UNIQUE DEVICE-SELECTION STRATEGIES FOR POWERED ELBOWS

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BACKGROUND

In an upper limb prosthetic system Mode Selection gives the user the ability to utilize one or two input signals to control more than one prosthetic device. Mode Selection is defined here as the means by which a user shifts control to the different electric devices in their prosthetic system. Mode selection has been done for many years in several forms, each of which has a benefit to the user. The simplest mode selection scheme uses a simple switch. Other types involve the use of myoelectric signals that cross a specific threshold, or a rapid co-activation of two myoelectric signals to perform the mode selection. This latter method of mode selection has become a basic cornerstone for mode selection. However, the performance of the prosthesis must match the desired goals of the user. If such a technique cannot be mastered then other approaches must be made available.

Mode Selection As A Function Of Myoelectric Control Signals

In most situations, the mode selection technique is based on the use of the same inputs that provide control of the selected device. The rapid co-activation is the most common method for mode selection. This technique can be difficult for some users to master, and in some cases, with the upper limb user, it can not be performed while the prosthesis is in certain positions. With this in mind, one of the new capabilities of the Boston Digital Arm System is to provide more than one means of mode selection at a time. With the situation in point, a simple switch can be added so that mode selection is accomplished by activating the switch, rather than rapid co-activation. This method is included in any Boston strategy that uses mode selection, so that should the user not be able to master the mode selection technique, a simple switch can be added at any time to perform the task, or both can be used as required.

If rapid co-activation is not an option for a specific client, then a level (threshold) based approach may be used. This means that both myoelectric signals must exceed set thresholds, to initiate mode selection. With the help of the Boston interface software, the change from rapid co-activation mode selection to level sensitive can be applied through a simple menu click, allowing the user to experiment with the different options available. This ability to quickly change mode selection technique means the user will not have to wait for the prosthetist to change plugs or settings to potentiometers.

Mode Selection With Other Myoelectric Inputs

Some cases have been found where a third myoelectric site is available. This site can be utilized as a third input, providing the user with the ability to mode select without having to interrupt the signals providing control to the system. As above, the myoelectric signal can be sampled for rate of change, or for exceeding a specific level. The signal from this site can have its' noise threshold and gain adjusted just like the primary sites.

The use of the third muscle opens new possibilities for mode selection. Rather than cycling through available devices in sequence, the user can now select which device to operate. This is similar to the operation of an Otto Bock Double Channel hand. Should the signal reach a specific threshold, one device is selected. If the signal does not reach the threshold, another device is selected. In this case, a default device must be selected, so that when a selected device is not operated, a revert time brings control back to the default device.

Selecting the Default Device

In the Boston interface software, the default device can be selected from a drop down menu, depending on the type of mode selection desired. If cycling through devices is preferred, then the drop down box contains all possible combinations.
In a 3-device system the possibilities would be;

Table 1

Default	2nd	3rd
1. Hand	Elbow	Wrist
2. Hand	Wrist	Elbow
3. Elbow	Hand	Wrist
4. Elbow	Wrist	Hand
5. Wrist	Hand	Elbow
6. Wrist	Elbow	Hand

Mode Selection in Non-Myoelectric Systems

In upper limb systems where no myoelectric signal is available, other inputs must be used. These currently include, linear transducers, Touch Pads™, and simple switches. The linear transducer is also referred to as a servo. (See Fig. 1)

Figure 1

The servo, or linear transducer, generates a voltage signal that increases as the transducer is pulled. This voltage can be used to control the position of the elbow, in which case the system is called a positional servo – transducer position controls elbow flexion angle. The voltage is similar to the output of a Touch Pad or Bock electrode, so it can also replace one of these as a signal source. When the servo is used in conjunction with one or two myoelectric inputs, the user has ability to control two devices simultaneously. As a case in point (Fig 2&3), a recent Boston system utilized three of these linear transducers, one acting as a servo. The other two controlled independent open and close, but the co-activation of these two resulted in mode selection. The two had to reach specific thresholds before mode selection would occur.
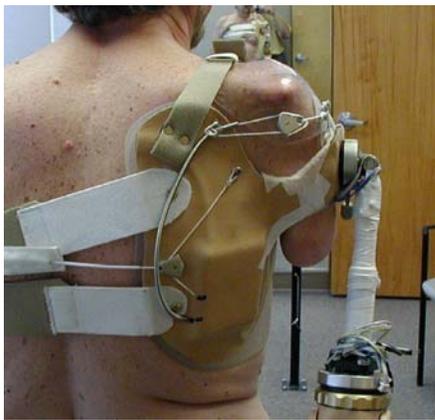

Figure 2 [1]

Figure 3 [2]

The use of Touch Pads, force sensitive resistors, is also appealing in upper limb prosthetic systems. The most common systems utilize three individual Touch Pad sites that can be activated by the user. Two of the sites are for function, while the third site is used for mode selection. Three often used sites use the tip of the acromion that is moved forward and back for control and up for mode selection. This mode selection scheme, similar to myoelectric, has adjustments for noise, gain, and the threshold setting for the mode selection site. Similar techniques, as described for myoelectric, can also be applied to the Touch Pad.

Simple switch systems rarely use mode selection, but when it is necessary, the Boston can interpret the signals differently. With switch control a single dual action switch usually controls direction while a second switch may be used to do mode selection. When the second switch is single action, it may be used to cycle through the system devices. With a dual action switch, each position can select a separate, non-default device.

User Feedback During Mode Selection

When changing control from one device to another, it is important to let the user know that the change has occurred. The Boston system does this in a variety of ways. The

simplest method is to have the system emit a tone. The pitch, volume, and duration of the tone can be modified through the interface software. Once training is completed, the user may elect to change these parameters, or disable them completely.

This method of feedback can be taken a step further. The Boston is capable of driving up to five devices. When cycling through the different devices, the controller can create sounds that have different pitch, volume, and duration based on the device that has been selected. Elbow selection might produce a long high-pitch sound, while hand selection could be indicated by a short low-pitch sound. The settings for each device are independent and can be set through the interface software.

Some users may find that the sound feedback is too irritating for continued use. In this situation, the system can use vibratory feedback to signal a successful mode change. This can be done whenever one of the five available outputs is not being used to operate a device. The user can then choose how intense and how long the vibration is applied. This vibration feedback can also utilize the same features as described for the sound. A unique intensity and duration of the vibration can be assigned to each device selected. So when the elbow is selected, a short intense vibration might be delivered, while the wrist selection might give a long and low intensity vibration. As with the sound, the vibration may be disabled at any time using the interface software.

When sound and vibration are not convenient for user feedback, light can be used. In particular, when a specified device is selected, an LED can flash red or green. To enhance this feature, an LED can remain lit to indicate, by color, which device is currently active. This insures the user will not "spill the cup of coffee".

CONCLUSION

This paper has shown that the microprocessor in the Boston Digital Arm System now offers a multitude of control and mode selection choices. With the interface software, the system can be tailored to the users needs and capabilities. When user skill increases, further complexity can be added, while some feedback may be removed. This system is typical of what you may expect from LTI and other suppliers in the near future.

REFERENCES
1. Photo appears courtesy of Prosthetic Orthotic Solutions International, Marlton, NJ.
2. Photo appears courtesy of Prosthetic Orthotic Solutions International, Marlton, NJ.