VOICE INTERFACED AUTONOMOUS ROVER WITH ROBOTIC ARM FOR INDUSTRIAL APPLICATION

Submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering Degree in Electronics and Communication Engineering

by

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY (DEEMED TO BE UNIVERSITY)
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APRIL 2020

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of K. JOSEPH PRANADEER REDDY (3613259) and J. MOHAN SATISH (3613252) who carried out the project entitled **"VOICE INTERFACED AUTONOMOUS ROVER WITH ROBOTIC ARM FOR INDUSTRIAL APPLICATION"** under our supervision from September 2019 to April 2020.

Internal Guide

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Submitted for Viva voce examination held on ____________________

Internal Examiner **External Examiner**

DECLARATION

We, **K. JOSEPH PRANADEER REDDY (3613259)** and **J. MOHAN SATISH (3613252)** hereby declare that the Project Report entitled **"VOICE INTERFACED AUTONOMOUS ROVER WITH ROBOTIC ARM FOR INDUSTRIAL APPLICATIONS"** done by us under the guidance of **Dr.E. LOGASHANMUGAM, M.E., Ph.D.** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

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DATE:
PLACE:

SIGNATURE OF THE CANDIDATES

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ABSTRACT

Robotics has become a booming area of research in the field of Engineering. It holds a great potential in reducing human effort by performing tasks faster while maintaining operational accuracy. Robotic arm has shown prominent role in the field of robotics to aid as an artificial human hand using its manipulator and gripping mechanism. Also, recent advances in the field of Artificial Intelligence has greatly helped to make instruments intelligent. Our proposed project integrates these fields of technology which can be implemented in numerous sectors. This project comprises three major portions- ground rover, robotic arm and image processing-based control. The rover has a rocker-bogie mechanism which makes it a robust vehicle to travel across various terrains. A robotic arm is attached to the rover allowing it to manipulate objects along its path. The functioning of this robotic arm is governed by image processing mechanism, enabling the device to identify the object to be manipulated. In order to obtain the desired output action, feedback error is given as input and rectified using PID control, improving the control over actuation. To promote the ease of access while providing input to the model, instead of furnishing with conventional remote buttons, the model is interfaced with voice recognition capability to take input from the user. Our project is designed to distinguish and categorize the objects specified by the user. The scope of application for this project is versatile, not limiting its functionality to a fixed application.

Keywords- Rover, Robotic Arm, Rocker-Bogie mechanism, Object detection, Raspberry Pi microprocessor

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LIST OF ABBREVIATIONS

DC	DIRECT CURRENT
DNN	DEEP NEURAL NETWORKS
GPIO	GENERAL PURPOSE INPUT OUTPUT
IC	INTEGRATED CIRCUIT
ITS	INTELLIGENT TRANSPORTATION SYSTEM
MIT	MIT APP INVENTOR
MPU	MICRO PROCESSOR UNIT
PCB	PRINTED CIRCUIT BOARD
PWM	PULSE WIDTH MODULATION
RPI	RASPBERRY PI
XML	EXTENSIBLE MARKUP LANGUAGE

CHAPTER 1
INTRODUCTION

1.1 ROBOTICS

Robotics is an interdisciplinary branch of engineering and science that includes mechanical engineering, electronic engineering, information engineering, computer science, and others. Robotics involves design, construction, operation, and use of robots, as well as computer systems for their perception, control, sensory feedback, and information processing. The goal of robotics is to design intelligent machines that can help and assist humans in their day-to-day lives and keep everyone safe.

Robotics develops machines that can substitute for humans and replicate human actions. Robots can be used in many situations and for lots of purposes, but today many are used in dangerous environments (including inspection of radioactive materials, bomb detection and deactivation), manufacturing processes, or where humans cannot survive (e.g. in space, under water, in high heat, and clean up and containment of hazardous materials and radiation).

1.2 AUTONOMOUS ROBOTS

An autonomous robot is a robot that performs behaviors or tasks with a high degree of autonomy (without external influence). Autonomous robotics is usually considered to be a subfield of artificial intelligence, robotics, and information engineering. Autonomous robots are particularly desirable in fields such as spaceflight, household maintenance (such as cleaning), waste water treatment, and delivering goods and services.

Some modern factory robots are "autonomous" within the strict confines of their direct environment. It may not be that every degree of freedom exists in their surrounding environment, but the factory robot's workplace is challenging and can often contain chaotic, unpredicted variables. The exact orientation and position of the next object of work and (in the more advanced factories) even the type of object and the required task must be determined. This can vary unpredictably (at least from the robot's point of view).

One important area of robotics research is to enable the robot to cope with its environment whether this be on land, underwater, in the air, underground, or in space.

A fully autonomous robot can:

- Gain information about the environment
- Work for an extended period without human intervention
- Move either all or part of itself throughout its operating environment without human assistance
- Avoid situations that are harmful to people, property, or itself unless those are part of its design specifications

An autonomous robot may also learn or gain new knowledge like adjusting for new methods of accomplishing its tasks or adapting to changing surroundings.

1.3 RECENT TRENDS AND FUTURE

There are basically three recent trends in robotics, such recent trends are as follows:

- Robot Training: AI is making robots easier to train, which in turn makes them a more viable investment for smaller companies as it reduces the cost of installation, training and ongoing programming. Robots like Baxter and Sawyer from Rethink Robotics can be trained by simply guiding their arms a few times – it learns through demonstration and programs the correct motion itself. The easier it is to teach a robot new thing, the more it can learn.
- 3D Vision: Even the simplest tasks a robot performs will depend on 3D machine vision to feed data into AI technology. Grasping an object, for example, without pre-determined locations and motions would be impossible without machine vision capable of reconstructing a 3D image, and AI to translate this visual information into a successful action on the part of the robot.
- Cloud Robotics: Robotic deep learning using image classification and speech recognition often relies on huge datasets with millions of examples. AI requires more data than can realistically reside on most local systems. In this way, advances in cloud robotics are necessary for the advancement of AI and robotics technologies. Cloud robotics allows intelligence to be shared across all robots in a connected environment.

Robot training, 3D vision and cloud robotics are three recent trends in Robotics technologies, regardless of whether they are used for industrial or collaborative application.

1.4 ORIGIN OF IDEA

Our team has always been interested in the field of space robotics. Rovers have been a revolution in Space Robotic Industry. Incorporating the idea of rovers to everyday life has intrigued us. So, we came up with the idea to make a Human Assistant supporting him in his everyday needs. Replacing the need of a Humanoid Robot to aid man, we designed a prototype of the rover with can do the same.

CHAPTER 2
LITERATURE REVIEW

2.1 LITERATURE SURVEY

Very few human assistants have been made using rovers. A reasonable number of works have found in the Literature. Although the techniques and equipment used int his project have already been proposed and are in use, we have used a unique combination of algorithms and mechanical structure which makes our proposed project novel.

Yasir ali memon, Imaaduddin motan, muhammad ali akbar, sarmad hameed and moez ul hasan (2016), have designed a Speech Recognition System for a Voice Controlled Robot with Real time Obstacle Detection and avoidance. The Apart from avoiding the obstacles and staying safe, the movement is actuated by voice commands, thus, utilizing Voice recognition system. The limitation to this system is that, for every action, voice command must be given which makes it troublesome for the user. Moreover, the robot can only detect an obstacle but not recognize the object.

N. U. Alka, A. A. Salihu, Y. S. Haruna and I. A. Dalyop (2017), have made a A Voice Controlled Pick and Place Robotic Arm Vehicle Using Android Application. The rover can be remotely actuated using Android Application utilizing Wireless means of communication. The model is also incorporated with voice recognition system. The drawback to such a model was that, only arm can be remotely operated and the movement of rover has to be verbally commanded making it a strenuous job to the user.

A. S. Silva, F. M. Q. Severgnini,M. L. Oliveira, V. M. S. Mendes and Z. M. A. Peixoto (2018) have developed an Object Tracking by Colour and Active Contour Models Segmentation. An object is identified by using color recognition in the HSV color space and active contour models (ACM). Such a system requires the object being traced to be stationary. Tracing a moving object reduces the accuracy identification.

Baoying Chen and Guofang Huang (2018) have conducted a Study on Target Tracking Algorithm Integrating Color and Contour Features. An object tracking algorithm with integrating color and contour features has been proposed. This system is suitable for both stationary and dynamic environments. The accuracy of the system is hindered by the environmental factors such as Brightness.

San Hlaing Oo, Aung Aung Soe and Sai Saing Won **(2018) have elaborated** on Remote Controlled Ground Rover for Collecting Objects and Sensing Environment. Their Idea was to incorporate various sensors to a Rover with has been attached with a Robotic Arm. The Sensors would record the Environmental conditions. The Disadvantage with such a system is that, the functioning has to be controlled manually all the time

Tian Wang, Yuting Yao, Yang Chen, Mengyi Zhang and Fei Tao, Hichem Snoussi (2018), have implemented an Auto-sorting System Towards Smart Factory based on Deep learning for Image Segmentation. In this prototype, a Robotic arm is powered by Deep Learning Algorithms which help for classification of objects. The processor identifies the object and using the principles of inverse kinematics, the Arm locates the object and categorizes the objects. The only withholding factor to such a smart system is its mobility. The Arm is located in a single location.

2.2 PROBLEM STATEMENTS FROM SURVEY

Many Algorithms and works have been proposed and developed to achieve a better Robotic System. Nevertheless, every proposed system lacks a few features. Even though the drawbacks of one system have been compensated in the other, No system as a hole can work autonomously, reducing the effort put in by the user.

Most of the work done on object tracking robots makes use of sensors such as infra-red sensor, photo diodes, and color sensors to detect the objects. Use of such sensors adds to the size of the model. Furthermore, the system becomes proportionately complex. Power handling becomes a frequent problem in such cases. Also, the robotic arm attached to the vehicle makes its movement unstable due to the carrying load or non-uniform terrains.

2.3 OBJECTIVE

The sole purpose of this project is to search for the object specified by the user's voice command, collect the object using the Robotic Arm and bring it back to the user. This procedure involves a lot a complication. The audio signals from the voice command has to be converted to machine language to understand the given command. The object from the command has to be understood by the processor and start searching for it. The image processing technique used has to be more efficient utilizing less computational power so that there is no breakdown while performing. Once the object is detected, the rover has to be aligned in the direction of the object and then move towards it. Finally, identifying the coordinates of the object, the robotic arm has to grab the object and bring it back. Power supply to the entire system plays an essential role to achieve the goal.

- A Rover attached with a Robotic Arm.
- The Rover is equipped with Rocker-Bogie mechanism to handle rugged terrains.
- Robotic Arm is used for handling various objects.
- Camera and Ultra Sonic Sensor help for environment analysis which aids Path planning and Object detection.
- The commands are given as voice input.
- The entire functioning is handled by Raspberry Pi microprocessor.

CHAPTER 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 PROPOSED METHODOLOGIES

- Our proposed project integrates all the requirements to compensate the specified drawbacks.
- The rover's movement is made stable using rocker-bogie mechanism.
- Instead of using multiple sensors, camera is used for object detection.
- The system is designed to make decisions on its own, once the user specifies the object.

3.2 AREA OF PROJECT WORK AND APPLICATION

Robotic arm has shown prominent role in the field of robotics to aid as an artificial human hand using its manipulator and gripping mechanism. Also, recent advances in the field of Artificial Intelligence has greatly helped to make instruments intelligent. Our proposed project integrates these fields of technology which can be implemented in numerous sectors. This project comprises three major portions- ground rover, robotic arm and image processing-based control. The rover has a rocker-bogie mechanism which makes it a robust vehicle to travel across various terrains. A robotic arm is attached to the rover allowing it to manipulate objects along its path. The functioning of this robotic arm is governed by image processing mechanism, enabling the device to identify the object to be manipulated. In order to obtain the desired output action, feedback error is given as input and rectified using PID control, improving the control over actuation. To promote the ease of access while providing input to the model, instead of furnishing with conventional remote buttons, the model is interfaced with voice recognition capability to take input from the user. Our project is designed to distinguish and categorize the objects specified by the user.

The scope of application for this project is versatile, not limiting its functionality to a fixed application. It can used as an exoplanetary rover, to explore unknown environments and analyze it in real-time. This project can also aid agricultural sector by analyzing the crop field and categorizing the ripe fruits or vegetables from that of spoiled ones and placing them in separate baskets. It can help laying bricks or carry materials in construction sector. The limits of this project's application are only ones thinking capacity.

3.3 ROCKER BOGIE MECHANISM

This mechanism is used to handle one of the drawbacks which could not be addressed by many proposals mentioned in the literature survey.

3.3.1 OVERVIEW

The rocker-bogie system is the suspension arrangement developed in 1988 for use in NASA's Mars rover Sojourner and which has since become NASA's favored design for rovers.[4] It has been used in the 2003 Mars Exploration Rover mission robots Spirit and Opportunity, on the 2012 Mars Science Laboratory (MSL) mission's rover Curiosity and is slated for use in the Mars 2020 rover.

The "rocker" part of the term comes from the rocking aspect of the larger, forward leg on each side of the suspension system. These rockers are connected to each other and the vehicle chassis through a differential. Relative to the chassis, when one rocker goes up, the other goes down. The chassis maintains the average pitch angle of both rockers. One end of a rocker is fitted with a drive wheel, and the other end is pivoted to the bogie.

The "bogie" part of the term refers to the smaller, rearward leg that pivots to the rocker in the middle and which has a drive wheel at each end. Bogies were commonly used as load wheels in the tracks of army tanks as idlers distributing the load over the terrain, and were also quite commonly used in trailers of semi-trailer trucks. Both tanks and semi-trailers now prefer trailing arm suspensions.

3.3.2 DESIGN

The rocker-bogie design has no springs or stub axles for each wheel, allowing the rover to climb over obstacles (such as rocks) that are up to twice the wheel's diameter in size while keeping all six wheels on the ground. As with any suspension system, the tilt stability is limited by the height of the center of gravity. Systems using springs tend to tip more easily as the loaded side yields. Based on the center of mass, the Curiosity rover of the Mars Science Laboratory mission can withstand a tilt of at least 45 degrees in any direction without overturning, but automatic sensors limit the rover from exceeding 30-degree tilts. The system is designed to be used at slow speed of around 10 centimeters per second (3.9 in/s) so as to minimize dynamic shocks and consequential damage to the vehicle when surmounting sizable obstacles.

The Jet Propulsion Laboratory states that this rocker bogie system reduces the motion of the main MER vehicle body by half compared to other suspension systems.[citation needed] Each of the Curiosity rover's six wheels has an independent motor. The two front and two rear wheels have individual steering motors which allow the vehicle to turn in place. Each wheel also has cleats, providing grip for climbing in soft sand and scrambling over rocks. The maximum speed of the robots operated in this way is limited to eliminate as many dynamic effects as possible so that the motors can be geared down, thus enabling each wheel to individually lift a large portion of the entire vehicle's mass.

In order to go over a vertical obstacle face, the front wheels are forced against the obstacle by the center and rear wheels. The rotation of the front wheel then lifts the front of the vehicle up and over the obstacle. The middle wheel is then pressed against the obstacle by the rear wheels and pulled against the obstacle by the front until it is lifted up and over. Finally, the rear wheel is pulled over the obstacle by the front two wheels. During each wheel's traversal of the obstacle, forward progress of the vehicle is slowed or completely halted. This is not an issue for the operational speeds at which these vehicles have been operated to date.

One of the future applications of rovers will be to assist astronauts during surface operations. To be a useful assistant, the rover will need to be able to move at least as fast as human walking speed. Other missions which have been proposed, such as the Sun-Synchronous Lunar Polar Rover, require even greater speeds (4–10 km/h).

3.4 OBJECT RECOGNITION TECHNIQUE

There are many object recognition techniques available. Each technique has its own drawbacks. So necessary knowledge is required to utilize a technique balancing all the needs.

3.4.1 OVERVIEW OF IMAGE PROCESSING

INTRODUCTION:

Image processing is the process of manipulating pixel data in order to make it suitable for computer vision applications or to make it suitable to present it to humans. For example, changing brightness or contrast is an image processing task which make the image visually pleasing for humans or suitable for further processing for a certain computer vision application.

SOFTWARE AND HARDWARE REQUIREMENTS

Hardware:

- OS – Windows 7, 8 and 10 (32 and 64 bit)
- RAM – 4GB

Software:

- Python

3.4.2 PYTHON OVERVIEW

Python is a high-level, interpreted, interactive and object-oriented scripting language. Python is designed to be highly readable. It uses English keywords frequently where as other languages use punctuation, and it has fewer syntactical constructions than other languages.

- **Python is Interpreted:** Python is processed at runtime by the interpreter. You do not need to compile your program before executing it. This is similar to PERL and PHP.

- **Python is Interactive:** You can actually sit at a Python prompt and interact with the interpreter directly to write your programs.

- **Python is Object-Oriented:** Python supports Object-Oriented style or technique of programming that encapsulates code within objects.

- **Python is a Beginner's Language:** Python is a great language for the beginner-level programmers and supports the development of a wide range of applications from simple text processing to WWW browsers to games.

PYTHON ENVIRONMENT

Python is available on a wide variety of platforms including Linux and Mac OS X. Let's understand how to set up our Python environment.

Python's standard library

- Pandas
- NumPy
- Sklearn
- seaborn
- matplotlib
- Importing Datasets
- OpenCV

3.4.3 INTRODUCTION TO OPEN CV

OpenCV is Open Computer Vision Library. It was initially launched in 1999 by Intel. With more updates, it has been modified since then to aim for the real-time computer vision. This library has been written under programming languages like C and C+. It can be easily run on operating systems Windows and Linux. This library can be easily interface with programing languages like Python, MATLAB, Ruby and others as well. Along with NumPy and Python image processing (shape & color detection) can be performed at ease.

Read an Image

First, a sample image in which processing is to be applied is to be read. It's done using a pre-defined Python function: CV2.imread(). The sample image should be available in current folder or the full location of the image is to be mentioned as an argument. For reading an image, we can use functions like imread_color, imread_grayscale,imread_unchanged etc.

NUMPY

NumPy is one such powerful library for array processing along with a large collection of high-level mathematical functions to operate on these arrays. These functions fall into categories like Linear Algebra, Trigonometry, Statistics, Matrix manipulation, etc.

Getting NumPy

NumPy's main object is a homogeneous multidimensional array. Unlike python's array class which only handles one-dimensional array, NumPy's Nd array class can handle multidimensional array and provides more functionality. NumPy's dimensions are known as axes. For example, the array below has 2 dimensions or 2 axes namely rows and columns. Sometimes dimension is also known as a rank of that particular array or matrix.

Importing NumPy

NumPy is imported using the following command. Note here np is the convention followed for the alias so that we don't need to write NumPy every time.

- import numpy as np

NumPy is the basic library for scientific computations in Python and this article illustrates some of its most frequently used functions. Understanding NumPy is the first major step in the journey of machine learning and deep learning.

3.4.4 *OBJECT RECOGNITION*

Conventionally, Deep Neural Networks (DNN) method using TensorFlow and TensorFlow Lite Framework have been used with SSD Class model with gave FPS of 2-3 and 4-5 and substantially increased the temperature of Raspberry Pi to 70 degrees Celsius. A high amount of accuracy can be obtained using such complex and high computation power drawing techniques.

In order to compensate for the high computation and increasing processor heating condition, a simple and fast Object Recognition Technique has been implemented in our system. We have used ‘Template Matching Technique’ is used for Object Detection and Recognition. Using this method, 12-15 FPS has been obtained with less computation power consumed. High Speed with a moderate accuracy has been obtained. This method uses an image as reference for detection of object. The pixel values of the Reference image is compared with the Stream of Input images (which form Real-Time Video Processing). Thus, Real-time detection and recognition is obtained.

CHAPTER 4
MATERIALS AND METHODS USED

4.1 PROCESSOR

Raspberry Pi

Raspberry Pi is a small single-board Computer developed in UK by Raspberry Pi foundation to promote the teaching of computer science in schools and in developing countries. Original model become far more popular than anticipated sealing outside of its target market, for uses such as robots.

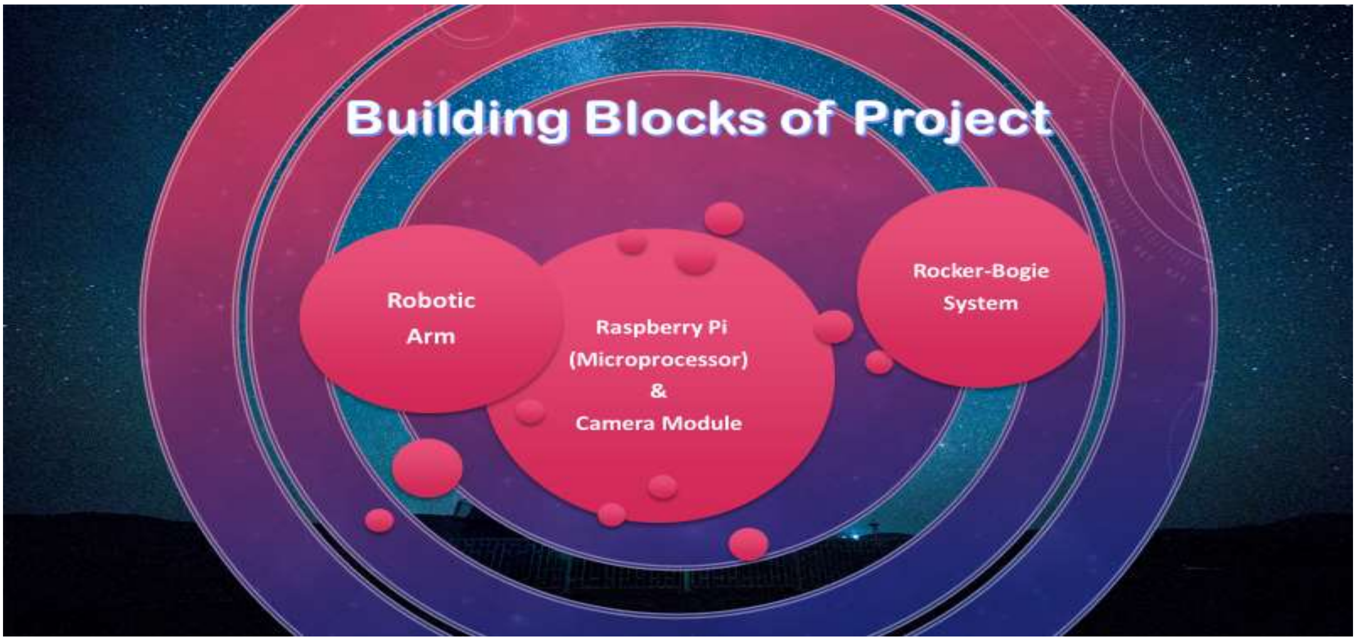


Fig: 4.1: Building Blocks of the Project

4.1.1 Raspberry Pi 4 SPECIFICATIONS

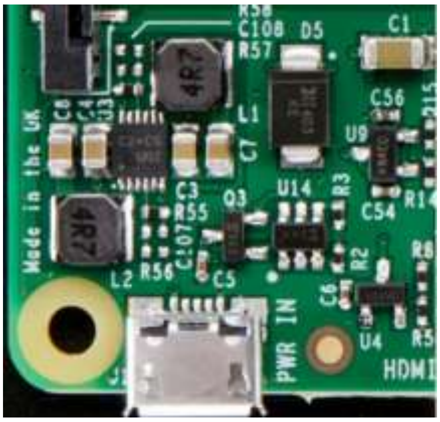
The processor at the heart of the Raspberry Pi is a Broadcom BCM28XX. The Raspberry Pi 4 Model B is the forth generation Raspberry Pi. This powerful credit-card sized single board computer can be used for many applications and supersedes the original Raspberry Pi Model B+, Raspberry Pi 2 Model B and Raspberry Pi 3 Model B.

- Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
- 1GB, 2GB or 4GB LPDDR4-3200 SDRAM (depending on model)
- 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0, BLE
- Gigabit Ethernet

- 2 USB 3.0 ports; 2 USB 2.0 ports.
- Raspberry Pi standard 40 pin GPIO header (fully backwards compatible with previous boards)
- 2 × micro-HDMI ports (up to 4kp60 supported)
- 2-lane MIPI DSI display port
- 2-lane MIPI CSI camera port
- 4-pole stereo audio and composite video port
- H.265 (4kp60 decode), H264 (1080p60 decode, 1080p30 encode)
- OpenGL ES 3.0 graphics
- Micro-SD card slot for loading operating system and data storage
- 5V DC via USB-C connector (minimum 3A*)
- 5V DC via GPIO header (minimum 3A*)
- Power over Ethernet (PoE) enabled (requires separate PoE HAT)
- Operating temperature: 0 – 50 degrees C ambient

RASPBERRY PI POWER SUPPLY

Model B+ Power Supply To make the B+ more reliable and actually reduce the current draw, the power supply is completely redesigned.



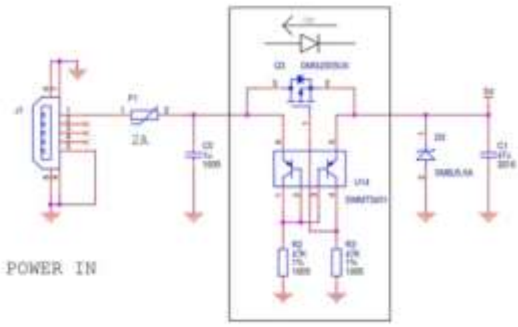


Fig: 4.2: PCB Exterior Look ***Fig: 4.3: PCB Internal Look***

There's still the microUSB jack on the left, and the 1A fuse has been upgraded to a 2A fuse. There's also a DMG2305UX (http://adafru.it/dGU) P-Channel MOSFET. This acts as a polarity protection switch but is much lower 'drop-out' than a diode. Raspberry Pi 4 consumes about 5V and 3amps making total power consumption of 15V

RASPBERRY PI MODEL B+ GPIO PORT:

Fig: 4.4: GPIO Pin Layout

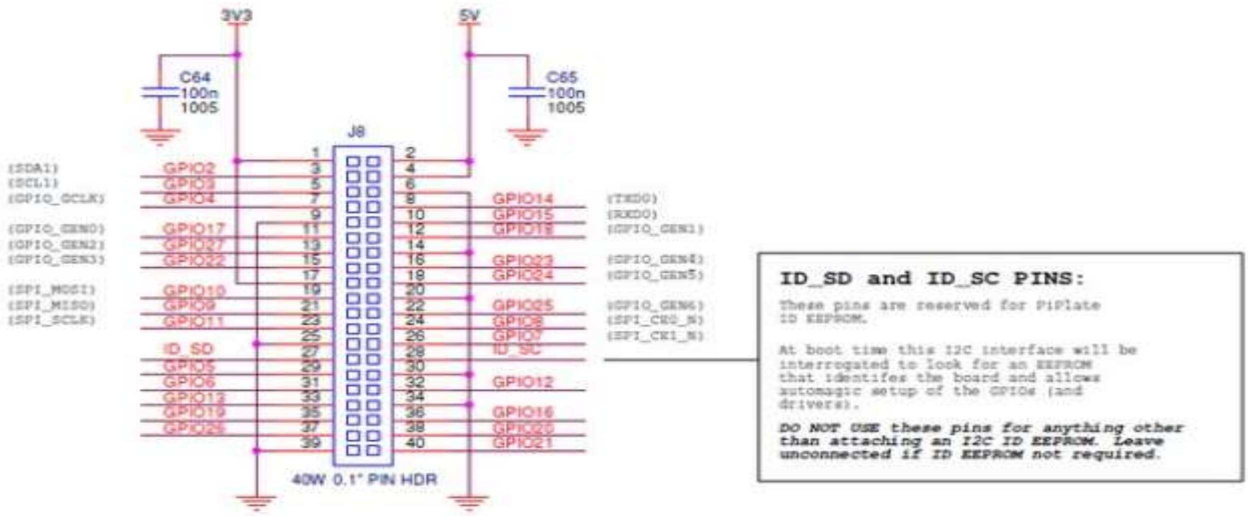


Fig 4.5: GPIO Pins Circuitry

First thing to notice, the top 26 pins of the 40-pin connector are the same as the original That means that most/many Pi Plates that plug into the Model B will plug into the B+ just fine. They won't sit in the same location - they'll be slid down just a bit but electrically-wise its the same.

4.1.2 ARCHITECHTURE

ARM vs. x86

The processor at the heart of the Raspberry Pi system is a Broadcom BCM2837 system-on-chip (SoC) multimedia processor. This means that the vast majority of the system's components, including its central and graphics processing units along with the audio and communications hardware, are built onto that single component hidden beneath the 256 MB memory chip at the center of the board.

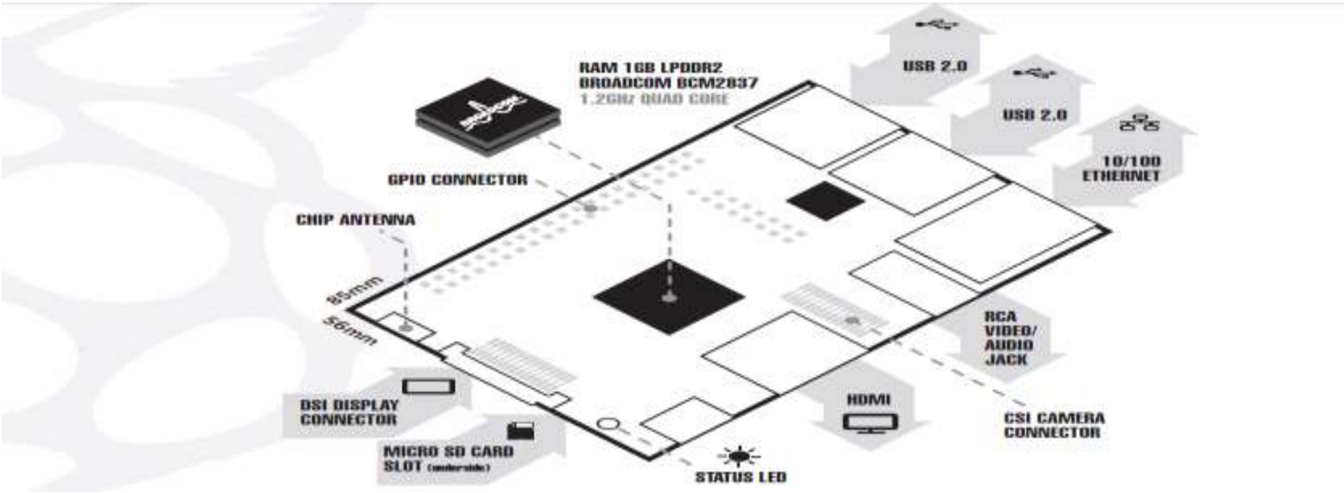


Fig: 4.6: RPI Architecture

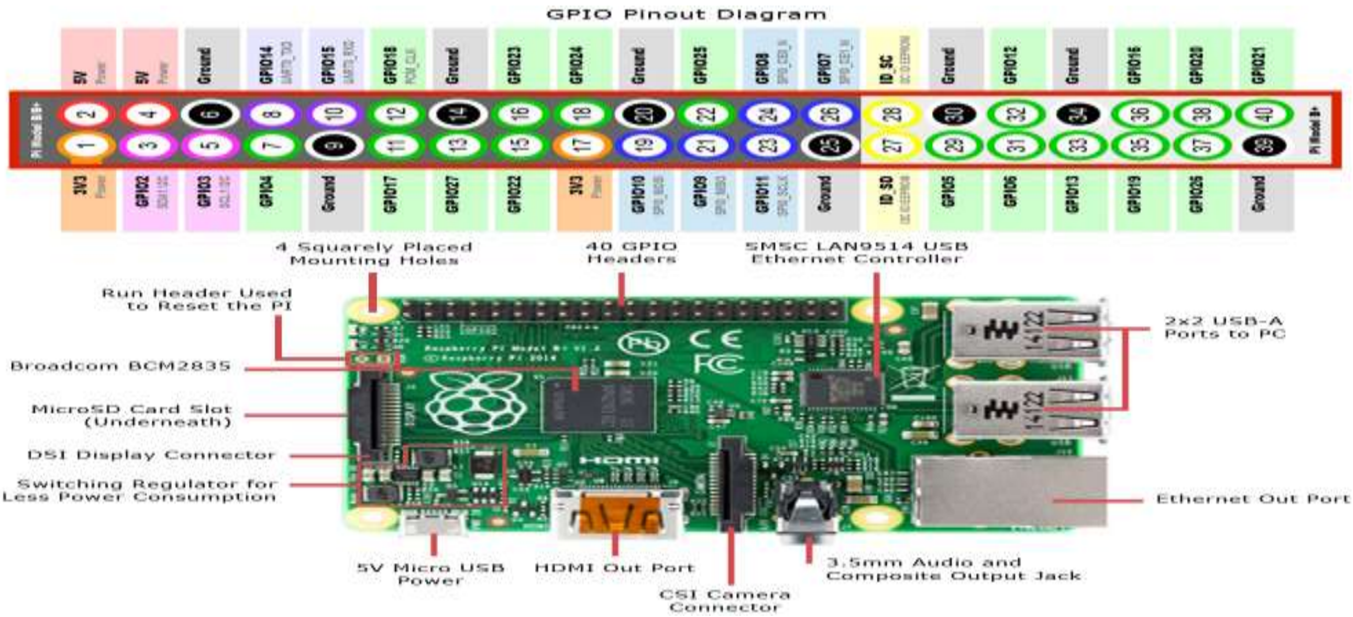


Fig: 4.7: RPI Pin Details

4.1.3 RASPBERRY PI SOFTWARE

LINUX

Linux is a free open source operating system and it belongs to the Unix operating systems. Actually, Linux means the kernel itself which is the heart of the operating system and handles the communication between the user and hardware. Normally Linux is used to refer to the whole Linux distribution.

Linux distribution is a collection of software based on the Linux Kernel. It consists of the GNU-project's components and applications. Because Linux is an open source project, anyone can modify and distribute it. That is the reason why there are many variations of Linux distributions.

Most popular distributions are Ubuntu, Red Hat Linux, Debian GNU/Linux and SuSe Linux. (Kuutti, W. & Rantala, A. 2007, 2.)

4.1.4 HEAT SINK

Under normal conditions, the Raspberry Pi 4 runs great without any sort of external heatsink and the software throttling keeps everything within safe operating temperatures. However, while performing high end applications, use of a set of quality heatsinks is best. Raspberry Pi 4 starts Thermal Throttling at a on board temperature of 82-86 Degrees Celsius - it lowers its operating speed to protect itself from harm.

Pre-built in Command- “vccmdgen measure_temp” can be used to check the on-board temperature of Raspberry Pi. Usually Heat Sink’s are made of Aluminum. Usage of Cooling Fan is more efficient than Heat Sink.

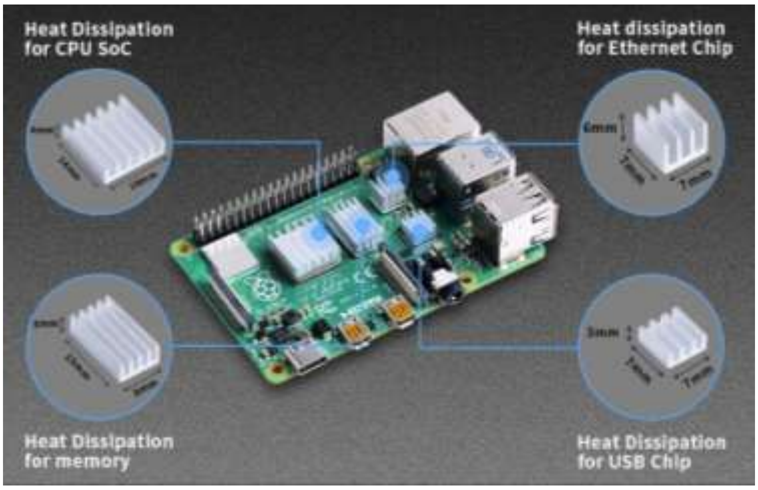


Fig: 4.8: Heat Sink Locations

Fig: 4.9: Actual Heat Sink Installation

4.2 HARDWARE SETUP

The hardware setup consists of many interfacing many components in an organized manner. The physical capability of the project is dependent on the hardware setup. An organized manner of setup helps to identify the error easily.

4.2.1 ROCKER BOGIE CHASSIS

It is a 6 Wheel Drive Chassis which can handle a load up to 3kg’s. Uses 6 Geared DC Motors with power handling Capacity of 10V-12V., providing 150rpm. DC Motors are low cost devices which provide high speed. Usage of Rocker- Bogie System enables to climb up various terrains. This Mechanism is famous in the exo-planetary rovers by NASA.

The Rover is controlled using ‘L298N Motor Driver’, which handle input supply of 5V-35V and can drive 3-30V DC Motor, provided with necessary voltage regulators and Heat sink. Usage of this motor driver is robust to various power supply and can also handle issues from temperature variations. Necessary soldering work was done for power distribution.

Fig: 4.10: Initially Built Rover

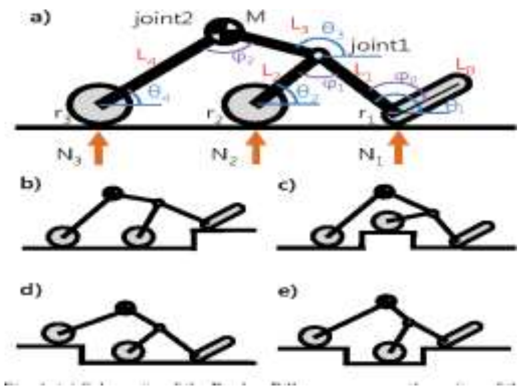


Fig: 4.11: Rocker Bogie Mechanism

4.2.2 DC Motors and L298N Motor Driver

A machine that converts DC electrical power into mechanical power is known as a Direct Current motor. DC motor working is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force.

Fig: 4.12: General DC Motor

WORKING PRINCIPLE OF A DC MOTOR

An electric motor is an electrical machine which converts electrical energy into mechanical energy. The basic working principle of a DC motor is: "whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force". The direction of this force is given by Fleming's left-hand rule and its magnitude is given by F = BIL. Where, B = magnetic flux density, I = current and L = length of the conductor within the magnetic field.

FLEMING'S LEFT HAND RULE

If we stretch the first finger, second finger and thumb of our left hand to be perpendicular to each other, and the direction of magnetic field is represented by the first finger, direction of the current is represented by the second finger, then the thumb represents direction of the force experienced by the current carrying conductor.

When armature windings are connected to a DC supply, an electric current sets up in the winding. Magnetic field may be provided by field winding (electromagnetism) or by using permanent magnets. In this case, current carrying armature conductors experience a force due to the magnetic field, according to the principle stated above.

Commutator is made segmented to achieve unidirectional torque. Otherwise, the direction of force would have reversed every time when the direction of movement of conductor is reversed in the magnetic field.

BACK EMF

According to fundamental laws of nature, no energy conversion is possible until there is something to oppose the conversion. In case of generators this opposition is provided by magnetic drag, but in case of dc motors there is back emf.

When the armature of a motor is rotating, the conductors are also cutting the magnetic flux lines and hence according to the Faraday's law of electromagnetic induction, an emf induces in the armature conductors. The direction of this induced emf is such that it opposes the armature current (I_a). The circuit diagram below illustrates the direction of the back emf and armature current. Magnitude of the Back emf can be given by emf equation of a DC generator.

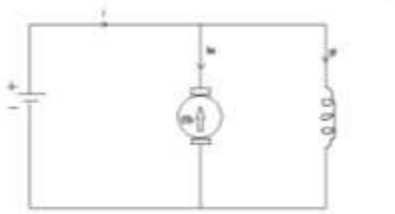


Fig: 4.13: DC Motor Circuit

SIGNIFICANCE OF BACK EMF:

Magnitude of back emf is directly proportional to speed of the motor. Consider the load on a dc motor is suddenly reduced. In this case, required torque will be small as compared to the current torque. Speed of the motor will start increasing due to the excess torque. Hence, being proportional to the speed, magnitude of the back emf will also increase. With increasing back emf armature current will start decreasing. Torque being proportional to the armature current, it will also decrease until it becomes sufficient for the load. Thus, speed of the motor will regulate.

On the other hand, if a dc motor is suddenly loaded, the load will cause decrease in the speed. Due to decrease in speed, back emf will also decrease allowing more armature current. Increased armature current will increase the torque to satisfy the load requirement. Hence, presence of the **back emf makes a dc motor 'self-regulating'**.

APPLICATIONS OF A DC MOTOR

It depends on the type of DC motor, which applications are ideal. Generally speaking, the following applications are common:

- Cranes
- Conveyors
- Pumps
- Fans
- Machine tools
- Air compressors
- Toys
- Motor starters in cars

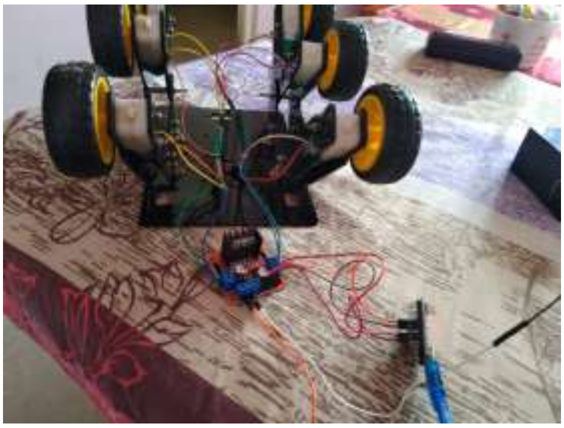


Fig: 4.14: Motor Testing

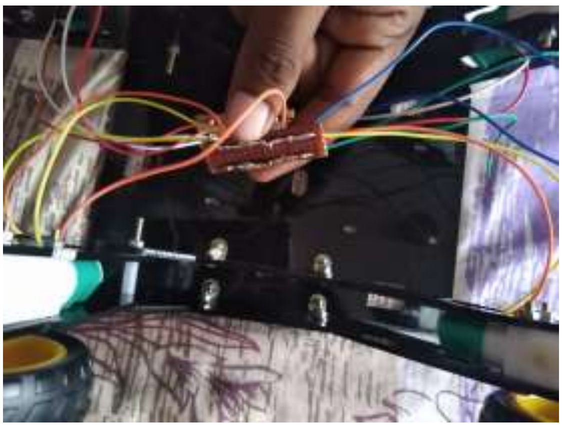


Fig: 4.15: Soldering the circuit

4.2.3 L298N MOTOR DRIVER BOARD

Double H driver module uses ST L298N dual full-bridge driver, an integrated monolithic circuit in a 15- lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the con-nection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

HARDWARE DIAGRAM

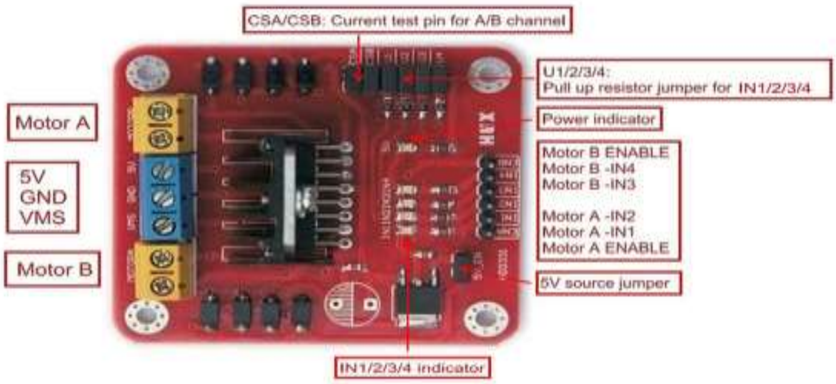


Fig: 4.16: Details of Motor Driver- L298N

- CSA: The current test pin for motor A, this pin can be wired a resistor for current testing or tied a jumper to disable it.
- CSB: The current test pin for motor B, this pin can be wired a resistor for current testing or tied a jumper to disable it.
- VMS: VMS is the 5V-35V power source for motor. VMS is positive, GND is negtive.
- 5V: Power input for the logic circuit on the board.
- 5V-EN: 5V source jumper. When the jumper is put on, The 78M05 supplies the 5V power for logic circuit on the board from the VMS port(7V < VMS < 18V). The power of logic circuit of the board is supplied by the 5V port when this jumper put off.
- U1/2/3/4: Pull up resistor for IN1/2/3/4. Putting on the jumper enable the pull up resistor for the microcontroller, putting off it disable it.
- EA/EB: EA/EB is the enable pin for the two motor A/B, the motor speed also can be controlled by the PWM of this pin.
- IN1/2/3/4: IN1/2/3/4 is the pin for the motor control. Motor B is same as Motor A.

TABLE 4.1: INPUT PINS AND ITS FUNCTIONING

INPUT		FUNCTION
EA = H	IN1 = H, IN2 = L	Forward
	IN1 = L, IN2 = H	Reverse
	IN1 = IN2	Fast Motor Stop
EA = L	IN1 = X, IN2 = X	Free Running Motor Stop

L = LOW, H = HIGH, X = DON'T CARE

H-BRIDGE DC MOTOR CONTROL

On the other hand, for controlling the rotation direction, we just need to inverse the direction of the current flow through the motor, and the most common method of doing that is by using an H-Bridge. An H-Bridge circuit contains four switching elements, transistors or MOSFETs, with the motor at the center forming an H-like configuration. By activating two particular switches at the same time we can change the direction of the current flow, thus change the rotation direction of the motor.

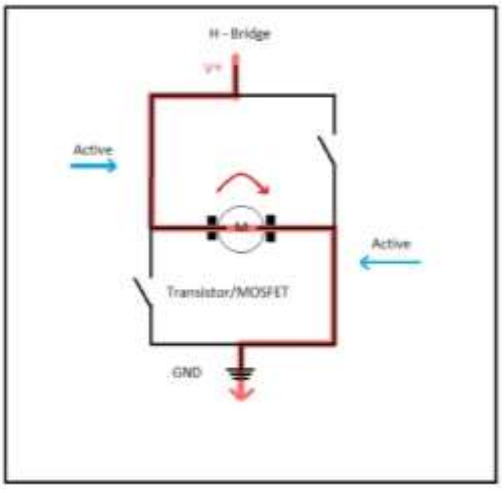


Fig: 4.17: H-Bridge Circuit

So, if we combine these two methods, the PWM and the H-Bridge, we can have a complete control over the DC motor. There are many DC motor drivers that have these features and the L298N is one of them.

4.3 ROBOTIC ARM

A robotic arm (not robotic hand) is a type of mechanical arm, usually programmable, with similar functions to a human arm; the arm may be the sum total of the mechanism or may be part of a more complex robot. The links of such a manipulator are connected by joints allowing either rotational motion (such as in an articulated robot) or translational (linear) displacement.[1][2] The links of the manipulator can be considered to form a kinematic chain. The terminus of the kinematic chain of the manipulator is called the end effector and it is analogous to the human hand.

It is 3D printed construction fixed with 4 servo motors and hence has 3 'Degrees of Freedom'. The Degrees of freedom are provided by Base, Shoulder and Elbow, which are controlled by servo motors. 'sg90 servo motor', which have an operating voltage of 5V and Rotation angle of 180 degrees have been used.

Servo motors provide precise control over rotation/ positioning. These are High in cost but also provide high torque and speed. Necessary soldering work was done for power distribution. Arm is mounted on top of rover behind the camera module.

Fig: 4.18: ARM Construction

Fig: 4.19: ARM Mounting on Rover

4.3.1 SERVO MOTOR

The servo motor is most commonly used for high technology devices in the industrial applications like automation technology. It is a self-contained electrical device, that rotates parts of machine with high efficiency and great precision. Moreover the output shaft of this motor can be moved to a particular angle. Servo motors are mainly used in home electronics, toys, cars, airplanes and many more devices.

DEFINITION

A servo motor is a rotary actuator or a motor that allows for a precise control in terms of the angular position, acceleration, and velocity. Basically it has certain capabilities that a regular motor does not have. Consequently it makes use of a regular motor and pairs it with a sensor for position feedback.

Fig: 4.20: Servo Motor SG90

PRINCIPLE OF WORKING

Servo motor works on the PWM (Pulse Width Modulation) principle, which means its angle of rotation, is controlled by the duration of pulse applied to its control PIN. Basically servo motor is made up of DC motor which is controlled by a variable resistor (potentiometer) and some gears.

MECHANISM OF SERVOMOTOR

Basically, a servo motor is a closed-loop servomechanism that uses position feedback to control its motion and final position. Moreover, the input to its control is a signal (either analogue or digital) representing the position commanded for the output shaft.

The motor is incorporating some type of encoder to provide position and speed feedback. In the simplest case, we measure only the position. Then the measured position of the output is compared with the command position, the external input to controller. Now if the output position differs from that of the expected output, an error signal generates. This then causes the motor to rotate in either direction, as per need to bring the output shaft to the appropriate position. As the position approaches, the error signal reduces to zero. Finally, the motor stops.

The very simple servomotors can position only sensing via a potentiometer and bang-bang control of their motor. Further the motor always rotates at full speed. Though this type of servomotor doesn’t have many uses in industrial motion control, however it forms the basis of simple and cheap servo used for radio control models.

Servomotors also find uses in optical rotary encoders to measure the speed of output shaft and a variable-speed drive to control the motor speed. Now this, when combined with a PID control algorithm further allows the servomotor to be in its command position more quickly and more precisely with less overshooting.

WORKING OF SERVOMOTORS

Servo motors control position and speed very precisely. Now a potentiometer can sense the mechanical position of the shaft. Hence it couples with the motor shaft through gears. The current position of the shaft is converted into electrical signal by potentiometer, and is compared with the command input signal. In modern servo motors, electronic encoders or sensors sense the position of the shaft

We give command input according to the position of shaft. If the feedback signal differs from the given input, an error signal alerts the user. We amplify this error signal and apply as the input to the motor, hence the motor rotates. And when the shaft reaches to the require position error signal become zero , and hence the motor stays standstill holding the position.

The command input is in form of electrical pulses as the actual input to the motor is the difference between feedback signal (current position) and required signal, hence speed of the motor is proportional to the difference between the current position and required position. The amount of power require by the motor is proportional to the distance it needs to travel.

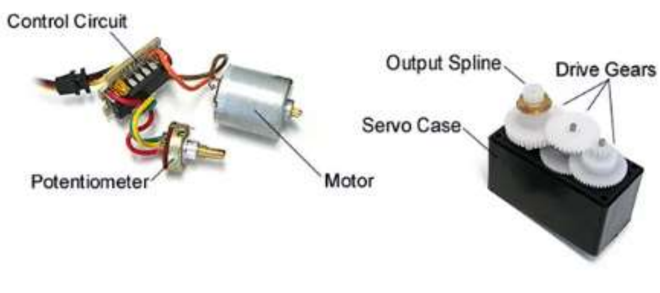


Fig: 4.21: Servo Motor Internal Structure [6]

CONTROLLING SERVO MOTOR

All motors have three wires coming out of them. Out of which two will be used for Supply (positive and negative) and one will be used for the signal that is to be sent from the MCU.

Servo motor is controlled by PWM (Pulse with Modulation) which is provided by the control wires. There is a minimum pulse, a maximum pulse and a repetition rate. Servo motor can turn 90 degree from either direction form its neutral position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90° position, such as if pulse is shorter than 1.5ms shaft moves to 0° and if it is longer than 1.5ms than it will turn the servo to 180°.

Servo motor works on **PWM (Pulse width modulation)** principle, means its angle of rotation is controlled by the duration of applied pulse to its Control PIN. Basically servo motor is made up of **DC motor which is controlled by a variable resistor (potentiometer) and some gears**. High speed force of DC motor is converted into torque by Gears. We know that WORK= FORCE X DISTANCE, in DC motor Force is less and distance (speed) is high and in Servo, force is High and distance is less. Potentiometer is connected to the output shaft of the Servo, to calculate the angle and stop the DC motor on required angle.

Fig: 4.22: Timing Diagrams of sg90 [5]

Servo motor can be rotated from 0 to 180 degree, but it can go up to 210 degree, depending on the manufacturing. This degree of rotation can be controlled by applying the **Electrical Pulse** of proper width, to its Control pin. Servo checks the pulse in every 20 milliseconds. Pulse of 1 ms (1 millisecond) width can rotate servo to 0 degree, 1.5ms can rotate to 90 degree (neutral position) and 2 ms pulse can rotate it to 180 degree.

All servo motors work directly with your +5V supply rails but we have to be careful on the amount of current the motor would consume, if you are planning to use more than two servo motors a proper servo shield should be designed.

APPLICATIONS

- Robotics: At every joint of the robot, we connect a servomotor. Thus giving the robot arm its precise angle.

- Conveyor belts: servo motors move, stop, and start conveyor belts carrying product along to various stages, for example, in product packaging/ bottling, and labeling.
- Camera auto focus: A highly precise servo motor build into the camera corrects a camera lens to sharpen out of focus images.
- Solar tracking system: Servo motors adjust the angle of solar panels throughout the day and hence each panel continues to face the sun which results in harnessing maximum energy from sunup to sundown.

ADVANTAGES

- If a heavy load is placed on the motor, the driver will increase the current to the motor coil as it attempts to rotate the motor. Basically, there is no out-of-step condition.
- High-speed operation is possible.

DISADVANTAGES

- Since the servomotor tries to rotate according to the command pulses, but lags behind, it is not suitable for precision control of rotation.
- Higher cost.
- When stopped, the motor’s rotor continues to move back and forth one pulse, so that it is not suitable if you need to prevent vibration.

4.4 CAMERA

It is an important component which governs the processing of visual information to the processor. As eyes are to a human, Camera is to a system. All the image processing algorithms are dependent on the information from this component.

4.4.1 PRODUCT INFORMATION

8-megapixel camera capable of taking photographs of 3280 x 2464 pixels. Captures video at 1080p30, 720p60 and 640x480p90 resolutions. All software is supported within the latest version of Raspbian Operating System. Applications of such cameras are CCTV security camera, motion detection, time lapse photography. These cameras are compatible with all Models of Raspberry Pi 1, 2 & 3. Camera is connected to Raspberry Pi Camera Board through Ribbon Cable.

IMPROVED RESOLUTION

- 8-megapixel native resolution high quality Sony IMX219 image sensor.
- Cameras are capable of 3280 x 2464-pixel static images.

REMAINING HIGH QUALITY

Captures video at 1080p30, 720p60 and 640x480p90 resolutions. All software is supported within the latest version of Raspbian Operating System. 1.12 µm X 1.12 µm pixel with OmniBSI technology for high performance (high sensitivity, low crosstalk, low noise). Optical size of 1/4".

4.4.2 PRODUCT OVERVIEW

The Raspberry Pi Camera Board v2 is a high quality 8 megapixel Sony IMX219 image sensor custom designed add-on board for Raspberry Pi, featuring a fixed focus lens. It's capable of 3280 x 2464 pixel static images, and also supports 1080p30, 720p60, and 640x480p90 video.

It attaches to the Pi by way of one of the small sockets on the board's upper surface and uses the dedicated CSi interface, designed especially for interfacing to cameras.

Fig: 4.23: Types of Pi Cam [3]

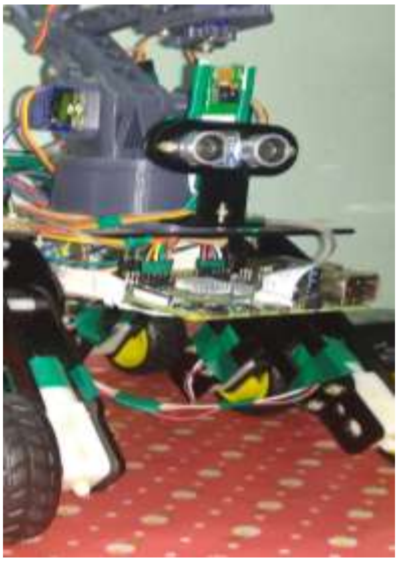


Fig: 4.24: Pi Cam interfaced on Rover

- The Raspberry Pi Camera Board plugs directly into CSI connector on the Raspberry Pi.
- 5MP Omnivision 5647 Camera Module
- Still Picture Resolution: 2592 x 1944
- Video: Supports 1080p @ 30fps, 720p @ 60fps and 640x480p 60/90 Recording

- The module attaches to Raspberry Pi, by way of a 15 Pin Ribbon Cable, to the dedicated 15-pin MIPI Camera Serial Interface (CSI), and it exclusively carries pixel data to the BCM2835 processor.
- Size: 20 x 25 x 9mm
- Weight 3g

4.5 ULTRASONIC SENSOR

Ultrasonic sensors measure distance by using ultrasonic waves. The sensor head emits an ultrasonic wave and receives the wave reflected back from the target. Ultrasonic Sensors measure the distance to the target by measuring the time between the emission and reception.

Fig: 4.25: Ultrasonic Sensor [8]

An optical sensor has a transmitter and receiver, whereas an ultrasonic sensor uses a single ultrasonic element for both emission and reception. In a reflective model ultrasonic sensor, a single oscillator emits and receives ultrasonic waves alternately. This enables miniaturization of the sensor head.

4.5.1 HC-SR04 ULTRASONIC SENSOR - WORKING

As shown above the HC-SR04 Ultrasonic (US) sensor is a 4-pin module, whose pin names are Vcc, Trigger, Echo and Ground respectively. This sensor is a very popular sensor used in many applications where measuring distance or sensing objects are required. The module has two eyes like projects in the front which forms the Ultrasonic transmitter and Receiver. The sensor works with the simple high school formula that **Distance = Speed × Time ------------------>** (4.1)

The Ultrasonic transmitter transmits an ultrasonic wave, this wave travels in air and when it gets objected by any material it gets reflected back toward the sensor this reflected wave is observed by the Ultrasonic receiver module as shown in the picture below

Fig: 4.26: Ultrasonic sensor Working [8]

Now, to calculate the distance using the above formulae, we should know the Speed and time. Since we are using the Ultrasonic wave, we know the universal speed of US wave at room conditions which is 330m/s. The circuitry inbuilt on the module will calculate the time taken for the US wave to come back and turns on the echo pin high for that same particular amount of time, this way we can also know the time taken. Now simply calculate the distance using a microcontroller or microprocessor.

HOW TO USE THE HC-SR04 ULTRASONIC SENSOR

HC-SR04 distance sensor is commonly used with both microcontroller and microprocessor platforms like Arduino, ARM, PIC, Raspberry Pie etc. The following guide is universally since it has to be followed irrespective of the type of computational device used.

Fig: 4.27: Ultrasonic pin Details [8]

Power the Sensor using a regulated +5V through the Vcc ad Ground pins of the sensor. The current consumed by the sensor is less than 15mA and hence can be directly powered by the on board 5V pins (If available). The Trigger and the Echo pins are both I/O pins and hence they can be connected to I/O pins of the microcontroller. To start the measurement, the trigger pin has to be made high for 10uS and then turned off. This action will trigger an ultrasonic wave at frequency of 40Hz from the transmitter and the receiver will wait for the wave to return. Once the wave is returned after it getting reflected by any object the Echo pin goes high for a particular amount of time which will be equal to the time taken for the wave to return back to the sensor.

The amount of time during which the Echo pin stays high is measured by the MCU/MPU as it gives the information about the time taken for the wave to return back to the Sensor. Using this information, the distance is measured as explained in the above heading.

TABLE 4.2: ULTRASONIC SENSOR PIN CONFIGURATION

Pin Number	Pin Name	Description
1	Vcc	The Vcc pin powers the sensor, typically with +5V
2	Trigger	Trigger pin is an Input pin. This pin has to be kept high for 10us to initialize measurement by sending US wave.
3	Echo	Echo pin is an Output pin. This pin goes high for a period of time which will be equal to the time taken for the US wave to return back to the sensor.
4	Ground	This pin is connected to the Ground of the system.

4.5.2 HC-SR04 SENSOR FEATURES

- Operating voltage: +5V
- Theoretical Measuring Distance: 2cm to 450cm
- Practical Measuring Distance: 2cm to 80cm
- Accuracy: 3mm
- Measuring angle covered: <15°
- Operating Current: <15mA
- Operating Frequency: 40Hz

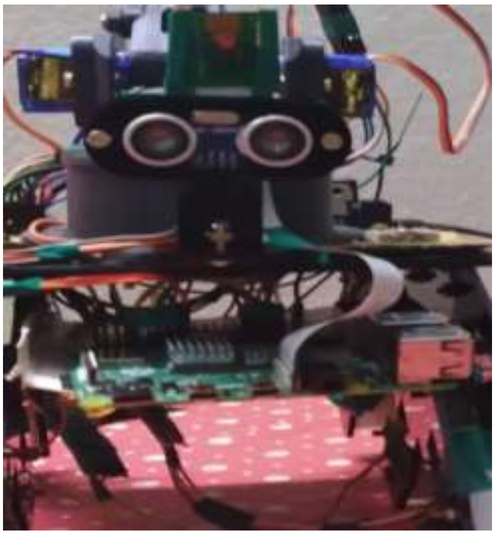


Fig: 4.28: Interfacing Ultrasonic Sensor on Rover

APPLICATIONS

- Used to avoid and detect obstacles with robots like biped robot, obstacle avoider robot, path finding robot etc.
- Used to measure the distance within a wide range of 2cm to 400cm
- Can be used to map the objects surrounding the sensor by rotating it
- Depth of certain places like wells, pits etc can be measured since the waves can penetrate through water

4.6 POWER SUPPLY

A 12V, 1.3Ah Lead-Acid External power supply is used to power up the components. The battery is charged using ‘Battery Eliminator’. This battery on full charge can run the Rover up to 4-5hrs, depending on the usage.

Fig: 4.29: 12V Lead Acid Battery

Fig: 4.30: Battery Charger

A Power distribution board is used to regulate the voltage into 12V, 5V and 3.3V. The distribution board has a flexible power input system. The board can be powered by using either wires connected to a battery or using an Adaptor compatible with the board. The LED's present on the board indicated the power consumption. Raspberry Pi is powered using external power source as this processor demands high power consumption. Hence, a power bank is used to power Rpi4.

Fig: 4.31: Power Distribution Board

4.7 WEB SERVER AND APP

Web Server is used to Establish means of Communication between Raspberry Pi and Mobile App. Bluetooth Communication can also be used, but is has been unsteady and does not provide long range communication. "easycoding.tw" framework has been used for developing the code. Using this framework, python version as well as xml version of the algorithm can be generated. Python Programming has been used for coding. Different port ID's have been assigned for sending the commands through the server.

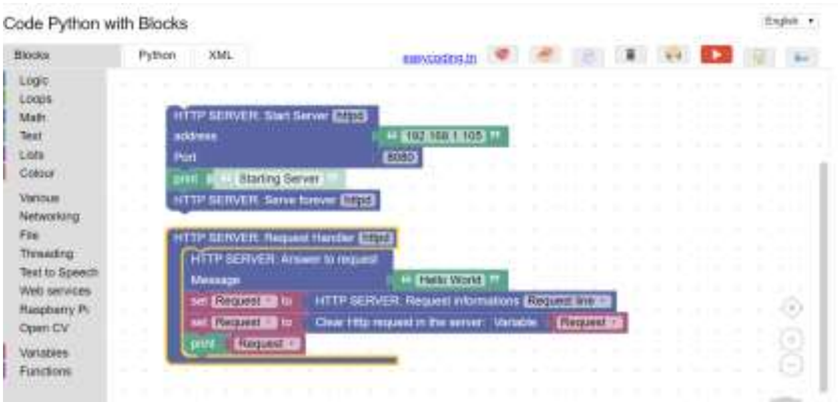


Fig: 4.32: Building Blocks of Web Server

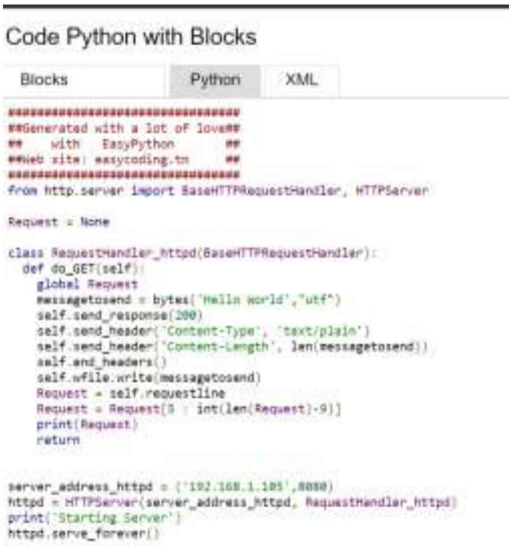


Fig: 4.33: Python Code of Web Server

Fig: 4.34: XML Code of Web Server

MIT App inventor has been used to develop the APP. The APP is designed to give 'Manual Control' over the Model, as well as give commands so that the system works autonomously. No special programming knowledge is needed for using this framework. The Algorithms have to be designed carefully; bug free.

Fig: 4.35: MIT APP Inventor Website

Fig: 4.36: Designing the UI

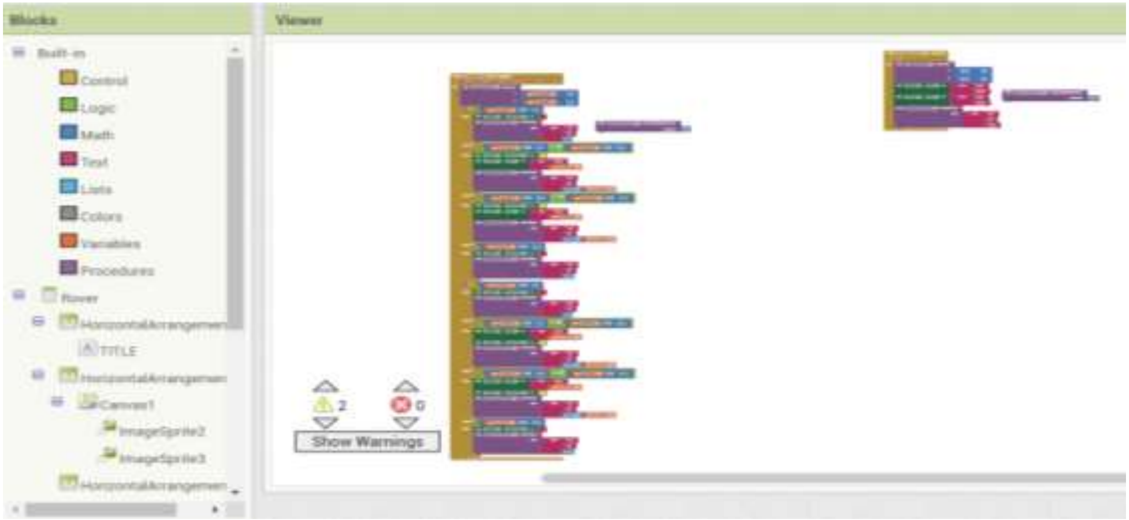


Fig: 4.37: Developing the Algorithm

4.8 DESCRIPTION DIAGRAM (BLOCK DIAGRAM)

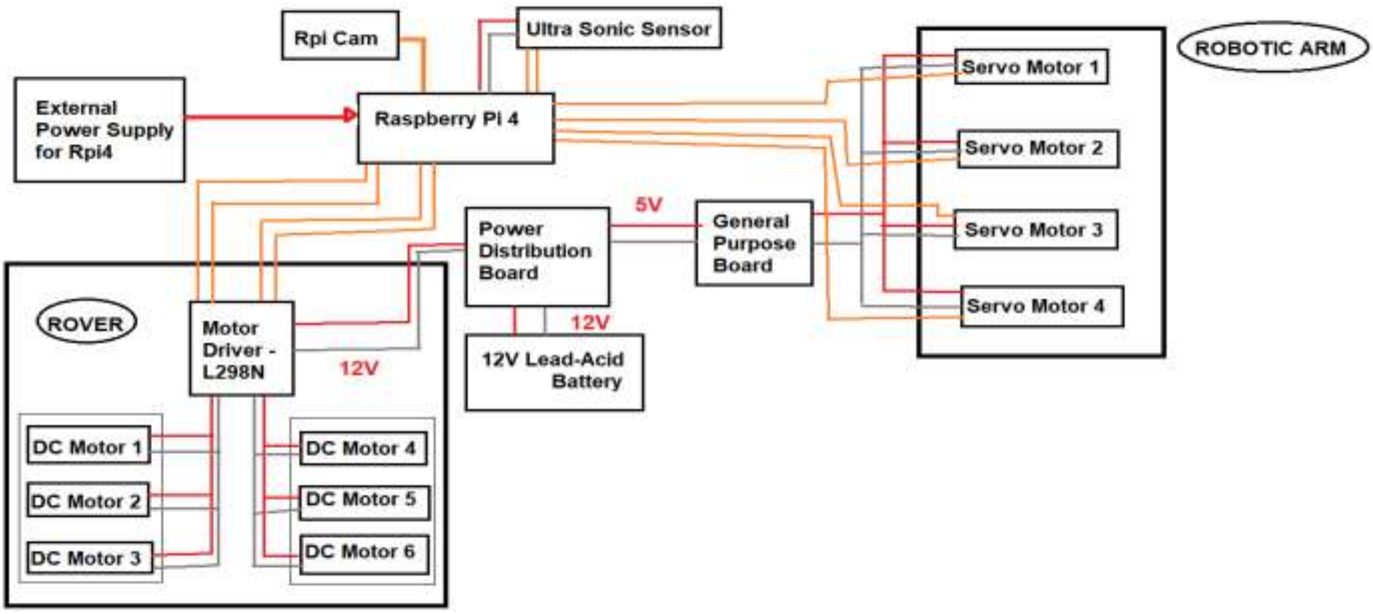


Fig: 4.38: Circuit Design of Project

Raspberry pi 4 us connected to external power bank. The battery is connected to Power distribution board from where the power is split. The motor driver consumes 12V and gives 10V output to the DC Motors (using up 2V for Voltage Regulation and Heat Control is achieved using Aluminum heat sink attached to the Motor Driver. Servo Motors draw a Voltage of 5V.

The necessary control Signals are sent by Rpi4. The Servos are connected to PWM pins of Rpi4, thus controlling them. Ultra-sonic sensor draws power from the Raspberry pi power pins. Pi Camera doesn't need any special power. It stays active as long as Raspberry Pi gets necessary Power. The web server is activated by using Raspberry Pi. Heat sinks have been placed on Raspberry Pi, to control the processing temperature. The Algorithms have also been designed to draw less computational Power and faster processing.

4.9 WORKING METHOD

The program starts by initiating the web server. Different port Id's have been assigned to control various flow of information. Initially, web server with port id 8080 is activated which sets the rover in manual control mode. In this mode the user can move the rover manually using the joystick present in the app. Distance of the object against it can also be obtained on the App monitor. This mode also allows to capture photos and videos on command while hovering the rover.

To make the rover switch from manual to autonomous mode, port id 8081 is activated. The autonomous sequence is started when the user gives the voice command. The voice command should specify the object to be searched and collected by the rover. Now that the voice command is given, the system checks if the given command matches any the objects it is trained with.

Currently, the system is trained for detection and recognition of the Chess Coins- White and Black Kings. Once the given command matches the object that the system is trained with, the rover starts hovering around to detect the object. The Object recognition technique used here is 'Template Matching', which draws very less computational power consumption and has reasonably high Frames per second. Once the object is detected, the rover aligns itself towards the line of motion to reach the detected object. The rover stops, 11.3cm away from the object. Robotic Arm collects the object. Here a 2 Degrees of Freedom Robotic Arm is used by making the base of the Arm stationary.

4.10 SOFTWARE ALGORITHMS (FLOW CHART)

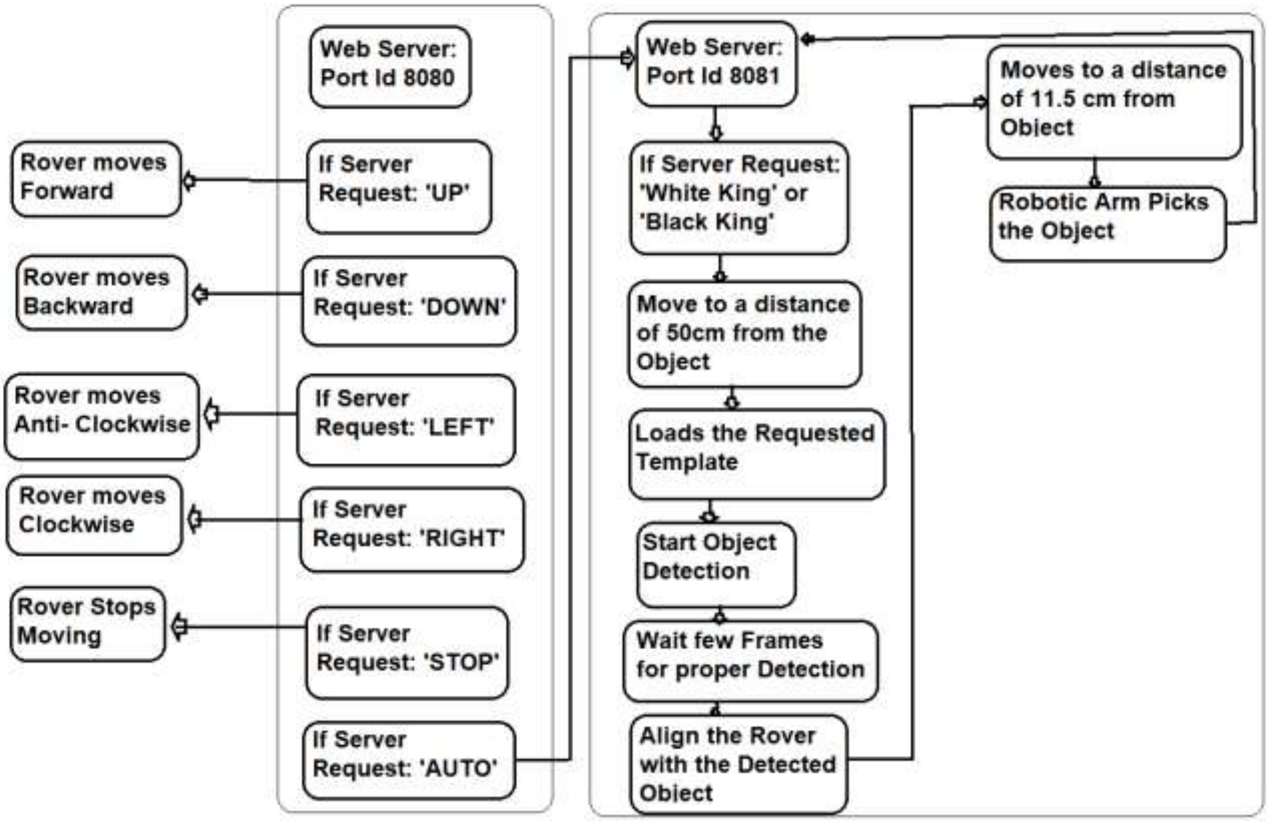


Fig: 4.39: Flow Chart of Working Procedure

The Flowchart for the working mechanism has been plotted.

CHAPTER 5
RESULT AND DISCUSSION

5.1 ROAD BLOCKS DURING TESTING

There were few setbacks when trying to make the model work.

- The toothed gears of the DC Motor lost their quality overtime due to usage. The primary reason for it was due to the overload on the rover, which had their impact on the Wheels carrying the weight and hence the DC Motor which actuate the wheels. Also, most hinderance in the movement occurred when turning the Rover i.e. towards either left or right.
- There was a time delay when using Ultra-sonic sensor. It was very difficult to synchronize the functioning of the rover in accordance with the Calculated Distance. As a result, the rover would not start or stop at the desired distance. After many experimentations, the Sync was established.
- The Robotic Arm could not be positioned properly. As a result, when the Robotic Arm would stretch far wide, it would end up hitting the camera module.
- Different algorithms were tested for Object Detection to find a balance between, less heat dissipated due to over use of computational power and achieve higher frames per second. Neglecting this issue would lead to breakdown of the working process on raspberry pi, due to overheating.

Fig: 4.40: Finally Developed Model

5.2 LIMITATIONS

In spite of trying the best to rectify the errors, there are a few limitations under which the device has to be operated.

- The object to be collected has to be placed at a height of above 22.3cm. Using the Rocker Bogie Mechanism demanded the Arm to be placed at a height. So, the Robotic Arm cannot reach any object placed below 22.3cm, from ground.
- As ‘Template Matching ‘technique is used, the lighting conditions have to be maintained as that of the template used to trained the system, so that the Detection is accurate.
- The battery is the most heavy component used in the design, so when the rover is used for climbing any inclined surfaces, the battery pulls back the rover. So, it has to be ensured that the terrain is not too steep.
- The joints of Robotic Arm, limit the action of Arm’s movement. So, the joint have to be neither too tightly fitted nor too loosely held.

CHAPTER 6
CONCLUSION AND FUTURE WORKS

6.1 CONCLUSION

In Conclusion, a prototype of a multi-purpose rover has been designed. The scope of application for this project is versatile, not limiting its functionality to a fixed application. It can used as an exoplanetary rover, to explore unknown environments and analyze it in real-time. This project can also aid agricultural sector by analyzing the crop field and categorizing the ripe fruits or vegetables from that of spoiled ones and placing them in separate baskets. It can help laying bricks or carry materials in construction sector. The limits of this project's application are only ones thinking capacity.

6.2 FUTURE WORKS

- The image processing techniques used now are simple and fast but not accurate and reliable. So, next we will be working on using Deep Neural Networks for Image Processing so that, high accuracy is obtained.
- Improvisation of Gripper is also be worked on. In spite of using a classic 2 finger gripper, using the concept of Soft Robotics, Plastic Mold Gripper will be developed which is powered by Air piston, using which can help better grip and gentle grasp of Objects being Manipulated.
- With the development of Artificial Intelligence, there are endless opportunities. Further plans on training the Rover to be a A.I. Powered Home Assistant, will be taken into consideration.

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