From “MEC '02 The Next Generation,” Proceedings of the 2002 MyoElectric Controls/Powered Prosthetics Symposium
Fredericton, New Brunswick, Canada: August 21–23, 2002. Copyright University of New Brunswick.

MINI JOYSTICK for Upper Limbs Prostheses

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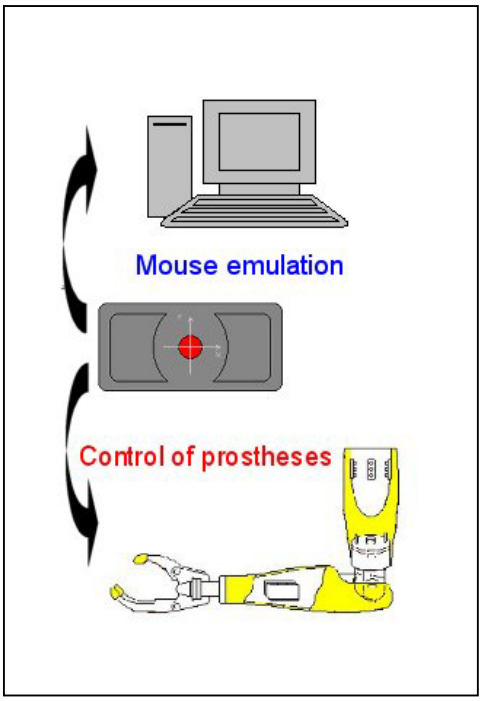
Introduction

The use of myoelectric command is often difficult to apply to congenital pathologies of the upper limb, which alternative solutions such as pressure sensors or common microswitches are often used. In such cases, prosthesis command entails the use of the same techniques used with the myoelectric method, in other words, the activation of the various hand, wrist and elbow functions by means of a cyclic system or one based on subdividing the signal detected by the sensors into various levels. In movements involving more than one joint, only one function is activated at any one time, which, although extremely safe, often makes these operations lengthier and sometimes unnatural. Therefore using a mini-joystick for prosthesis control can prove extremely convenient as it permits combined control the functions of the artificial limb simultaneously according to the direction in which the joystick is moved.

In today’s society, the possibility to access a PC is increasingly important for people with prostheses and the possibility of using the joystick to emulate a PC mouse becomes essential for patients, especially those with proximal pathologies, as using a traditional mouse with an artificial limb is problematic and awkward.
This device permits the setting of two function modes:

a) Prosthesis control mode
b) Mouse emulation mode



The two modes are mutually exclusive; the patient usually uses the joystick to control the prosthesis as described below; for use with a PC, the patient connects a cable to the prosthesis that will redirect the data from the mini-joystick to the PC rather than to the prosthesis. The decision to use a commercial component, on the one hand means having immediate access to a low-cost device with a PC compatible interface and that is therefore able to function directly as a mouse emulator and on the other, requires the implementation of a software interface integrated into the prosthesis control circuit that is able to receive information in mouse format.

Various devices with different characteristics were analysed in order to choose the product that:

- best exploits residual mobility in the remaining body segment;
- supplies a sufficiently accurate output to be processed by the algorithm that controls the limb movement actuators.

- is able to handle the control, event simultaneously, of three degrees of freedom, precisely, the opening/closure of the hand, rotation of the wrist and flexion and extension of the elbow.

Other important characteristics for the choice of the control device are:

- limited dimensions;
- limited weight;
- reliability;
- low consumption

The analysis of the various commercial devices available resulted in the choice of the product manufactured by Interlink. It is composed of a 360° directional control joystick and two buttons, on a support of just 7.5 x 3 cm and supplied with clamping holes.

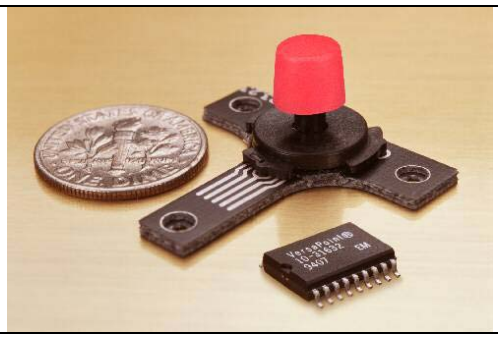
It is compatible with Microsoft DOS, Windows 9x, 200, 3.x and OS/2 operating systems and is supplied with RS232C hardware interfaces for PS/2 mouse, USB and direct serial ports with TTL levels.

It consumes < 6 mA at 5V DC and < 3 mA at 3,3V DC.

Each action of the device, supplies 3-byte packages that, after suitable processing, provide information on the pressure of one of the two buttons and joystick position, with a variability range of -128 to +127 on both the x and y axes.

The thickness and the weight (1 cm at the highest point and < 15 gr respectively) are almost negligible.

Assembled versions



Version with separate components

In addition to the version of the mini-joystick used for this project, another non-assembled version of the joystick is available, composed of the MicroJoystick, the microcontroller for sensor handling and communication with the PC and buttons, which provide maximum assembly versatility, in order to exploit the extremely limited dimensions of the single components without altering the other functional characteristics.

MOUSE EMULATOR

Communication protocol is in Microsoft mouse serial format. Each time the mini-joystick is moved, three bytes, each of which has 7 bit data, 1 stop bit and no parity bit, are sent at the speed of 1200 bps. Movements on the x-axis are positive towards the right and negative towards the left; movements on the y-axis are positive downwards and negative upwards. The L and R bits are at 1 when the left or right button respectively is pressed. X7-X0 and Y7-Y0 are the X and Y co-ordinates expressed in 2’s complement format (range from –128 to 127).

Byte	B6	B5	B4	B3	B2	B1	B0
1	1	L	R	Y7	Y6	X7	X6
2	0	X5	X4	X3	X2	X1	X0
3	0	Y5	Y4	Y3	Y2	Y1	Y0

A driver is supplied with the device in order to use the mini-joystick as a mouse for PC with DOS, Windows 3.x, W9x and W2000 operating systems. Software for handling device function parameters for defining the device’s functional characteristics as desired (e.g. the speed and acceleration of the cursor, orientation, etc.) is also supplied. The interface towards the PC is available in serial and USB versions.

Prosthesis control

Prosthesis control must include commanding the three electromechanical joints that can be present: hand, wrist and elbow, for a total of 6 functions. For example, the joystick can be used to control elbow and wrist movements and the 2 buttons can be used for hand control (one for opening and one for closure), even simultaneously. Considering the movement of the joystick on a perpendicular Cartesian plane, each joystick position has a pair of values (x,y), which univocally identifies two variables that will then be processed by the system to provide the desired limb movement.

For example, by associating the hand movement to the x co-ordinate and the elbow movement to the y co-ordinate, according to the position of the joystick (both co-ordinates have a range of –128 to +127) data can be processed and handled with suitable algorithms for controlling the actuators associated to them, thus also providing a proportional command to the motors. In this case, the two lateral buttons are used for wrist movements.

The chart below defines the commands that are given by moving the joystick:

Close hand Flex elbow	Flex elbow	Open hand Flex elbow
Close hand	Stop	Open hand
Close hand Extend elbow	Extend elbow	Open hand Extend elbow

Referring to the chart, it can be observed that by moving on the main axis, the command action refers to one degree of freedom only, whereas by moving diagonally the command action involves 2 degrees of freedom. A 3rd degree of freedom could be activated by the buttons, and this movement would also be simultaneous with the other two degrees of freedom. In order to vary the speed of the actuators and make prosthesis movements even more natural, it is possible to establish thresholds within each sub-quadrant within which the speed of the actuator has a different value: for small movements beyond the speed threshold null the actuators move with low speeds that gradually increase towards the outside of the quadrant.

The association of commands to the actuators, the definition of thresholds and the laws that regulate the speed of the actuators inside the quadrants can be set according to patient requirements. It should also be pointed out that defining the thresholds in an appropriate manner makes it possible to eliminate the simultaneous movement of more than one joint. A software package that permits the technician to calibrate the threshold and parameters according to the patient’s abilities and residual functionality has also been developed. It should also be pointed out that the use of the joystick as a mouse emulator has made it immediately possible to use various commercial software packages (video games, etc.) as training software for patients on device use.

Despite the fact that the use of a standard device has a number of advantages, it also requires the implementation of the communication protocol with the mini-joystick module within the control circuit. With the current version, the control circuit must be programmed by indicating that the command is provided by mini-joystick rather than electrodes or microswitches; work is currently in progress on the creation of a system that permits the controller to adapt to the connected sensors automatically.

CONCLUSIONS

The system has now been tested for approximately a year on 4 patients fitted with prostheses with electromechanical elbows and the results would appear to be very good. The aspect that is most appreciated is the possibility to command the computer mouse directly, whereas only two of the patients appreciate using the combined elbow and hand movement. All the patients were already prosthesis wearers and this doubtlessly influenced their opinion. However, the number of cases is still too limited to draw any definite conclusions.