A LOW-COST ROBOTIC ARM WITH FINGER MOVEMENT INPUT: CONCEPT AND PRELIMINARY DESIGN

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Abstract: Robotics has been applied on the rehabilitation of patients suffering from upper limb related diseases such as stroke, upper spinal cord injuries or neuromuscular diseases (e.g. muscular dystrophy) alone, or combined with appropriate orthotic devices. In all cases, expensive industrial manipulators, as much as relatively low-cost commercial systems with specific modifications have been used. However, no reference has been made in the literature on the technology of such devices.

This article presents the development of a joystick-computer system for the control of a stepper motor. Reference in made on the technology on which the circuitry is based, as well on the design concept of it. Further research can lead to the development of a low-cost robotic arm with residual finger movement input.

Introduction

Rehabilitation nowadays as an aim for research laboratories worldwide is the development of innovative treatments that take advantage of robotics and informatics for rehabilitation. This includes the development and use of robots to assist persons with disabilities, as much as the creation of robot aids to support and help clinicians in their efforts to facilitate a disabled individual's functional recovery [1].

Robotic aid can introduce new efficiencies into routine therapy activities following stroke [2-5], and can also provide a reach stream of objective data to assist in patient diagnosis and therapy. Additionally, its use on (non-)commercial systems in neuromuscular disorder and upper spinal cord injury rehabilitation can contribute to quality of life and patient independence [1].

Individuals who suffer from neuromuscular abnormalities are left with muscular weakness, but with no associated sensory or cortical spinal tract involvement. These individuals fall into those with arrested (e.g. Poliomyelitis, Arthrogryposis Multiplex Congenita) and progressive (e.g. Spinal Muscular Atrophy) Anterior Horn Cell Disease [6] and those with muscular disorders [7] (e.g. Duchenne & Becker Muscular Dystrophy, Congenital Myopathies (Nemaline, Myotubular, Central Core), rare Mitochondrial Dystrophies, Amyotrophic Lateral Sclerosis). In both types the proximal musculature of the upper and lower extremities is affected and individuals finally lose the ability to use their arms and legs. All the same, all patients retain residual distal movement of the wrist and fingers throughout their lives and hand strength remains sufficient to manipulate objects of moderate weight like wheelchairs, joysticks, panels, computers etc.; this is a characteristic that could be used successfully for rehabilitation.

To help patients with neuromuscular diseases pursue activities of daily living more independently, a number of research projects have focused on developing orthotic devices for mechanically guiding the arm while counteracting effects of gravity, as much as on implementing commercial robotic devices that can use wrist, finger, speech or vision input to help patients perform basic functions.

In the first case, the complexity of developed prototypes has ranged from simple passive devices that support the arm vertically against gravity, or from more sophisticated unpowered systems [8], to complex powered exoskeletons [9-10]. Designs of intermediate complexity support the arm, generally at the forearm, and allow one or several powered degrees of freedom [11]. Other motorized upper-limb orthotic systems are being developed [12-13], with the aim of the creation of a low-cost, commercial product.

In the second case, industrial robots have been used for rehabilitation in cases where the residual distal movement capacity has been successfully implemented to decrease orthopedic deformity [14]. The instantaneous control afforded by finger movements via direct joystick manipulation or via a touch-sensitive control panel makes a direct manipulator control possible. However, although the use of finger movements takes advantage of sensory feedback and provides a closer match with the mental representation of the movement being performed, many laboratories have focused on voice-operated manipulators and in particular fixed location manipulators, which are of prohibitive cost. Therefore, more attention should be given to modification of available and inexpensive finger or wrist-controlled portable robot systems. Some authors [14] propose the modification, with small cost in parts and labor, of low-cost (<$1000) programmable industrial training manipulators to bypass limitations derived from expensive units; should hand function be

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completely lost, small changes could render speech or vision input possible. However, to the best of our knowledge, the technology and design of a laboratory-made low-cost manipulator for neuromuscular rehabilitation are not described in the literature.

The aim of this article is the presentation of a PC-centered system that controls robotic arthroses with a joystick input. Specific software has been developed with the use of optical programming for the processing of the joystick signals and the motor control through relatively simple hardware. Further research can lead to the development of a fully-automated manipulator.

Materials and Methods

Input of signals

Graphical programming with Labview 6.0 has been applied for the implementation of the system. First, an object that takes advantage of a neuromuscular patient's residual distal upper limb movement was needed for an input. This has been achieved with the use of a Microsoft Side Winder joystick, which was inputted to the PC through the USB port. Next, three Digital Numeric Control and five Digital Numeric Indicator Labview objects have been used at the software.

A number used by a specially developed '*joystick.dll*' file has been inputted in the first Control object; this file is designed to read the USB port and through it the joystick signals can be recognized by the software as 5-digit numbers. In the second and third Control objects, two register numbers for the PC's parallel port (378 and 37A for Microsoft Windows XP accordingly) are inputted; through this port, the joystick signals are used to drive the step motors (Figure 1).

All 5 Indicator objects have been used for the inputting of the joystick movements. The first two implement the joystick's 2-axes (vertical and horizontal axes) movement into 2 five-digit integer numbers, the second two define the desired clockwise or anti-clockwise movement of the step motors and implement two of the joystick's buttons, while the fifth is used to define a movement that can be used as a grasp-or-leave movement (Figure 1).

Call Library Function objects can be used for the immediate call of standard or dynamic link libraries (e.g. 'joystick.dll'), which in general contain data or functions that can be used in various Windows applications. Such objects consist of a node at the left, where an input signal can be placed, and an according node at the right, where the output signal is given. The software platform's *configure* menu gives a dialog box where the desired for use in each object libraries are inputted (directory/path and name), as much as the output data type. Bearing this into mind, such objects have been used for all Numeric Controls and Indicators and are viewed in Figure 2.

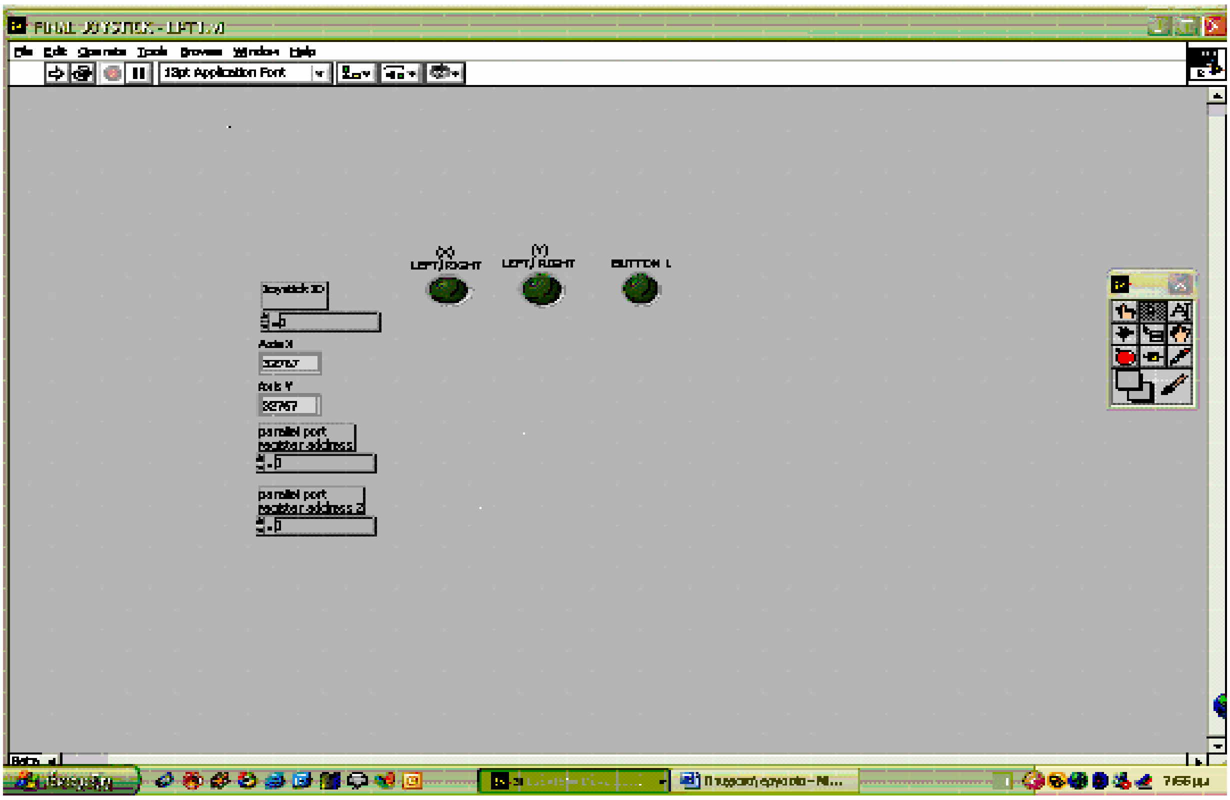

Figure 1: The Virtual Instrument's front panel

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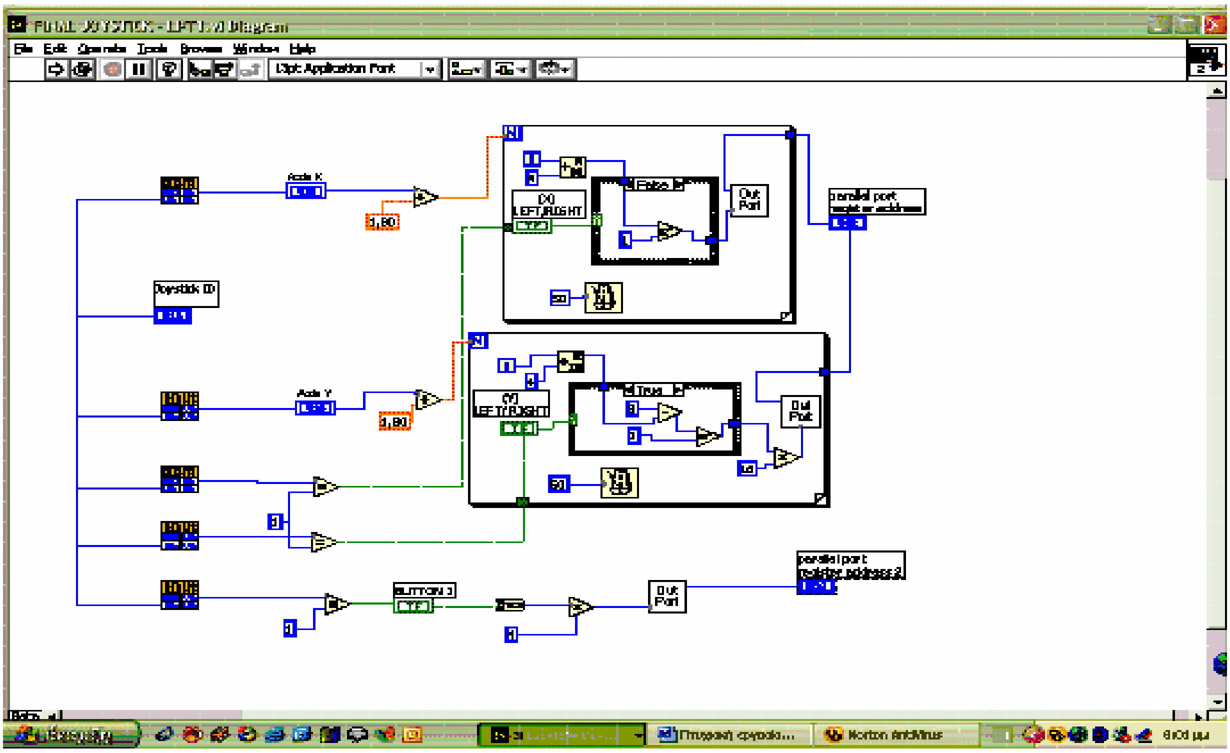

Figure 2: The Virtual Instrument's diagram

Output of signals

The signals which are given by the joystick movements, after having been read by the software, are headed to the parallel port (output) so as to drive two step motors and a grasp-and-leave object through specifically designed hardware. For this reason, three Out Port Labview objects have been applied. An Out Port object receives as input the register address of the parallel port and the value that is heading for output at this port. The same object uses a Call Library Function object, where the Windows '*cvirte.dll*' file that is used by Windows XP to control the PC's parallel port is loaded and transfers the data (to LPT1 in our case).

Control of a step motor

A step motor has the ability to convert electrical pulses to according mechanical movements. Every 360^0 rotation is a series of solitary steps, that-is-to-say angular displacements which result from electrical pulses sent to the motor. The number of steps required for a full rotation depends on the step motor. In our research the Isert Electronics Art-Nr 3450 motors have been used, which require 200 pulses for full rotation (1.8^o rotation for each pulse).

The step motor receives an input via four wires. In this way, four consecutive signals in the wires are required for angular rotation of one step. This is achieved with the use of a 4-channel push-pull driver (ST Microelectronics L293B integrated circuit), which sends the LPT1 signals to the step motor. The software is designed in such a way that pins 2-5 of LPT1 are used as the output of the joystick's x-axis signal and pins 6-9 are used as the output of the joystick's y-axis signal. In this way, two integrated circuits are required. Each one has four inputs (pins 2-5 and 6-9 accordingly) and four output signals, which are the four-wire inputs of one step motor. For the control of the grasp-and-leave object, the pin 16 of LPT1 is used (Figure 3).

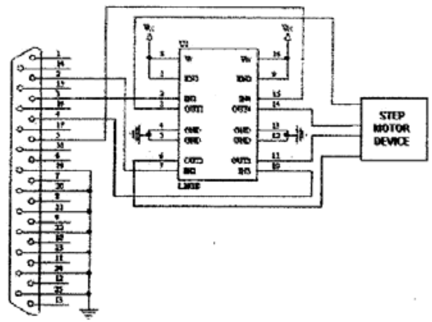

Figure 3: The hardware block diagram

Results

For the verification of the software's right function, a '*parmon.exe*' program has been applied. This software is designed to read all data which are sent to the output ports. Its menu allows the user to specify the port for verification and running of the Labview software indicates the signals in the LPT1's pins. In this way, it has been shown that the movement of the joystick in the x-axis gives signals in LPT1's pins 2-5, the duration of whose is analog to the magnitude of the joystick movement. The according occurs for pins 6-9 and the y-axis movement, as much as for button 1 indicator and LPT's pin 16.

Moreover, the stepper motor movements have proven to be analog to the magnitude of the joystick

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movements in the vertical and horizontal axes. This has been achieved through the software, which defines the magnitude of the motor rotation according to the relative movements of the joystick (Figure 2).

Discussion

All subjects who suffer from neuromuscular diseases have weakened musculature, which progressively deteriorates. All the same, they retain residual upper limb distal movement ability, which is one great advantage that can be used effectively in rehabilitation [13]. This paper describes a low-cost (~$150) laboratory-designed and developed system oriented for such individuals. The technology for the control of two step motors and a grasp-and-leave object through a PC is described. Specific software has been written in Labview 6.0 for the processing of input signals generated by a joystick's movements, which has the ability to use the residual upper limb movement. Then, relatively simple hardware which is used as a LPT1-step motor interface has been developed. As a whole, the joystick movements in 1 plain are used to produce 4-digit signals which move 2 step motors accordingly. Moreover, a joystick's button is used to drive a grasp-and-leave object which offers one more degree of freedom.

This low-cost, simple in design system can be accordingly expanded to create a fully articulated robot. 2 step motors can be used as substitutes of the shoulder and elbow joints, while for the wrist joint a grasp-and-leave object can be applied, forming in this way a 3-degree-of-freedom automated system. The placement of the robotic arm on a bench where it can be moved leftwise or rightwise offers one more degree of freedom. Steel wires may be utilized as substitutes of the upper limb bones between articulations in order to integrate the robotic arm. Research is conducted at the moment by the author at this aim.

Conclusions

Non-algorithmic programming and relatively simple hardware yields the ability for the development of a PC-centered low-cost system for neuromuscular rehabilitation.

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