Direction and Speed Control of DC Motor using Raspberry PI and Python based GUI

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Direction and Speed Control of DC Motor Using Raspberry PI and Python-Based GUI

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ABSTRACT

This paper presents the design and implementation of control strategy for both the speed and direction of a direct current (DC) motor using Android-based application in smart phone. The Raspberry Pi 3 with a motor driver controller has been used to implement the control action via Python-based user-defined programming. The Android application has been developed using Android Developer Tools (ADT) in Java platform. The Android apps work like a client and communicates with Raspberry Pi through wi-fi connectivity. Finally, a small graphical user interface (GUI) has been created in Python in order to interface and control the motor with buttons in GUI. The advantages of GUI are that it is attractive, user friendly, and even a layman can work with the application developed in GUI.

KEYWORDS

Android Developer Tools (ADT), DC Motor, Python, Raspberry PI, Tkinter (Tk) Module

1. INTRODUCTION

Wireless connectivity is more efficient and cost effective as compared with wired systems where data transmission is done by the electromagnetic waves that do not affect the environmental conditions and also reduce electrical losses. DC motors have multipurpose utilization from industry to home because of their low cost, higher efficiency and less complex control structure and variable speed-torque characteristics. In this work speed and direction of a DC motor have been controlled through wireless operation via Raspberry Pi. Raspberry Pi is a low cost, small single motherboard processor which can able to perform all the above possible tasks with consumption of low power.

The next generation operating systems might not be the desktops or mainframe computers instead it may be open and on the small devices like mobile phone. Android is popular open source mobile device operating software based on the upgraded version of the Linux kernel. In this work, a network server program has been developed using Python programming that runs in Raspberry Pi. The server program accepts information from *Android Application* that runs on Android Smart Phone using TCP/IP. The server program sends the control information through GPIO (General-purpose Input/output) pins toL293d motor driver module. L293d motor driver module then runs directly DC motor according to the control action signal received from Raspberry Pi.

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2. LITERATURE STUDY

The study on a DC Motor speed control and its direction with wireless ssensors and Android Smart Phones has been carried out by several authors based on different controlling devices like Arduino-uno, Raspberry Pi etc. Various control algorithms such as Fuzzy Logic, PID algorithm, GUI based etc are also employed by many researchers. However, controlling speed of a DC Motor is still an important and evolving task to the researchers over past two decades or more and is a vividly literature rich topic to explore.

The topology of fuzzy logic has been utilized in (Thepasatom et al., 2006) for controlling speed of a separately excited DC motor, where the fuzzy rule and control logic has been implemented in LabVIEW. The performance of the designed Fuzzy logic controller has been compared also with the with PI and PID Controller.A remote control strategy for a two-tank level control system has been shown in (Brito, et. al., 2009) where both the on-off control and PID algorithm has been implemented in LabVIEW system. In (Palpankar et al., 2015) a low cost and efficient technique for speed control of an Induction motor has been shown where the variation of speed of the induction motor has been achieved by short range stator terminal voltage control by controlling the firing angle of the semiconductor power devices, TRIAC.

A cost effective and open-ended wireless sensing, monitoring and control has been demonstrated in (Rao & Uma, 2015) for application in home appliances. In this work smart phone has been used for remotely accessing and controlling devices with an embedded controller through IP connectivity. The suggested system offers a novel communication protocol to monitor and control the home appliances without dedicated server. In this home control system, essential components like power plug, switches, current sensors and temperature sensors etc. are incorporated to validate demonstration. An interactive GUI based control of DC motor has been created in (Patel, 2017) with Raspberry Pi board. Here, the algorithm for controlling direction (clockwise and anticlockwise) has been implemented through Python programming language. In (Šustek et al., 2017) Raspberry Pi 2B was chosen for controlling servo-motor as well as and DC motors. This paper illustrates a basic understanding on the Python programming syntaxes for controlling and also given insides for connection of DC motors with Raspberry Pi Board.

An efficient and economical method of Induction Motor speed control has been proposed in (Thangalakshmi & Dinesh, 2017) where the speed variation of the Induction Motor can be by controlling the firing angle of the semiconductor devices. The work in (Pavangopal, et al., 2018) aims to provide a speech control interface using NodeMCU for home automation and control. Here the user's speech command is used to control a line following robot. The proposed technique can be helpful for the elderly and disabled persons for quick completion of work. The work presented in (Yfoulis et al., 2018) exhibits two main objectives; first, it has revealed the usefulness of an Arduino-based low cost embedded speed control system, and secondly, it explored the topology of design and testing of switching PI control laws which can be further extended to various other application cases.

The (Kamalakannan & Devadharshini, 2019) has focused on controlling the speed of the conveyor belt through the controlling speed of a stepper motor using the microprocessor namely, Raspberry Pi 3B+. The speed level of the stepper motor is reduced through the time variation of the conveyor belt. The application is suitable especially for food industry. An interactive GUI based Simulink module for the regulation of DC motor systems has been demonstrated in (Dash&Vasudevan, 2011). The GUI based interface incorporates the changes in voltage, speed and armature current with respect to the changes in parameters of the DC motor and relay setting, in addition with PI controller.

In the present work the speed and direction of a Direct Current (DC) motor has been controlled using *Android* based application through smart phone. The Raspberry Pi 3 in conjunctions with the motor driver controller have been used to produce the control action via *Python* based user defines programming. A small GUI has also been created in Python in order to implement interactive interface and control of the motor with the GUI. To the best of authors knowledge the present work has not been explored details and has limited implementation in existing literatures. The work illustrated in this paper can avoid emergency situation without human interface. In emergency or critical situation, when operators unable to stop physically DC Motor, then through this smart application it is possible to stop the Motor.

3. MOTIVATION FOR USING RASPBERRY PI BOARD

The Raspberry Pi has been developed with a set of open source technologies in connection with communication and multimedia applications. It is a single board computer which can execute many important tasks as general purpose computers can do. Raspberry works in Linux operating system, and many Linux version are optimized for the Raspberry Pi. Besides that there are many operating systems like Raspbian, Ubuntu MATE, Windows 10 IoT core, OSMC, LibreELEC, Mozilla Web Things, PiNet, RISC OS, Ichigo Jam RPi, Pidora, Arch Linux ARM, Gentoo Linux, FreeBSD, Kali Linux etc. which are possible to load up into Raspberry for general purpose computing. Among these operating systems most popular option is the *Raspbian* which is based on the *Debian* operating system. Many programming Languages like Java, C, C++, SCRATCH, Python, HTML5, JavaScript, JQuery are also utilized for programming of Raspberry Pi for different purposes. The general circuit of controller board of Raspberry Pi 3B is shown in Figure 1.

These days there are many options are available along with the Raspberry Pi Board. Arduino board, All winner A20, CuBox etc. Processors can be replaced by the Raspberry Pi. The superiorities of Raspberry Pi over the other microcontroller are that it is high speed, more portable, user friendly and are available at cheap rate. It has also high profile graphics processing unit, Wi-Fi connectivity and ffull HDMI Support. The comparisons between all these three microcontroller boards are presented in Table I. Unlike Arduino, which is simply a microcontroller and does not run on any specific operating systems instead it runs by specific syntax of code.

4. ESSENTIAL HARDWARE SETUP

4.1 Raspberry Pi

The Raspberry Pi board used in this work has following features; it has 1.2GHz, Quad Core, 1.2GHz, 64bit Broadcom BCM2837 CPU (Asadi, 2014). The board has 1GB RAM, 40-pin extended GPIO with BCM43438 wireless LAN and on board Bluetooth connectivity. There are full size HDMI facilities and a micro SD port for loading operating system, storing user defined Program and data. Besides that it has 4 USB 2 ports, 4 Pole stereo output and composite video and CSI camera port. The L293D DC Motor Driver Module is connected with the Raspberry Pi board through extended GPIO.

4.2 Driver Module L293D for DC Motor

The most popular motor driver modules are belongs to the L293 series (L293D, L293NE, etc). These motor driver modules are integrated circuit chips which act as an interface between Raspberry Pi and the motor for controlling purpose. Usually 02 (two) DC motors can be interfaced simultaneously with these ICs. In the present work motor driver IC, L293D has been used. The L293D motor driver modules is shown in Figure 2. It is a 16 pin Integrated Chip of which eight dedicated pins in each sides are used to provide control signals for the two motors. For controlling each motor there are 02 (two) INPUT pins, 02 (two) OUTPUT pins and has 01 (one) ENABLE pin. IC L293D driver contains two H-bridge circuits as shown in Figure 3. It is to be noted that the H-bridge circuit is very simple and effective for controlling a low power rating motor. Now depending upon the configurations of the Input and the Enable pins, the motors will rotate in either clockwise or anticlockwise direction. When the Enable pin is HIGH the motor will rotate at full speed and it is possible to rotate the motor with less or any controlled speed when the Enable pin is actuated with PWM signal. It has been assumed

Figure 1. Raspberry Pi 3 Model B Board

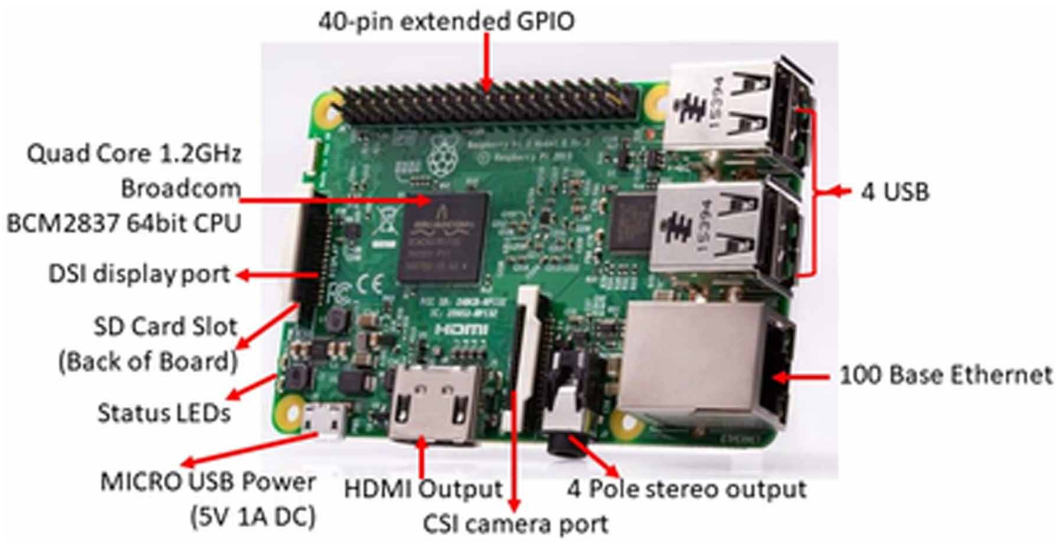


Table 1. Comparison of features of different boards

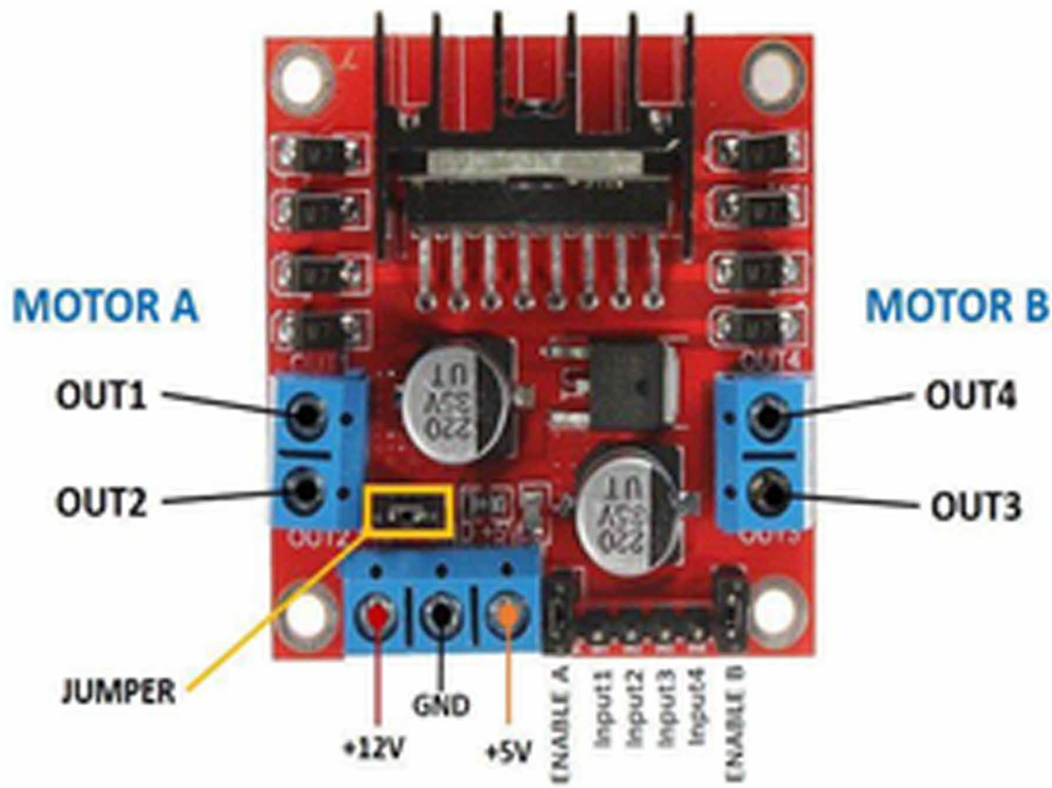
Features	Raspberry Pi 3B	All winner A20	CuBox
Price	Rs. 2,950	Rs. 7,600	Rs. 9,500
Video	1080p hardware accelerated video playback; HDMI or composite RCA	2160p hardware accelerated Video playback; 2 24-pin RGB/ TTL interfaces, HDMI out	1080p video playback; HDMI
GPU	Broadcom Video Core IV, OpenGL ES 2.0, 1080p30 h.264/MPEG-4 AVC high profile decode	Power VR SGX544MP1 Comply with OpenGL ES 2.0 Open-CL	OpenGL Embedded Standard 2.0 Graphics Engine
Other	40-pin extended GPIO (SPI, I²C, UART, +3.3 V, +5 V)	GPIO, I2C, PWM, Keyboard Matrix (8x8), built-in resistive touch screen controller	Infrared receiver, Micro USB for debug console

that to move the left motor in clockwise direction the Enable pin is made HIGH and the Input 1 and Input 2 are configured with HIGH and LOW signals respectively.

4.3 Direct Current (DC) Motor

DC Motor is important electrical drive equipment traditionally used in domestic to many industrial applications such as rolling mills, electric vehicle tractions, electric trains etc depending upon its types and ranges. It very popular because of low initial cost, excellent drive performance, low maintenance and the noise limit. It converts electrical energy to mechanical energy. According to their electrical connections, the most common types of DC motors are; series shunt and compound motors. In this paper a miniature small DC motor has been used. It is worthwhile to mention that the L293D motor

Figure 2. L293D DC Motor Driver Module



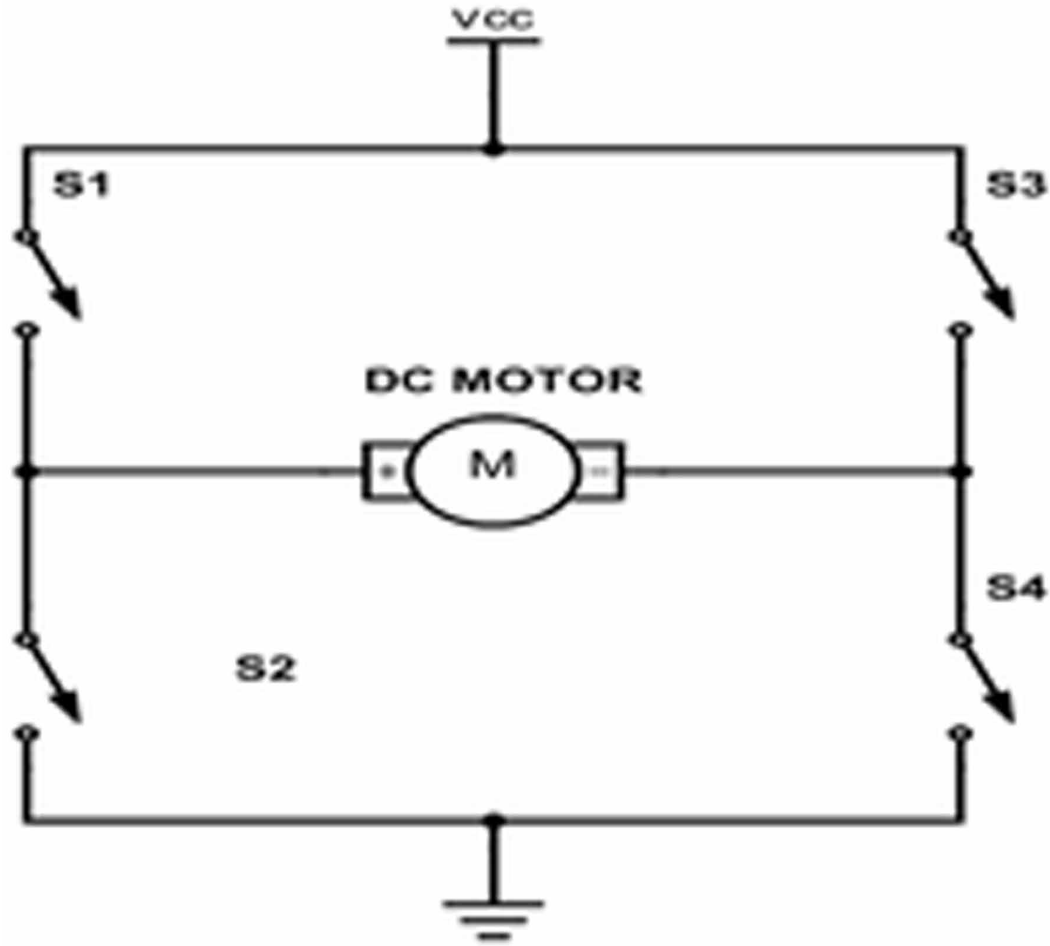
driver IC controls the speed and direction of the motor. The driver IC, L293D is able to provide up to 600 am bidirectional drive currents with a range of voltages from 4.5 V to 36 V.

The motor under control can be energized from any DC power supply or through a standard battery with appropriate rating. GPIO Pins of Pi Controller board are configured through programming. DC motor is connected through wires with the GPIO pins. Battery power is connected to the motor driver IC and also the Raspberry Pi's 5.0 V dc Power pin. Thus, in this way the Raspberry Pi and the L293D motor driver IC Module are powered up with the help of battery. Detail steps of hardware connectivity of the equipments have been described in the following section.

5. HARDWARE CONNECTIVITY

1. First, Supply the power in L293D DC Motor driver module. From L293D DC Motor driver module initialize the power of DC Motor.
2. From L293D DC Motor Driver Module connect Raspberry Pi 3 pin 2 with positive (+ve) power supply which is 5V power.
3. Connect pin 6 with negative (-ve) power supply for creating common ground.
4. Pass Enable of L293D to pin 7 [GPIO4 (GPIO_GCLK)] of Raspberry Pi 3.
5. Pass input signal to L293D DC Motor driver module by connecting any of the two out of six GPIO_GEN pin to Input Motor pin (pin 2 and pin 7 of IC L293D). In this case pin 13 which is GPIO 27(GPIO_GEN2) and pin 15 which is GPIO 22 (GPIO_GEN3) are connected to two motor I/P pin.

Figure 3. H-Bridge for L293D DC Motor Driver Module



6. Connect DC motor in motor output pins (pin 3 and pin 8 of IC L293D).

The detail circuit diagram of the DC Motor with Pi Board is demonstrated in Figure 4 and Figure 5.

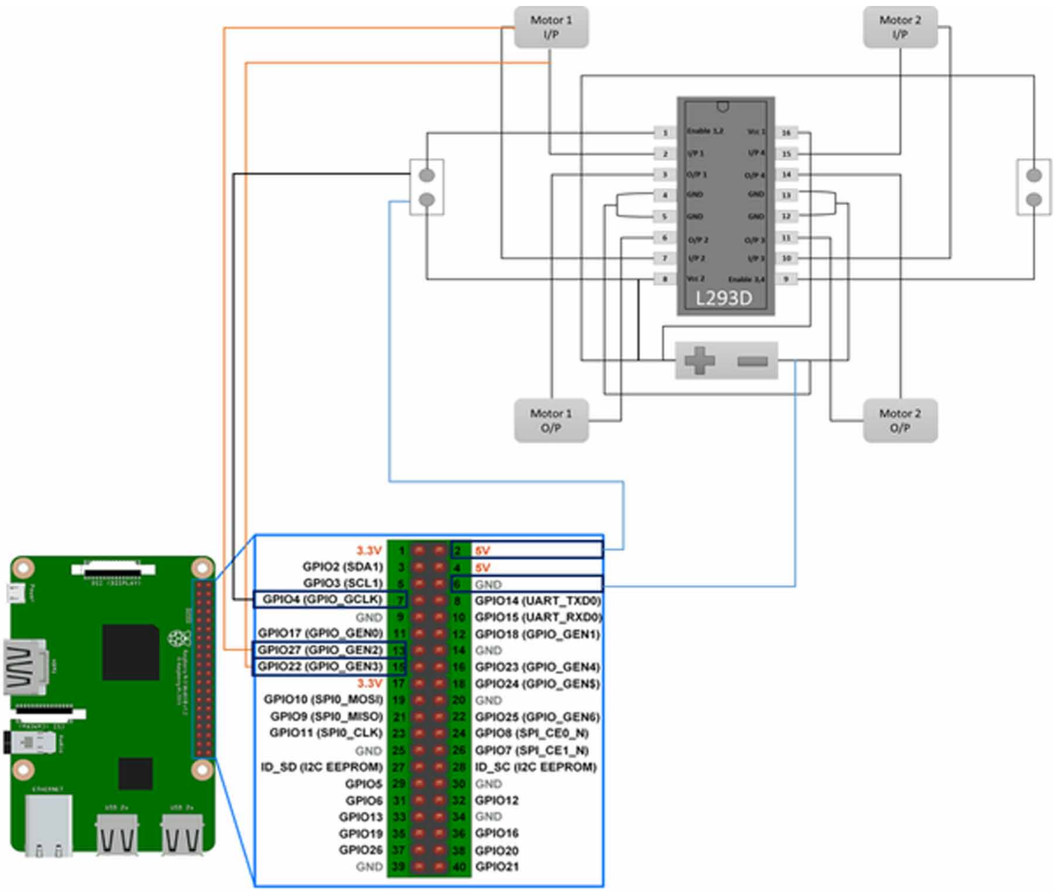
6. SOFTWARE METHODOLOGY

In this work following software methodologies has been employed in order to develop the operation & control of DC motor movement using Android Smart Phone client server architecture and Raspbian Operating System

6.1 Raspbian

Raspbian is a Debian based free operating system optimized for the Raspberry Pi hardware (Peter & David, 2013). An operating system installation manager for the Raspberry Pi, New out of Box Software (NOOBS) has been used to store the *Raspbian* Operating systems in a formatted SD card which is plugged into the SD Card slot of the Raspberry Pi to install the Raspbian Operating System. After successful installation the boot file of the Raspbian Operating System has been modified. Some

Figure 4. Circuit diagram of the DC motor with Pi Controller Board



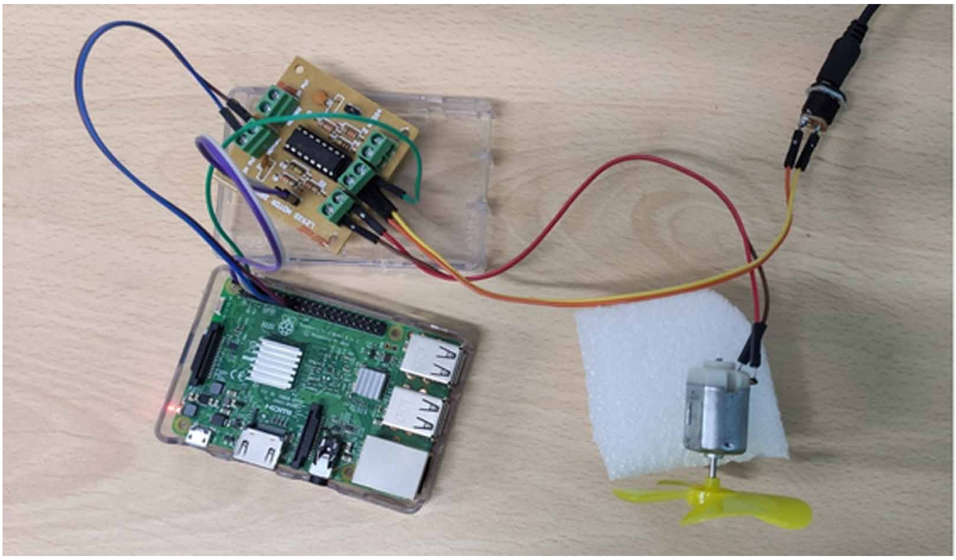
additional functionality has also been included into the system which will run immediately after completion of loading of the operating systems. One is Turn On the *WiFi Hotspot* after loading of operating system is complete and another is a specific program which will start the *Python Server*.

6.2 Android Client Application

An android application is developed using the ADT in java platform for running the programs on mobile devices that will communicate with Raspberry Pi. The Android application in the Android Phone works like a Client and the Android App sends data to the Raspberry Pi's server using Wi-Fi connection (Monk, 2016).The screenshot of the Android App configuration is shown in Figure 6. There are five interacting soft buttons, one IP address input box and two radio buttons. The "+" button is for increasing the speed of the DC motor whereas "-" button is for decreasing the speed. "FULL SPEED MOTOR" button has been configured for rotating the motor at 100% duty cycle. To turn off rotation of the motor "SWITCH OFF MOTOR" button has been used. The two radio buttons "Clock Wise Rotation" and "Anti Clock Wise Rotation" are given for rotating the motor in clock wise and also in anti clock wise directions respectively. "TURN OFF SERVER" button has been utilized for switch off the Raspberry Pi.

It is required to enter the Raspberry Pi's Hotspot IP address and port in the IP address input box, through which information will be sent to Raspberry Pi from Android Mobile.

Figure 5. Physical connection of DC motor with the Raspberry Pi Board



6.3 Python Server Program for Android Based Control

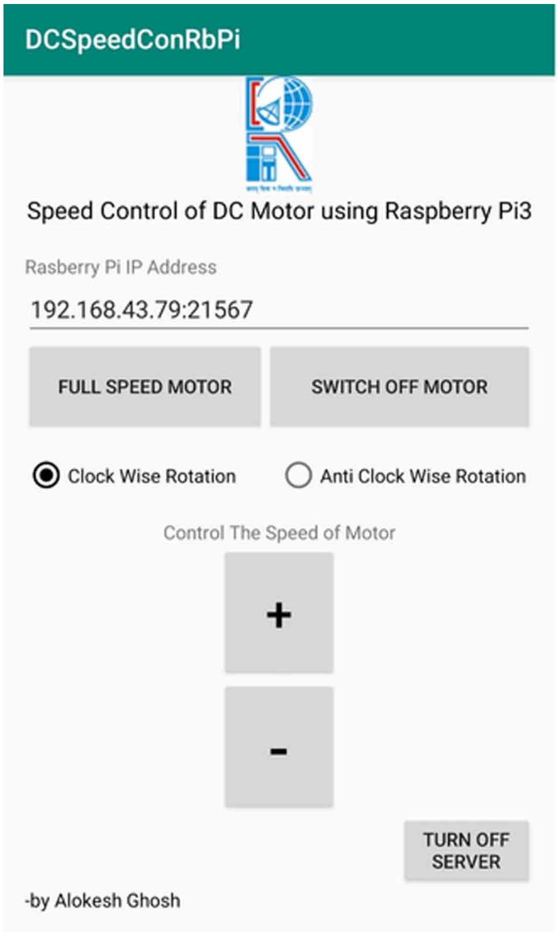
The Server program in the Raspberry Pi has been developed using Python programming Language. Python programs are similar to shell programming. The scripts of Python programs are developed through a series of commands which are executed from top line to the bottom line. It is interesting to be pointed out that Python programs need not require compilation before run like other programming languages, C or C++. Here only requirement is the installation of Python interpreter on computer. The Python interpreter executes step by step python codes through reading from the user defined Python files. The steps for execution of the used defined Python program for the present work are described in section VII.

At first motor control python program has been set as start-up program in the *Raspbian* Operating System for less input / output device access and for this, the *.*bashrc* file in the Raspbian is modified. With the *.*bashrc* method, python program will run on boot when every time a new terminal is opened, or when a new Secure Socket Shell (SSH) connection is made.

7. STEPS FOR OPERATION AND PROGRAM EXECUTION

Step I. Power on the Device. Start the Python server program with the completion of Raspbian operating system loading and initialize the GPIO module. Also, create Raspberry Pi Hotspot (using Hotspot any Android Device can be connected with Raspberry Pi and send information) with completion of Raspbian operating system loading.
Step II. Set naming modes to name all the pins (Input/output) on the board.
Step III. Set Duty Cycle to 0 (Zero) to both the Pins that work as DC Motor Input Signal.
Step IV. Turn on the Wifi in Android Mobile Device and it shows all available WiFi devices. From available list of devices find the WiFi of Raspberry Pi and connect with it by entering predefined password.
Step V. Send information from Android App to Raspberry Pi using IP and predefined Server Port.
Step VI. If "+" button was clicked by setting "Clock Wise Rotation" option then Sever sets the Duty Cycle of the Motor Input 1 to 5% and Input 2 to 0 and stores the current Duty Cycle. If again If

Figure 6. Screenshot of Android Application



"+" button was clicked by setting "Clock Wise Rotation" option then Sever sets the Duty Cycle of the Motor Input 1 to Previous Duty Cycle + 5% and Input 2 to 0 and stores the current Duty Cycle. Thus, Speed of the DC Motor can be increased in clockwise direction. Maximum duty cycle can be increased to 100%.

Step VII. If "-" button was clicked by setting "Clock Wise Rotation" option then Sever sets the Duty Cycle of the Motor Input 1 to Previous Duty Cycle - 5% and Input 2 to 0 and stores the current Duty Cycle. Thus, Speed of the DC Motor can be decreased in clockwise direction. Maximum duty cycle can be increased to 0%.

Step VIII. If "+" button was clicked by setting "Anti Clock Wise Rotation" option then Sever sets the Duty Cycle of the Motor Input 1 to 0 and Input 2 to 5% and stores the current Duty Cycle. If again If "+" button was clicked by setting "Anti Clock Wise Rotation" option then Sever sets the Duty Cycle of the Motor Input 1 to 0 and Input 2 to Previous Duty Cycle + 5% and stores the current Duty Cycle. Thus, Speed of the DC Motor can be increased in anti-clockwise direction. Maximum duty cycle can be increased to 100%.

Step IX. If "-" button was clicked by setting "Anti Clock Wise Rotation" option then Sever sets the Duty Cycle of the Motor Input 1 to 0 and Input 2 to Previous Duty Cycle - 5% and stores the current Duty Cycle. Thus, Speed of the DC Motor can be decreased in anti-clockwise direction. Maximum duty cycle can be increased to 0%.

Step X. If “FULL SPEED MOTOR” button was clicked by setting “Clock Wise Rotation” option then Sever sets the Duty Cycle of the Motor Input 1 to 100% and Input 2 to 0 and the DC Motor runs in maximum speed in clockwise direction.

Step XI. If “FULL SPEED MOTOR” button was clicked by setting “Anti Clock Wise Rotation” option then Sever sets the Duty Cycle of the Motor Input 1 to 0 and Input 2 to 100% and the DC Motor runs in maximum speed in anti-clockwise direction.

Step XII. If “SWITCH OFF MOTOR” button was clicked then the Python Sever sets the Duty Cycle of the both Motor Input to 0 and the rotation of the DC Motor will be stopped.

Step XIII. If “Turn off Server” button was clicked then the Python Sever program will be stopped and the Raspberry Pi will be turned off.

8. PYTHON BASED GUI FOR DC MOTOR SPEED CONTROL

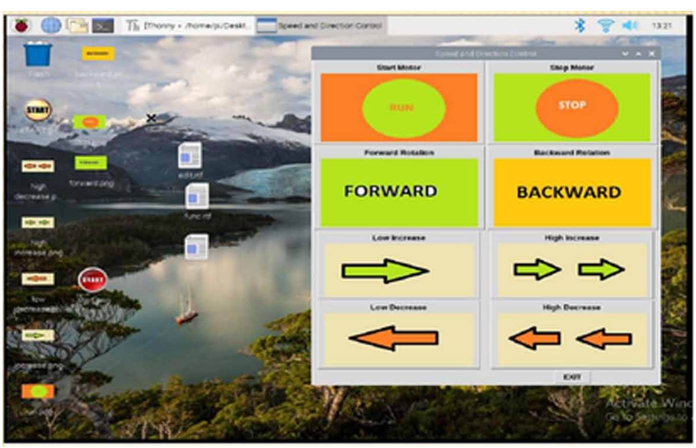
In this section authors have configured a GUI based interface using Python Programming for direction and speed control of DC motor. Python offers “*tkinter*” (Tk) module to create graphics programs and GUI interface. To work in GUI environment Raspberry pi is connected with computer in SSH mode using “Tera Term” software which establish a remote desktop connection with Raspberry pi. An open-source remote desktop software application “*TightVNC*” is employed to view the raspberry desktop on computer.

8.1 “Tkinter” Module and Tera Term Connector

The “*tkinter”* module represents a “toolkit” interface to create GUI in Python (Nageswara Rao, 2019). Python programmers enable this toolkit to use the classes of TK/TCL (Tool Command Language). TK module provides standard GUI not only for TCL but also for any other dynamic programming languages and can be suitable for web and desktop application, networking, administration etc.

“*Tera Term*” is an open sourcefreesoftware which is implemented for terminal emulator or for the wirelessly communications program of the personal computer. It also supports to wirelessly connect between Laptop and Raspberry Pi cluster. It can emulates different types of computer terminals, from DEC VT100 to DEC VT382 and supports telnet, SSH 1 & 2 and serial port connections. To connect Raspberry pi using SSH mode a remote login protocol is used to transfer files or folders

Figure 7. GUI view for speed control



among two or more nodes. It also has a built-in macro scripting language and a few other useful plug-ins.RSA encryption algorithms is used in SSH to produce private and public keys and provides one time *login* credential.

8.2 Tight Virtual Network Computing (TightVNC)

In this task, Tight Virtual Network Computing (TightVNC) software has been employed to access Raspberry Pi through remote desktop. TightVNC is a free remote control software package which is popularly used in graphical desktop sharing system based on client-server architecture. VNC supports to manage remote computer over a network connection. VNC server package is installed in a remote computer and client package is installed in a local computer. Then local computer displays the duplicate screen of the server through virtual network connection system and then it is possible to transmit the actions like mouse clicks and keyboard button presses. In this work GUI display monitor has been designed to connect Raspberry Pi through VNC server in order to control DC motor from remote Desktop. The configuration of the GUI view for speed control of a DC motor has been presented in Figure 7.

9. CONCLUSION

The development of wireless devices and with simultaneously increasing demand of wireless communication has leading to significant usage of microcontrollers in order to perform wide varieties of tasks in the field of engineering & technology. In this paper authors intention is to provide an elementary understanding of the programming and use of microcontroller for controlling a DC motor through wireless communication. The most popular and cheaply available microcontroller, Raspberry Pi 3B has been utilized to execute the whole research works. It has been observed that the Raspberry Pi 3B is capable to provide satisfactory performance to run and control a 5V DC motor via the motor driver L293D.

It is to be noted that the work presented in this paper is purely experimental and the investigation is yet to be made on real robotic platform. The control algorithm is developed in Python programming language however, need to use there GPIO pins and the module RPi. GPIO must be imported into the main program.

This paper finally concludes that this research can enable the way of e-Control of DC motor with the help of Android Smart phone. Both the directions and speed of rotation can be controlled through interactive mode via Android Application and integrating it with the Raspberry Pi board and writing simple lines of code in Python programming language.

10. FUTURE WORK

Although the final product of the present work is very successful at accomplishing the objectives, however there are several ways which could be implemented to improve the performance. It must be kept in mind that the products produced in this work is a simple prototype and need much more work to make it marketable.

Several areas that can also be improved are like the size of the devices, the cost of the devices, the power sources used and the range of communication. Currently, the communication is unidirectional communication. Android app transmits data to Raspberry Pi and the Raspberry Pi acts upon the information. But no acknowledge signal is sent form Raspberry Pi.

Based on application areas different type of sensors like temperature sensor, speed sensor etc can be incorporated with the Raspberry Pi system for automatic feedback and control of the DC motor using Android app.

Besides above authors have planned to implement this work in a 4-wheeled robotic chassis and also aimed to extend the control and wireless communication system for Long-Term Evolution (LTE) standard.

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