QUADRUPED SPIDER

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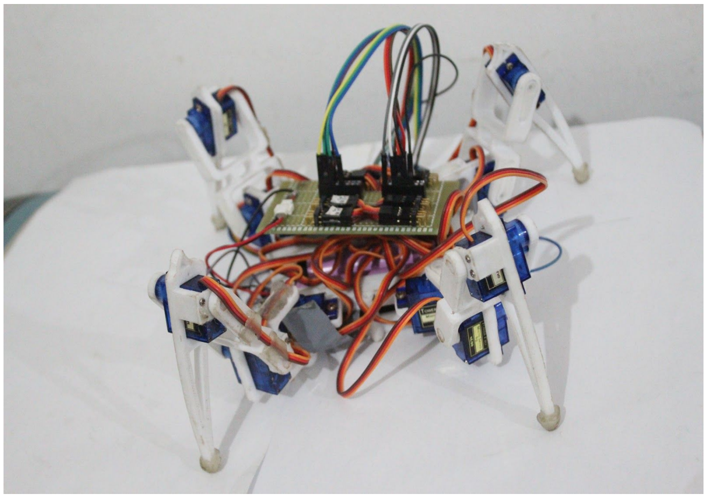

August 2018

DECLARATION

We do hereby declare that the work reported in this report was exclusively carried out by us under the supervision of Dr.C.I.Keppitiyagama. It does not contain any material previously published or written by another person or our self and only it describes the results of our own independent work except where due reference has been made in the text.

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I endorse the declaration by the candidates.

……………………………………. Date: ……………………………

Supervisor,

Dr.C.I.Keppitiyagama
designation

Abstract

The purpose of this report is to provide a detailed description of our group project of 3rd year academic course. Our project is regarding an already built robot which was built by a student at Score Lab. The robot was with no functionality at all and our task was to provide functionalities to the robot.

Autonomous vision based robots are intelligent robots which take visual data, process it and provide appropriate output. Our objective was to create the robot to track a specific object by avoiding obstacles by moving towards it.

These robots are totally independent and don't need any kind of human intervention since they are preferred with instructions. A robot is designed on Raspberry Pi using OpenCV, which is used for object detection based on its colour, size and shape. Here only a single object is being detected at a time. The tracking of the object is based on division of the image into virtual grids. The movement of the robot is based on the position of the object in the grid. Idea behind robotic vision is: viewing an object from the robot's perspective, deciding on object of interest and to act accordingly. It is about giving artificial sight to robots.The implemented robot can be used in various chemical industries, military application, coin separation, pencil industry.

Moreover this report consists the information related to our project regarding introduction, requirements, implementation method, system manual and user manual for further clarification.

Acknowledgment

We would like to express our sincere gratitude for :

Dr.C.I.Keppetiyagama (Supervisor) :

Dr. Chamath acted as the project supervisor. He provided guidance and support throughout the project in the form of project management, specification and review of the report and guided us in every single way we could achieve the success of the project.

Mr. J.P.K Kumarasinghe (Co-Supervisor):

Mr. Kumarasinghe was the Co-Supervisor of the project. He provided support in the form of face-to-face meetings, Skype online discussions, technical advice and report review and always motivated us to reach the success. Mr. Kumarasinghe along with the help of Dr.C.I.Keppetiyagama, helped direct the author in determining the scope of the project and handling necessary modifications to the project specification.

Mr. T.W.D.Lakshan & Miss.Chobodhi Damsarani (Mentor) :

Guided us from early stages of the project till the end of the project by suggesting us new technologies and providing insight into correct scientific conduct during projects. Both of them motivated us whenever we failed to complete a specific task.

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List of Abbreviations

- OpenCV : Open Source Computer Vision
- RGB : Red Green Blue
- IDE : Integrated Development Environment
- SoC : System on Chip
- MATLAB : Mathematics Laboratory
- COM : Communication Port
- MCU : Microcontroller
- FTDI : Future Technology Devices International
- CPU : Central Processing Unit
- GPU : Graphic Processing Units
- DMA : Direct Memory Access
- DC : Direct Current
- HD : High Definition
- PWM : Pulse Width Modulation
- USB : Universal Serial Bus

Chapter 1. Introduction

1.1 Introduction

Less than half the Earth's landmass is accessible to wheeled and tracked vehicles, yet people and animals can go almost anywhere on Earth. This situation motivates the development of robot vehicles that use legs for their locomotion, thereby embracing nature’s mobility solution.

We were given with an already-built quadruped robot with no functionalities.We developed the robot to detect a specific object and to move towards the object by avoiding obstacles.

1.2 Goals and Objectives

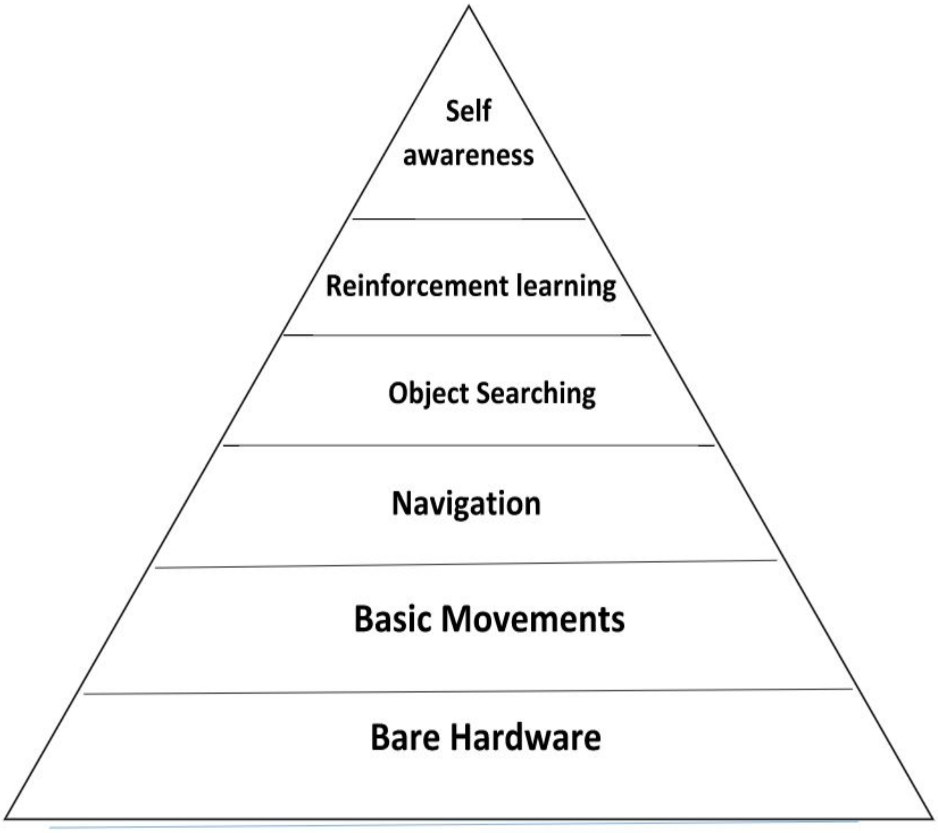


Figure 1.1

The project goal was to develop robot to detect a specific objects in 3 dimensional space and move towards it. The aim of the project was to begin from this spec, and design a solution to the functionality less robot. After a satisfactory solution was designed, the task came to implement the solution. Throughout the project, many problems arose. These problems varied from performance issues related to code, and from implementation issues related to limitations of software technologies used. All attempts at overcoming these problems are discussed in this report. Following are the main goals and objectives of the project.

- Developing basic movement functionalities of the robot.
- Developing the robot to detect obstacles and move avoiding them.
- Developing the object to detect a specific object and move towards the object.

1.3 Scope

The Robot was created in Score Lab by an intern student with no functionality. So the main stakeholders is the Score Lab. This project consists of developing functionalities for the robot to detect a specific object and move towards it avoiding obstacles. Robot should be able to detect a specific object (Ex: Green ball) and move towards the object. While moving towards the object the robot should sense whether there is an obstacle and calculate the distance to the obstacle to move by avoiding them. It took 5 months to complete the project and now the robot has functionalities mentioned above. This type of robots can be used as

- Agriculture robot.
- Mining robots.
- robotic household appliance.
- robot for a shopping mall.

1.4 Chapter Summary

This project is regarding giving functionalities for an already built robot. Robot should move towards a specific object by detecting obstacles and avoiding them. Main stakeholders of the project is Score Lab.

Chapter 2. System Analysis

2.1 Similar Systems/ Background

There are Robots who track real time object motion. But our project is regarding tracking a static object and moving towards it.

2.2 Requirements

2.2.1 Requirement Gathering Techniques

- Data analysis.
  - Analysing the documents like Use Case diagrams.
- Discussion with our supervisors and mentors and collecting new ideas from them.
- Data gathering.
  - Brainstorming-Thinking in group wise
- Expert judgement in diagramming techniques.

2.2.2 Functional Requirements

- Basic movement functions.
- Object detection (Ex: green ball)
- Moving by avoiding obstacles.

2.2.3 Non-Functional Requirements

- Concurrency and Capacity.
  - Robot can handle multiple computations executing simultaneously. Movement , image processing , sensing are at the same time
- Performance.
- Maintainability.

2.3 Methodology Used

2.3.1 Developing movement functionalities.

Used an Arduino pro mini and Raspberry pi connected to each other with a serial communication to give commands for the movement of the robot. The code is written in C language and it is been executed by the Raspbian OS through serial communication.

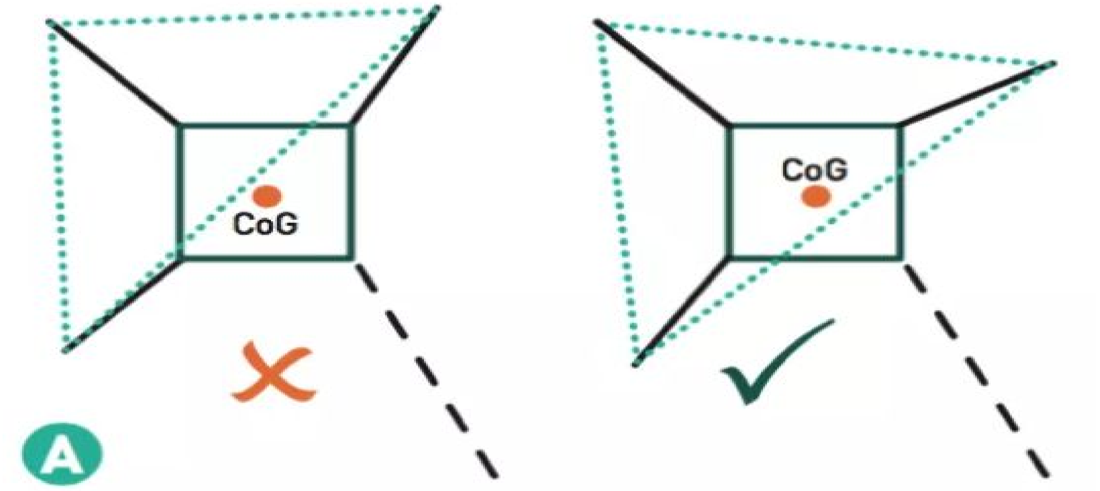


Figure 2.1

For the movement of each arm the theory of center of gravity is been used. The steps of movements of the robot is as follows.

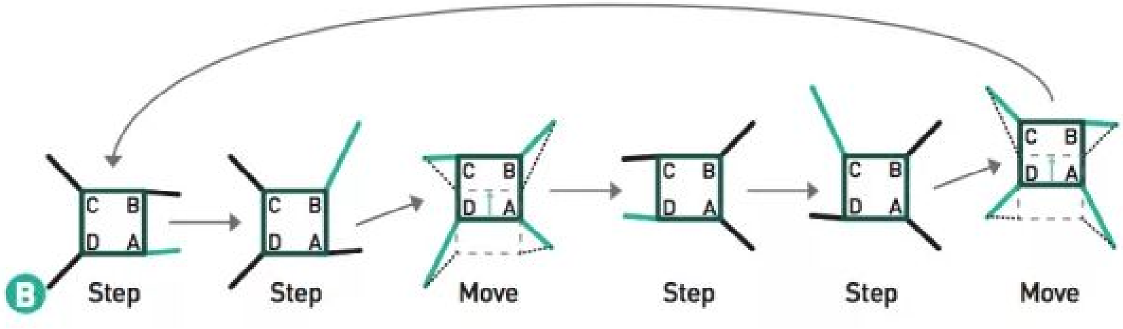


Figure 2.2

2.3.2 Developing obstacle detection functionality.

There are four sonar sensors fixed to the robot in front, back, right and left. The Ultrasonic Sensor sends out a high-frequency sound pulse and then times how long it takes for the echo of the sound to reflect back. The sensor has 2 openings on its front. One opening transmits ultrasonic waves, (like a tiny speaker), the other receives them, (like a tiny microphone). The ultrasonic sensor uses this information along with the time difference between sending and receiving the sound pulse to determine the distance to an object. When the distance is equal or greater than the threshold value it understands it as an obstacle and deviates.

2.3.3 Developing object detection functionalities.

Screen of the ultrasonic sensor is divided into 5 parts.When the power supply is given to the robot the pi camera checks in which part the object to be detected is located in. Then the robot turn and change its center to the side of the object. Calculate the distance to the object and move towards the object.

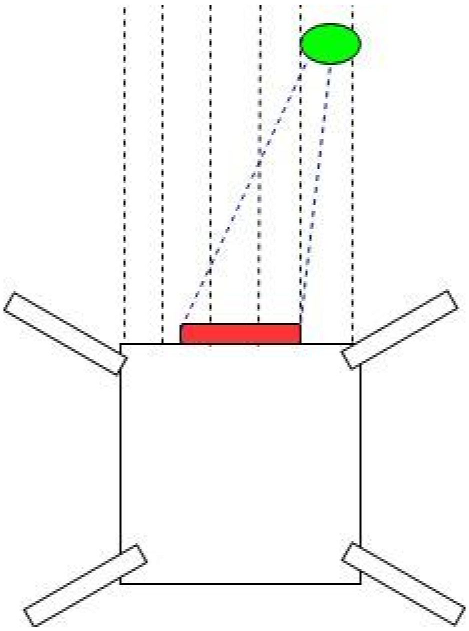


Figure 2.3

2.4 Prerequisites of the system

- Power supply of the Robot must be charged before giving power to the robot to do its functionalities otherwise some arms of the robot may function abnormally.
- Servo motors of each arm of the robot must work properly and should be tested before giving instructions to move.
- Robot is kept inside a box with a green ball for the robot to detect and move towards it.

Chapter 3. Design

3.1 Use Case Diagram

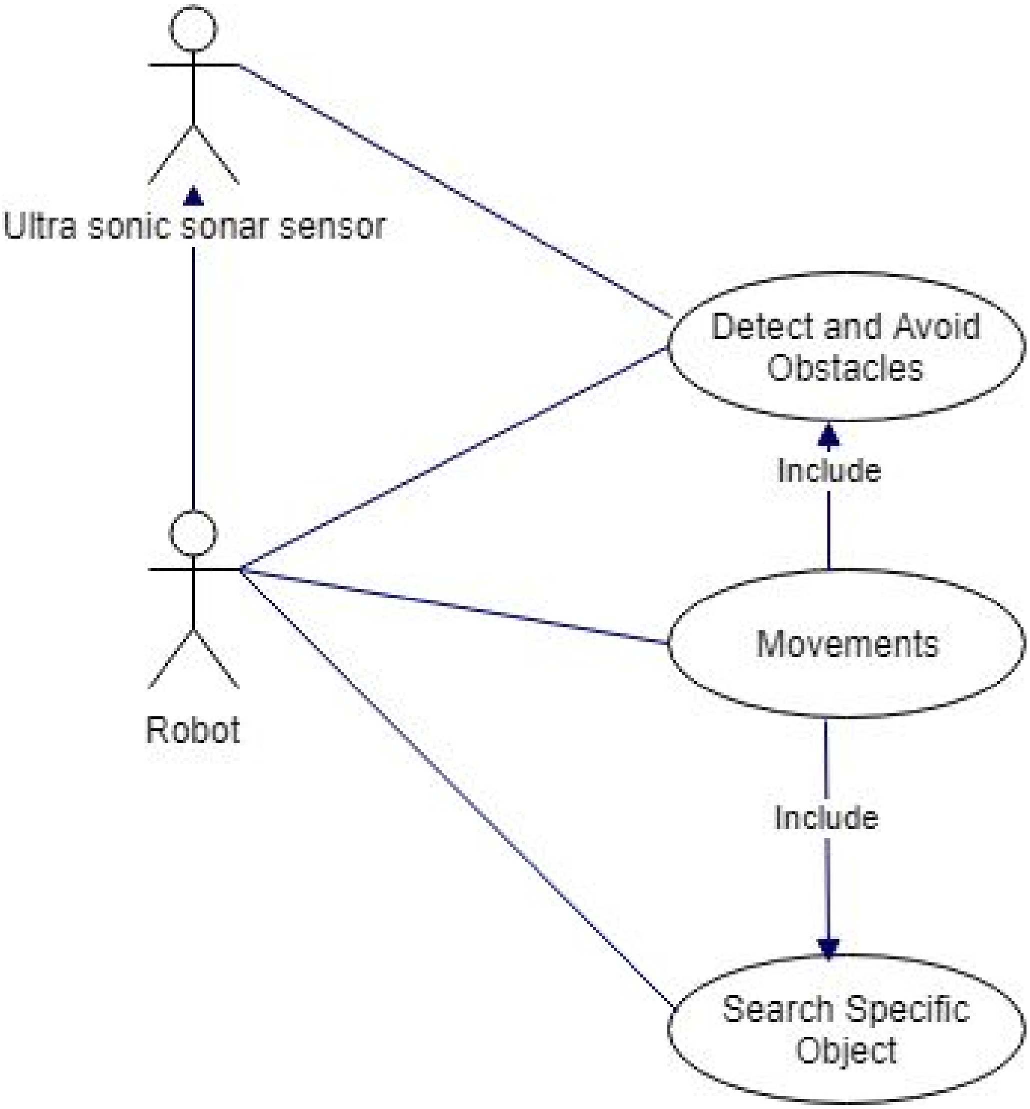


Figure 3.1

3.1.1 Use Case Narratives

Use Case 1	**Detect and avoid obstacles**
Actor	Robot and Ultrasonic sonar sensor
Pre-Condition	Should consist sonar sensors
Scenario	

Table 3.1

Use Case 2	**Movements**
Actor	Robot
Pre-Condition	Servo motors of the four arms should connected with the driver board
Scenario	

Table 3.2

Use Case 3	**Search Specific Objects**
Actor	Robot
Pre-Condition	It should have the functionality of movement to get towards the specific object
Scenario	

Table 3.3

3.2 Data Flow Diagram

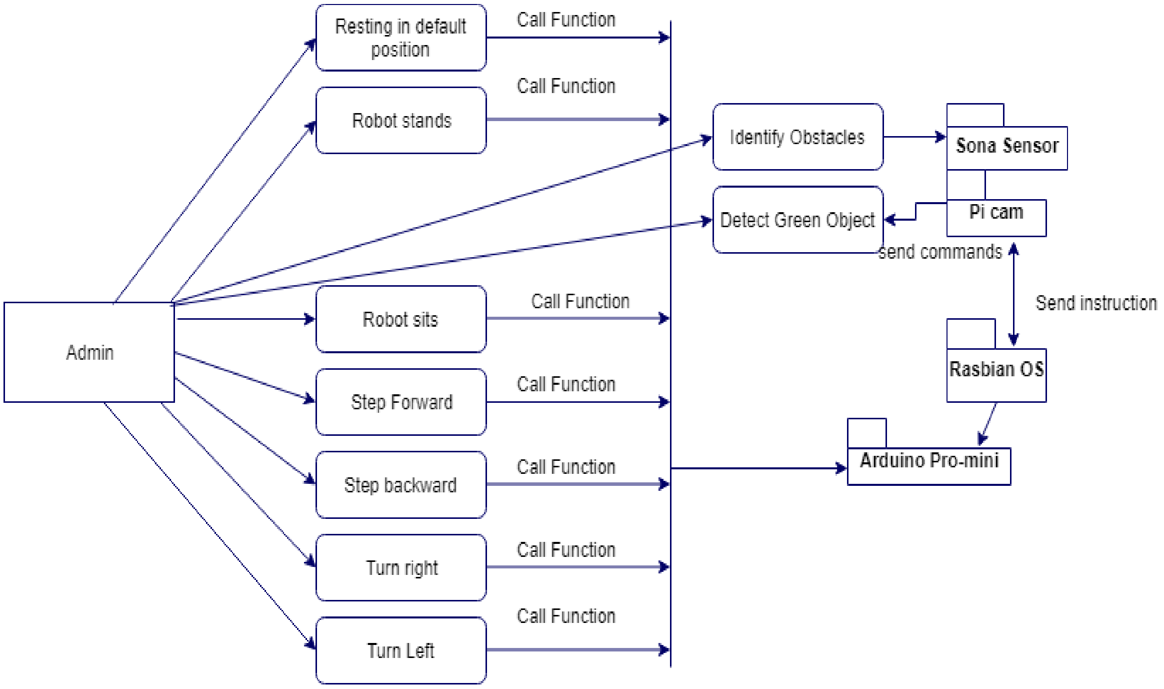


Figure 3.2

3.3 Class Diagram

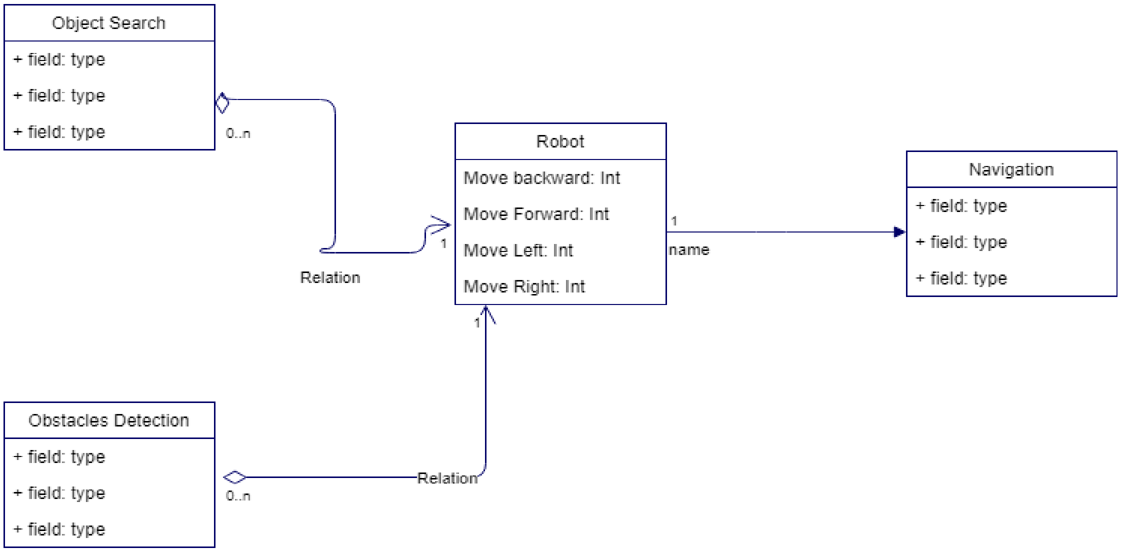


Figure 3.3

Chapter 4. Implementation

4.1 List of softwares and Hardware

This section provide what are the technologies were used and the way of the technologies being used.

4.1.1 Software

1. Python IDE to built the functions in python programming language
2. Opencv for object detection
3. Arduino IDE

4.1.2 Hardware

A chassis is used as a base on which following hardware components are fit:

1. Raspberry Pi for GPU and CPU computations.
2. Wifi dongle to connect to Pi remotely.
3. Motor driver which can control two motors
4. Batteries to provide power.
5. Jumper wires to connect individual components.
6. Web camera.
7. Servo motor to control the arm of the robot.

4.2 Software and Hardware description

4.2.1 Python IDE

We are using python language which is an interpreted high-level programming language for general-purpose programming. Python has a design philosophy that emphasizes code readability, notably using significant whitespace. It provides constructs that enable clear programming on both small and large scales. Its syntax allows the programmers to express concepts in fewer lines of code when compared with other languages like C, C++or java.

4.2.2 Open Computer Vision

OpenCV (Open Source Computer Vision Library) is an open source computer vision and machine learning software library which is generally used for image processing. Its library has more than 2500 optimized algorithms, which include both old and new computer vision and machine learning algorithms. These algorithms are used to detect faces, objects, sorting human reactions in video frames, follow eye movements, and track any detected object. It has C++, C, Python, Java and MATLAB interfaces. In this project OpenCV libraries is used for object detection on real time video frames.

4.2.3 Arduino IDE

Arduino IDE is a software that allows us to communicate with Arduino board via using COM ports. It is also has a compiler that compiles the source codes before loading it on Arduino board. Arduino IDE uses C language as a programming language. C is a high level programming language which is generally used in electronic hardware programming.

4.2.4 Numpy

Numpy is a package that defines a multidimensional array object and associated fast math functions that operate on it.Numpy is an extension to the Python programming language, adding support for large, multidimensional arrays and matrices, along with a large library of high –level mathematical functions to operate on these arrays.

4.2.5 Servo Motors

Servo motor is kind of a DC motor used in electronics applications. The difference between standard DC motor and servo motor is angular controllability factor. Conventional DC motors are designed for high rotational speed with no angular control. On the other hand, servo motors are designed for angle sensitive applications. Servo motors rotational speeds are low but have high torque. Thus we have chosen servo motor. In this project, we need servo motors to rotate camera in vertical and horizontal axises via using pan/tilt mechanism. We have two axis therefore we need two servo motors. In order to application specific design for this project, we need small enough servos to fit into pan/tilt mechanism and high enough torqued servos for rotating camera module properly.

Figure 4.1

4.2.6 Raspberry Pi

The Raspberry Pi is a credit card-sized single-board computer. All models use the same SoC (System on Chip - combined CPU & GPU), but hardware features differ. Raspberry Pi Foundation as the primary operating system for the family of Raspberry Pi single-board computers. In our project we are using the raspberry pi zero version.

Figure 4.2

4.2.7 Pi Cam

A Pi Cam is a video camera that feeds or streams its image in real time to or through a raspberry pi. The Raspberry Pi Camera v2 is the new official camera board released by the Raspberry Pi Foundation.The Raspberry Pi Camera Module v2 is a high quality 8 megapixel Sony IMX219 image sensor custom designed add-on board for Raspberry Pi, featuring a fixed focus lens. Quality and configurability of the camera module is highly superior to a standard USB webcam.

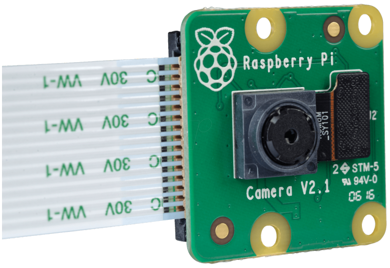


Figure 4.3

4.2.8 Driver Board

The Quadstepper motor driver board allows you to control up to 4 bipolar stepper motors simultaneously using logic level Input and Output pins. Each motor driver has an output drive capacity of 35V and 1 Amps. The board is capable of driving motors in full, half, quarter, eighth, and sixteenth-step modes. The logic levels are selectable between 3.3V and 5V by way of a jumper. The bus header allows you to control all four motors with only 6 Input and Output pins by controlling the enable (EN pins) for each motor, although each motor will be activated alone, not simultaneously. Be sure to close all of the ‘Bus Enable’ jumpers on the back of the board in order to use the Bus header.

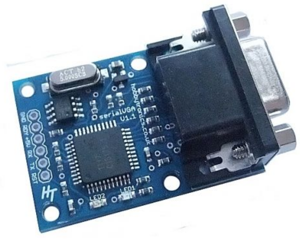


Figure 4.4

4.2.9 Arduino Pro Mini

.Arduino is an open-source microprocessor card. The Arduino Pro Mini is a microcontroller board. It has 14 digital input/output pins of which 6 can be used as PWM(Pulse Width Modulation) outputs, 6 analog inputs, an on-board resonator, a reset button, and holes for mounting pin headers. A six pin header can be connected to an FTDI cable is a USB to Serial converter which allows the serial communication and also to provide USB power and communication to the board. Arduino boards are very easy to develop a program while designing robotic and electronic applications and also this is a open source coded. Projects can be both programmed and tested on the same board. Uses a easy programming language. According to the project Arduino Pro Mini is used for serial communication with Raspbian Zero.

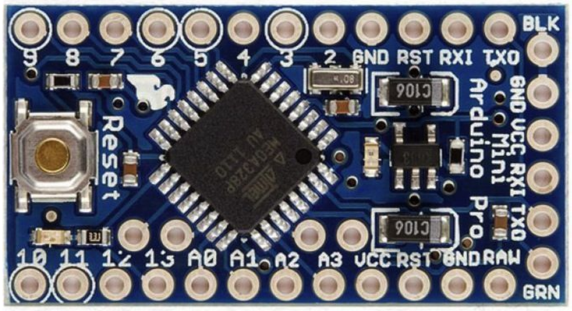


Figure 4.5

4.2.10 Sonar Sensors

It emits an ultrasound at 40 000 Hz which travels through the air and if there is an object or obstacle on its path It will bounce back to the module. Considering the travel time and the speed of the sound you can calculate the distance.

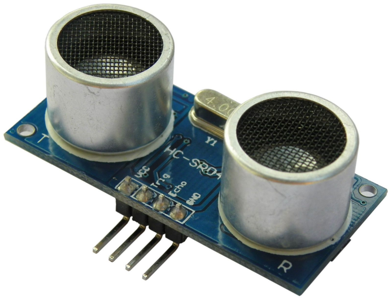


Figure 4.6

4.2.11 Wifi dongle

The Wi-Fi dongle is attached to the USB port in Raspberry Pi in order to connect to it wirelessly. Since raspberry pi needed its own IP, it needs to be connected to a Wi-Fi router or Hotspot. For the same we need to make some changes in the field specified so as to make raspberry pi recognize the router every time it boots up.

4.3 System Architecture

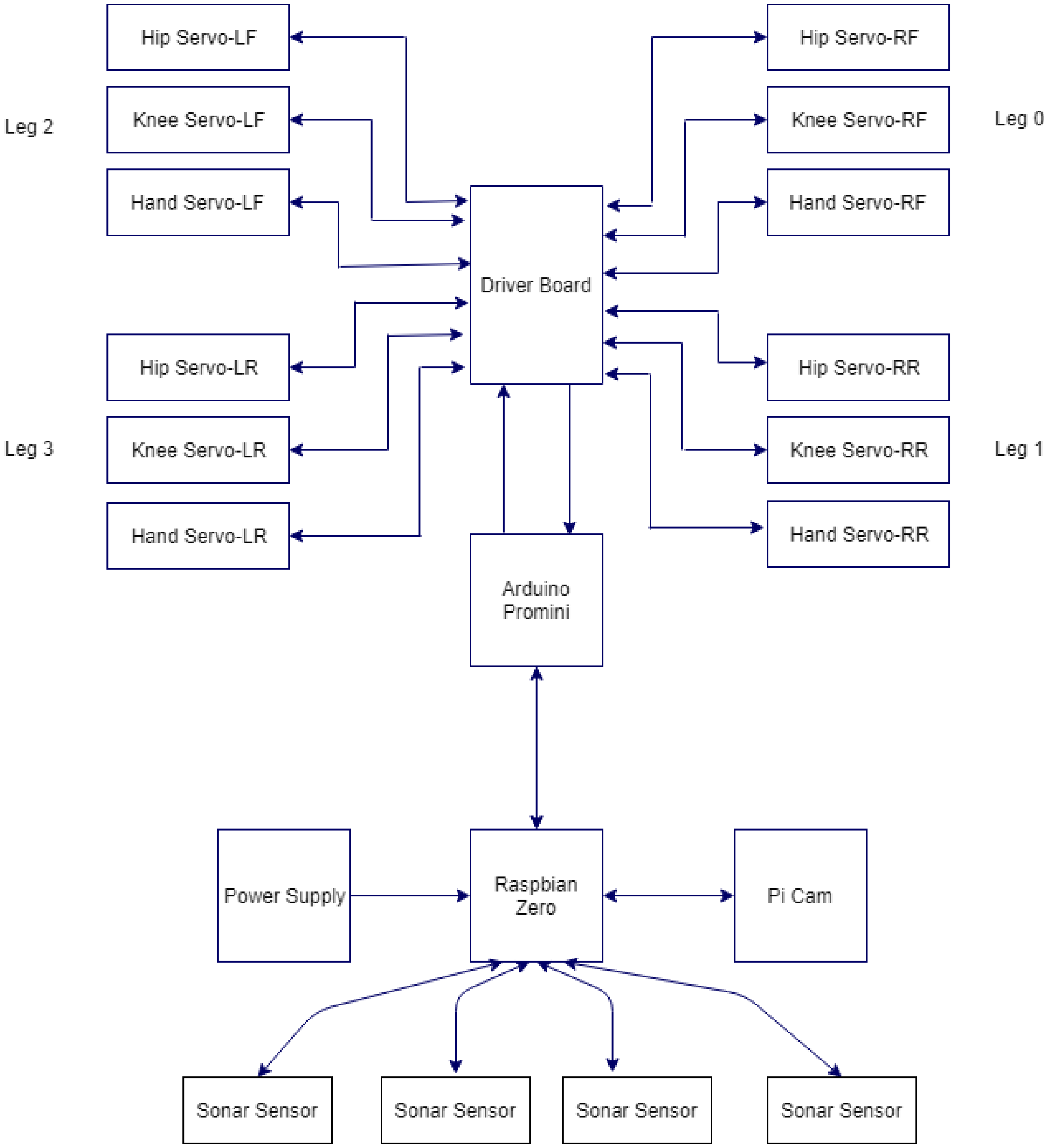
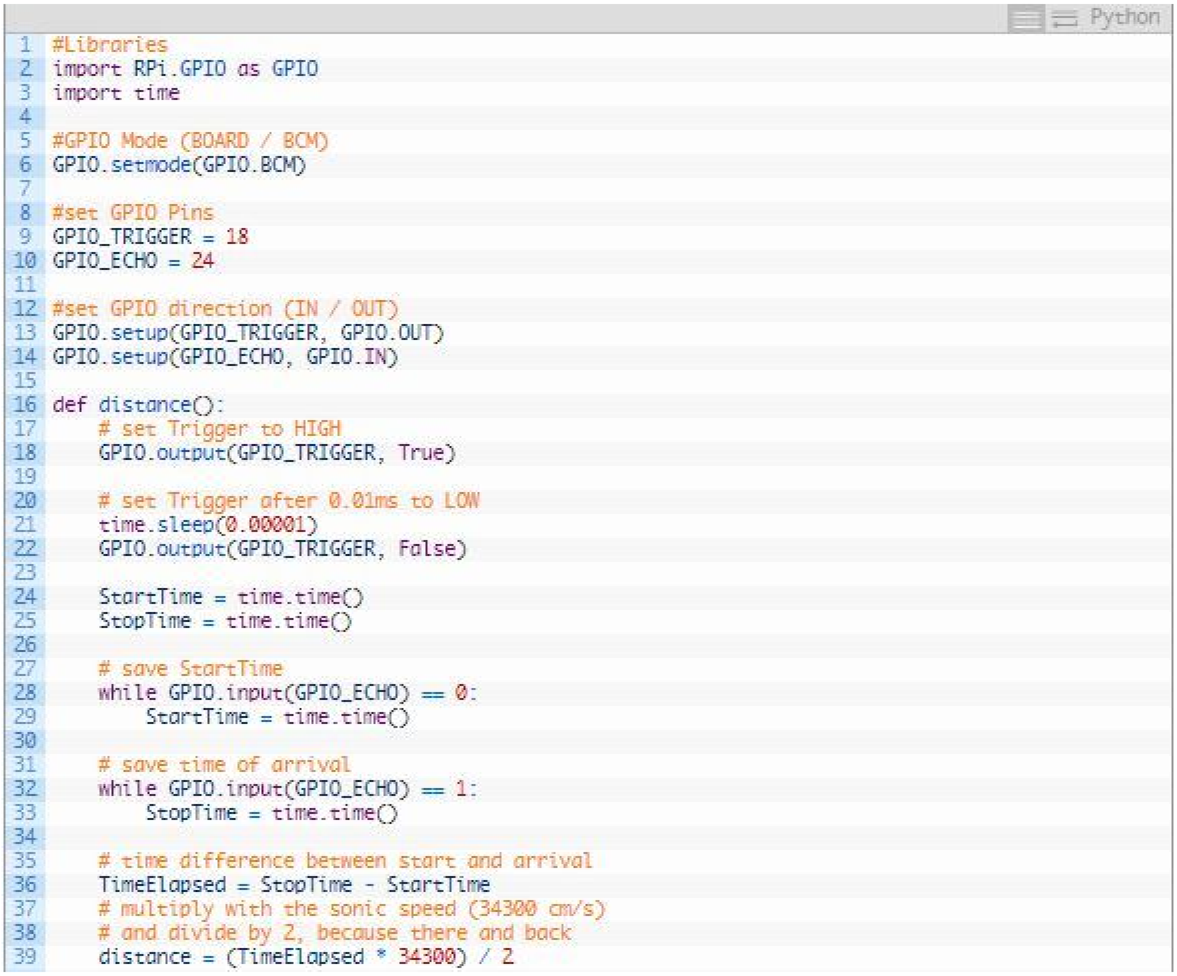


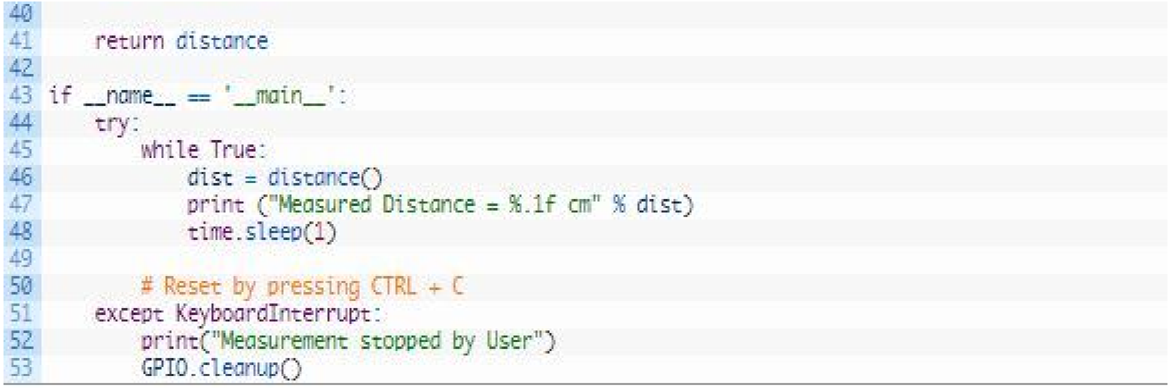
Figure 4.7

Chapter 5. Evaluation

5.1 Testing sona sensors

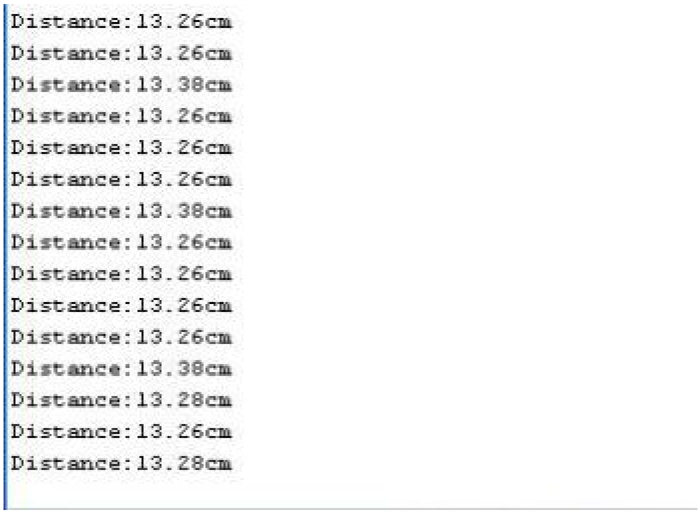


```python
#Libraries
import RPi.GPIO as GPIO
import time

#GPIO Mode (BOARD / BCM)
GPIO.setmode(GPIO.BCM)

#set GPIO Pins
GPIO_TRIGGER = 18
GPIO_ECHO = 24

#set GPIO direction (IN / OUT)
GPIO.setup(GPIO_TRIGGER, GPIO.OUT)
GPIO.setup(GPIO_ECHO, GPIO.IN)

def distance():
    # set Trigger to HIGH
    GPIO.output(GPIO_TRIGGER, True)

    # set Trigger after 0.01ms to LOW
    time.sleep(0.00001)
    GPIO.output(GPIO_TRIGGER, False)

    StartTime = time.time()
    StopTime = time.time()

    # save StartTime
    while GPIO.input(GPIO_ECHO) == 0:
        StartTime = time.time()

    # save time of arrival
    while GPIO.input(GPIO_ECHO) == 1:
        StopTime = time.time()

    # time difference between start and arrival
    TimeElapsed = StopTime - StartTime
    # multiply with the sonic speed (34300 cm/s)
    # and divide by 2, because there and back
    distance = (TimeElapsed * 34300) / 2
```



```python

    return distance

if __name__ == '__main__':
    try:
        while True:
            dist = distance()
            print ("Measured Distance = %.1f cm" % dist)
            time.sleep(1)

        # Reset by pressing CTRL + C
    except KeyboardInterrupt:
        print("Measurement stopped by User")
        GPIO.cleanup()
```

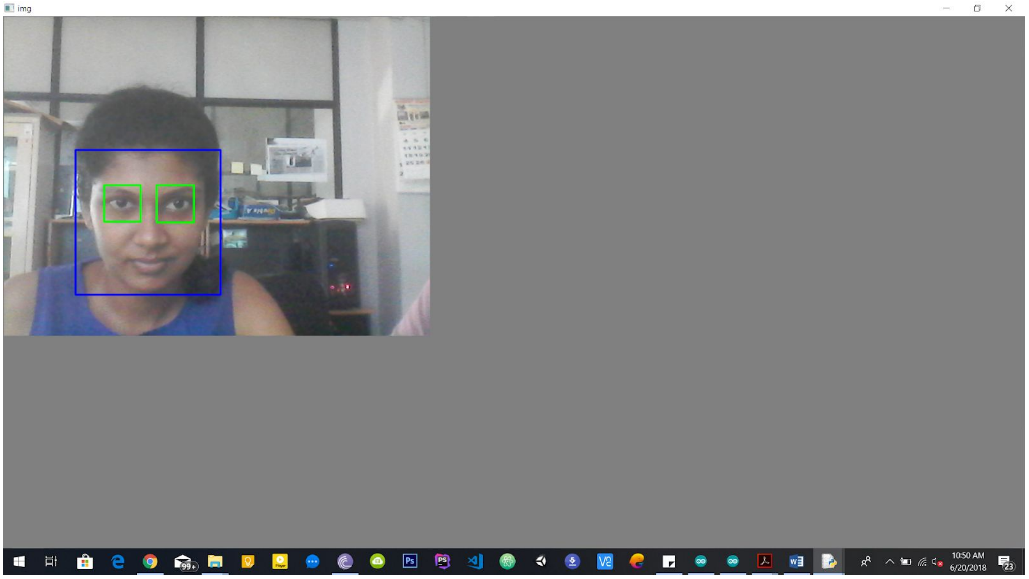
By running the above code the distance will be measured until the script is cancelled by pressing CTRL + C. Test results are as belows.



```
Distance:13.26cm
Distance:13.26cm
Distance:13.38cm
Distance:13.26cm
Distance:13.26cm
Distance:13.26cm
Distance:13.38cm
Distance:13.26cm
Distance:13.26cm
Distance:13.26cm
Distance:13.26cm
Distance:13.38cm
Distance:13.28cm
Distance:13.26cm
Distance:13.28cm
```

5.2 Testing pi camera

Tested face detection using pi cam.



Chapter 6. Conclusion

6.1 Conclusion

The concept we used in this report make use of raspberry pi kit along with pi camera to track the object effectively. The robot movement here used along servo motor for accurate measurements. Real time object detection and moving towards the object is the main target of the project. To easily accessible product, the project constructed as low cost project. In this project, several methods are presented. We implemented different detecting and tracking methods. The results are good for starting. further modification we can do that use of raspberry pi remote to operate the manual supply like tv, so wired system can be reduced.

6.2 Future work

Presently the quadruped can detect and navigate to a certain object which is in its visible surrounding. Moving forward we are planning on developing this to detect objects and navigate to them in a known or unknown environment using pathing algorithm search.

Chapter 7. Reference

https://github.com/timestocome/RaspberryPi-Robot

https://circuitdigest.com/microcontroller-projects/raspberry-pi-ball-tracking-robot-using-processing

https://www.instructables.com/id/Raspberry-Pi-Arduino-Serial-Communication/

https://maker.pro/raspberry-pi/tutorial/how-to-connect-and-interface-raspberry-pi-with-arduino

https://www.youtube.com/watch?v=dKpRsdYSCLQ

https://github.com/scogswell/ArduinoSerialCommand/tree/master/examples/SerialCommandExample

Appendix A- User Manual

USER'S MANUAL

Quadruped Robot

Quadruped spider

USER MANUAL

1.0 GENERAL INFORMATION

1.1 System Overview

Robot provides the following functionalities.

- Movement functionalities.
- Detecting obstacles and moving avoiding them
- Detecting a specific object and travelling towards the object.

2.0 SYSTEM SUMMARY

2.1 System Configuration

Quadruped spider uses raspbian OS to do it's all operations.Serial communication is used for the movement functionalities of the robot. The robot requires connection to Internet in order to retrieve data & to execute instructions to. The Robot is executed by the commands entered in the desktop.

2.2 User Access Levels

Robot can be functioned by any member. He/she should enter the commands and proper inputs needed to execute the robots functionalities.

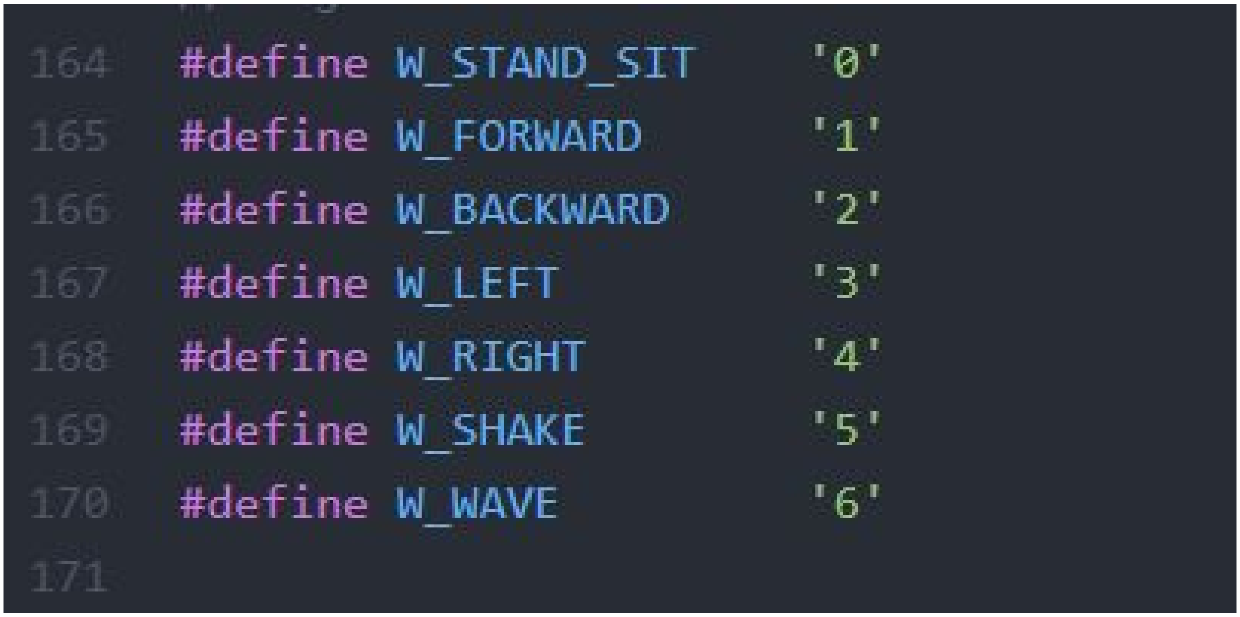
2.3 Contingencies

- Can occur connection losts.
- Servo motors can work abnormally
- Power supply can be weak or lost
- Lose connection in wires can occur abnormal movements.

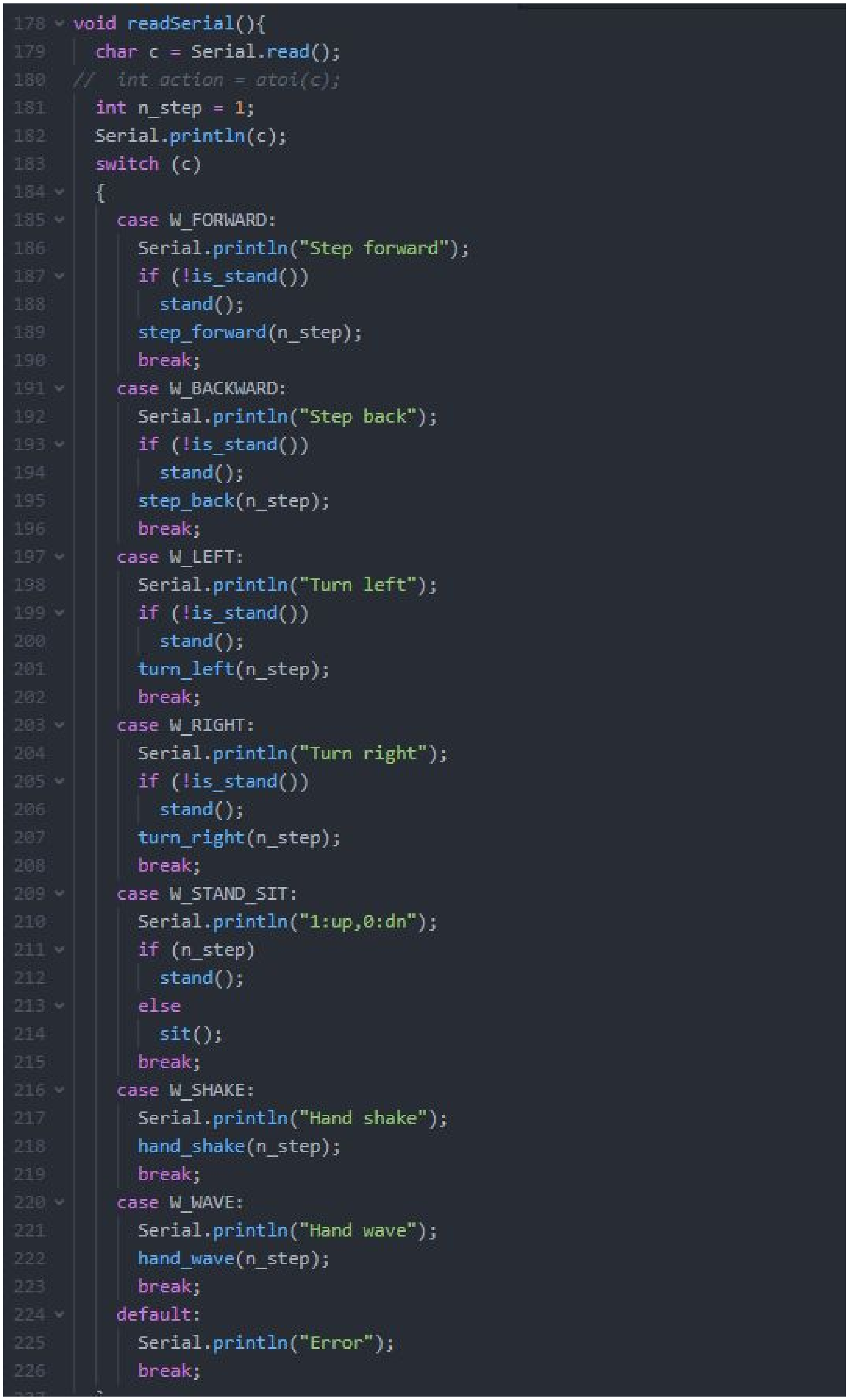
3.0 USING THE ROBOT

3.1 Getting started

Raspberry pi is connected to the desktop via network connection. Raspberry pi is connected to arduino via serial communication. When we insert commands in desktop the robots starts functioning.



```
#define W_STAND_SIT    '0'
#define W_FORWARD      '1'
#define W_BACKWARD     '2'
#define W_LEFT         '3'
#define W_RIGHT        '4'
#define W_SHAKE        '5'
#define W_WAVE         '6'

```



```
void readSerial(){
  char c = Serial.read();
//  int action = atoi(c);
  int n_step = 1;
  Serial.println(c);
  switch (c)
  {
    case W_FORWARD:
      Serial.println("Step forward");
      if (!is_stand())
        stand();
      step_forward(n_step);
      break;
    case W_BACKWARD:
      Serial.println("Step back");
      if (!is_stand())
        stand();
      step_back(n_step);
      break;
    case W_LEFT:
      Serial.println("Turn left");
      if (!is_stand())
        stand();
      turn_left(n_step);
      break;
    case W_RIGHT:
      Serial.println("Turn right");
      if (!is_stand())
        stand();
      turn_right(n_step);
      break;
    case W_STAND_SIT:
      Serial.println("1:up,0:dn");
      if (n_step)
        stand();
      else
        sit();
      break;
    case W_SHAKE:
      Serial.println("Hand shake");
      hand_shake(n_step);
      break;
    case W_WAVE:
      Serial.println("Hand wave");
      hand_wave(n_step);
      break;
    default:
      Serial.println("Error");
      break;
  }
```

3.2 tracking object

Keep the specific object to be detected in robot’s environment and give the robot power supply. Robot will move towards the object.

3.3 expected output

- If there is no object in the visible area of the pi cam, robot starts turning around to see whether there is an object behind.
- If there is no object around the robot it will not move.
- If the robot can see the specific object to its visible area, it turns towards the object and travel towards it and stops

Appendix B- System Manual

SYSTEM'S MANUAL

Overview

We were given with an already-built quadruped robot with no functionalities at all. We were assign to develop the robot to detect a specific object and to move towards the object by avoiding obstacles. These robots are totally independent and don't need any kind of human intervention since they are preferred with instructions.

1. GENERAL INFORMATION

1.1 Introduction and Purpose

The component mainly consists with the built quadruped Robot(Hardware Component) and Software components like arduino IDE. This system manual provides the necessary guidance for the users to setup the Robot and instructions to operate the Quadruped Robot.

1.2 Project References

1.2.1 User Manual

User manual is attached with this. It provides the guidance for the system users to use this Robot System effectively.

1.2.2 Test Case

To ensure the actual functionality of the system, several system testings has been conducted.

2. SYSTEM ORGANISATION

2.2 Hardware Inventory

- Sonar Sensors
    - HC-SR04 Ultrasonic sensor
- Arduino Board
    - Arduino pro mini
- Battery Pack
    - lithium Ion 18650

2.3 Software Inventory

- Arduino
- Opencv
    - To detect objects
- Python IDE
- Numpy
    - For mathematical operations