

## **PROGRAMMABLE CONTROL: CLINICAL EXPERIENCE AT BLOORVIEW MACMILLAN CENTRE**

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### **INTRODUCTION**

Advances in microprocessor technology in recent years have led to the introduction of programmable control systems for powered prosthetics. These systems allow amputees to try a variety of control schemes and choose the one that suits them best. Prosthetists, no longer limited to preprogrammed control schemes, can devise new schemes that are suited for the amputee's individual needs. Over the past few years, Bloorview MacMillan Centre has fit approximately 20 clients with programmable control systems. A retrospective analysis of this group, which includes amputation levels from below-elbow to shoulder disarticulation, demonstrates the benefits this approach. The benefits fall into four general categories: 1) evolution of the control system as the user's needs and abilities change, 2) the amputee's ability to choose their own preferred strategy, 3) accommodation of abnormal and noisy signals and 4) ability to accommodate high-level amputees. This paper will summarize our clinical experience with programmable control. Case studies illustrating this approach and its various benefits will be presented.

### **BACKGROUND**

Developments in microprocessor technology in recent years are having a significant impact on the delivery of prosthetic systems. Microprocessors have been designed for battery operation at a wide range of voltages using little power. These processors are available in very small packages and incorporate all of the features needed for prosthetic control. Many microprocessors are available with on-chip field-programmable memory. It is the field-programmable feature of these chips that allows them to be adapted to the needs of a wide range of amputees.

Manufacturers of prosthetic hardware have taken advantage of these developments by creating prosthetic controllers that can be programmed and customized by prosthetists in the field. Animated Prosthetics, Liberty Technology, Motion Control and Variety Ability Systems Incorporated (VASI) have all introduced field programmable prosthetic controllers.

The powered upper extremity prosthetics team at Bloorview MacMillan Centre in Toronto has had extensive experience using MyoMicro, a graphical software programming tool that is compatible with the Liberty and VASI controllers to meet the diverse needs of a wide range of clients. This experience has confirmed the versatility of the microprocessor-based programmable approach.

### **CLINICAL EXPERIENCE**

#### **Evolving control systems**

Choosing a control system for an amputee's prosthesis involves assessing the amputee's functional goals and needs, ability to control multiple myoelectric and mechanical inputs, tolerance of componentry and cost. Regardless of how thorough the clinical team is in making this assessment, the above factors are likely to change over time. Programmable control allows the clinical team to change the control system as the needs and abilities of the amputee change without incurring the cost purchasing and installing a new control system.

A common example of control system evolution is the clinical practice of using a voluntary-opening or "cookie crusher" control system for congenital amputees under 3 years of age and switching to 2-site myoelectric control when the child is ready<sup>1</sup>. Currently, this switch is done by purchasing new hardware for the child's prosthesis. Using a programmable controller, the change in control system can be done without changing the hardware, by reprogramming the prosthetic controller. Control system evolution is also common in the case of traumatic amputees whose tolerance for complex and heavy componentry increases as they become accustomed to their injury and to wearing a prosthesis. This is illustrated in the following case from Bloorview MacMillan Centre's recent clinical experience.

### **Case 1**

The client is a 16 year old female, competitive figure skater who suffered a traumatic, very short AE amputation as a result of a boating accident. She was initially fitted with a lightweight passive cosmetic prosthesis. The initial goal was to condition her to wearing a prosthesis and accommodate her short-term need for cosmesis to be a bridesmaid.

Upon assessment for an active prosthesis only one weak EMG signal site on the deltoids was found but there was sufficient humeral flexion and extension to operate force sensitive resistors (FSR's). The VASI programmable controller was programmed to pick up signals from 2 FSR's mounted in a check socket. The family was anxious to have an electric elbow incorporated but the clinical team felt it was not advisable for the first fitting since the client is very petite and still emotionally fragile. The team decided to use programmable control now so that the elbow option could be added at a later time if she is able to handle the additional weight and control system complexity.

### **Implementing control strategies that are not commercially available**

Often clients with special needs require customized control systems because they have difficulty controlling commercially available systems. In the past, this type of customization was expensive and generally avoided by the clinical team. With programmable control, the prosthetic team can create virtually any control scheme that suits a client's unique abilities.

The Bloorview MacMillan Centre powered prosthetics team has taken advantage of programmable control for clients who had been fitted many years earlier with control systems that are no longer commercially available. These clients have become accustomed to their prostheses since early childhood and changing the control system would have resulted in degradation of control accuracy. This is illustrated in the following case.

### **Case 2**

The client was a 31 year old male with a congenital short below-elbow deficiency, employed full-time as a forklift operator. He used a conventional, body-powered prosthesis until age 13 and was admitted in 1982 for myoelectric fitting. In spite of prolonged assessment and control training, it was not possible to overcome a muscle co-contraction problem. The client was eventually fitted with a Variety Village version of the UNB 3-state system and became a successful, full-timer user of his myoelectric prosthesis.

In May of 1997, he required a replacement of his myoelectric prosthesis but the UNB system was no longer available. Programmable control was used to assess his ability and his preference between rate and level sensitive strategies. The client preferred to continue to use a level-sensitive approach and the programmable controller was configured to emulate the system to which he was accustomed.

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<sup>1</sup> Hubbard, S., Bush, G., Kurtz, I., & Naumann, S. "Myoelectric Prostheses for the Limb-Deficient Child", *Physical Medicine and Rehabilitation Clinics of North America*, 2:4, 847-866, November, 1991

### **Overcoming interference problems**

Interference, or noise, poses a significant challenge to successful myoelectric fitting. Interference may come from other muscles in the client's residual limb, external electrical sources and inadvertent cocontraction of the controlling muscle. Programmable control opens the possibility for a number of innovative ways to overcome interference in a myoelectric system. For example, digital filters and time delays can be introduced in the signal path to make the system more selective to the desired signals. The control logic can also be changed. For example, the system can be programmed to ignore a muscle signal if antagonist muscles are active at the same time. Alternatively, the system can react to the first muscle to contract and ignore the second muscle. In some cases, cocontraction itself is the most reliable way for users to communicate their intentions to the system. The following case illustrates the use of programmable control to overcome electrical interference due to an amputee's pacemaker.

#### **Case 3**

A male War veteran sustained an amputation above the left elbow. His arm was blown off in battle and severe tissue damage resulted. Burned tissue and skin grafting cover the residual limb and part of his upper body. This patient's circumstances are also complicated by the fact that he wears a pacemaker. Upon the initial assessment by the team, it appeared that he had adequate biceps and triceps control to operate a myoelectric prosthesis. A closer examination revealed otherwise. A strong biceps muscle signal was obtained only when the muscle gained a fair size muscle belly. The muscle would not achieve the same signal strength when the development of its muscle belly was hindered, such as is the case when containing the residual limb in a prosthetic socket. In addition to the fitting difficulties associated with stump pain and flaccid tissue, a major problem arose when interference, generated by his pacemaker, was picked up by the electrodes in a conventional two-site myoelectric control system.

In order to fit this man with a 2-site myoelectric prosthesis controlling an electric elbow and hand, a programmable control system was used. Through the Myomicro software, the electrode gains were altered to enable the muscle signal fluctuation of the biceps to be picked up when it was not able to gain its full muscle belly while contained in the prosthetic socket. The pacemaker signal problem was addressed by implementing time-delay filters in the input signal path. A biceps - triceps co-contraction selects the device to be activated with an automatic revert to hand default.

#### **High-level amputees**

The most challenging powered upper extremity fittings involve amputations above the elbow and higher. These clients have the most complex needs but they often have the fewest sites for control. The process of choosing the control strategy that is most appropriate for these clients and optimizing the control parameters for them is greatly enhanced by the programmable control approach that allows clients to try a variety of options and refine the one that best suits them. The following case illustrates the usefulness of programmable control for a high-level client.

#### **Case 4**

The client is a 46 year old woman who suffered a complete transverse amputation of her left arm. She was very motivated to attain restoration of bimanual function in order to resume her duties as a general physician in a busy family practice. Cosmesis and function were equally important and our goal was to provide her with a prosthesis which would optimize function while appearing as natural as possible both statically and dynamically.

The clinic team along with the client, decided that a prosthesis with a passive shoulder, an electric elbow and electric hand would best serve her needs. The programmable controller was included to give us the flexibility to design the most effective control strategy possible. The major problem was a limited number of control sites, due in part, to her distorted proprioception in the shoulder region. We were able to identify only 3 distinct shoulder

movements; protraction, retraction and elevation. Using the MyoMicro controller we were able to explore various control options including rate and level sensitive 3-state control. It was finally determined that the best strategy for this client was a control system that permitted mode selection between the hand and elbow control.

In the client's prosthesis, two Force Sensing Resistors are used as input devices and were chosen because they are low profile and offer proportionality. The FSR's are positioned on the socket at specific points anterior and posterior to the acromion process. Protraction of the shoulder controls hand closing and elbow flexion, while retraction of the shoulder controls hand opening and elbow extension. By using the MyoMicro software, the sensitivity levels of each FSR can be independently adjusted to refine control.

Attempts to position the FSR's to allow shoulder elevation to activate both devices simultaneously as a mode selection signal were abandoned due to the difficulty of this approach for the client. Instead, the mode selection function is provided by a microswitch positioned over the acromion process and accessed by the third movement, shoulder elevation. To avoid mode switching due to inadvertent activation of the microswitch a time delay filter was introduced. The controller's capacity to fine tune the system resulted in a prosthesis which satisfies the client's need for subtle movements for hand and elbow control.