Design and Development of Electrical Powered Wheelchair Model for Navigation Control

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***Abstract*—Manual wheelchair used to help the elderly and the handicapped for their mobility with assisted from other person. This paper presents a model of electrical powered wheelchair (EPW) which moves according to the motion mode of a joystick operated by one person. The wheelchair model move when user moves the joystick according to any direction. The signal from joystick is converted to digital signal by Analogue to Digital Converter (ADC). This digital signal will enable the microcontroller to perform simple control algorithm to drive the DC motor to move forward or backward. The navigation also is aided by the sonar range sensor. The sensor will sense hole on pathway then automatically avoid the hole and alert the user from buzzer sound. The design of the system was compact and small thus suitable to be implemented into real wheelchair.**

***Keyword*— wheelchair model, joystick, DC motor, forward and backward**

I. INTRODUCTION

Malaysia has a population of 27.73 million people by the year 2008. A totals of 261,154 disabled people have registered with the Department of Social Welfare Malaysia (DSW) at the end of June 2009. While for the age more than 65 years old, 1.23 million people was reported based on population census 2000. However, this figure is not a true reflection of the number of disabled people as registration is voluntary. By taking all this value, this shows too many people have low level of moving impairment. These people usually facing difficulties in movement and they must be given the same opportunities as everyone else to live life as independently as possible. Such independence is impossible at the moment because of the physical barriers in the environment.

Today modern society, disabled and aged people majorly demands in using wheelchair for mobility. As the number of senior citizens has been increasing years by years, demand for human-friendly wheelchairs as mobility aids also growing. And there are various types of robotic wheelchairs have been proposed to meet this need [1]. Wheelchair can be manual or powered. To move, the manual wheelchair needs the human force either from another person or the user himself. Among the types of manual wheelchair are self-propelled, attendant-propelled and wheelbase. It is seen, driving the manual wheelchair for a long time can cause pain and injury in wrist, elbow and shoulder. More worsen, the pain increases with long use of manual wheelchair [2]. As for the powered wheelchair, a one-side-handicapped person does not require pushing the rim anymore and it surely help themselves moving. The model of powered wheelchair used in this paper is shown in Fig. 1.

Figure 1. Powered wheelchair model

The proposed powered wheelchair model is built to show navigation system based on joystick. The model is catered with dual tires bind to twin-motor and a front caster. Those will work for support and also movement of the wheelchair. Two independent motors and gearboxes are packed in a compact housing. The user can control the direction movement through joystick. The joystick is applicable to be placed either on the right armrest or on the left armrest according to the convenience of user. When user goes for a specific position of joystick, the joystick generates a unique set of voltages, which is received by the microcontroller. Then, the microcontroller give the specific control input for the current mode controlled converter to the motor.

The wheel design was based on robot design. There are limited literatures about modeling with two rear-wheel-drive wheelchairs with a front caster. The conventional electric-powered-wheelchair (EPW) design often exhibit directional instability while driving backward due to the dynamics of the vehicles [3]. These due to the front caster orientation may cause unexpected side to side bucking or swaying of the EPW when user does reverse driving. The research of wheelchair on two wheels have been work out such in [4] while push rim wheelchair on three wheels had reported deliver worldwide

II. METHODOLOGY

A. Hardware Development

Finger operated joysticks

Finger operated joystick comes with small single axis handler. To control, it require minimal effort to move the handles which fit comfortably with finger and thumb operation. These joysticks are suitable for intermittent duty and will not withstand the same abuse as heavy duty joysticks. This joystick is puts on due to the limit in space and it is two-dimensional which mean having two axes of movement. It is configured so that moving the stick left or right signals movement along the X axis, and moving it forward (up) or back (down) signals movement along the Y axis. Fig.2 below shows analogue outputs with switched reference signals that are proportional to the distance and direction over which the handle is moved.

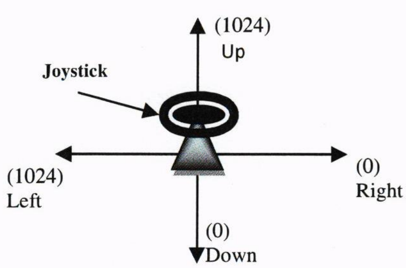

Figure 2. Joystick configuration

Tamiya Twin Motor Gearbox Kit

The Tamiya twin-motor gearbox consists of two small DC motors that drive separate 3mm hexagonal output shafts. The motor have been built with 58:1 gear ratio in order to provide plenty of power to drive any small robot. Gear ratio can be defined as the relationship between the numbers of teeth on two gears that are meshed. The general specifications for the motor that run at typical operating voltage range of 3V to 6V is shown in Table 1

Table I Tamiya Twin Motor Gearbox

Specification	Value
Free-run motor shaft speed	12300 rpm
Free-run current	150 mA
Stall current	2100 mA
Motor shaft stall torque	0.5 oz·in

Based on Table 1, the free-run current is the no-load current of the motor when disconnected from the gears in the gearbox. The no-load current of the entire gearbox with the motor connected will be slightly higher and will vary depending on the gear ratio.

L298 Driver Motor

This chip is much more widely used and adopted in applications and specifically it is known as L298HN. It will require two PWM (Pulse Width Modulation) inputs in order to drive the motor fast, slow, forwards or backwards. It has 15 pins in total although not all of the pins are used. It also allows the motor to rotate in either direction by adding an H-Bridge output stage.

Pins 5 and pin 7 in the chip pinout as in Fig.3 below are input 1 and input 2 respectively. These inputs take what is called a PWM input. The frequency of the PWM is dependent upon the motor. Taking 1 KHz as input frequency gives the motor speed to be updates 1 thousand times a second. The duty cycle of the PWM will determine the speed and direction of the motor.

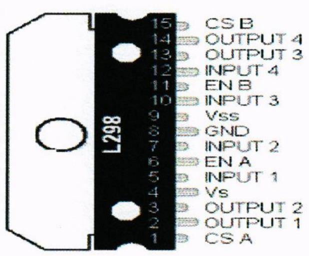

Figure 3. Pinout for L298HN Driver Motor

PIC 40-Pins Daughter Board

The board consists of connector for UIC00A ICSP USB Programmer, toggle switch for power supply, DC power adaptor socket, mini jumper, 5V voltage regulator and 40 pin IC socket for PIC MCU. The overview of the board as seen in Fig. 4

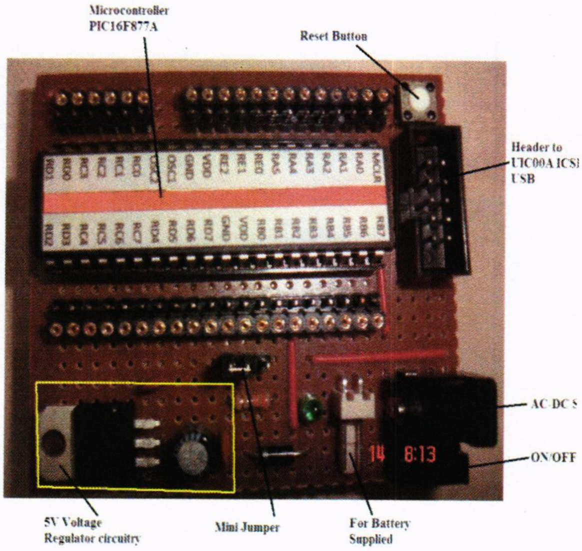

Figure 4. 40-Pins Daughter Board

The microcontroller used in this project is PIC16F877A which work as its main brain in moving the motor. Among the features that this PIC has are I/O Ports, Timer, PWM Module, Master Synchronous Serial Port (MSSP) Module, Addressable Universal Synchronous Asynchronous Receiver Transmitter (USART), Analog-to-Digital Converter (A/D) Module and Comparator Module.

The board was added up with UIC00A ICSP USB programmer connector which a powerful tool used to download the program into MCU through free-programming-software, MPLAB. The connector is very convenience because it offers simple way for transferring program and save plenty of development time. DC power adaptor socket is purposely for user to plug in AC-DC adaptor which the input voltage should be ranged from 6V to 12V. The mini jumper functions as a turn pin to supply the MCU with secondary power when using USB port. Thus, the external power from AC-DC adaptor may not be needed for transferring the program into MCU.

Sonar Range Sensor

Ultrasonic ranging is another technique for distance measurement. The speed of sound travelling over a few meters and reflecting from a solid object gives a kind of delay in milliseconds. This is suitable for the measurement by a hardware timer in microcontroller.

The sensor operation start when a short burst of high-frequency sound such as 40 kHz is transmitted and then should finished by the time the reflection return. This is required to avoid the signals being confused by the receiver. To determine the distance to an object, sensors calculate the time interval between sending the signal and receiving the echo.

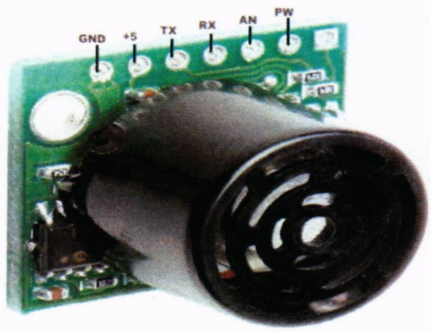

Figure 5. MaxSonar® sensor

The MaxSonar-EZ1 High Performance Sonar Range Finder as shown in Fig.5 is used in this project. The chosen was based on No Dead Zone and Custom Beam Width. Other ultrasonic range finders especially single sensor range finders have dead zones. Dead zones are problematic for many applications such as robot mini sumo and robot wall following situations. For the Custom Sensor Beam Widths, users can choose the detection pattern that matches the application.

In this project, the sensor will need to supply 5V. By using a microcontroller, it takes only one pin to monitor analog outputs (AN pin is used) since one sensor is used.

B. Software Development

PIC16F877A microcontroller unit (MCU) used to control software for the powered wheelchair to function properly. Its embedded circuit consisting of a relatively simple CPU combined with support functions such as a crystal oscillator, timers, watchdog timer, serial and analog I/O. These MCU operate at 20MHz clock rate frequency. This is fair enough for many typical applications which also enabling low power consumption as low as in milliwatts. Generally, they have the ability to retain functionality while waiting for an event such as a button press or other interrupt; power consumption may be just nanowatts, making many of them well suited for long lasting battery applications.

In Fig. 6, the programming for this project was very straight forward. A PWM signal is generated and input into the motor driver using the PORTC and PORTD on the PIC. The wheelchair software has one forward speed set points and one reverse speed set point. As user move joystick, microcontroller read and analyzes the ADC input. The outputs from microcontroller indicate as the input for the motor to move either forward or backward.

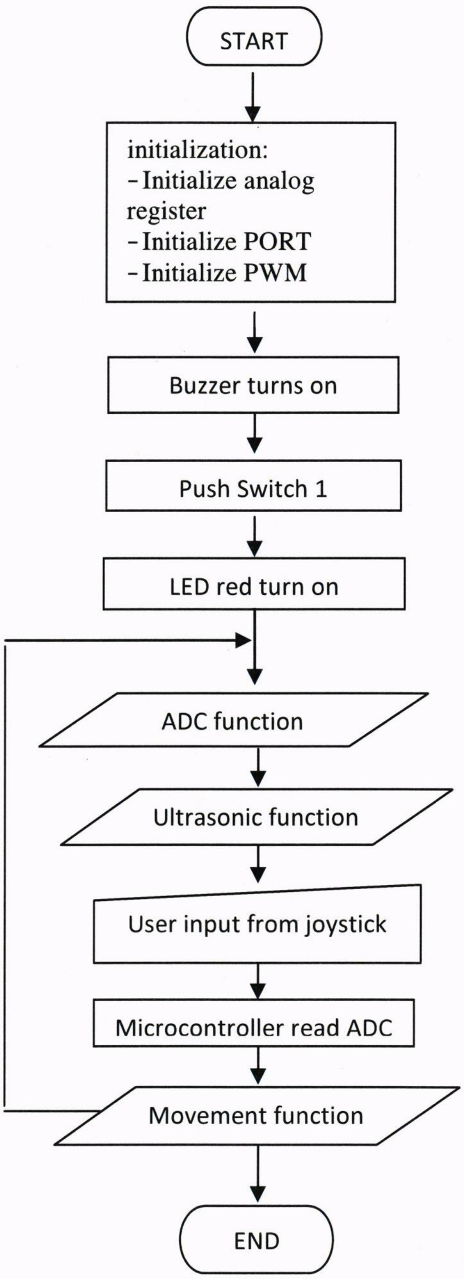

Figure 6. Flowchart of main operation.

Software implementation of the L298 to drive motors is shown Table II. The signal indicates the movement of wheelchair model.

Table II. Motor main operation.

Signal on				Result/action
LA	LB	RA	RB	
0	1	1	0	Forward
1	0	0	1	Backward
0	1	0	0	Turn Right
0	0	1	0	Turn Left
1	1	1	1	Motor Stop

MCU can analyzes output from the sensor either in PWM mode (connect with PW pin) or ADC mode (connect with AN pin). There also another pin that is used for transmit the sonar which is TX pin. The sonar range sensor in this project will operate based on the ADC function.

III. RESULT AND DISCUSSIONS

The following test has been set up to evaluate the performance of the wheelchair.

The result was based on AC-DC adapter with maximum of 500mA to supply the wheelchair model. The motor did not move at all when supplied with 6V and lower. Thus, the starting supply was at 7.5V. Based on Fig.7, the model took 15.6 seconds to move in 1 meter at 7.5V supply. At 9V supply, it took 9.2 second to move on same distance. The wheelchair model took shorter time when supplied at 9V, thus this shows as the voltage increase the speed also increases.

The motor not moving at starting voltage of 6V because of the motor need 6V supply while the PIC board need 5V supply. Given 6V supply will not enough to support both components. Based from reading, the Pololu motor itself has been tested and lead to lower the voltage supplied will longer the motor lifespan. Thus, for the motor to work in longer time it is recommended at 7.5V.

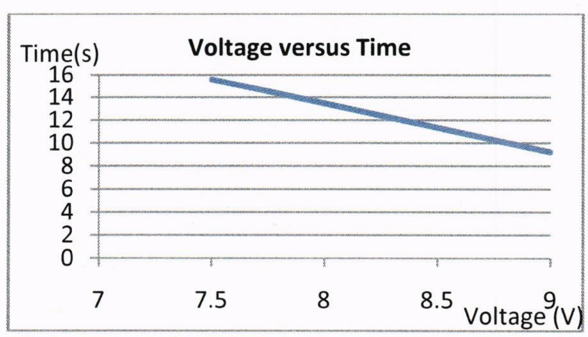

Figure 7. Time measurement based on varies supply

Fig.8 shows the experimental results of the time taken for the wheelchair to carry load at constant 9V supply. The wheelchair model can carry up to 1 kilogram load before it is hardly moving. The speed is accordance to the maximum load carried by the wheelchair model. The speed performance becomes poor as more load attached to the wheelchair. By taking this result, it suggests that every 0.2kg load, the speed decrease by $0.01ms^{-1}$.

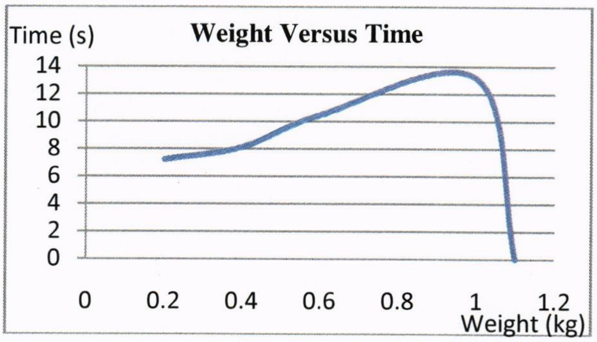

Figure 8. Time measurement based on varies load

Based on observation, using motor in a long time caused the motor to move slowly. This might due to using high supply which then caused damage to the brushes in motor. Unfortunately, since these are small 'toy' motors, the manufacturer really doesn't offer any cycle-life numbers, even when operating the motor at the recommended 3V or less.

There also another condition involving rolling friction that can be discussed. The resistance encountered when tires are moved in contact on a surface can be called as rolling friction. Rolling friction can be considered as the load on the wheelchair and it depends on the type of tire and road surface. The rolling friction for a specific road can be calculated by measuring the time taken by wheelchair to travel the known length at constant speed. The input power is also measured for the same time. Since the surface is flat power remains constant for whole length.

The wheelchair was observed to move along in a straight line as in Fig. 9(i). However, its front caster tend to follow the rail on the floor as in Fig. 9(ii)

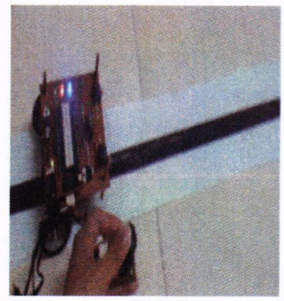

Figure 9(i)

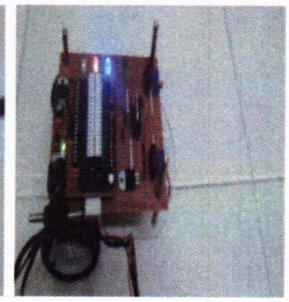

Figure 9(ii)

During the experiment set up the speed for left-motor and right-motor was not synchronize especially for wheelchair to move forward and backward. It was found that the right-motor move faster during forward operation. While during backward, the left-motor move faster. However, the problem was solved by observe and finding suitable PWM for both motors.

Table III shows the result based on observation during the sonar range sensor operation.

Table III. Observation on sonar range sensor

ACTION	OBSERVATIONS
Put the sensor vertical to the ground	No operation occurs. Expecting the wheelchair will move backward with buzzer turn ON
Put the sensor inclined high about 30º	The motor slowly move backward with buzzer turn ON
Put sensor facing a long range object	As the sensor slowly facing the far object, motor increase its speed gradually
Moving forward	Sensor interrupts the process sometimes not regarding the specific distance. The interruption makes the wheelchair move backward, not continuously but in three steps. When changing the program, buzzer sometime not sounded when sensor was in operation.

Based on observation, sensor not functioning well because when an object is too close facing the sensor, the sensor may ignore objects at that distance. This means that the sensor acting like no object in front of it. In addition, the sensor also have high sensitivity which if the temperature increases, the sensor is more likely to have false close readings. The sensor also has to calibrate during powered up.
It is important that objects not be close to the sensor during this calibration cycle. It is stated that the best sensitivity for calibration is obtained when it is about fourteen inches. However, due to small size model that had been built this is hardly to achieve

IV.CONCLUSIONS

This project has been successful establish joystick in movement of EPW model. In addition, the navigation is aided by sonar range sensor which successfully installed. Many difficulties related to navigation system have been overcome in software programming. Moreover, this system controller is responsible for generating the PWM signals that will be delivered to the motor and insuring it move at only one speed point

Three wheels was implemented and found working satisfactory for navigation. The efficiency is depends on the load. At lower load, it is possible to get still higher efficiency. The wheelchair model can bring 1 Kg load and travel in $0.0456\, ms^{-1}$ with 500 mA battery and this range could be further increased by adding battery in parallel. The effort made by rider is reduced considerably as compare to manual wheelchair.

Motor will be overheated which can be caused by excessive stalling, even at very low voltages. Thus, it is important to know the exact current of the motor so that it has long lifespan.

The performance of the model indicates there is a cautious possibility today to build a functional intelligent wheelchair that is practical and helpful to people with certain types and degrees of handicap.

V. FUTURE RECOMMENDATIONS

The front caster moving along rail will be added as disadvantage of the design that could be overcome in the future. It is recommended to put sonar sensor at the front castor. The sensor will be used to allow only specific hole for castor to be able move. In addition, the sensor will provide a safe trip to the user

The L298HN motor driver has advantages in dc motor control. For examples, it accepts PWM input, control two dc motors simultaneously and also capable controlling stepper motors for a future means. The motor driver also can be used into the real wheelchair, which the motor will have high torque and take up to 24V supply voltage. In addition, the range speed of motor can be modified using the driver.

The test should be more variety such as jerkiness test, collision risk test, rough terrain test and smooth hallway test course in order to improve the wheelchair navigation system in the future.

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