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Smart Wheelchair Design for Elderly and Disabled People

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Abstract – This paper proposes a gesture based wheelchair design using Raspberry Pi. A wheelchair is designed where physically disabled or elderly people can control the wheelchair and a nearby person can see the status message on the LCD. These tasks can be performed using hand gestures. This enables the disabled person to drive the wheelchair and move more efficiently from one place to another. The Raspberry Pi acts as a brain that enables the components to fulfil their tasks. Flex sensors detect hand movements and are transferred as data input to the Raspberry Pi. The motor driver drives the motors. The system status is reflected as a message on the LCD screen and the operations are monitored. In return for four hand movements, the wheelchair can be controlled in forward, left and right directions and stop command. If desired, the design can be edited and the motor movement and LCD screen message can be rearranged for different hand movements. With the advantage of flexible design, personalized needs can be met. This makes the design more flexible and improvable than a joystick-controlled wheelchair and more cost-effective than a voice-controlled wheelchair.

Keywords –Flex Sensor, Python, Raspberry Pi, Smart Wheelchair, Elderly People, Motors

I. INTRODUCTION

Recent advances in research areas such as robotics and sensor technology are contributing to applications such as smart wheelchairs that support people with disabilities. The need for wheelchairs for the elderly and disabled people brings technological changes in this direction using modern electronic and mechanical systems. Due to these needs, embedded systems and digital information technologies are becoming more important in our daily lives [1]. Traditional wheelchairs have various disadvantages in terms of versatility, volume and functionality.

A smart wheelchair can generally consist of standard motors and motor drive, control unit, sensors and display. The electronic brain of the system processes sensor information, automatically generates motor commands and display messages. The control module of the smart wheelchair can consist of a standard wheelchair joystick [2], voice recognition based control [3], facial expressions control [4], and even eye-gaze control [5] etc. The overall architecture of a wheelchair control system is shown in Figure 1.

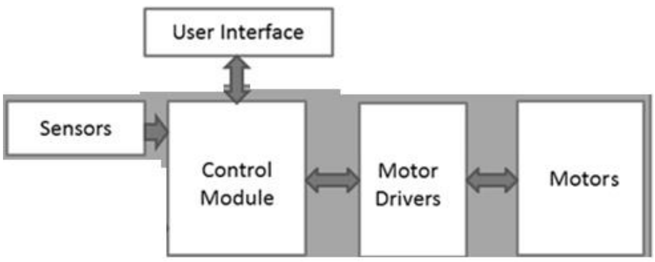

Fig. 1 Basic components of a smart wheelchair system

In recent years, various smart wheelchair prototypes have been developed and a large number of researches have been published in this field. Approaches to design a smart wheelchair utilize different sensors for data collection and control of the chair, as well as some microcontrollers with information processing capability. An example design [6] consists of three components including a positioning system, an autonomous wheelchair system and special procedures that can optimize the whole program. The smart antenna detects the path that the smart wheelchair can follow, compares it with the initial path chosen by the user and displays the result on the graphical user interface. By developing an IoT-based condition monitoring and precise point positioning technique system for smart wheelchairs, this study aims to provide a more comfortable and safer experience for wheelchair users by monitoring discomfort levels and providing precise positioning.

New control techniques have been developed that go beyond using joysticks to control an electric wheelchair. This could replace joystick-operated wheelchairs that are impossible to control for people with disabilities in their upper limbs. In one study [7] a head motion system for controlling an electric wheelchair is presented.

The hardware components of the smart wheelchair system used in another example [8] include a microcontroller unit (MCU), joystick, accelerometer, heart rate sensor, battery charger, battery level indicator, siren, flashlight and a fan to remove waste heat. These components are systematically arranged in an aluminum housing called the main module. The smart wheelchair is a device that can be controlled using hand gestures instead of the traditional keypad system.

In a similar study, it aims to develop a prototype with the help of embedded systems to control a smart wheelchair that can be useful for paralyzed, elderly or physically disabled etc. [9].

In this work, we propose a smart wheelchair design with flex sensor, Raspberry Pi, motor driver, motor and LCD screen. This design allows users to synchronize their hand movements with the movement of the wheelchair. The main goal is to design a wheelchair that can be flexibly customized to provide mobility specific to the needs of each individual.

II. MATERIALS AND METHOD

The block diagram of the Raspberry Pi controlled motion-based system is shown in Figure 2.

Motor drivers are circuits that receive signals from the digital outputs of the microcontroller and provide the appropriate voltage and current to the motors.

Motor drivers can be of different types and features. Some motor drivers that can be used with microcontroller are as follows: L293D is a 4-channel motor driver and can control 2 DC motors or 1 stepper motor. L293D can provide maximum 36V and 600mA. L298N is a 2-channel motor driver and can control 2 DC motors or 1 stepper motor. L298N can provide a maximum of 46V and 2A. TB6612FNG is a 2-channel motor driver and can control 2 DC motors or 1 stepper motor. TB6612FNG can provide a maximum power of 13.5V and 1.2A. DRV8833 is a 2-channel motor driver and can control 2 DC motors or 1 stepper motor. DRV8833 can provide a maximum power of 10.8V and 1.5A. A4988 is a single channel stepper motor driver. The A4988 can increase the precision of the stepper motor by operating in microstep mode. A4988 can provide maximum 35V and 2A power. In this study, L293D motor driver is preferred because it is suitable for general use.

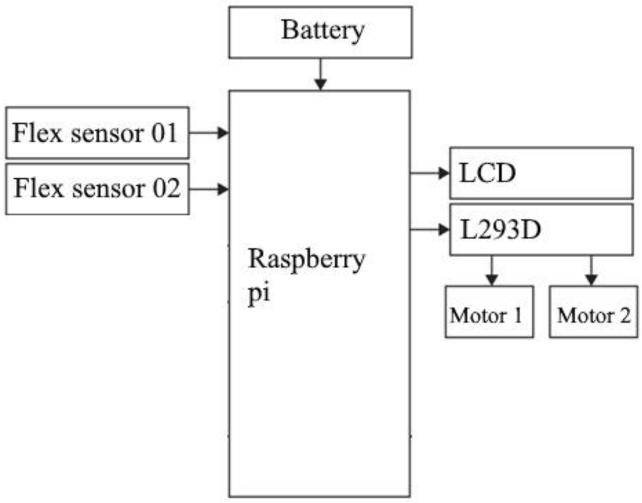

Fig. 2 Block diagram of the Raspberry Pi-controlled gesture-based system.

Motors are devices that convert electrical energy into mechanical energy. Motors can be of different types and features. Some motors that can be used with microcontrollers are DC, stepper and servo motors. DC motor is a direct current motor. The speed and direction of the DC motor depends on the magnitude and polarity of the applied voltage. DC motors are widely used because they are simple and cheap. A stepper motor is a motor that rotates at certain angles according to electrical signals. The speed and direction of the stepper motor depends on the number and frequency of applied pulses. Stepper motors are used in applications that require precise and controlled movement. Servo motor is a motor that can stop at the desired angle with a feedback mechanism. The angle and torque of the servo motor depends on the width of the applied PWM signal. Servo motors are used in applications such as robotics or model airplanes. DC motors are preferred in this study.

LCD displays consist of components such as backlight, polarizing filters, liquid crystal layer and electrodes. The backlight is a white light source that comes from behind the LCD screen. Polarizing filters ensure that light only passes in a certain direction. The liquid crystal layer consists of small molecules that change shape depending on the electric field. Electrodes apply an electric field to the liquid crystal layer. LCD displays usually have a 16-pin interface. Some of these pins are connected to the power supply, some to the ground line, some to contrast adjustment, and some to data transmission. LCD displays can use parallel or serial communication protocols. In parallel communication, 8 bits of data are sent simultaneously for each character of the LCD display. In serial communication, data is sent bit by bit. It is low cost and easy to program. It is an alphanumeric display that can print both alphabet and numbers. In this study, 16x2 LCD screen was used.

Flexible sensors are low-cost, wearable and lightweight, as well as having a simple structure according to the requirements of engineering applications. Moreover, flex sensors require high sensitivity and stretchability for many potential applications such as human health monitoring, robotics, wearable electronics and artificial intelligence.

Figure 3 shows the relationship between flexible sensor bending angle, θ, and resistance, R_1. The resistance value and the associated voltage drop resulting from the bend value can then be processed by the microcontroller as desired.

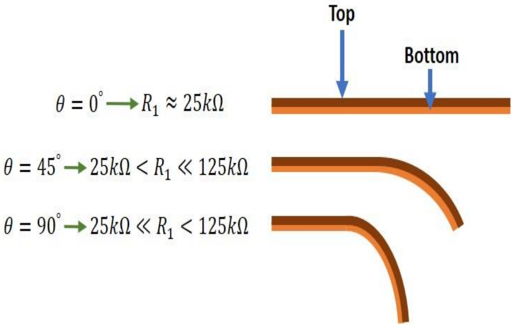

Fig. 3 Bending and resistance states of the flexible sensor

A voltage divider circuit is created with, for example, a 10k ohm series resistor connected to a flex sensor. The purpose of this circuit is to create a split voltage V_0 between the flex sensor and the additional resistor coming from a 5 V supply voltage. Figure 4 shows voltage divider circuit with variable resistor (R_1) of flex sensor and series resistor (R_6).

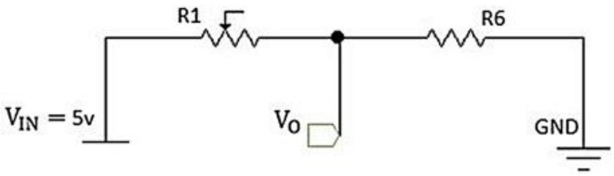

Fig. 4 Voltage divider with variable resistor of flex sensor and series resistor

The output voltage Vo of the voltage divider [10] can be calculated according to the following equation:

$$V_0 = V_{in} \times \left(\frac{R_1}{R_1 + R_6} \right) \quad (1)$$

Where V_O represents the output voltage to the analog pin of the microprocessor, V_{IN} represents the external input voltage supply, R_6 represents the variable resistance of the flex sensor and R_1 represents the fixed resistance.

A. *Flex Sensor Library for Simulation Software*

Flex sensors, which can be classified as analog or digital, can be used in different applications such as gloves, clothes, toys, robots and prostheses. Analog flex sensors, which work like potentiometers, are flex sensors whose resistance changes continuously when they are bent and produce a voltage signal proportional to their resistance. Analog flex sensors can be connected to the analog input pins of microcontrollers. Digital flex sensors are flex sensors whose resistance changes according to certain thresholds when they are bent. Working like a switch, digital flex sensors produce a logical signal (0 or 1) proportional to their resistance. Digital flex sensors can be connected to the digital input pins of microcontrollers.

Proteus is a simulation software tool primarily used for simulating and testing electronic circuits and microcontroller-based projects. It provides a wide range of components and libraries to simulate various electronic components, including sensors. Thanks to the Proteus simulation software, everything from schematic capture to source code generation, design simulation and debugging can be done in one place. Due to these features, the proposed design was preferred to be done with Proteus simulation software.

In the Proteus simulation program, the analog flex sensor has four pins as shown in Figure 5a. The G pin is the ground pin, which will be connected to the ground voltage. The out pin indicates whether the sensor detects the flex value or not. The voltage supply pin supplies 5V power to the sensor. The Test pin gives the flex value in the HIGH state for Proteus simulation.

In the Proteus simulation program, the ON or OFF state is detected rather than the digital sensor bend level. Two of the four pins on the digital sensor, Vcc and Gnd, provide 5V operating voltage and ground to the sensor respectively. If another pin, Test pin, is HIGH, the output is high. Figures 5b and 5c [11] show both flat and bent cases for the digital flex sensor.

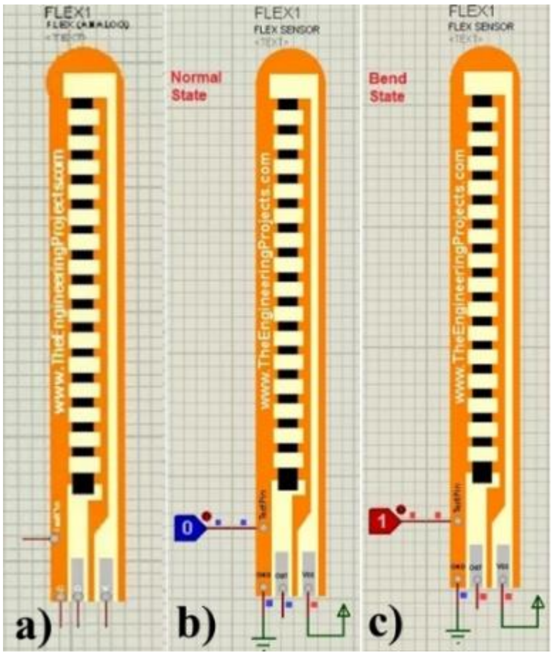

Fig. 5 Flex sensor library for simulation software

B. *Raspberry Pi*

Raspberry Pi 3 (see Figure 6) is a single-board computer. The Raspberry Pi 3 has a quad-core 64-bit ARM Cortex A53 processor running at 1.2 GHz, which is faster than the previous models. It also has 1 GB of LPDDR2-900 SDRAM, which is sufficient for most applications. The GPU is a 400 MHz VideoCore IV multimedia, which supports OpenGL ES 1.1 and 2.0 graphics and can decode H.264 videos at 1080p301.

The Raspberry Pi 3 requires a 5 V/2.5 A DC power supply via a micro USB connector or the GPIO header1. The power consumption depends on the workload and peripherals, but it is typically around 3 W.

The Raspberry Pi 3 has a 40-pin GPIO header that provides access to various digital and analog signals, such as UART, SPI, I2C, PWM, and ADC. The GPIO pins can be controlled by various programming languages, such as Python, C, and Scratch. The GPIO functionality can be customized by using device trees and overlays.

The Raspberry Pi 3 supports various programming languages, such as Python, C, C++, Java, JavaScript, Ruby, Perl, and PHP. It also comes with several pre-installed software tools for learning and development, such as Scratch, Thonny, Sonic Pi, and Mathematica.

The Raspberry Pi 3 has a high educational value for students and teachers of all ages and levels. It can help them learn about computer science, programming, electronics, robotics, mathematics, physics, art, music, and more. It can also inspire them to create their own projects and share them with the global community of Raspberry Pi enthusiasts.

Fig. 6 Raspberry Pi 3

C. *Smart wheelchair design*

The one-handed glove system (see Figure 7) includes a Raspberry Pi 3, two flexible sensors, an LCD display, a power switch, a motor driver and two DC motors.

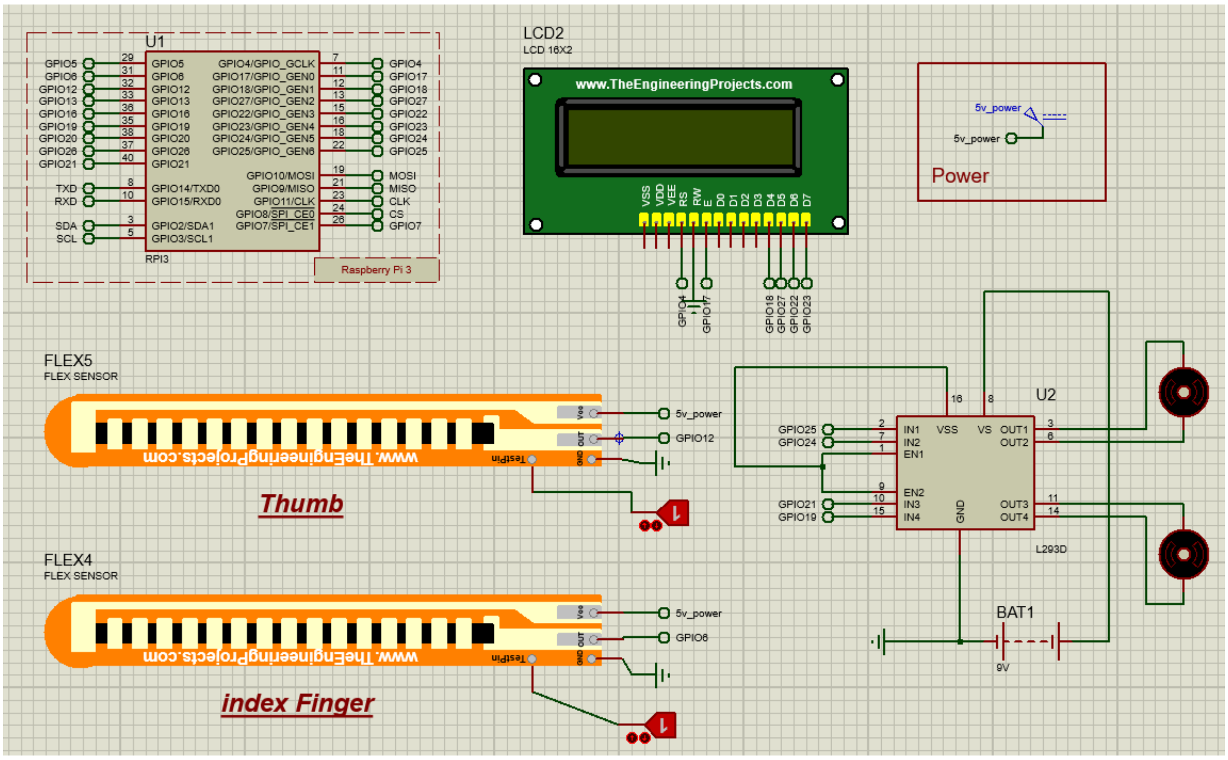

Fig. 7 Overview of smart wheelchair design

As shown in Figure 8, the flex sensors are attached to the thumb and index fingers of a glove and the outputs of the flex sensor are changed by bending the fingers. Digital flex sensors were preferred for ease of use. If desired, analog flex sensors can be selected and different motion assignments can be made at intermediate values of bending.

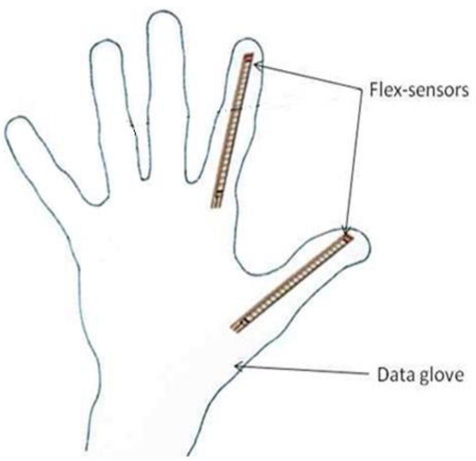

Fig. 8 Glove with flex-sensors

As shown in Figure 9, four different gestures were determined by different opening and closing of two fingers. Accordingly, the hand is formed into a fist with all fingers closed. This movement is assigned to the forward movement of the motor. Two motors are energized at the same time. If both fingers are opened, this movement is assigned the stop command of the motor. Both motors of the wheelchair are de-energized. If only the index finger is raised, one motor is energized and the wheelchair turns left. If only the thumb is raised, the other motor is energized and the wheelchair turns right.

The Raspberry Pi perceives the Flex sensor outputs as input data and generates both the data to be sent to the motor driver and the message information to be sent to the LCD screen. Table 1 shows the M_1 and M_2 motor energizations according to the state of the F_1 and F_2 flex sensors.

Fig. 9 Finger gestures and motor directional responses

Table 1. Selection table for wheelchair direction

Thumb	Index finger	Motor Status	
F1	F2	M1	M2
0	0	OFF	OFF
1	0	ON	OFF
0	1	OFF	ON
1	1	ON	ON

III. RESULTS AND DISCUSSION

The smart wheelchair in this study is designed to assist people with various levels of mobility. The device has electronics to help the user generate motion sequences based on hand gestures. The motor has forward, stop, left and right movement possibilities (see Figure 10). If desired, the ability to go backwards can also be added. The LCD shows the directions of movement of the wheelchair. For ease of design, digital flex sensors were preferred in the simulation. If desired, the design can be redesigned with analog flex sensors and new commands can be added to the system for intermediate values of bending.

The aim of this work is to help people with disabilities by providing alternative methods to control the equipment using flexible sensors for the wheelchair, thus serving many disabilities. The functional smart wheelchair is practical and useful for people with certain types and degrees of disabilities. The proposed smart wheelchair can be used in many places such as hospitals and old age homes etc.

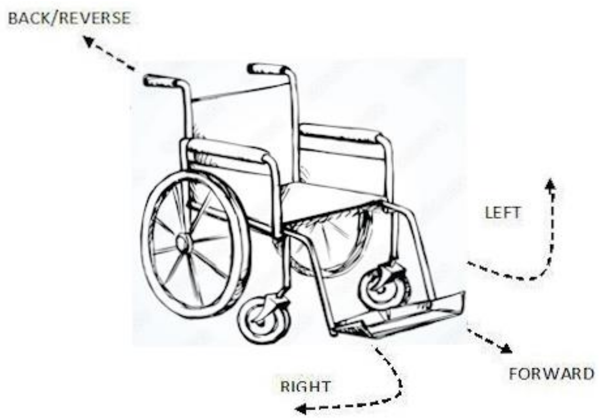

Fig. 10 Wheelchair movements

IV. CONCLUSION

It is possible to make improvements to the system. Thanks to the capabilities of Raspberry Pi, a monitoring system can be successfully implemented in the future, which will help track the movements of the wheelchair occupant by sending the data obtained from the flex sensor to the cloud. In addition, the implementation of a health monitoring system that can provide a large number of data such as blood pressure, fever, heart rate monitoring can be among the system improvements. To extend the motion tracking system, GPS can be installed to give the real-time location of the user. With this and similar add-ons, the system is open to innovation and development.

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