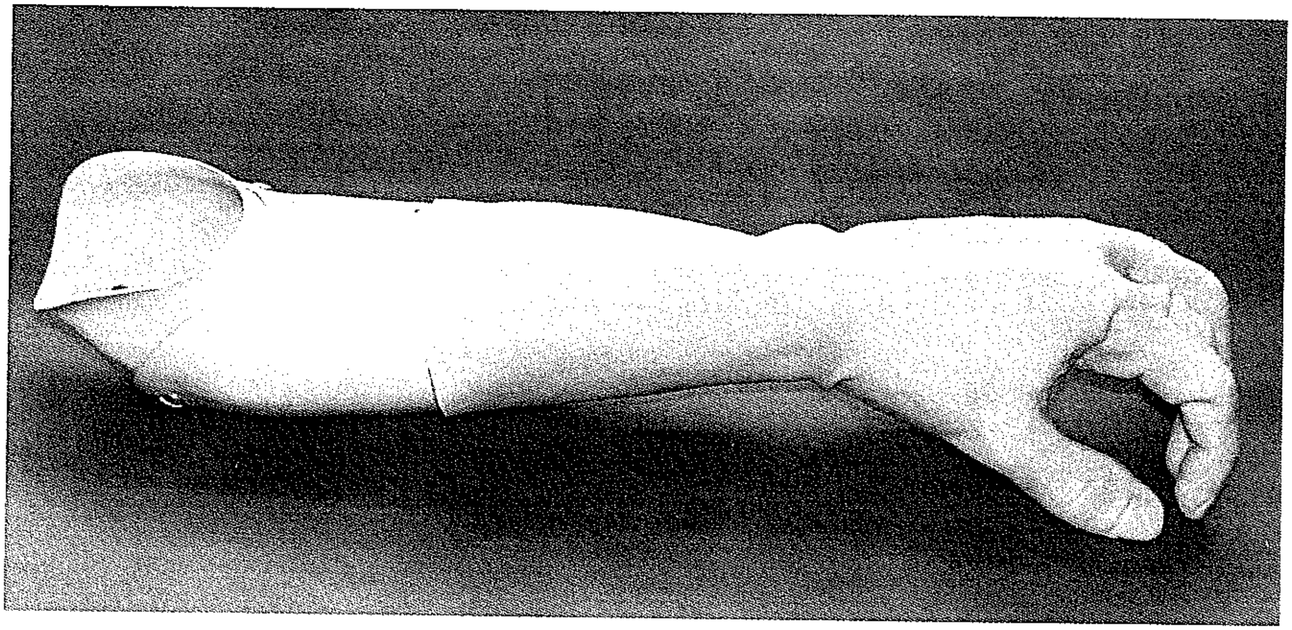

Figure 2 - LO/SH Hand

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