Sudan University of Science and Technology
College of Engineering
Electronics Engineering

Design of Autonomous Car

A Research Submitted in Partial fulfillment for the Requirements of the Degree of B.Sc. (Honors) in Electronics Engineering

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الآيــة

بسم الله الرحمن الرحيم

قال تعالى:

﴿إقرأ باسم ربك الذي خلق۞خلق الإنسان من علق ۞ إقرأ وربك الأكرم ۞ الذي علم بالقلم ۞علم الإنسان ما لم يعلم۞﴾

صدق الله العظيم

سورة العلق، الآيات (1-5)

الشكر والعرفان

الحمدلله الذي وفقنا لهذا ولم نكن لنصل اليه لو لا فضل الله علينا اما بعد، نهدي هذا العمل المتواضع الى اباءنا وامهاتنا بدعواتهم نحن ننجح وبثقتهم يصبح كل ذا عسر يسر، ندين لهم بما نحن عليه وبما سنكون غدا، الى اخواتنا واخواننا الذين لهم الفضل في امتصاص الجهد وتسهيل الصعوبات وجعل كل شيء هين.

الى مشرفنا الدكتور هشام الذي اضاء بعلمه عق ل غيره او هدى بالجواب الصحيح حيرة سائله فـ اظهر بسماحته تواضع العلماء وبرحابته سماحة العارفين:

نحن نهدي ثمرة جهدنا هذا الى دفعتنا العزيزة وخرجيها السابقون وما يلحقونا غدا

ABSTRACT

Autonomous car is a mobile robot integrating multi-sensor navigation and positioning intelligent decision making and control technology. Because of multiple accidents and injuring that people faced while driving the car, and the big problem for that car is accurate position estimation we build it to reduce crashes, energy consumption and pollution as well as cut costs associated with congestion. The system of the car is consisting of three basic subsystems: input unit that consist of the camera that putted in the front of the car to captured images (traffic light) and then the raspberry pi analyzing the frame by digital image processing, radar that calculating the speed and distance in any time and in different sides, ultrasonic sensor that measuring the speed by knowing the speed of the sound, GPS to provides time and location information at any point and show where the car in and its destination, processing unit or computer(raspberry pi), and car control unit. This successful practical implementation of the autonomous car with complete system gives the car a very thorough understanding of surrounding areas including other vehicles, pedestrians, traffic light and more.

المستخلص

السيارة ذاتية التحكم هي روبوت محمول يدمج بين ملاحة استشعار متعددة وتحديد المواقع، وبين صنع القرار الذكي وتكنولوجيا التحكم. بسبب الحوادث المتعددة والإصابات التي واجهت الاشخاص أثناء قيادة السيارة، ومشكلة تقدير موقف دقيق; تم عمل السيارة للحد من الحوادث واستهلاك الطاقة والتلوث وكذلك خفض التكاليف المرتبطة بالازدحام. يتكون نظام السيارة من ثلاثة أنظمة فرعية اساسية: وحدة الإدخال التي تتكون من الكاميرا التي وضعت في الجزء الامامي من السيارة لالتقاط الصور (أشارت المرور) بعد ذلك تقوم الراسبيري باي بتحليل الصورة عن طريق معالجة الصورة الرقمية، الرادار الذي يقوم بحساب السرعة والمسافة في أي وقت ومن جوانب السيارة المختلفة، وأجهزة الاستشعار التي تعمل بالموجات فوق الصوتية وتقيس السرعة من خلال معرفة سرعة الصوت، ونظام تحديد المواقع لتزويد المستخدم بمعلومات الوقت والمكان في أي نقطه ويحدد موقع السيارة الحالي ووجهتها، وحدة المعالجة أو الكمبيوتر (الراسبيري باي)، بالإضافة الى وحدة تحكم السيارة. هذا التنفيذ العملي الناجح للسيارة ذاتية التحكم مع نظام متكامل يعطي السيارة فهم دقيق جدا للمناطق المحيطة بها بما في ذلك المركبات الاخرى، المشاة، والإشارات الضوئية وغيرها.

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Abbreviations

ADAS	Advanced Driver Assistance System
DSI	Display Serial Interface
DIP	Digital Image Processing
GND	Ground.
GPIO	General Purpose Input Output
GPS	Global Positioning System.
LED	Light Emmiting Diode.
MIPI	Mobile Industry Processor Interface
OpenCV	Open Computer VISION.
RADAR	Radio Detection and Ranging.
RX	Receiver.
SDHC	Source Digital High Capacity
SDXC	Source Digital Extend Capacity.
SOC	System On Chip
TX	Transmitter.
USB	Universal Serial Port

Chapter One

Introduction

1.1 Preface

Imagine if everyone could get around easily and safely, regardless of their ability to drive, an autonomous is vehicle that is capable of sensing it’s environment and navigating without human input, the driving skills are based on knowledge of the traffic rules and prior driving experience.

An autonomous car will theoretically be able to transport any person, including blinded and disabled people and those without a driver license. In effect, this makes any person a potential research subject in figuring out if autonomous transportation will allow for productive activities. And it has also the potential to not only free up time otherwise spent driving both one’s self and others around, but also the potential to travel faster.

Autonomous cars are being introduced to society more and more and will be the next big step in the progression of personal cars, as of now, several major companies including Toyota, Lexus, Audi, and Google are developing and testing their own prototype vehicles with plans to eventually release the technology to market, there are a number of factors that decides how fast this new technology will be adopted. Safety, reliability, ethics and cost to name a few.

Autonomous car can detect surrounding and uses input from a variety of sources as GPS, sensors, radar, motors and cameras, Software uses the information from these inputs and creates a 3-dimensional environment around the car and calculates in which way the car should maneuver.

1.2 Problem Statement

Because of multiple accidents and injuring that people faced while driving the car, crashes, energy consumption and pollution as well as cut costs associated with congestion.

One of the major reasons for the accidents is disobeying of traffic rules such as using mobile while driving, over speed and careless.

1.3 Proposed Solutions

Autonomous cars are designed to provide safety to the passenger as well as surrounding, and to prevent accidents using Raspberry Pi in which car will be automatically controlled during emergency situation, this car alters the direction of the vehicle whenever the driver is not aware of the driving situation and will avoid collision.

1.4 Aim and Objectives

The aims of the project are to build an autonomous car prototype using Raspberry Pi as a computer which can do many of the things a desktop PC can do. A camera module is interfaced with the processing unit for the signal detection which will detect the color of signal.

The car is capable of reaching the given destination safely and intelligently thus avoiding the risk of human errors.

The main objectives:

- To design the control system for the autonomous car.
- To design the navigation system.
- Digital image processing.

1.5 Methodology

The system of the car is consisting of three basic subsystems: input unit that consist of the camera, ultrasonic sensor, GPS, processing unit or computer (Raspberry Pi), radar, and car control unit.

Camera is putted in front of the car to read the traffic light, this camera captured image and the raspberry pi analyzing the frame by digital image processing. To measure the distance between the obstacles and the vehicle we used an ultrasonic sensor, this distance is analyzed by the processing unit to alter the direction of the vehicle.

GPS is applied in the vehicle to provides time and location information at any point and show where the car in and it is destination.

1.6 Research Outlines

Chapter one: is a theoretical background and related works in a field of autonomous car.

Chapter two: describes steps of hardware design the vehicle tracker and how to view it in a software application.

Chapter three: describes steps of hardware design the vehicle tracking system using android.

Chapter four: discusses the results of simulation and implementation for the project.

Chapter five: explain the conclusion and the future ideas that can be performed.

Chapter Two

Literature Review

2.1 Technical background

The purpose of this chapter is to establish a definition of an autonomous car and provide an overview of the developments within autonomous car technology.

The definition of autonomous car is namely a car without a driver, so that it is a vehicle that is capable of sensing its environment and navigating without human inputs.

2.1.1 Raspberry Pi

A Raspberry Pi is a credit card-sized computer it is board contains Broadcom based ARM Processor, Graphics Chip, RAM, GPIO and other connectors for external devices as shown in Figure 2-1.

Like any other computer, where operating system acts as backbone for operation. Raspberry Pi, facilitates open source operating systems based on Linux.

2.1.1.1 Components of Raspberry Pi- Computer

Raspberry Pi comprise of following components [1]**:**

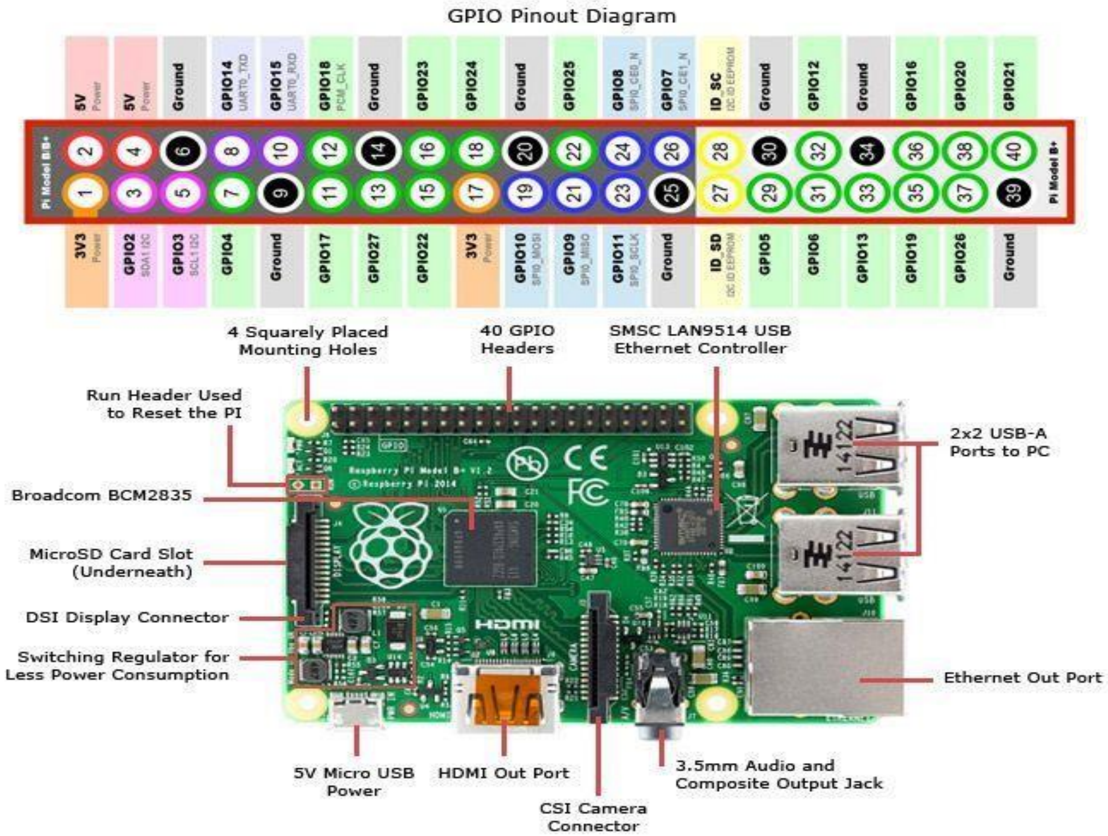


Figure 2-1: Raspberry Pi (Components explanation) [1]

- Micro-USB power supply

  Raspberry Pi requires 5 volts.

- SD card slot

  Secure Digital Card slot is a solid-state removable storage device which is required to run operating systems on Raspberry Pi as Raspberry Pi doesn't have any onboard memory and data storage functionality. It supports both SDHC (Secure Digital High Capacity) and SDXC (Secure Digital extended Capacity). The best suited card for proper running of all sorts of operating systems without any hiccup is Class 10 with speed @ 10MB/sec.

- USB Ports and Ethernet port

  USB ports enable the connectivity of external peripherals like Keyboard, Mouse, USB-Hub, etc.

Ethernet Port enable Internet connection online and to update the software, or to install latest packages from online repositories, it supports Ethernet Connection. Raspberry Pi comprise of RJ45 Ethernet Jack which supports CAT5/6 cables. It enables Raspberry Pi to be connected to wireless router, ADSL model or any other internet connectivity sharing device.

- HDMI (High Definition Multimedia Interface)

  Enables Raspberry Pi to be connected to HDTV via HDMI cable. Raspberry Pi supports maximum resolution of 1920x1200.

- Video out (RCA Cable)

  In addition to HDMI connectivity which facilitates HD connection, Raspberry Pi also has provision to be connected to standard monitor or TV using RCA video cable. RCA cable is less expensive as compared to HDMI but along with RCA cable, the user has to buy 3.5mm stereo cable for audio facilitation.

- Status LEDS

Raspberry Pi comprise of 5 main LEDS as shown in Figure 2-2 performing the following functions:

a. ACT (Color-Green): The main function of ACT LED is to show card status.

b. PWR (Color-Red): The main function of PWR led is power. This led is continuously ON when raspberry Pi is switched on and keep on till switched off.

c. FDX (Color-Orange): The main function of FDX led is full duplex.

d. LNK (Color- Orange): The function performed by LNK led is Link.

This LED is powered on when Ethernet connection is established and packet transfer starts taking place.

e. 100 (Color-Orange): The 100 led objective is to show 100 Mbps connection.

Figure 2-2: Raspberry Pi leds [1]

- CSI Camera Connector

Raspberry Pi has a Mobile Industry Processor Interface (MIPI) Camera Serial Interface type 2 (CSI-2), it facilitates connection of small camera to Broadcom BCM 2835 processor. The function of this interface is to standardize the attachment of camera modules to the processors for the mobile phone industry.

- GPIO (General Purpose Input Output)

GPIO facilitates connecting all sorts of peripheral devices to Raspberry Pi. Raspberry Pi has onboard GPIO with 40 pins, 26 of which are used as digital inputs or outputs. More importantly, 9 of the 14 new GPIO pins are dedicated inputs or outputs, it also facilitates the onboard UART, I2C, SPI Bus and still large amount of free GPIO pins are there for add on attachments shown in Figure 2-3.

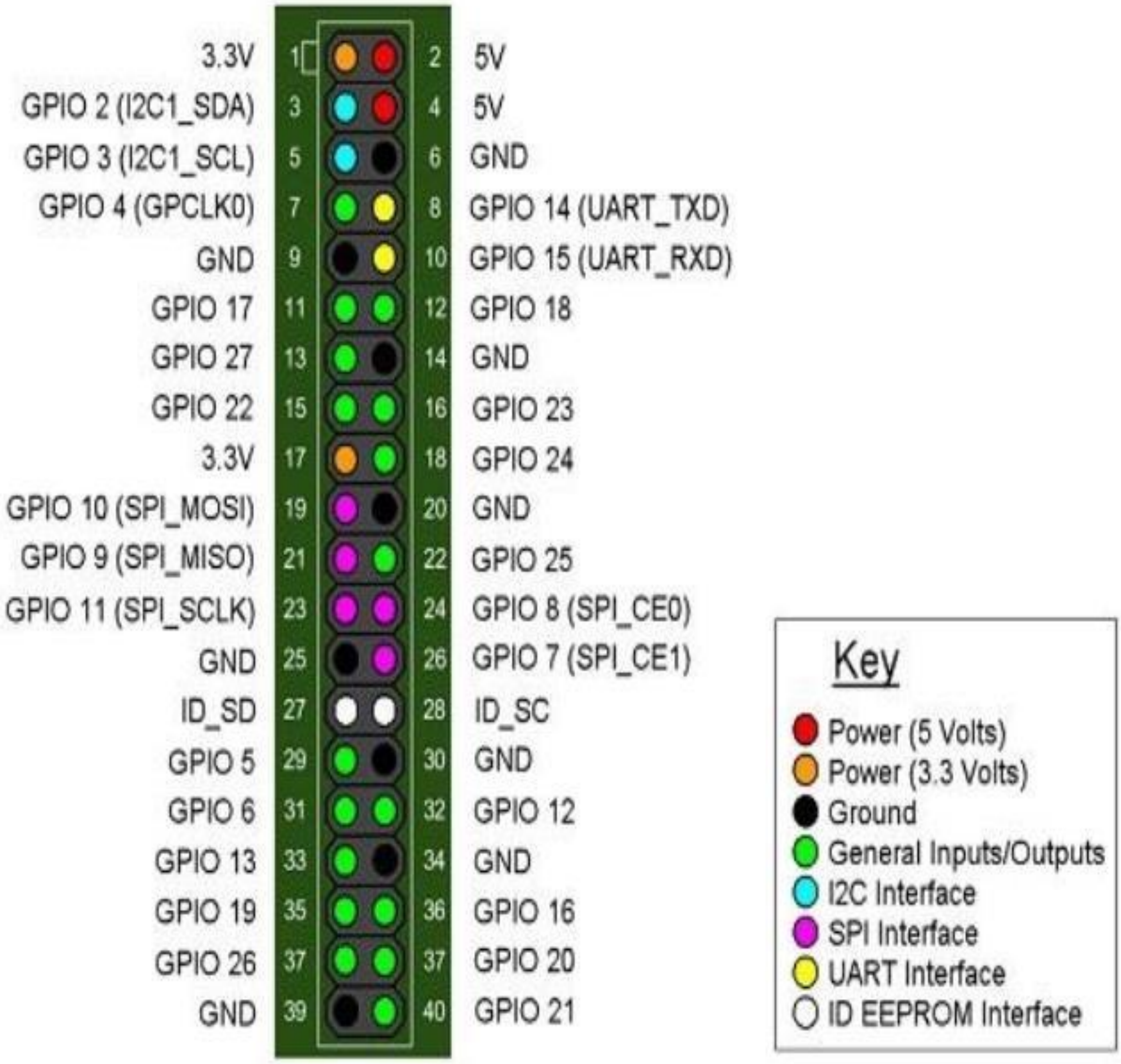


Figure 2-3: GPIO PINS of Raspberry Pi [1]

2.1.1.2 Advantages of Raspberry Pi

Raspberry Pi has many advantages such as [1]:

i. Raspberry Pi is regarded as a small, powerful and efficient. And we can use it to do small and medium level tasks like Running as Web Server, Database Server, and Media Server. So, in turn lots of money on purchase of various servers can be saved.

ii. Can act as single platform for extensive programming experience. Python is the main programming language and it is less complex and easy to understand.

iii. Supports open source operating system and open source applications.

iv. Supports add on hardware like Camera.

v. Easy to recycle and saves lots of money on cooling solutions.

In this project we used raspberry pi 3 model B because it includes [1]:

- CPU: Quad-core 64-bit
- GPU: 400MHz VideoCore IV multimedia
- Memory: 1GB LPDDR2-900 SDRAM
- USB ports: 4
- Video outputs: HDMI, composite video (PAL and NTSC) via 3.5 mm jack
- Network: 10/100Mbps Ethernet and 802.1in Wireless LAN
- Peripherals: 17 GPIO
- Bluetooth: 4.1
- Power source: 5 V
- Size: 85.60mm × 56.5mm
- Weight: 45g

2.1.2 Ultrasonic sensor

There are different types and shapes of this sensor, in this project we used the HC-SR04 ultrasonic sensor.

2.1.2.1 Ultrasonic module HC - SR04

Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The module includes ultrasonic transmitters, receiver and control circuit as shown in Figure 2-4.

2.1.2.2 Description

The description of Hc-rs04 module [2]:

i. Hc-sr04 ultrasonic module can offer non-contact distance sensing function.
ii. Includes ultrasonic transmitter, receiver and control circuit. iii. Operation requirement: take i/o port trig to trigger ranging.
iv. Operating principle: can send 8 pros 40 kHz square wave automatically, and will test if there is any signal returned. If there is signal returned, output one high level signal via I/O port ECHO. The duration of the high level signal is the time from transmitter to receiving with the ultrasonic.

2.1.2.3 HC-SR04 Specifications

Table 2-1: Electric Parameter

Working Voltage	**DC 5 V**
Working Current	**15mA**
Working Frequency	**40Hz**
Max Range	**4m**
Min Range	**2cm**
MeasuringAngle	**15 degree**
Trigger Input Signal	**10uS TTL pulse**
Echo Output Signal	**Input TTL lever signal and the range in proportion**
Dimension	**45*20*15mm**

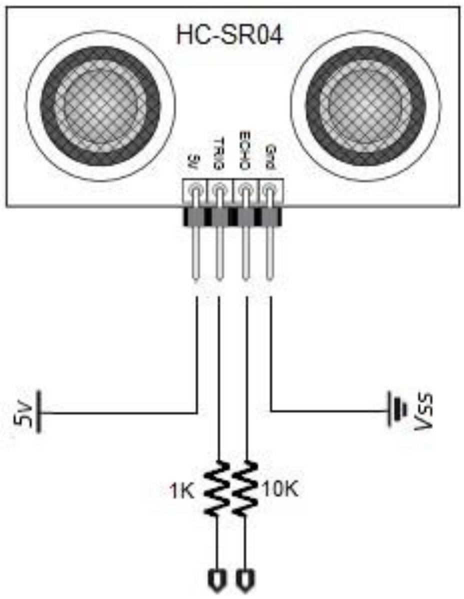


Figure 2-4: Ultrasonic sensor module HC-SR04 [2]

- VCC: Connect to 5v of positive voltage for power.
- Trig: A pulse is send here for the sensor to go into ranging mode for object detection.
- Echo: The echo sends a signal back if an object has been detected or not. If a signal is returned, an object has been detected. If not, no object has been detected.
- GND: Completes electrical pathway of the power.

2.1.2.4 Advantages of ultrasonic sensors

Ultrasonic sensor has many advantages such as [2]:

- The output value is linear with the distance between the sensor and the target.
- Sensor response is not dependent on the colors, transparency of objects, optical reflection properties, or by the surface texture of the object.

- Designed for contact-free detection.
- Sensors with digital (ON/OFF) outputs have excellent repeat sensing accuracy.
- Accurate detection even of small objects.
- Ultrasonic sensors can work in critical conditions such as dirt and dust.
- They are available in cuboid or cylinder forms, which is better for a freedom design.

2.1.3 Global Positioning System (GPS)

GPS is a system composed of a network of 24 satellites of the US. The satellites periodically emit radio signal to GPS receivers. The GPS receiver receives the signal from at least three satellites using triangular technique to compute two-dimensions, or four satellites to compute three dimensions (latitude, longitude and altitude) [3]

2.1.3.1 GY-NEO6MV2 GPS Module

Gy-neo6mv2 GPS module is one of NEO-6 family which has many features: high performance, flexible, cost effective receivers, their compact architecture, power and memory options make it ideal for battery operated mobile devices with very strict cost and space constraints, also the dedicated acquisition engine with 2 million correlators is capable of massive parallel time and frequency space searches, enabling it to find satellites instantly [4].

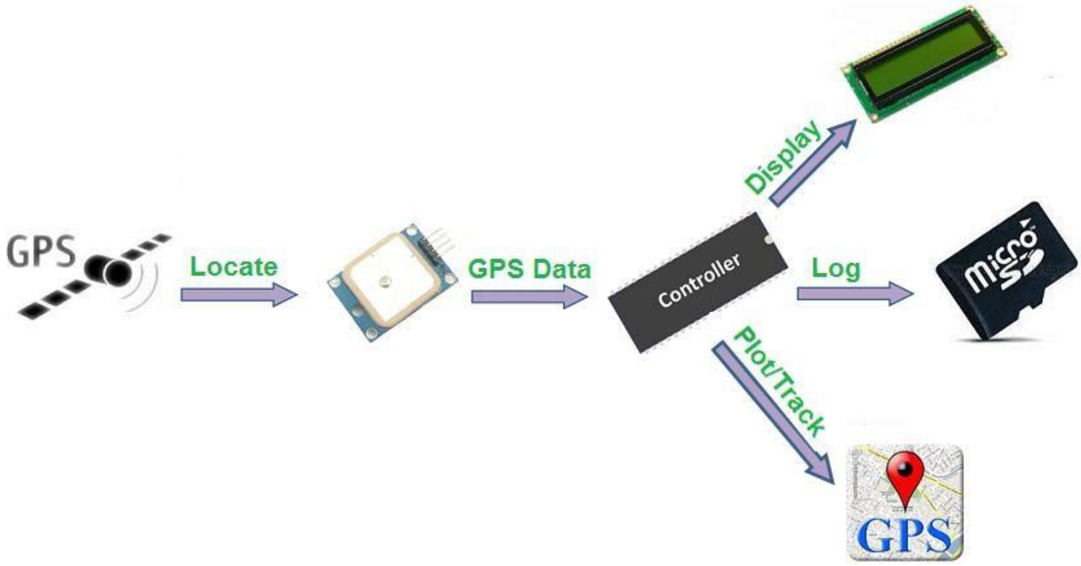


Figure 2-5: GPS transmitting data

We choose NEO-6 GPS receivers because it has excellent navigation performance even in the most challenging environments**.**

2.1.3.2 The GY-NEO6MV2 GPS Module Specifications

- Power Supply Range: 3 V to 5 V
- Model: GY-GPS6MV2
- Ceramic antenna
- EEPROM for saving the configuration data when powered off
- Backup battery
- LED signal indicator
- Antenna Size: 25 x 25 mm
- Module Size: 25 x 35 mm
- Mounting Hole Diameter: 3 mm
- Default Baud Rate: 9600 bps [4]

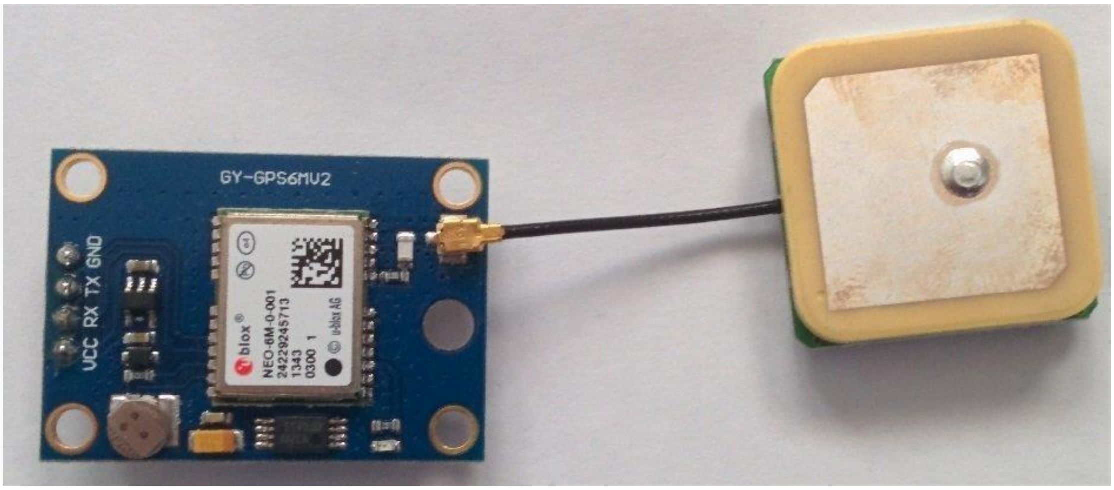


Figure 2-6: The GY-NEO6MV2 GPS Module

2.1.3.3 Pin description

GY-NEO6MV2 has four pins as shown in Figure 2-6.

- VCC-Supply Voltage
- GND-Ground pin
- TX and RX-These 2 pins acts as an UART interface for communication

2.1.4 USB camera

The USB webcam used to detect the traffic light and capture images in sequence, the image is analyzing by digital image processing.

It has a still sensor image resolution of 10 megapixels, with maximum resolution 4000*3000, the frame rate is 30 fps, lens view angle 51 degrees and dimension 53x53x25. The camera is easy to plug in raspberry pi board and supports all Linux based OS.

2.1.5 OpenCV (Open Computer Vision)

It is a library of programming functions mainly aimed at real-time computer vision. It has over 2500 optimized algorithms which can be used for image processing, detection, object identification, classification actions, traces, and other functions. This library allows these features be implemented on computers with relative ease, provide a simple computer vision infrastructure to prototype quickly sophisticated applications [5].

2.1.6 Python

Python is a widely used general-purpose, high-level programming language, its syntax allows the programmers to express concepts in fewer lines of code when compared with other languages [5].

2.1.7 L293 motor driver

L293d is an integrated circuit chip which is used to control motors in the car, it designed to control 2 DC motors simultaneously. L293D consist of two H-bridge. H-bridge is the simplest circuit for controlling a low current rated motor [5].

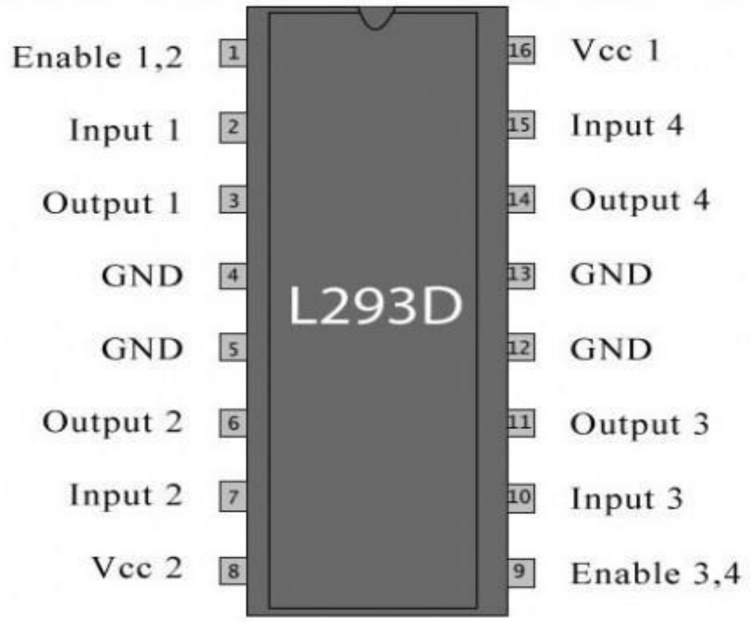


Figure 2-7: The L293 motor driver Module

2.1.7.1 Pin configuration

L293D has 16 pins as shown in Figure 2-7, they are comprised as follows: Ground Pins – 4

- Input Pins – 4
- Output Pins – 4
- Enable pins _ 2
- Voltage Pins _2

2.2 Related Work

Since its inception of the commercial auto industry in the late 1890s, cars have become increasingly safe and convenient. Recently, carmakers have begun to introduce advanced driver assistance systems (ADAS) such as adaptive cruise control (which automates accelerating and braking) and active lane assist (which automates steering) [6].

These systems have become capable enough that new luxury vehicles can drive themselves in slow-moving highway traffic. Research into autonomous cars has progressed remarkably since the first demonstrations in the 1980s [6].

Technology has evolved to the point where autonomous cars will be a common sight in the very near future. The benefits of autonomous cars are plentiful: increased safety for car passengers, who no longer have to fear drunk, reckless, or distracted drivers, increased productivity for passengers who can use the travel time to accomplish tasks, decreased reliance on fuel as the cars often incorporate solar panels and automatically adjust speed to maximize fuel efficiency, and decreased traffic congestion as the cars can identify upcoming trouble spots and take alternate routes to avoid delay.

Raju et al [7] design and development of semi-autonomous vehicle to prevent accident and to provide safety to the passenger as well as to the surrounding. Obstacle avoidance system where the human driver has full control of the vehicle until the system detects that the vehicle is headed for a collision or is too close to an obstacle for safety.

When hazard is detected, the system will take control of the vehicle, alters the movement and then hand over the control back to driver, we monitor the distance between the obstacle and the vehicle to identify occurrence of abnormality, it also allows the driver to follow traffic rules like if the signal glows red the vehicle has to stop, the cameras placed in the vehicle senses the signal color and alters the vehicle mobility.

The proposed system is implemented with the help of ultrasonic sensor, camera module and raspberry pi This project helps the society in reducing accidents. for more accuracy LIDAR and DISTRONIC sensors can be used which is of high cost.

Singh et al [5] design project aims to create a monocular vision autonomous car prototype using Raspberry Pi as a processing chip, along with an HD camera, ultrasonic sensors, they set out to create an autonomous car that can detect obstacles, roads, and perform the autonomous tasks necessary for the car.

The purpose of their research is to research cars capable of reaching a given destination safely, and help avoid the risk of human errors during driving. that attempts to create an autonomous car were successful and to simplify the implementation of autonomous driving on actual human drivable automobiles more similar to what Google and Tesla have and are doing currently.

Ujjainiya and Chakravarthi [8] presents a viability study to design an effective system for real time environment, which detects the presence of obstacles in the track of the vehicle. In the proposed work Raspberry Pi Camera module is employed for object detection and image acquisition, a thorough investigation is performed on a test image in order to validate the best algorithm suitable for edge detection of images, sufficient analysis is performed to consolidate the results.

An illustrative comparative analysis is performed on the test image captured by USB webcam and the edge detection operations are performed in OpenCV on Raspberry – Pi board.

Duffy and Hopkins [9] presents a viability study of autonomous cars which are a hybrid between vehicles and computers as they are operated by a complex computer system consisting of cameras, laser sensors, GPS software, and a multitude of other mechanisms that create a 3-D image of the world around the vehicle, The computer system navigates the vehicle through its environment with no human involvement, for example, the vehicle immediately stops moving when frontal sensors detect an obstacle in the car’s path, such as a pedestrian.

The computer system also adjusts the car’s speed, gear, and route in response to road conditions, such as potholes and changes in land slope, when detected by the sensors and cameras on the vehicle.

Upon input of a destination, a satellite-GPS program directs the vehicle to its destination. Autonomous cars can essentially drive themselves with little to no human interaction.

Goncalves et al [10] presents a viability study on autonomous car driving in highways using low cost sensors for environment perception, the solution is based on a simple behaviors-based architecture implementing the standard perception-to-action scheme.

The perception of the surrounding environment is obtained through the construction of an occupancy grid based on the processing of data from a single video camera and a small number of ultrasound sensors, a finite automaton integrates a set of primitive behaviors defined after the typical human highway driving behaviors.

The system was successfully tested in both simulations and in a laboratory environment using a mobile robot to emulate the carlike vehicle.

The robot was able to navigate in an autonomous and safe manner, performing trajectories similar to the ones carried out by human drivers by use of additional sensors, such as more cameras and laser range finders, would give the system enhanced capabilities. Still, the experiments presented clearly demonstrate the viability of using low cost sensors for autonomous highway driving of automobile vehicles.

Pierre Lamon et al [11] present an approach towards mapping and safe navigation in real, large-scale environments with an autonomous car. The goal is to enable the car to autonomously navigate on roads while avoiding obstacles and while simultaneously learning an accurate three-dimensional model of the environment.

To achieve these goals, they apply probabilistic state estimation techniques, network-based pose optimization, and a sensor-based travers ability analysis approach, in order to achieve fast map learning, the system compresses the sensor data using multi-level surface maps. The overall systems run on a modified Smart car equipped with different types of sensors.

They present several results obtained from extensive experiments which illustrate the capabilities of vehicle.

2.2.1 Example of companies that developed autonomous car

Many other car companies are also engaged in the developments of autonomous car technology [12]:

- Tesla’s go-to-market strategy for autonomous technology is incremental. The company’s cars are equipped with sensors from the factory, and are upgradable through software updates. In Software Update 7.1, a feature called Summon was released, allowing a Tesla Model S and Model X to be summoned (without a driver) on private property (The Tesla Motors Team, 2016). While the summon feature is only allowed on private property for the time being, the car is in effect a Level 4 car within those physical bounds, requiring no human interaction while being summoned.

- Volvo has not publicly announced a date for market readiness of driverless cars, the company has stated, that the technology is crucial in helping reach its goal; that nobody should be killed or injured in a new Volvo by 2020 (Volvo, 2016).

- In August 2013, Mercedes-Benz developed an S-class limousine which drove between Mannheim and Pforzheim without driver input and the company is considering to set up large fleets of autonomous cars, offering a premium transportation service (Taylor, 2015).

- BMW is trying to achieve the “ultimate driving machines” and the next logical step is driverless technology (Adams, 2015).

- The Japanese car company, Honda Motor Co. in March 2016 announced it is implementing its most advanced self-driving features into their entry-level Honda Civic. While not a Level 4 car, it can drive itself autonomously on highways (Stoll, 2016).

- In January 2016 Ford announced a tripling of its test-fleet of fully autonomous vehicles to 30 to be tested on the roads of California, Arizona and Michigan. (Ford, 2016) According to Raj Nair, Ford's Executive Vice President, Global Product Development, the company is committed to make autonomous cars available to millions of people.

- In August 2013 Nissan announced its plans to launch several driverless cars by 2020. The company is building in Japan a dedicated autonomous driving proving ground, to be completed in 2014. Nissan installed its autonomous car technology in a Nissan Leaf electric car for demonstration purposes.

- Google

The internet company, Google has been actively involved in the development of autonomous car technology since 2010, with the goal to create and help bring to market a vehicle (Google FAQ, 2016). Google initially retrofitted sensors and other hardware onto traditional cars, but in 2014 the company unveiled a vehicle, built up from the ground to be autonomous.

The Google fleet of self-driving cars has logged more than 1,4 million miles across California and Texas.

the project, the Google cars have been involved in 12 minor accidents, with none caused by the self-driving cars (Google Self Driving Car Project Monthly Report, 2015). However, on February 14 2016, the first accident caused by an autonomous Google was reported (Google Report February, 2016). While the technology does not prevent accidents completely [12].

Chapter Three

System Design and Implementation

This chapter cover the design and implementation of an autonomous car.

3.1 Design of autonomous car

It consists of hardware design and software design.

3.1.1 Hardware design

The prototype is built from a 3-wheeled robot base connected to a DC motor to control the movement and stirrings, to know its distance to the crash barrier the car has an ultrasonic sensor of model HC-SR04 that provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The module includes ultrasonic transmitters, receiver and control circuit mounted at its side, and it is measure the distances between the vehicle and the front car.

To provides time and location information anywhere and to navigation we use GPS (global positioning system), it is a device that communicates with a network of satellites to pinpoint its current location, or a network of orbiting satellites that send precise details of their positon in space back to earth.

To controlling the traffic light a camera will be installed alongside the traffic light, it will capture image sequences, the image sequence will then be analyzed using digital image processing (DIP) for vehicle detection, and according to traffic condition on the rood traffic light can be controlled.

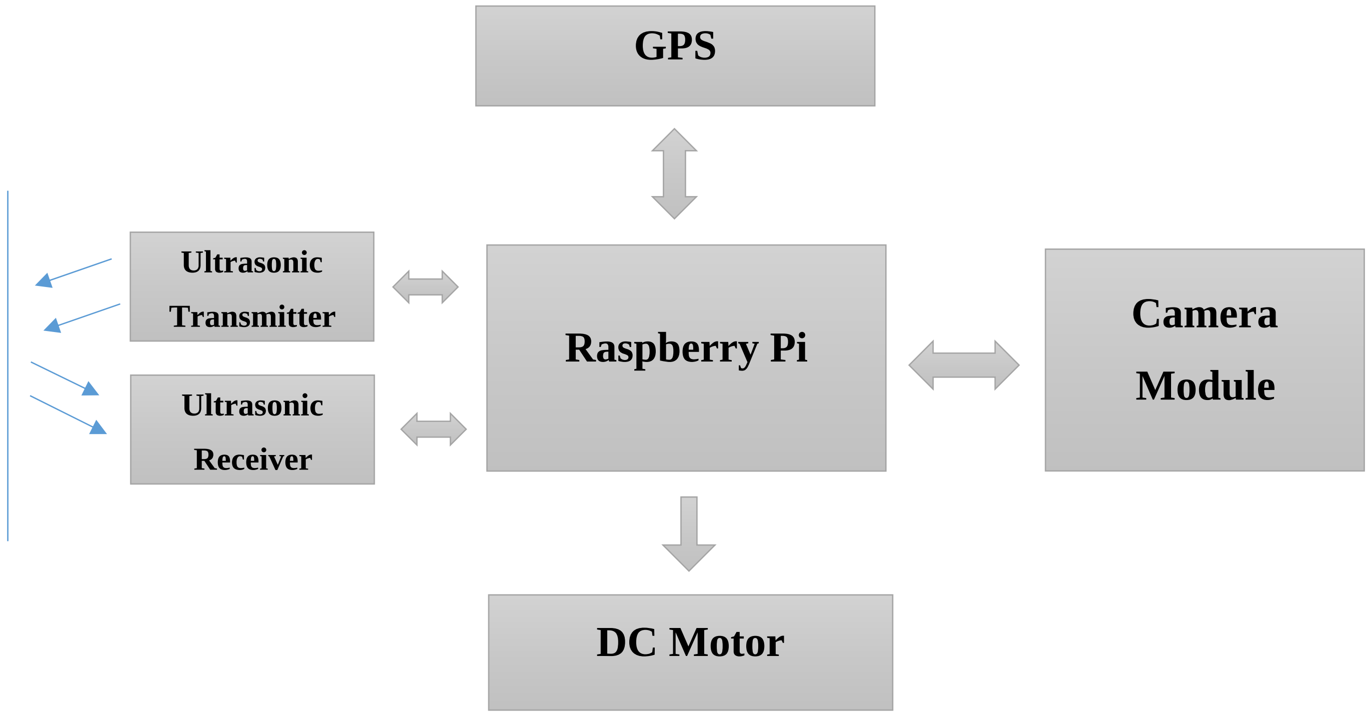


Figure 3.1: System Block Diagram.

As shown as a block diagram above the system consists of seven blocks which are represent the design and implementation of the system.

3.1.1.1 GPS navigation system

Global Positioning System is a network of orbiting satellites that send precise details of their position in space back to earth.

The signals are obtained by GPS receivers, that used to navigation and to calculate the exact position, speed and time at the vehicles location by knowing the latitude, longitude and the heading of pinpoint.

The latitude and the longitude of the goal must be determined before the car movement, the path to the goal position is calculated by the pass planner then if there are nearby obstacles the attractive planner calculates the best movement that keep the car away from collision and at same time tracking its goal, pass planner finds the quarter that the goal is in assuming an [x,y] Cartesian axes that the car is the center of it, then it calculates the angle to the goal.

3.1.1.2 Ultrasonic sensor (HC-SR04 Module)

Ultrasonic distance sensors are designed to measure distance between the source and target using ultrasonic waves, it uses sonar to measure distance with high accuracy and stable readings.

One ultrasonic sensors are used in order to measure the obstacles distance from one direction (forward) to help the car to avoid obstacles**.**

The transmitter transmits short bursts which gets reflected by target and are picked up by the receiver, the time difference between transmission and reception of ultrasonic signals is calculated by using the speed of sound equation

$$\text{Distance} = \frac{\text{time} \times \text{speed of sound } (340\text{m/s})}{2}$$

The value is multiplied by 1/2 because the time for go and return distance.

3.1.1.3 Traffic light detection

The USB camera will capture image sequences, then the image be analyzed using digital image processing for car detection, and according to traffic condition on the rood traffic light can be controlled.

Raspberry pi chip act like the processing unit and the webcam can be easily connecting to the chip through USB ports.

Python version 2.7 as image processing software comprising of specialized modules that perform specific tasks has been used. To make this tasks Some libraries are used like numpy and openCV2.

3.1.1.4 Digital image processing (DIP)

Digital image processing: processing digital image by a digital computer

❖ Step of digital image processing

There are several steps for digital image processing:

- Image acquisition
- Image enhancement
- Restoration
- Color image processing
- Multi resolution processing
- Compression
- Morphological processing
- Segmentation
- Representation and description
- Object recognition

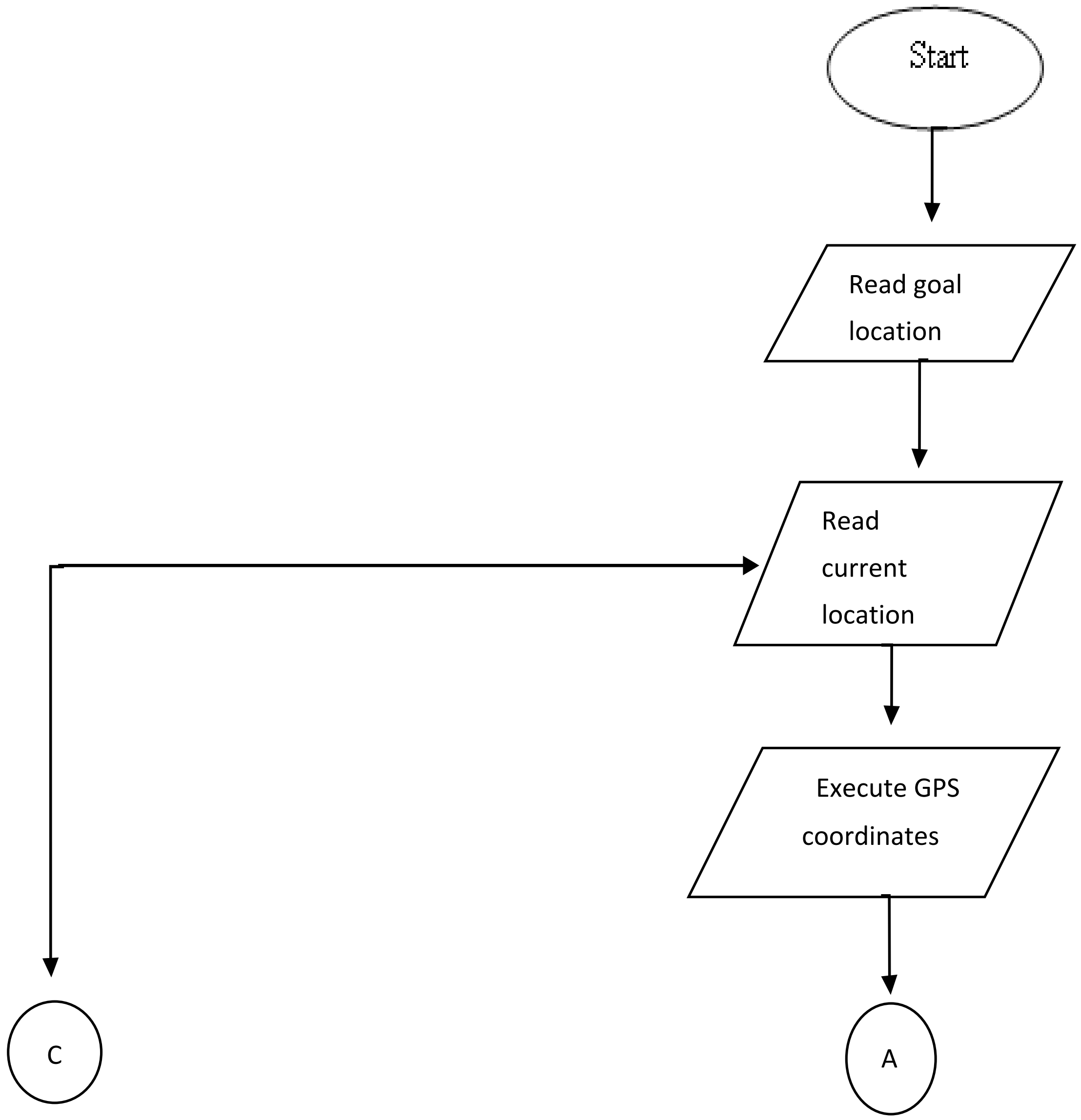
The camera capture sequence of image frame f(x, y, t,) taken from changing world frames are usually capture at fixed time interval were: x, y are spatial coordinate and t represent t-th frame in the sequence.

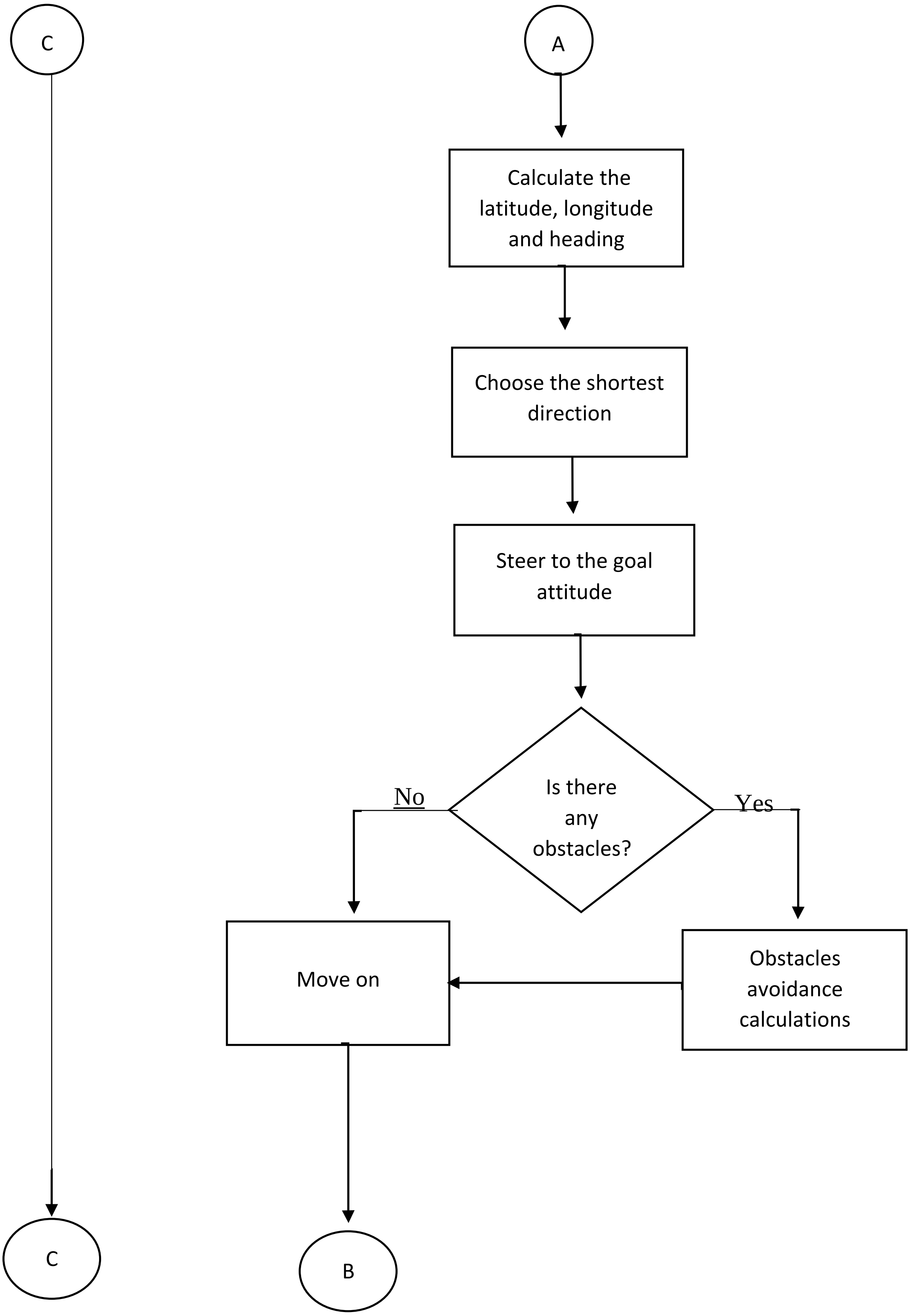
The image changes are due to relative motion between the scene objects and the camera, here the camera is moving and the traffic light is stationary.

We will use camera to sense the traffic light and analyzing the frames by RGB (red, green, blue) method to determine which color is.

3.1.2 Software design

- Flow chart show how system works:




C
A
Calculate the latitude, longitude and heading
Choose the shortest direction
Steer to the goal attitude
Is there any obstacles?
No
Yes
Move on
Obstacles avoidance calculations
C
B

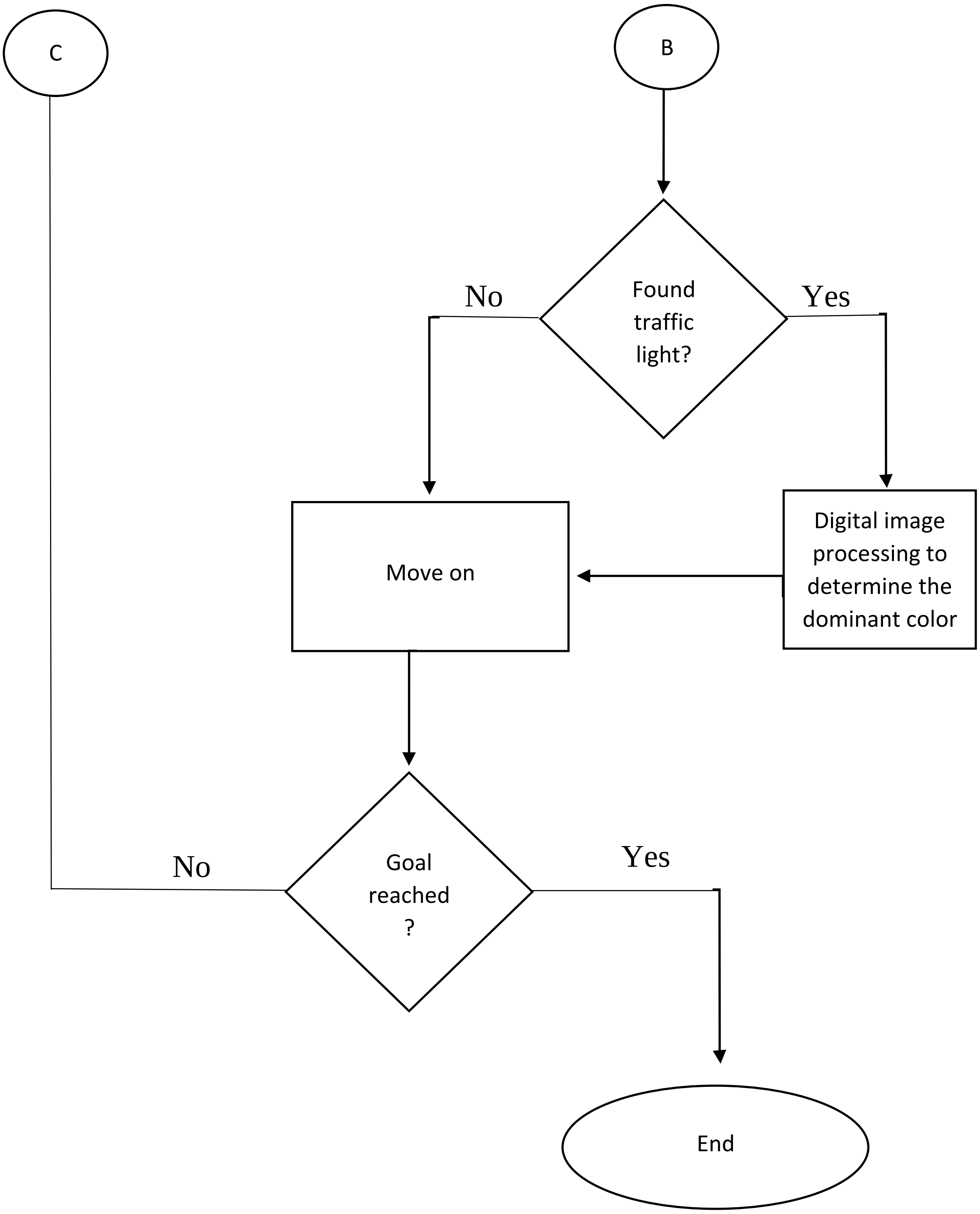


Figure 3-2: Main software algorithm

- Flow chart show how DIP to determine the dominant color:

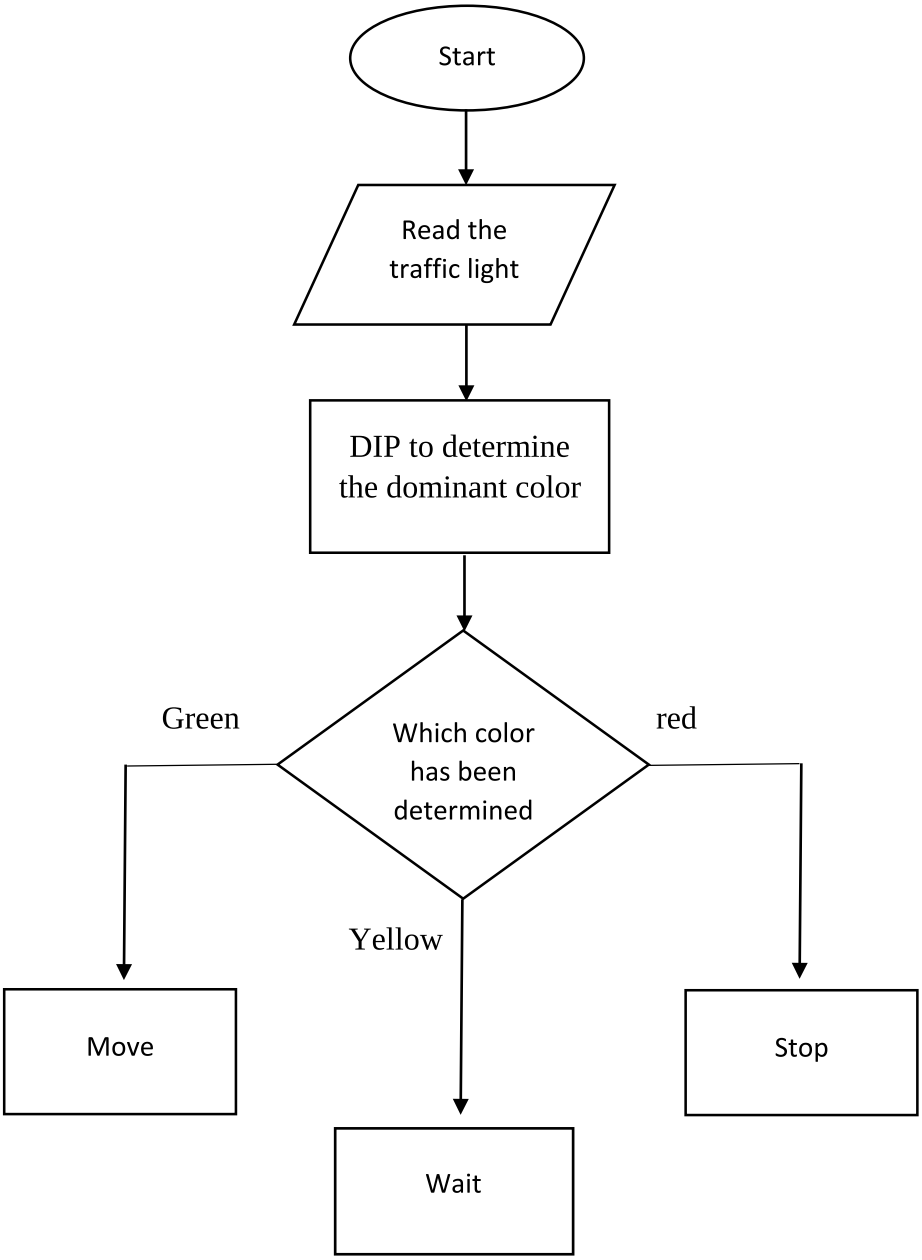


Figure 3-5: Traffic light algorithm

3.2 Hardware implementation of autonomous car

This section describes how to connect the component that used in the project.

3.2.1 NEO6MV2 GPS Module with Raspberry Pi

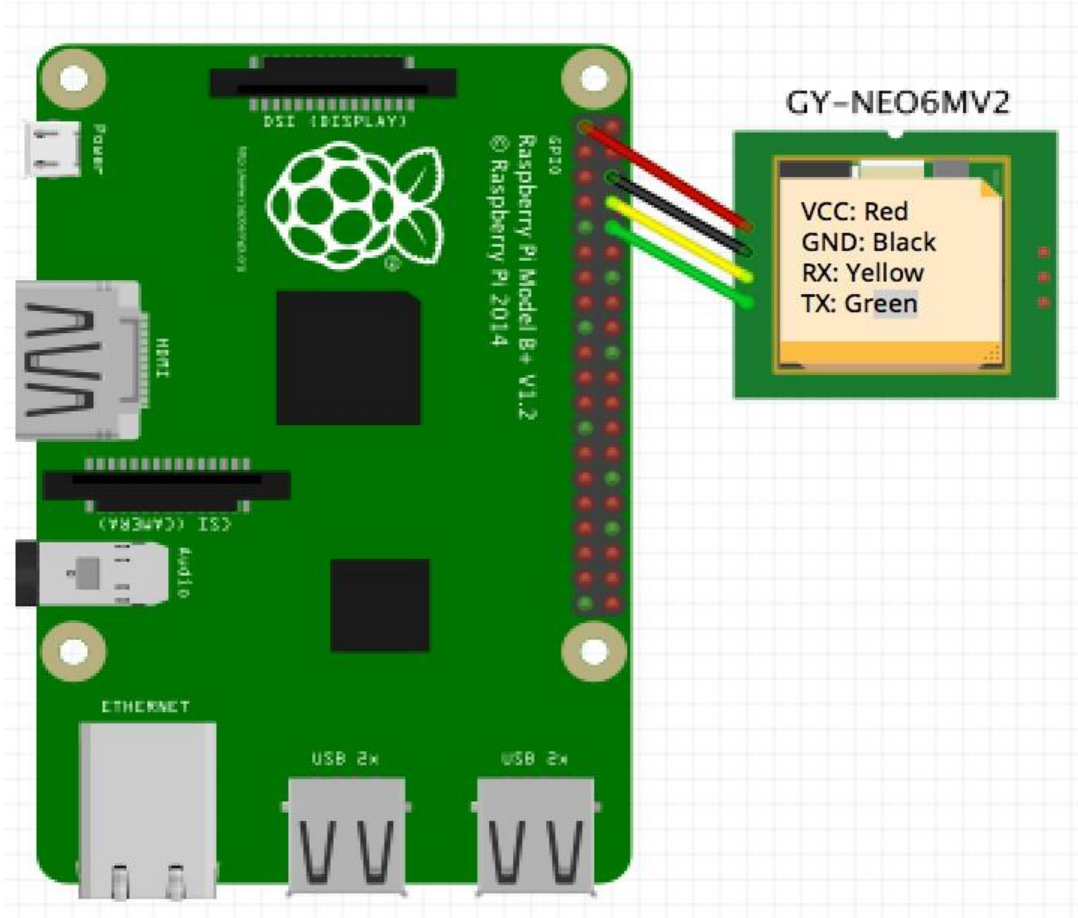


Figure 3-3: Neo6mv2 module connection with raspberry pi.

- TX to RX Pin 10
- RX to TX Pin 8
- GND to GND Pin 6
- VCC to Pin 1

3.2.2 Interfacing Raspberry Pi with ultrasonic (HC-SR04)

There are four pins on the ultrasound module that are connected to the Raspberry Figure 3-4:

- VCC to VCC

The ECHO output is of (5V). The input pin of Raspberry Pi GPIO is rated at (3.3V). So (5V) cannot be directly given to the unprotected

(3.3V) input pin. Therefore, we use a voltage divider circuit to bring down the voltage to (3.3V)

- GND to GND
- TRIG to GPIO18
- Connect the 330Ω resistor to ECHO

On its end you connect it to GPIO24 and through a 470Ω resistor you connect it also to GND.

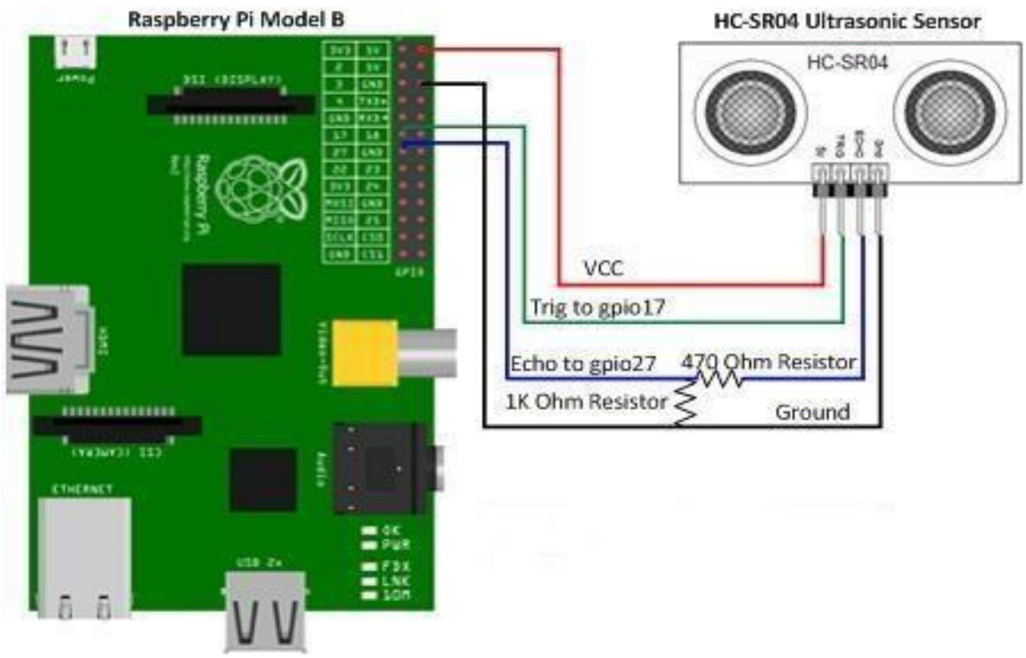


Figure 3-4: Interfacing Raspberry Pi with ultrasonic (HC-SR04)

3.2.3 Collecting of the car parts

The prototype consists of 3-weehles with two DC motors as shown in Figure 3.5.

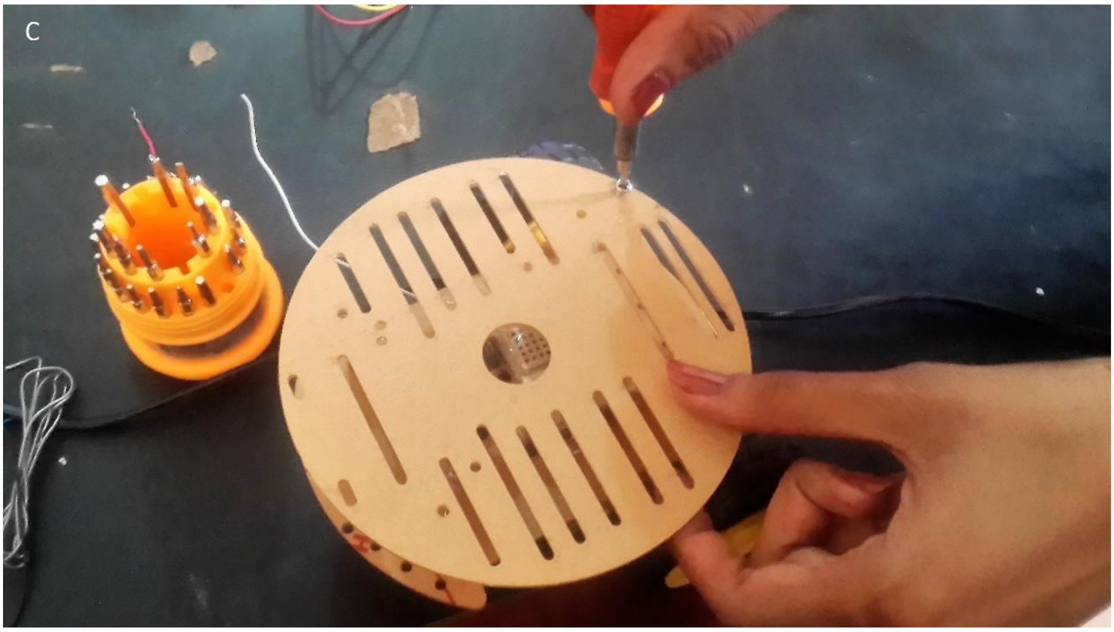


Figure 3-5: Collection of the car part

Chapter Four

Result and Discussion

4.1 Overview

This chapter covers the results obtained from the hardware design.

4.2 Result of GPS location

Figure 4.1 show the frame of $GPRMC and the reading of the latitude and longitude and heading.

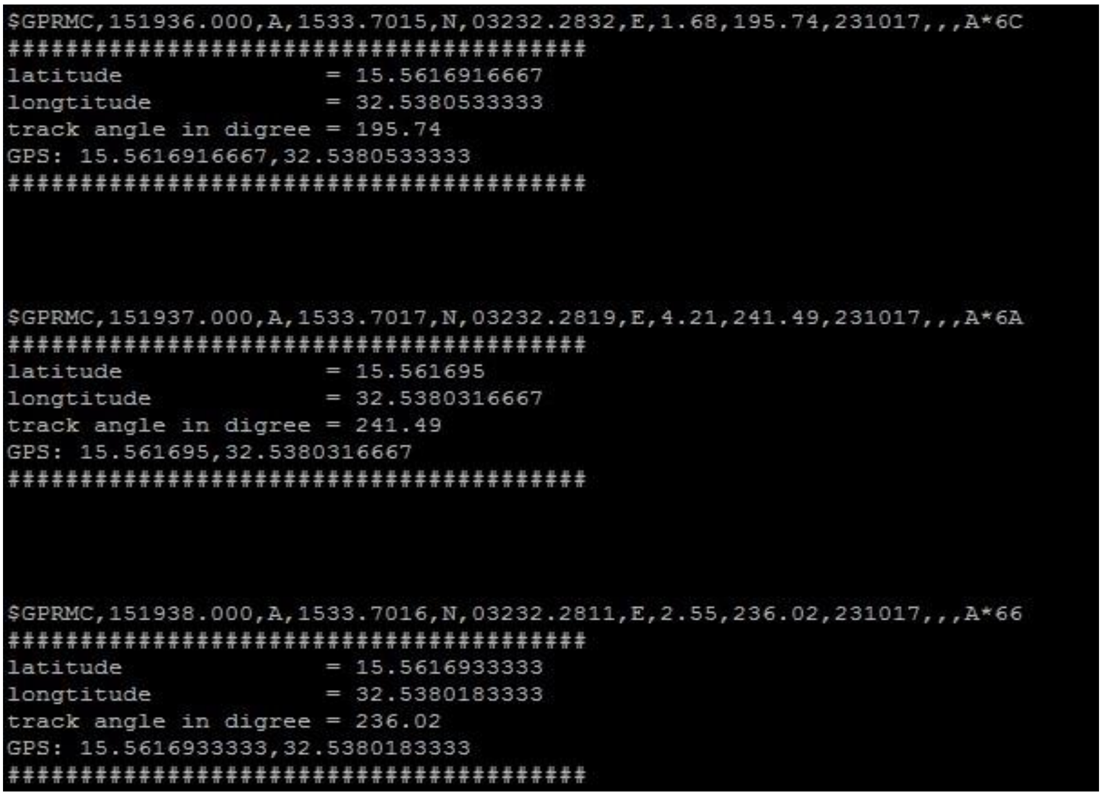


Figure 4-1: $GPRMC frame

4.3 Result of ultrasonic sensor

Ultrasonic sensor gives us the distance between the vehicle and an object by knowing the speed and calculating the time that the signal need to transmitting and reserving as shown in Figure 4.2

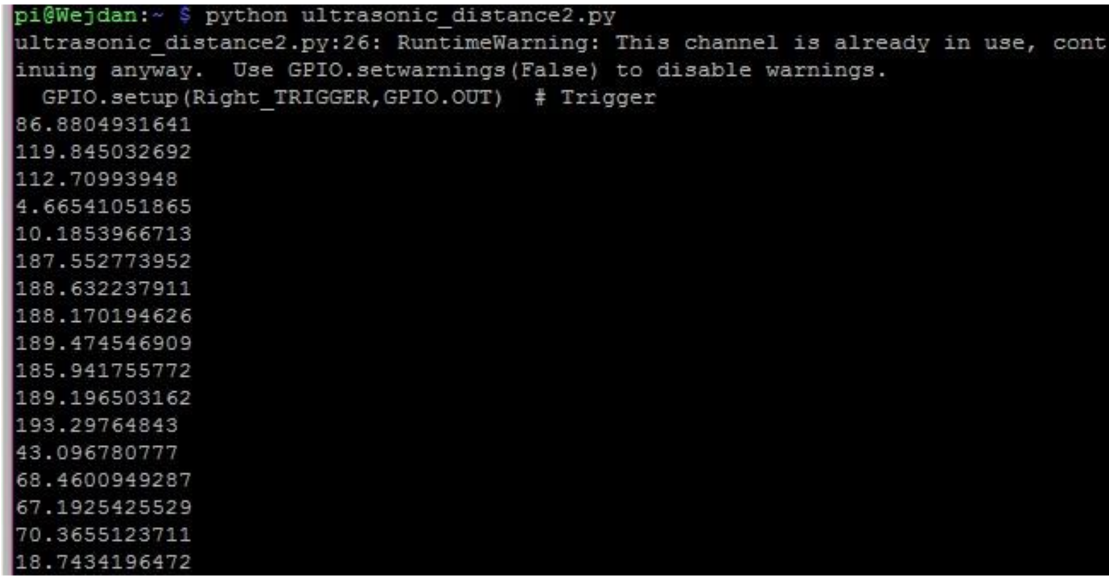


Figure 4-2: Ultrasonic distance

4.5 Result of reading colors and the dominant color

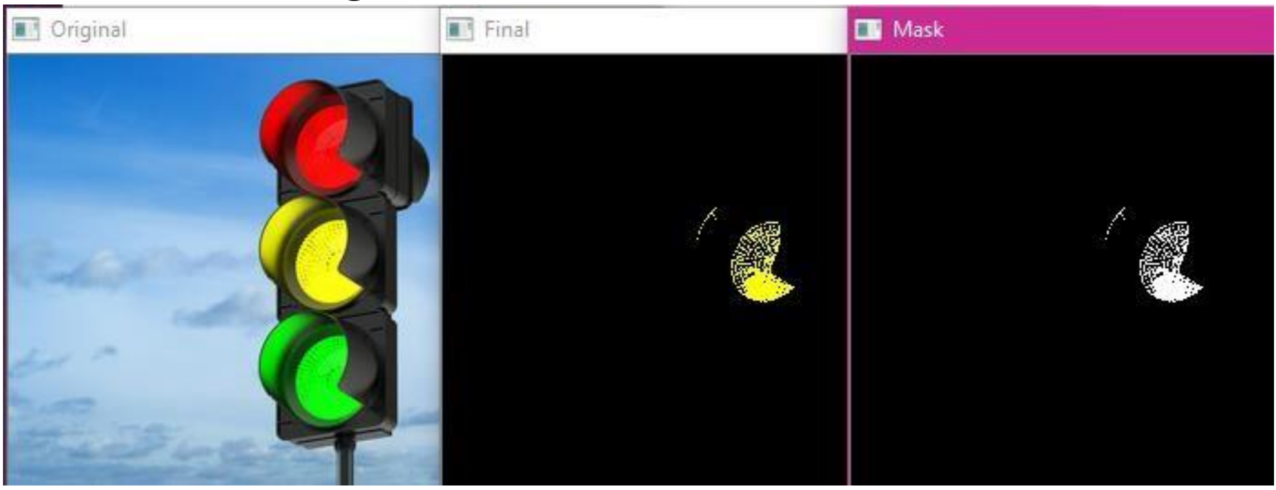


Figure 4-3: Reading traffic light from image

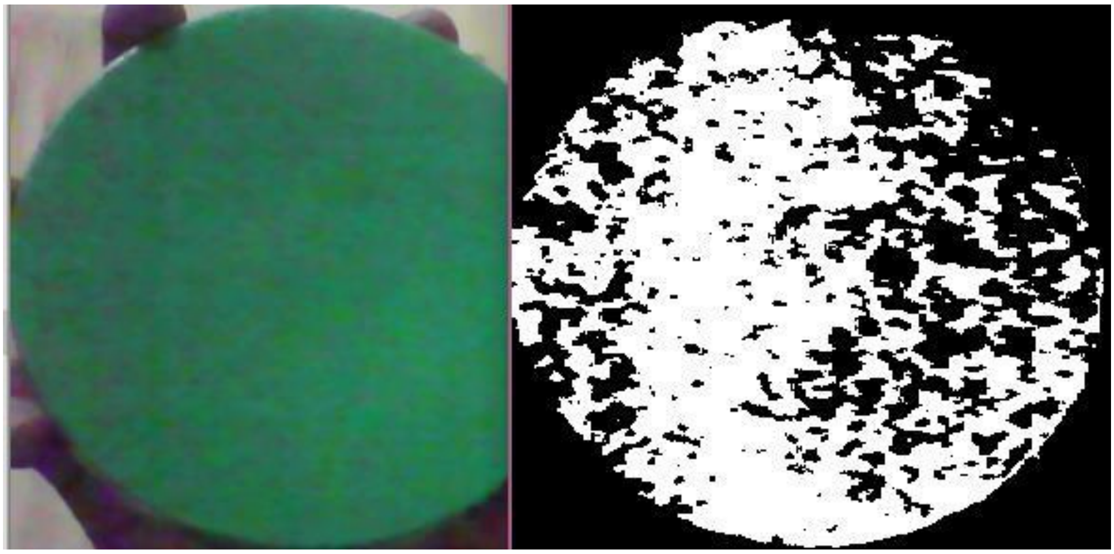


Figure 4-4: Reading green color from USB camera

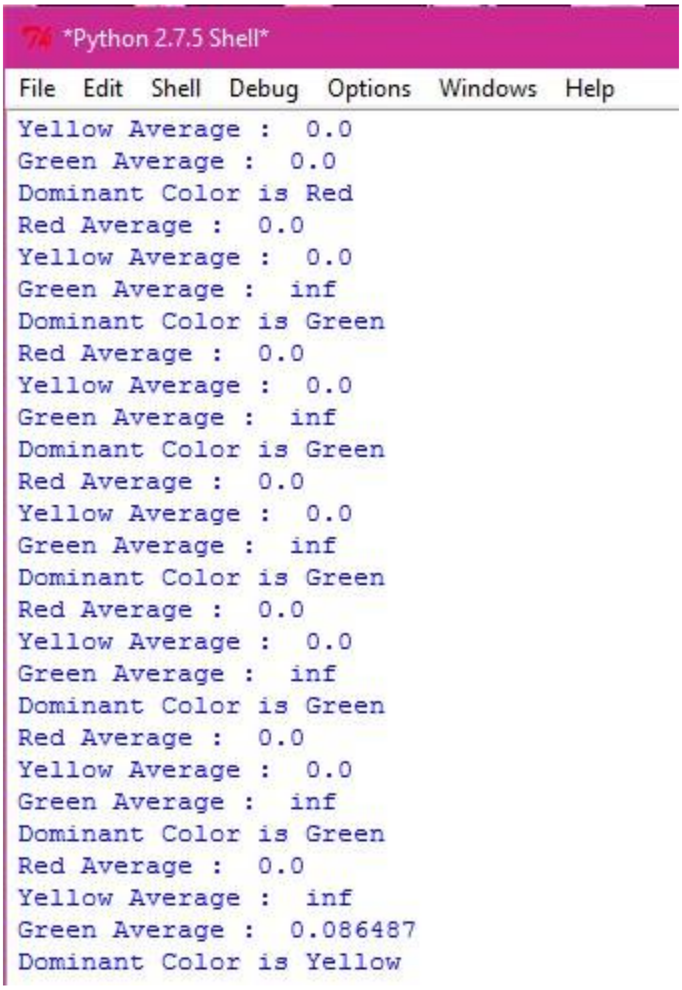


Figure 4-5: Determine the dominant color.

4.6 Hardware implementation

Figure 4.6 and Figure 4.7 shows the hardware implementation of the system which includes the GPS with its antenna, ultrasonic sensor, USB camera and the main controller raspberry pi that connected with battery.

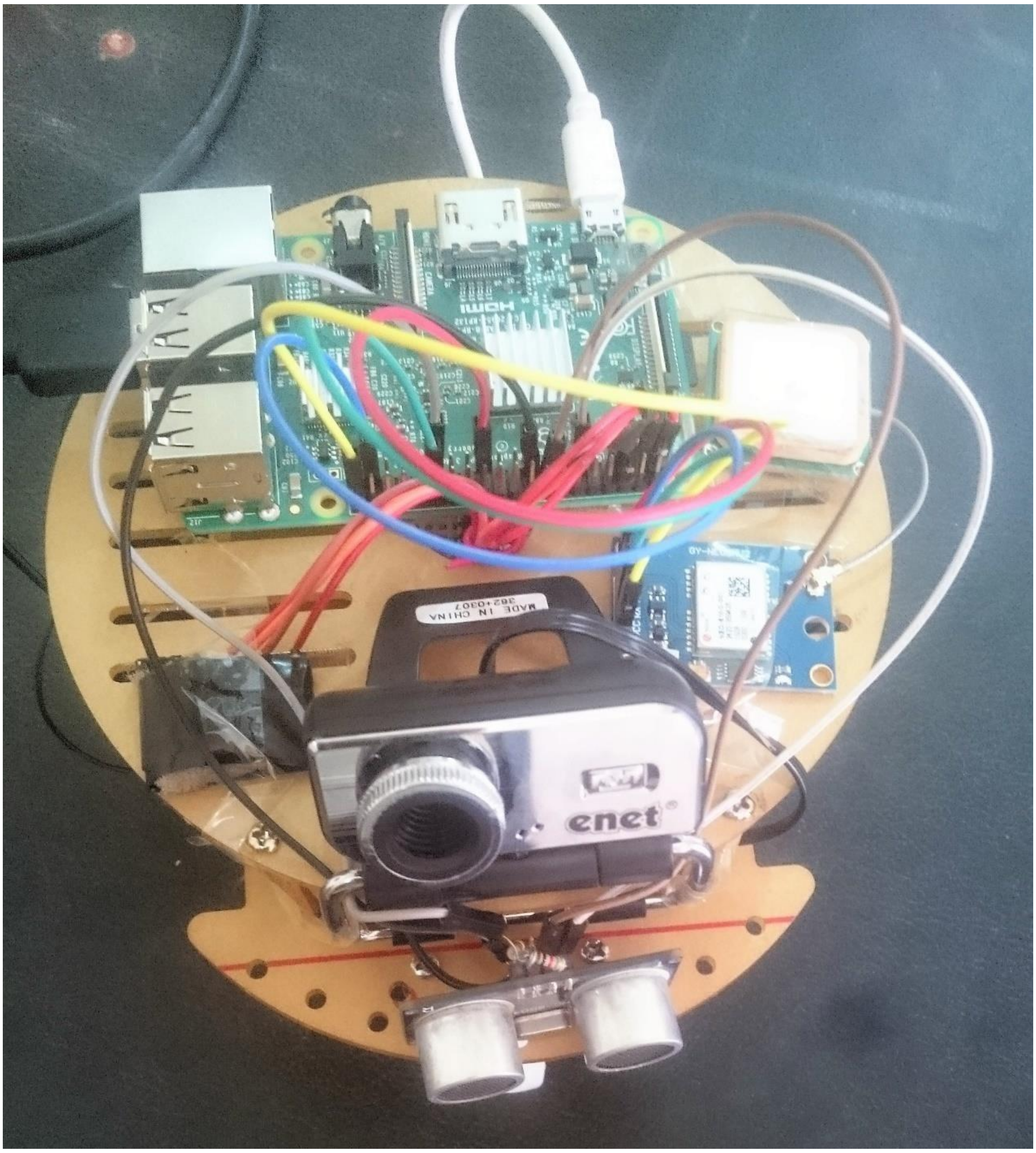


Figure 4-6: Hardware design

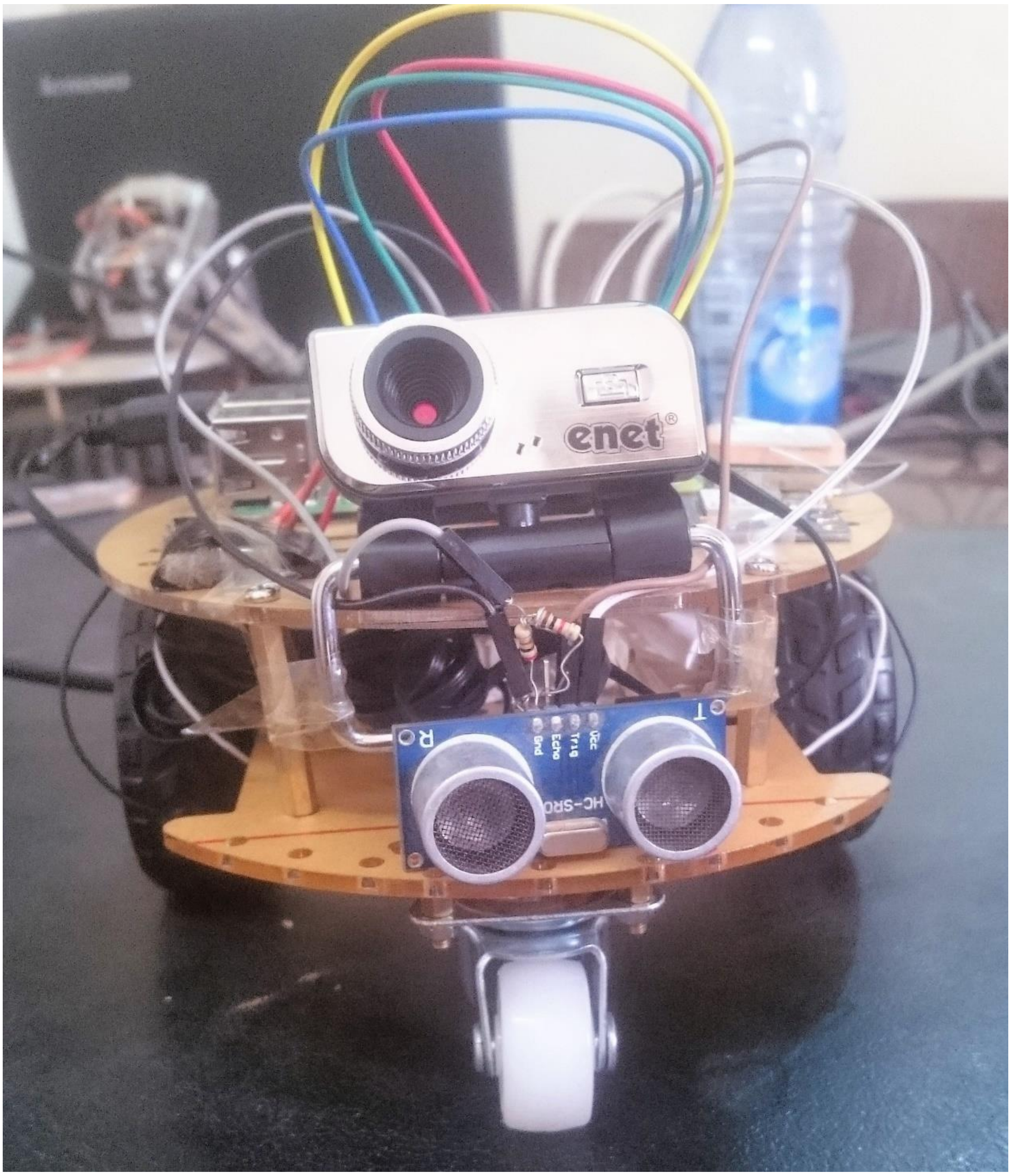


Figure 4-7: Hardware design

Chapter Five

Conclusion and Recommendation

5.1 Conclusion

In this research a successful practical implementation of autonomous car has been done, with a complete system consisting of a camera, GPS and sensors. Which gives the car a very thorough understanding of surrounding areas including other vehicles, pedestrians, traffic light and more.

The data from these sensors are interpreted by software running on a computer inside the vehicle. The software uses a combination of pattern matching and pre-implemented rules to autonomously control the car.

All these elements work together to move the car without an argument for human intervention.

This independent car can analyze the traffic signal on the road, the study showed that image processing is a better technique to control the state change of the traffic light, it can reduce the traffic congestion and avoids the time being wasted by a green light on an empty road.

Autonomous car avoids obstacles and walk to a designated destination with the help of satellite through GPS to ensure safe access to your destination. The passenger or carrier must control only the final destination.

This makes the car very successful and ensures quick access to passengers without accidents or damage caused by faulty driving. At the same time, be able to do other work while driving along the way.

Overall, the system is good but it still needs improvement to achieve a hundred percent accuracy.

5.2 Recommendation

This project can be improved to more advanced projects for autonomous vehicles and making it more efficient recommended to:

- Add more ultrasonic sensors in order to give the car more information about its environment and develop software to make car drive around obstacles.
- Barking system.

References

[1] P. Green, J. Hughes, R. Mullins and R. Mullins, "Raspberry Pi- A Small, Powerful, Cost Effective and Efficient Form actor Computer: A Review," *International Journal of Advanced Research in Computer Science and Software Engineering*, vol. 5, no. 12, p. 18, December 2015.

[2] "electroschematics," 2006. [Online]. Available: http://www.electroschematics.com/wp-content/uploads/2013/07/HCSR04datasheet-version-1.pdf. [Accessed 11 7 2017].

[3] "encyclopedia," [Online]. Available: [http://www.encyclopedia.com/science-andtechnology/technology/technology-terms-and-concepts/global-positioning-systemgps]. . [Accessed 10 8 2017].

[4] "u-blox," [Online]. Available: [https://www.ublox.com/sites/default/files/products/documents/NEO-6_DataSheet_(GPS.G6-HW09005).pdf].. [Accessed 10 7 2017].

[5] M. D. Dawud, G. . S. Pannu and P. Gupta, "Design and Implementation of Autonomous Car using Raspberry Pi," *International Journal of Computer Applications (0975 – 8887),* vol. 113, p. 8, 2015.

[6] . H. Ratan and G. Long, "Self Driving Cars," *Fung Technical Report No. 2013.05.29,* p. 19, 2013.

[7] Raju, Madhini and Sanjay, "Semi Autonomous Vehicle To Prevent Accident," *INTERNATIONAL JOURNAL OF TECHNOLOGY ENHANCEMENTS AND EMERGING ENGINEERING RESEARCH,* vol. 2, no. 5, p. 42.

[8] L. Ujjainiya and K. Chakravarthi, "RASPBERRY – PI BASED COST EFFECTIVE VEHICLE COLLISION AVOIDANCE SYSTEM USING IMAGE PROCESSING," *ARPN Journal of Engineering and Applied Sciences,* vol. 10, p. 5, 2015.

[9] J. . P. Hopkins and S. Duffy, "SIT, STAY, DRIVE: THE FUTURE OF AUTONOMOUS CAR LIABILITY," p. 23, 2014.

[10] A. Gonc¸alves and J. Sequeira, "LOW COST SENSING FOR AUTONOMOUS CAR DRIVING IN HIGHWAYS," p. 8.

[11] P. Lamon and P. Pfaff, "Mapping with an Autonomous Car," *Eidgen¨ossische Technische Hochschule (ETH), Inst. of Robotics and Intelligent Systems, 8092 Zurich, Switzerland,* p. 11.

[12] M. Emsholm , "Driverless cars and their impact on productivity and efficiency," p. 102, 2016.

Appendixes

Appendix A: Reading of the longitude, latitude and heading from $GPRMC frame

```
import serial

import time

import pynmea2

from pynmea2.nmea import ChecksumError

from pynmea2.nmea import ParseError



serial_conn = serial.Serial('/dev/ttyS0',9600)

while True:

    try:

        report = serial_conn.readline()

        data = report.split('\n')

        for r in data:

            # print str(r)

            if str(r).startswith('$GPRMC'):

                print r

                #   print report

                # print str(report)
```

```
            msg = pynmea2.parse(report)
            print "#"*40
            print "latitude            = " + str(msg.latitude)
            print "longtitude          = " + str(msg.longitude)
            if str(report).split(',')[8] != None:
                print "track angle in digree = " +str(report).split(',')[8]
            else:
                print "track angle is not found"
            gps = str(msg.latitude) + "," + str(msg.longitude)
            print "GPS: " + gps
            print "#"*40
            print "\n\n\n"
        time.sleep(0.01)
except ChecksumError:
    pass
except ParseError:
    pass
```

Appendix B: Reading red, green and yellow by using USB camera and calculating the area of the color

```
#import libraries
import numpy as np
import cv2
import time
video_capture = cv2.VideoCapture(0)
time.sleep(3)
while(True):
    ret, frame = video_capture.read()
    gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
    #process
    low_red = np.array([5,0,193])
    high_red = np.array([70,132,255])
    low_yellow = np.array([0,180,180])
    high_yellow = np.array([100,255,255])
    low_green = np.array([0,100,0])
    high_green = np.array([90,255,90])

    maskRed = cv2.inRange(frame,low_red,high_red)
    maskYellow = cv2.inRange(frame,low_yellow,high_yellow)
    maskGreen = cv2.inRange(frame,low_green,high_green)

    averageRed = np.mean(maskRed,dtype = np.float16)
```

```
averageYellow = np.mean(maskYellow,dtype = np.float16)
averageGreen = np.mean(maskGreen,dtype = np.float16)


print 'Red Average : ' , averageRed
print 'Yellow Average : ' , averageYellow
print 'Green Average : ' , averageGreen


if averageRed > averageYellow :
    if averageRed > averageGreen :
        if averageRed > 2 :
            print 'Dominant Color is Red'
elif averageYellow > averageRed :
    if averageYellow > averageGreen:
        if averageYellow > 2 :
            print 'Dominant Color is Yellow'
elif averageGreen > averageRed :
    if averageGreen > averageYellow:
        if averageGreen > 2:
            print 'Dominant Color is Green'


maskRed.T
maskYellow.T
maskGreen.T
#show
```

```
    cv2.imshow('Original',frame)

    cv2.imshow('Final',res)

    cv2.imshow('Red',maskRed)

    cv2.imshow('Yellow',maskYellow)

    cv2.imshow('Green',maskGreen)

if cv2.waitKey(500) & 0B11111111 == ord('q'):

        break

video_capture.release()

cv2.destroyAllWindows()
```

Appendix C: Reading of ultrasonic sensor

```
import RPi.GPIO as GPIO

import time

GPIO.setmode(GPIO.BCM)


TRIG = 22

ECHO = 23


GPIO.setup(TRIG,GPIO.OUT)

GPIO.setup(ECHO,GPIO.IN)


GPIO.output(TRIG, False)

time.sleep(2)


GPIO.output(TRIG, True)

time.sleep(0.00001)

GPIO.output(TRIG, False)


while GPIO.input(ECHO)==0:

 pulse_start = time.time()


while GPIO.input(ECHO)==1:
```

```
 pulse_end = time.time()

 pulse_duration = pulse_end - pulse_start

distance = pulse_duration * 17150

distance = round(distance, 2)

print "distance:",distance,"cm"

GPIO.cleanup()
```