Design and Construction of a Prototype of an Electronic Wheelchair Drive for People with Motor Disabilities

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Summary
The project presents the design and construction of a prototype of an electronic wheelchair for people (children and adult) with motor disability. The prototype of the wheelchair was built using a small computer embedded in a chip known as a microcontroller, chosen for its low cost, in addition to its versatility and ability to handle signals and its performance in mathematical operations and communication with other electronic devices.

Key words:
Motor disability, microcontrollers, PIC 18F452, actuators.

1. Introduction

Technology continues to be vital to the development of many cities of the Mexican Republic. The digital divide between industrial cities and the developing world represents an opportunity for many universities to build sustainable models for the development of their students and their growth.
A peculiar trend is the development of useful technology for people with any disability and in particular motor disability. This paper is about the design and construction of a prototype for an electronic wheelchair, which is constructed using a small computer embedded in a chip, known as microcontroller, which allows programming of the logic control routines for the prototype. Using a remote control, this prototype can be manipulated to perform basic movements like forward, backward, turn left or right and stop. Also, the prototype will be used as a guide for future construction in real size. It is a fact that there is a need in the population of physically disabled people in our environment. That is why this project pretends to add value to the conventional wheelchair, using electronic remote control with the aim of improving the quality of life of those who use it, giving them a feeling of freedom and independence. This means less dependence on another people, making their movement for daily activities such as going to school, moving around his or her residence, spending time with other people, etc, safer and more practical. Added to this, the mood of the person will be improved by the ability of achievement he or she will experience by moving himself or herself from one place to another. The design and construction of the prototype, the objective of this project, will contribute as a basis for that. In the first instance, these benefits will be offered to people who attend Centros de Atención Múltiple (CAM) of the State of Yucatan, and later to the public of the southeastern states of Mexico.
Many studies have been made in this area; in [1] a system of man-machine communication through eye movements was established, which allowed a communication between a person and a computer by detecting and coding the eye movements. In [2] the authors describe an analytical model to evaluate user performance time. They are examples of an engineering approach to system evaluation. In [3], a description of the physical characteristics of various models of wheelchairs is made. In [4] a localization and Positioning System for Autonomous Wheelchairs was developed, whose overall objective was to design architecture to incorporate autonomous navigation performance in internal structures of motorized wheelchairs, having in mind the inherent peculiarities of these vehicles and users. Also, in [5] a study is presented which reviewed hardware architectures in the most common existing wheelchair prototypes, developed by different research groups in assistive technologies, and finally [6] described a Wheelchair Controlled by Voice, whose objective was to substantially improve the quality of life of people with physical limitations, allowing them to travel without human support, developing a technology based on voice commands such as a man-machine interface and technological innovation in the field of applied engineering and mechatronics.

2. Background

Unquestionably, improving the quality of life for people with motor disabilities is a priority demand in today's world this is the case in Mexico and especially in the State of Yucatan. Nationally, according to number from the National Institute of Statistics, Geography and Informatics (INEGI), 1.8% of Mexicans have a problem with limited capacity, and in the case of Yucatan the prevalence of disability (2.9%) is above the national average (1.8%) and, in four of every 10 households lives a person with these characteristics [7]. In Mexico there are over 1,795,000

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people with a limited capacity, of which 47,700 are from Yucatan. In the state, motor disability is predominant, followed by visual, auditory, speech and mental disabilities. The national annual average is 47,000 live births with a problem, of which the largest percentage is motor disability. In the case of Yucatan, in 2009, 21 cases were detected, compared with 2008, when there were only seven cases [8]. Most of the state's population with this kind of problem, have not best a conventional wheelchair that they can handle themselves, and when the disability doesn't allow them to move, human support is needed. Referring to this, it is important to mention that in different parts of the world, research groups have begun to develop technology to support people with disability. Some of the lines being developed are: In [9] we have been developing an automated wheelchair by voice, where its control is done through simple commands such as: forward, backward, right, left and stop. Moreover, we intend to control several daily processes from the wheelchair, such as controlling of doors and lights in the house. In studies by [6] at the Universidad Politécnica de Pachuca, a wheelchair is being developed capable of autonomously transporting people with disabilities, in which the voice plays a major role. In [1] of the University of Alcala, Spain, a new technique is described called electrooculography (EOG) that allows the establishment man-machine communication for people with substantial disabilities, who cannot use methods such as a keyboard, joystick or voice, etc. The EOG consists of detecting eye movements by recording the potential difference existing between the cornea and retina; both signals when captured and processed appropriately, calculates with reasonable accuracy the direction of gaze of the person, and if the person has a good control over it, he or she can use this information to communicate. Finally, [5] makes a study of the most common hardware architectures in the prototypes of Autonomous Wheelchairs (SRA), which focuses on the benefits and opportunities created by the use of the Serial Bus in these systems, mainly to open the field of interaction with the SRA's user environment, be it domestic, industrial or commercial.

3. Disability and Motor Disability

There are several ways to explain disability. In advanced Western societies the prevailing idea is based on the medical model. From this perspective, people are disabled as a result of physiological or individual cognitive shortcomings. This is tacked when trying to cure or rehabilitate people with disabilities [10].

The social model considers disability as a socially constructed idea that arises from the failure of the social environment to adapt the needs and aspirations that citizens are lacking. Thus, this model requires a collective responsibility to make the environmental modifications necessary to make possible the full participation of people with disabilities in all areas of social life [11].

The document *Classification of Disability Type*, from the National Institute of Statistics, Geography and Informatics, INEGI, defines disability as any restriction or lack of ability to perform an activity in the manner or within the range considered normal for a human being, as a result of a deficiency. Disabilities reflect, therefore, disorder at individual level. In particular, the motor impairment or motor disability is defined in this document as the disability caused by motor neuron disorders that is to say difficulties in the control of movement and posture of the body to varying degrees. This condition may or may not occur with other disabilities in people [7].

4. PIC Microcontrollers

It is now necessary to have electronic devices that enable control of the operation of a particular task or a product without excessive costs, i.e. small microcomputers.

Microcontrollers, often considered dedicated computers, are integrated circuits that countain the three functional units of a computer:

- A microprocessor (CPU).
- Memory (RAM and ROM).
- I/O Units.

In short, it is a complete computer, but with limited capacity, which is contained in a single chip (integrated circuit) and is intended to run a task or product where it is often embedded (figure 1).

Fig. 1 Microchip.

Microcontrollers are designed to reduce the cost and energy consumption of a particular system. So the size of the CPU, memory and peripherals included in the microcontroller we select will depend on the application requirements.

For example, the control of a simple appliance like a blender will use a very small processor (4 or 8 bits) because it will replace a finite automaton. But a music player and / or digital video player (mp3 or mp4) will require a 32 or 64 bit processor and one or more digital signal codec's (audio and / or video).

Microcontrollers are invading the world. They can be found in our homes, in our work and our lives. They are found in almost any electronic device such as mp3 players, washing machines, microwave ovens, telephones, digital watches, cameras, PDAs, stereos, televisions, automobiles and even greeting cards, and many more devices.
The architecture of a microcontroller refers to its internal construction and the interconnection of its parts is shown in figure 2.

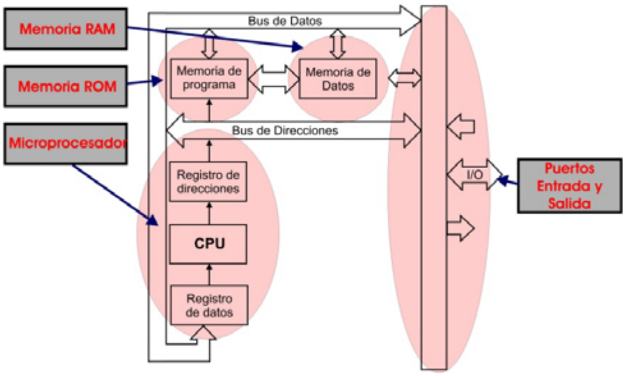

Fig. 2 Block diagram of a microcontroller.

In the development of the prototype presented here, the PIC 18F452 microcontroller (peripheral interface controller) was used.
The PIC has wide acceptance in the professional community engaged in the design of applications. The PIC has RISC (Reduced Instruction Set Computer) architecture, Harvard type, based on bank records, with a reduced instruction set of the same length and orthogonal, whose processing segmented [12]. Some other features are:

- Ease of use.
- Superb technical information.
- Adjusted price and good availability.
- Understandable and concise instructions.
- High average performance parameters: speed, power consumption, power, size, etc.
- Abundant, easy and inexpensive development tools.
- Support for software and hardware that facilitate mobility into higher models.
- Wide range of models to find the most appropriate for each case.
- Disposition from Microchip to support customers.

5. Prototype

A microcontroller differs from a microprocessor in many ways, the firstly and most importantly is its functionality. The microprocessor is the heart of a computer and to be used, other external chips such as memory and interfaces should be added to receive and send data. In the development of this project we proposed in the first instance using a laptop with a processor to control the logic of the chair, but because of the size of this, its cost and the energy used to make it run among other things, the original idea was discarded, replacing it with one that eliminates the problems presented, being this the microcontroller.
The microcontroller was designed to do all required functions in a single chip. No other external component is required for its application because all necessary peripherals are already built into it, this saves time and space needed to build the devices. [13] This is the reason why we chose to use a microcontroller.
The most important characteristics for which the 18F452 microcontroller was chosen are described below [14]:

High Performance Features:

- On-Chip Program Memory Flash 32 K.
- On-Chip Program Memory # Single Word Instructions 16384.
- On-Chip RAM 1536 bytes.
- Data EEPROM 256 bytes.
- Architecture RISC
- Up to 10 MIPs (Mega Instructions per Second) operation:
  - 4 MHz - 10 MHz osc/clock input.
- 16-bit wide instructions.

Peripheral Features:

- Timer2 module: 8-bit timer/counter with 8-bit period register (time-base for PWM).
- Two Capture/Compare/PWM (CCP) modules. CCP pins that can be configured as:
  - PWM output: PWM resolution is 1- to 10-bit, max. PWM freq. @: 8-bit resolution = 156 kHz.
    10-bit resolution = 39 kHz.

Special Microcontroller Features:

- 100,000 erase/write cycle Enhanced FLASH program memory typical.
- FLASH/Data EEPROM Retention: > 40 years.
- Programmable code protection.
- Power saving SLEEP mode.
- Single supply 5V In-Circuit Serial Programming™ (ICSP™) via two pins.

CMOS Technology:

- Wide operating voltage range (2.0V to 5.5V).
- Industrial and Extended temperature ranges.

- Low power consumption.

The proposed technology for the creation of the scale model of the wheelchair for this research is LEGO. It is important to emphasize that for this project we use only the components such as gears, axles, wheels and bricks. It should be mentioned that the part that refers to the programmable part has been developed with microcontrollers technology.

5.1 Design and Development of the Prototype

Having identified the components which were used to build the prototype of the chair, an electronic design was made, resulting in a circuit that was divided into four main modules (see Figure 3), these are:

- The power module.
- The wired remote control module.
- The module for the electronic logic control.
- The actuators module.

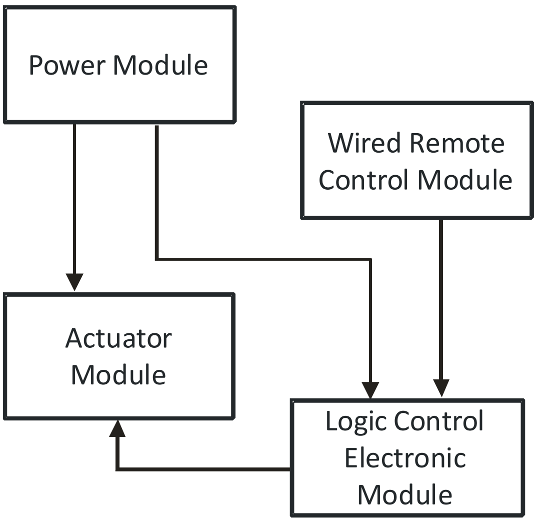

Fig. 3 Block diagram of the circuit.

The following section describes each one of these modules.

Power module: Considering that this is a low energy scale model, we decided to operate on batteries; specifically, squared, nine volt batteries were used, to which a voltage regulator known as LM7805 was applied to reduce battery voltage to five volts. This can be adapted to the TTL (Transistor Transistor Logic) voltage levels, which works with the microcontroller. In this module, a power indicator light for the circuit and a capacitor for energy were added, to make the power stable and independent from the consumption required by the other modules of the circuit, which may cause voltage variations that affect other parts of the circuit, such as the electronic logic control. The design of this module is shown in Figure 4.

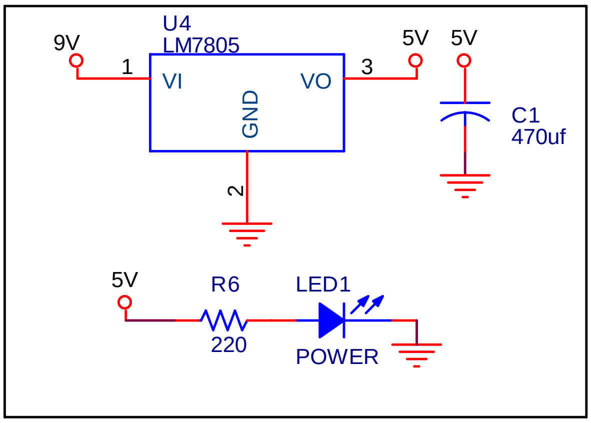

Fig. 4 Power module.

Wired remote control module: For this module we decided to use four buttons to indicate the direction of movement of the chair (forward, backward, left and right), as shown in Figure 5. The control is connected through a 4 bit bus to the logic control module.

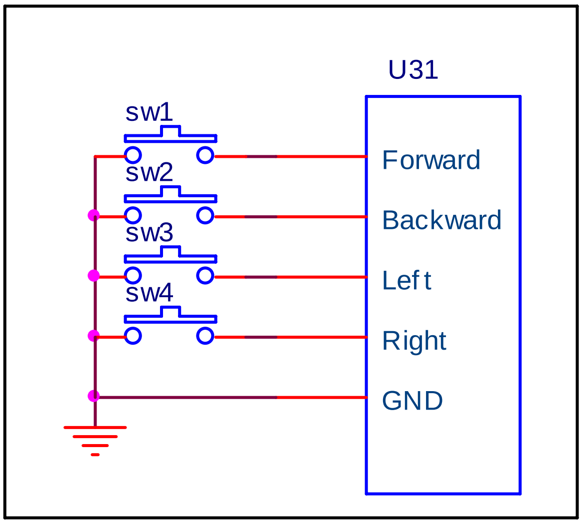

Fig. 5 Wired remote control module.

Module for the electronic logic control: This module is the main part of the circuit, where the main electronic components for the operation of the microcontroller are located. Here, programmed routines are stored to control all the actions of the chair. For the working frequency, a 10MHz oscillator was connected, considering an appropriate speed for the tasks scheduled. This module also contains an LCD (Liquid Crystal Display) that shows the actions taken by the remote control; this is a display of 16 columns by 2 lines that uses the HT4478 protocol and a

8-bit bus to transmit data from the microcontroller. The microcontroller is connected to the actuators module. See Figure 6.

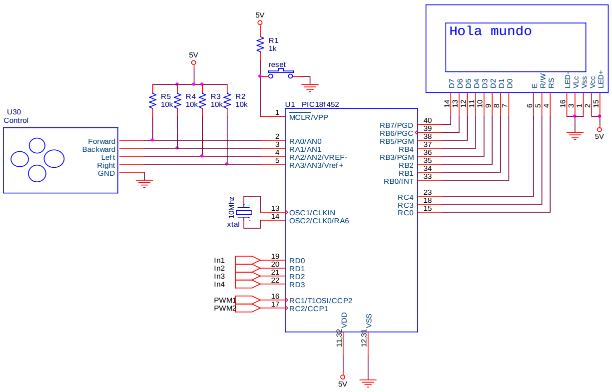

Fig. 6 Logic control electronic module.

Actuators Module: This module controls the servomotors in accordance with electrical signals received by the microcontroller. It uses a chip to interface signals from the microcontroller and provide the appropriate energy consumption required by the engines. Without it the microcontroller would be unable to provide the minimum energy for their operation. LM293 chip was implemented, which is a servomotor controller. This chip can connect two servomotors, which is appropriate to the prototype of a wheelchair (see Figure 7).

This chip receives six signals from the microcontroller, three for each engine, two of these signals are to control engine speed and the other four are to indicate the direction of rotation of the wheels. Internally, the LM293 implements an H bridge, which uses four transistors which allow a change in voltage levels, necessary to make small streams sent by the microcontroller in larger currents necessary to rotate the servomotors.

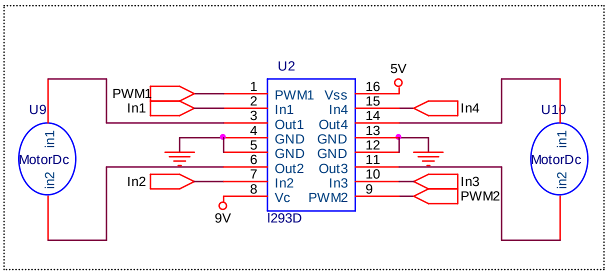

Fig. 7 Actuator module.

In this module the input pins 2 (In1) and 7 (In2) are used to indicate the direction of rotation of the left engine and the input pin 10 (In3) and 15 (In4) to indicate the direction of rotation of the right engine. Pins 1 (PWM1) and 9 (PWM2) are used to send PWM signals (Pulse Width Modulation, a very efficient way of providing intermediate amounts of electrical power between Fully on and Fully off), which controls the speed of the left and right motor respectively. The output pins 3(Out1) and 6 (Out2) send the amplified signal to the left engine based on the values received by the input pins 2 and 7. Similarly, output pins 11 (Out3) and 14 (Out4) send the amplified signal to the right engine in relation to the values received by the input pins 10 and 15. Pin 16 (Vss) receives from the power module the power required to operate the chip internally. Pin 8 (VC) receives electricity directly from the stack that is in the power module, which will be used for the operation of the servomotors. Finally, the pins 4, 5, 12, 13 (GND) are connected to ground.

Since the design of the chair was made with LEGO bricks, we decided to use LEGO servomotors coupled to the prototype.

Figure 8 shows the physical prototype of the electronic wheelchair that was built with the above components.

Fig. 8 Prototype of an Electronic Wheelchair.

5.2 Development Tools and Implementation

Routines to control the chair were programmed in C18, a language commonly used for 18F family microcontrollers from the Microchip Company. This language is based on C, and optimized during compilation to obtain the smallest number of machine instructions and thus reduce the amount of space needed in the microcontroller program memory. It also speeds up the processing time of each instruction. We chose to use this language because of the comprehensive support offered by Microchip coupled with the ease of programming and the fact that the development team is familiar with the language C.

Then the code of the main routine is presented where choices are made after receiving the input that comes from control of the action to be executed.

```
#include <p18f452.h>
#include "lcd.h"
#include <delays.h>
#define byte unsigned char
void sillaAtras()
   {PORTD=OB01011111;};
void sillaAdelante()
   {PORTD=OB10101111;};
void sillaIzquierda()
   {PORTD=OB01101111;};
void sillaDerecha()
   {PORTD=OB10011111;};
void configuraPerifericos()
   {  BANKSEL TRISB;
      TRISB = 0X00;
      TRISC = 0x00;
      BANKSEL PORTA;
      PORTA = 0X00;
      BANKSEL ADCON1;
      ADCON1 = 0X07;
      BANKSEL TRISA;
      TRISA = 0x0F; };

void main(void)
   {  byte salida;
      configuraPerifericos();
      OpenXLCD( EIGHT_BIT & LINES_5X7);
      while(1){   if (PORTA==0B00001101)
                   {  SetDDRamAddr (0x00);
                      putrsXLCD("Atras          ");
                      sillaAtras();
                      Delay10KTCYx(1000); }
                  if (PORTA==0B00001110)
                   {  SetDDRamAddr (0x00);
                      putrsXLCD("Adelante       ");
                      sillaAdelante();
                      Delay10KTCYx(1000); }
                  if (PORTA==0B00001011)
                   {  SetDDRamAddr (0x00);
                      putrsXLCD("Derecha        ");
                      sillaDerecha();
                      Delay10KTCYx(1000); }
                 if (PORTA==0B00000111)
                   {  SetDDRamAddr (0x00);
                      putrsXLCD("Izquierda      ");
                      sillaIzquierda();
                      Delay10KTCYx(1000);  } }
   }
```

6. Conclusions and Future Work

This paper presents the design and construction of a prototype of an electronic wheelchair motor drive for people with disabilities using electronic and computer technologies based particularly on the use of microcontrollers aimed at allowing users a greater degree of independence, which will improve their quality of life.

The prototype was first tested experimentally in the laboratory and was subsequently implemented and tested in a controlled environment by a limited number of users, which reported that the behavior of the prototype corresponded to that expected, they were also satisfied with the response times obtained.

The next step will be to design new tests and run them in an uncontrolled environment, for subsequent physical construction.

This paper is intended to serve as a basis for implementing further functions such as timely and accurate detection of obstacles to prevent the chair’s colliding with walls or other objects, as well as prevent the chair from falling down stairs or curbs. Another project that can be derived from this is handling it wirelessly via Bluetooth communication using an electronic device (cell phone or PDA), the wireless controller will perform the same movements as the manual control.

Referencias

[1] Barea, et, al. Sistema de Comunicación Hombre-Máquina Mediante Movimientos Oculares. Departamento de Electrónica. Universidad de Alcalá, España. 2000.

[2] Card, et, al. The Keystroke-Level Model for User Performance Time with Interactive Systems. Communications of the ACM, 1980.

[3] Dupes, Bill. Sillas de ruedas antes y ahora, algo nuevo bajo el sol. inMOTION, vol. 15, Num 3, Año 2005.

[4] García, Juan Carlos. Sistema de Posicionamiento y Autolocalización para Sillas de Ruedas Autónomas. Tesis. Universidad de Alcalá, España. 2001.

[5] García, et al. Sillas de Ruedas Autónomas: Buses Serie e Interacción con el Entorno. Departamento de Electrónica. Universidad de Alcalá, España. 2001

[6] Gutiérrez, et al. Silla de Ruedas Controlada por Voz. Universidad Politécnica de Pachuca, Ingeniería Mecatrónica. 6° Congreso Nacional de Mecatrónica. Asociación Mexicana de Mecatrónica A.C. México. 2006

[7] http://cuentame.inegi.gob.mx/poblacion/discapacidad.aspx?tema=P. Página web del INEGI. Última revisión 29 de abril de 2010.

[8] Pardavé Martínez, Ana. Yucatán sede del IV congreso Nacional de Prevención de la Discapacidad. Marzo, 2010. http://www.yucatanahora.com.mx/noticias/yucatan-sede-congreso-nacional-prevencion-discapacidad-3203/ Última revisión 29 de abril de 2010.

[9] Pardo, et, al. Automatización de una Silla de Ruedas Controlada por Comandos de Voz. Revista Colombiana de Tecnología Avanzada. Colombia. 2003.

[10] Barton, Len (Comp). Discapacidad y Sociedad. Ediciones Morata. 1998

[11] Landeros, Leticia G. Curso Taller Discapacidad y Discriminación. Consejo Nacional para prevenir la Discriminación. 2008.
[12] Valdés, et, al. Microcontroladores Fundamentos y Aplicaciones con PIC. 2007
[13] Angulo, et, al. Microcontroladores PIC, Diseño Práctico de Aplicaciones 1ª Parte. 4ª Edición. 2007.
[14] Microchip. PIC18FXX2, Data Sheet. High-Performance, Enhanced Flash Microcontrollers with 10-Bit A/D. Microchip Technology Inc. U.S.A. 2006.

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