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Mémoire

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Thème:

Improving Pob-Bot Robot hardware and software using Raspberry Pi for navigation outdoor

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Resume:

In this work, we deigned an new robot called RPI-Bot based on improvement of an old one “Bob-Bot”, we integrated more sensors for navigation and obstacle avoidance. The new designed robot, is based on Raspberry-PI SBC, this provide us with more memory space and implementation of some Machine learning modes. To test or Robot w implemented an ML Algorithm to detect and recognize some of traffic signs o help it in autonomous navigation outdoor. A robot design simulator were used and gave good results. The real-time tests on the new robot were excellent. By adding other sensors and using deep artificial intelligence algorithms, we can improve more the autonomous navigation of the robot to identify the external environment. Finally, we obtained very interesting results and another rich admirable technique during the tests which may help the future studies in this area.

Résumé :

Dans ce travail, nous avons conçu un nouveau robot appelé RPI-Bot basé sur l'amélioration d'un ancien robot appelé "Bob-Bot". Nous avons intégré davantage de capteurs pour la navigation et l'évitement des obstacles. Le nouveau robot conçu est basé sur Raspberry-PI SBC, ce qui nous offre plus d'espace mémoire et la possibilité de mettre en œuvre certains modèles d'apprentissage automatique. Pour tester notre robot, nous avons mis en place un algorithme d'apprentissage automatique pour détecter et reconnaître certains panneaux de signalisation afin de l'aider dans sa navigation autonome en extérieur. Un simulateur de conception de robot a été utilisé et a donné de bons résultats. Les tests en temps réel sur le nouveau robot ont été excellents. En ajoutant d'autres capteurs et en utilisant des algorithmes d'intelligence artificielle avancée, nous pouvons améliorer davantage la navigation autonome du robot pour identifier l'environnement externe. Enfin, nous avons obtenu des résultats très intéressants et une autre technique remarquable et riche pendant les tests, ce qui pourrait aider les études futures dans ce domaine.

الملخص :

في هذا العمل قمنا بتصميم روبوت جديد يسمي RPI-Botاستنادا الى تحسين روبوت قديم يسمى POB-Bot قمنا بدمج مزيد من الحساسات للتنقل وتجنب العوائق . يعتمد الروبوت الجديد على , Raspberry-Pi SBC مما يوفر لنا مساحة ذاكرة أكبر وتنفيد بعص نماذج التعلم الالي . لاختبار روبوت قمنا بتنفيذ خوارزمية تعلم الي لكشف وتعرف على بعض علامات المرور لمساعدته في التنقل الذاتي في الهواء الطلق. تم استخدام محاكي تصميم الروبوت وأعطى نتائج جديدة. كانت الاختبارات في الوقت الحقيقي على الروبوت الجديد ممتازة . من خلال إضافة حساسات أخرى و استخدام خوارزميات الذكاء الاصطناعي العميقة, يمكننا تحسين التنقل الذاتي للروبوت بشكل أكبر لتحديد البيئة الخارجية في النهاية. حصلنا على نتائج مثيرة للاهتمام جدا وتقنية أخرى رائعة تستحق الاعجاب خلال الاختبارات و التي قد تساعد في الدراسات المستقبلية في هذا المجال.

Keywords:

Mobile robot, Navigation, Pob-Bot, Webots, Sensors, Known environment, Prospection

Dedicace :

We thank God Almighty for enabling us to complete this work in the best condition. I thank my father and mother for all their efforts in standing beside me in the academic journey And in life in general, and I thank all my brothers and friends for the moral support they have provided . Not all words can describe how much their efforts mean to me.

I also dedicate my work to the sun and flowers of my life, the best friends I've ever met, each one having their own place inside me, I offer them my special compliments, for all their support and the amount of happy moments we've had together. I love you more than words can say and I will always and forever God bless you all. Thank you very much.

Thanks :

Before i begin this work presentation, i would like to thank a god the greatest who gave me the strength and patience to realize this work.

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I thank the president and the members of the jury to judge This thesis.

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Please accept my utmost respect and appreciation.

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CHAPTER N°05 : Hardware / Software Test and Result

SUMMARY :

CHAPTER N°01 :

Global Introduction

1.1 Introduction

In recent years, we have noticed an increasing demand for robotics, whether it is by humans, laboratory or companies. This indicates the many benefits that robots provide in the industrial, health and military fields, in general to help humans perform fast and safe tasks. All this is due to the scientific development in all fields, mechanics, electronics, sciences and computer science. It has become a necessary field due to its enormous benefits affecting human life, although the robot takes the human place in that area, it is suitable for security and reducing health risks.

Self-Driving Cars are considered one of the types of vehicles that do not need a person to direct and control them, as they use a set of modern technologies to navigate, determine the appropriate speed, and a safe distance. The design, creation and programming of mobile robots is one of the key issues of electronics and makes an important part in electronic education. A lot of robot navigation systems only work indoors, Outdoor operation meets with more challenges, fewer resources are available, harder to control to environment features like lighting conditions and climate. But since outdoor robots are used in a lot of fields like demining or exploration and also offer the potential for new application areas.

In this project, we have developed hardware and software for the mobile robot (POB-BOT) using the raspberry pi which is the mastermind that gives orders, and we have added a camera that help robot to read the traffic signal and a distance sensor to avoid obstacles .

1.2 Motion planning techniques :

- **In the first chapter:** we make research on the area and we finished with stat and analysis ,of the robots navigation , and result are posted on the table

- **In the second chapter:** In the beginning, we present a general view that speaks in detail about the importance of artificial intelligence In all areas it serves, We explain a general picture of the libraries that we use, with the different ways in their application and benefits

- **In the third chapter**: simulation for robot navigation We use the " Webot Simulation" software to manufacture a virtual robot from the structure, sensors, and a camera, and we create a environment that is represented in the university, including the Department of Civil Engineering, the Department of Electronics and the Department of Physics, and the trees that surround them. All this in order to put the robot in a semi-real form after putting programming on it, we put on the road some traffic signs that help it to navigate and distance sensors to avoid obstacles .

- **In the fourth chapter**: we will provide a justification for choosing the Raspberry Pi 4 card By explaining its importance and advantages instead of the other card and placing a general identification RPI 4 , Then we talk about a hardware improvement our POB-bot by including new sensor for navigation and implemented on AI-algorithm for traffic signs detection, we test the efficacy of add sensor : accelerometer and distance sensor

- **In the fifth chapter :** are present the hardware define and software algorithm that we used on RPI-bot , tests was made and explained in this chapter

- **conclusion:** we present a general summary of the experiments with a mention of the result , And we offer a proposal about the improvements that we can make to the robot.

1.3 Previous works :

We made a search on our project and we selected some of them, this is the main interested ones :

N° 1 in 2020 , Institute Of Engineering & Technology Vijayapura, VTU Belgavi, Karanataka, India . work for project Brain Computer Interface Based Robotic Car Using Raspberry Pi used Brain Sense which is workings under the standards of BCI. The Brain-Computer Interface It communicates with the Raspberry Pi via Bluetooth , The Raspberry Pi which will comes with built-in Bluetooth, so that it does not require for an exterior Bluetooth. once the system turn ON ,the wheel-chair start its movement, at this position by having one eye-blink, wheel-chair will turn to left direction and when two-blink is discovered the direction of the wheelchair is turned to right . If it recognizes for some abnormal blink of eyes then at that the wheel-chair will stops as a result [1].

N° 2 in 2022 , Department of Mechatronics, University of Debrecen, Debrecen 4028, Hungary . Work for project ' Self-Driving robotic car utilizing image processing and machine learning ' they've searched for an outdoor navigation for mobile robots using embedded system represented by a Raspberry Pi 3 which serves as the image processing and machine learning unit using OpenCV2 library with C++ programming, Raspberry Pi are analyze the images and will send binary signals to the Arduino UNO to control the direction and speed of the dc motors [2].

N°3 in2022, AMC Engineering College Banglore,India . Work for project ' Automated Guided Vehicle for Surveillance ' by Akash M, Srinivas K, S A Rohith Kumar, Swetha Rani L, Srinivas G N , they create a structure of wireless control of cars to transport more efficiently by using the phone , this is to use the camera and connect it with the phone to control the motors of car [3].

N°4 in 2020 , University Visvesvaraya College of Engineering, Bengaluru, India , work for project ' Self-Driving Car Model using Raspberry Pi ' by B P Harish and Ms. Pratibha I Golabhavi , This invention is a prototype of a low-cost car using primary tools , Connecting cameras with the mind to analyze the traffic light by colors , Ultrasonic sensor installed on the front detects and overcomes small objects and calculates its distance from the object dynamically , the IR sensor mounted on the left detects the object, car should move right and vice versa [4].

1.4 Table of some applications which have been done about this topic so far :

N°	Place	Hardware	Capture	software	Conclusion
1	Karanataka, India [1]	• Raspberry Pi • Robot chassis (Motor, Driver IC) • HDMI display screen	• Ultrasonic • Mind-wave mobile or Brain sense	• Raspbian OS • SD card Formatter	used Brain Sense which is workings under the standards of BCI , send the signal to raspberry pi that worked with a system Raspbian OS to control the wheelchair
2	University of Debrecen 4028, Hungary [2]	• Embedded system (Raspberry Pi 3 B+) • Microcontroller (Arduino UNO) • Power supplies	• Ultrasonic sensors • MIPI CSI-2 camera • proximity sensors	• Raspbian OS • Communication between Raspberry Pi and Arduino • OpenCV library	We use the camera connected with the raspberry to analyze the images , OpenCV library . output of the system is four binary signals sent to the Arduino UNO to control the rotation direction and the speed of the DC motors.
3	AMC Engineering College. Banglore,India [3]	• Arduino UNO • Servo Motors • Motor Driver (L293D, L298N) • ESP32cam • Micro SD	• Ov2640 camera	• Microcontroller Integrated DevelopmetEnvironmet (MICDE) • Arduino IDE	At first they must connect esp 32 with pc and program it , Using wifi for send images and pluethooth to control the rotation and speed of the motor

4	AMC Engineering College. Banglore,India [4]	• Embedded system (Raspberry Pi 3 B+) • Power supplies	• Accelerometr sensor • *infrared sensor* • Ultrasonic sensors • webcam	• OpenCV library • Raspbian OS • Deep Neural Network (DNN) • MobileNet-SSD • Traffic Light Detection System (TLDS)	web camera starts capturing the video and is sent to Raspberry Pi controller , The controller processes the traffic lights detection algorithm , If any color is detected is red ,car stops ,yellow is detected, car moves bit forward and stops , green color is detected, the car moves forward.

Table-1.1 applications about topic

based on these project ,we ejected our POB-bot by testing some sensor necessary for autonomous navigation outdoor

1.5 Problematic :

We would like to improve the POB-bot a self-driving robot, This robot does not have enough sensors , that means processor is an 'Arm' , low power campsite and low quality.

Our goal is to add sensors to the existing Pob-Bot platform. We must find a solution for how to enter the sensors needed for a robot so that can read traffic signs and add a distance sensor to avoid accidents and an accelerometer sensor. The robot must send the images captured by the camera to the computer, using a wireless connection.

We encountered many shortcomings which are:

- less memory space
- Camera quality located in POB-EYE (black and white camera)
- Ports are limited to increase sensors
- can't read complex AI algorithms because is limited on process memory
- Bluetooth and Wi-Fi are not available
- It does not contain a USB port

CHAPTER N°02 :

Artificial intelligence and Machine learning

2.1 Artificial Intelligence (AI) :

the word artificial intelligence has played a very prominent role, and of late, this term has been gaining much more popular due to the recent advances in the field of artificial intelligence and machine learning. Robotics and integration with the Internet of things devices have made machines think and work on a whole new level where they outsmart humans with their cognitive abilities and smartness. They have been known to learn, adapt and perform in a much faster way than what humans are supposed and programmed to do. In this chap, we are going to present about the vast importance of artificial intelligence [12].

2.1.A Importance of Artificial Intelligence AI:

These machines tend to speed up your tasks and a process along with a guaranteed level of precision and accuracy, and therefore this is what makes them a useful and important tool. Apart from making the world an error-free place by their simple and everyday techniques, these technologies and applications are not only related to our general and everyday lives. It is also impacting and holds importance for other domains as well.

2.1.B Uses of Artificial Intelligence :

- **In the field of Medical Sciences** [5]

Fig-2.1 AI in Medical Sciences

Artificial intelligence (AI) plays an increasing role in healthcare. It can automate repetitive tasks and help doctors to better diagnose certain cancers. Will AI soon be able to do diagnostics and predictions for disease and treatment which go beyond human's capacities

- **In the Field of Gaming and Entertainment** [6]

Fig-2.2 AI in Gaming and Entertainment

Until recently, the kind of self-learning AI — namely, the Deep Learning subset of the Machine Learning revolution — that has led to advances in self-driving cars, computer vision, and natural language processing has not entirely stepped foot into the commercial game development.

- **In the Field of Industry** [7]

Fig-2.3 AI in Industry

Artificial intelligence has brought in a new generation of robotics technology: Robotics 2.0. The principal challenge is the transformation from original manual programming methods to True autonomous learning. Faced with this challenge for innovation in AI robotics.

- **In the Field of Military** [8]

Fig-2.4 AI in Military

There are four major application areas for AI technology in the military: logistics, reconnaissance, cyberspace, and warfare.
In the first three areas, advanced AI applications are already in use or being tested. AI is helping to optimize logistics chains, predict needed maintenance, find vulnerabilities in software, and combine vast amounts of data into actionable information.
Artificial intelligence is therefore already having an impact on military operations. But the fighting itself is still primarily carried out by humans.

2.2 Machine learning (ML):

Machine learning (ML) is the subset of artificial intelligence (AI) as we see in the figure (Fig-2.5) where the machines are responsible for ending daily chores and are believed to be smarter than humans that focuses on building systems that learn—or improve performance—based on the data they consume. Machine learning and AI are often discussed together, and the terms are sometimes used interchangeably, but they don't mean the same thing. An important distinction is that although all machine learning is AI, not all AI is machine learning [11].

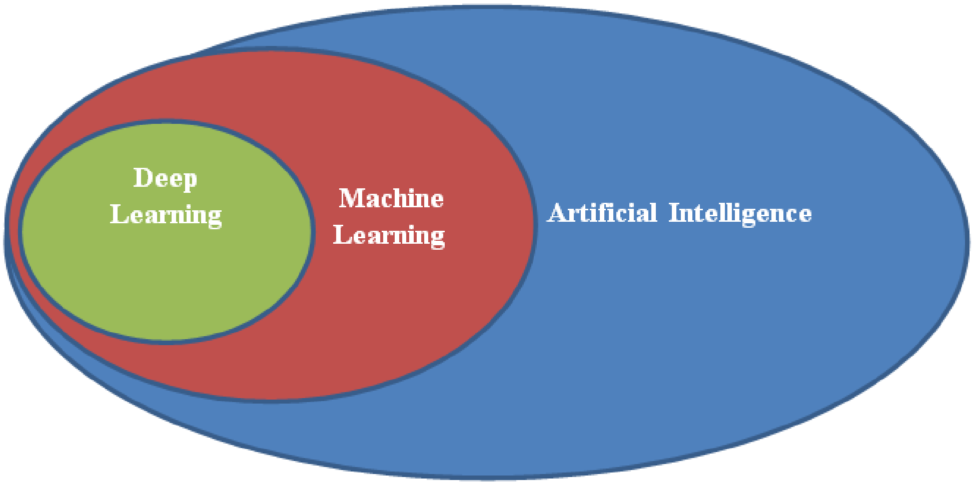


Fig-2.5 Machine learning

2.2.A machine learning work

Machine learning algorithms are molded on a training dataset to create a model. As new input data is introduced to the trained ML algorithm, it uses the developed model to make a prediction.

2.2.B Block diagram of machine learning :

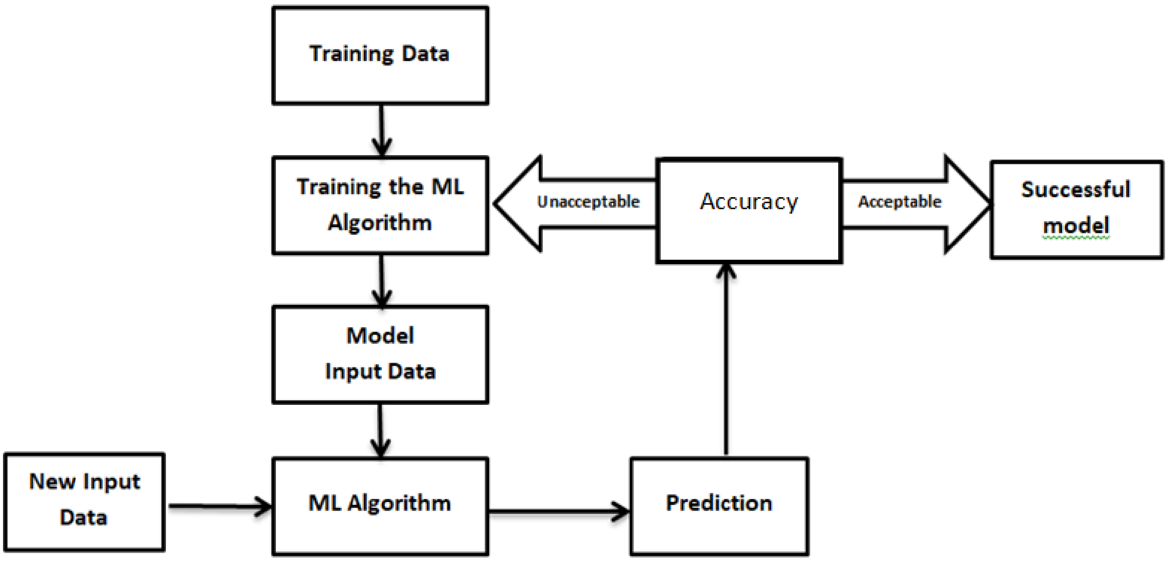


Fig-2.6 Block diagram of machine learning

2.2.C Advantages and Disadvantages of machine learning :

Advantages	Disadvantages
• Automation of Everything • Wide range of Applications • Scope of improvement • Efficient Handing of data • Best of education	• Possibility of high error • Algorithm selection • Data acquisition • Time and space

Table-2.1 Advantages and Disadvantages of machine learning

2.2.D some state of the art of machine learning [15]:

- **Linear Regression**

Linear regression analysis is used to predict the value of a variable based on the value of another variable Figure 3.1 shows the linear regression estimate to sales from TV ad spending using the the advertising data. The blue line is the linear regression fit found by least squares and has parameter values.

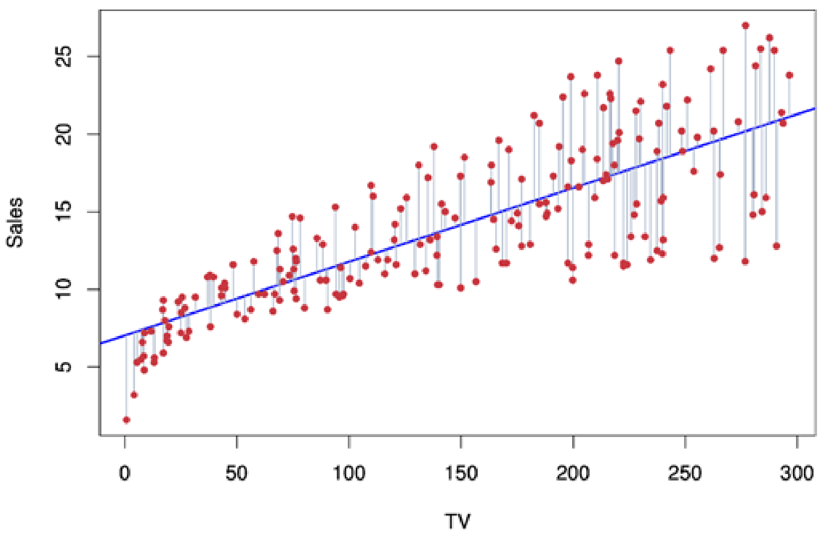


Fig-2.7 Linear Regression

- **Decision Tree**

Decision Tree algorithm in machine learning is one of the most popular algorithm in use today, this is a supervised learning algorithm that is used for classifying problems. It works well in classifying both categorical and continuous dependent variables. This algorithm divides the population into two or more homogeneous sets based on the most significant attributes/ independent variables.

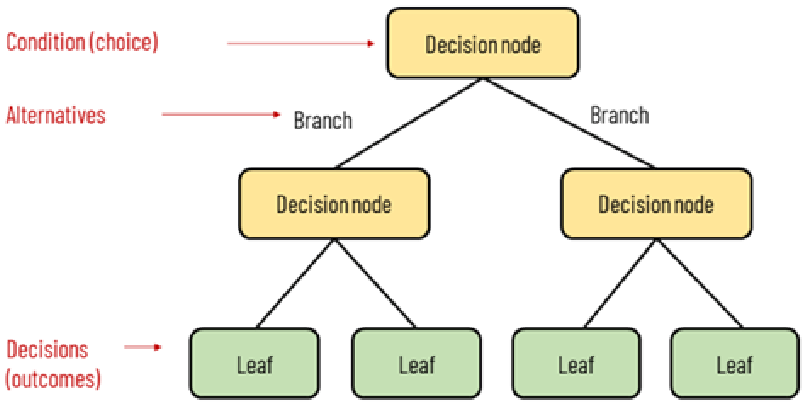


Fig-2.8 Decision Tree

- **SVM (Support Vector Machine) Algorithm**

SVM algorithm is a method of a classification algorithm in which you plot raw data as points in an n-dimensional space (where n is the number of features you have). The value of each feature is then tied to a particular coordinate, making it easy to classify the data. Lines called classifiers can be used to split the data and plot them on a graph.

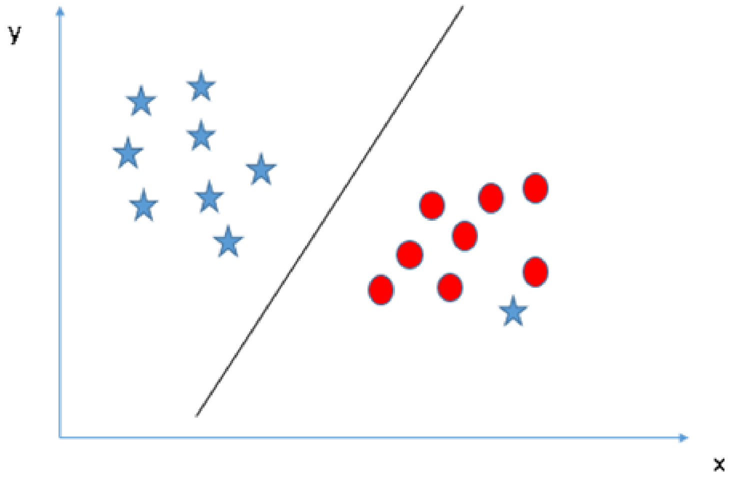


Fig-2.9 SVM Algorithm

- . **KNN (K- Nearest Neighbors) Algorithm**

This algorithm can be applied to both classification and regression problems. it's more widely used to solve classification problems. It’s a simple algorithm that stores all available cases and classifies any new cases by taking a majority vote of its k neighbors. The case is then assigned to the class with which it has the most in common.

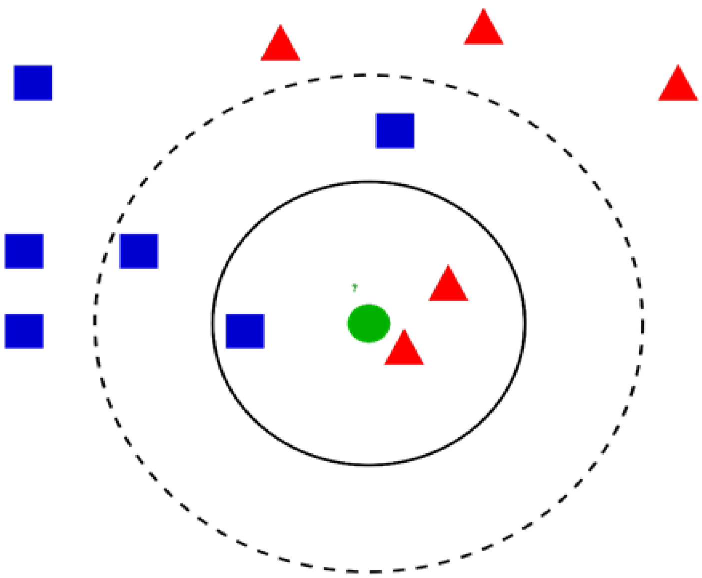


Fig-2.10 KNN Algorithm

- **K-Means**

It is an unsupervised learning algorithm that solves clustering problems. Data sets are classified into a particular number of clusters (let's call that number K) in such a way that all the data points within a cluster are homogenous and heterogeneous from the data in other clusters.

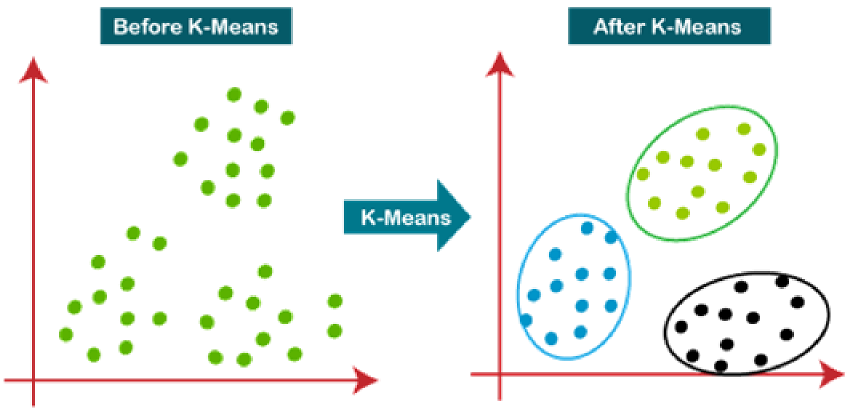


Fig-2.11 k-Means Algorithm

2.3 OpenCV

OpenCV is a library of programming functions mainly for real-time computer vision. Originally developed by Intel. OpenCV supports a wide variety of programming languages like Python, C++, Java, etc. It can process images and videos to identify objects, faces, or even the handwriting of a human. When it is integrated with various libraries, such as Numpy which is a highly optimized library for numerical operationsThen the number of weapons in your arsenal increases, that is, the operations one can do in Numpy can be combined with OpenCV [13].

2.3.A What can you do with OpenCV?

Using OpenCV, you can pretty much do every Computer Vision task that you can think of. Real-life problems require you to use many blocks together to achieve the desired result. So, you just need to understand what modules and functions to use to get what you want. Let's understand what OpenCV can do out of the box.

2.3.B Advantages and Disadvantages of OpenCV :

Advantages	Disadvantages
• Plus 30 Frames per second • High accuracy • Supports many languages • Well optimized • Runs on all possible unit	• Memory management • Rather difficult to use • Does not have its own editor

Table-2.2 Advantages and Disadvantages of OpenCV

2.3.C Computer Vision

The term Computer Vision (CV) is used and heard very often in artificial intelligence (AI) and deep learning (DL) applications. The term essentially means giving a computer the ability to see the world as we humans do.

Computer Vision is a field of study which enables computers to replicate the human visual system. As already mentioned above, It’s a subset of artificial intelligence which collects information from digital images or videos and processes them to define the attributes. The entire process involves image acquiring, screening, analyzing, identifying and extracting information. This extensive processing helps computers to understand any visual content and act on it accordingly.

Computer vision projects translate digital visual content into explicit descriptions to gather multi-dimensional data. This data is then turned into a computer-readable language to aid the decision-making process. The main objective of this branch of artificial intelligence is to teach machines to collect information from pixels. [9]

Fig-2.12 Computer Vision

2.3.D Computer image

we are probably looking for different shapes and colors in the image and this may help we determine that this is an image of a robot. But does the computer also see it the same way? The answer is no.
A digital image is an image composed of picture elements, also known as pixels, each with finite, discrete quantities of numeric representation for its intensity or grey level. So the computer sees an image as numerical values of these pixels and in order to recognize a certain image, it has to recognize the patterns and regularities in this numerical data.

Here is a hypothetical example (Fig-2.13) of how pixels form an image. The darker pixels are represented by a number closer to the zero and lighter pixels are represented by numbers approaching one. All other colors are represented by the numbers between 0 and 1. [10]

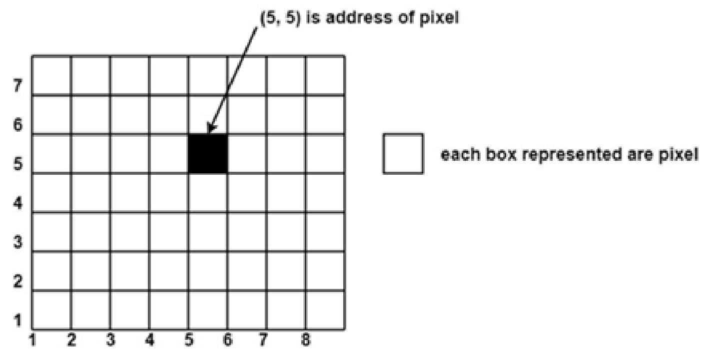


Fig- 2.13 Image Pixels

But usually, we find that for any color image, there are 3 primary channels – Red, green and blue and the value of each channel varies from 0-255. In more simpler terms we can say that a digital image is actually formed by the combination of three basic color channels Red, green, and blue whereas for a gray scale image we have only one channel whose values also vary from 0-255.

2.3.E Object Tracking:

Object tracking is a computer vision application where a program detects objects and then tracks their movements in space or across different camera angles. Object tracking can identify and follow multiple objects in an image.

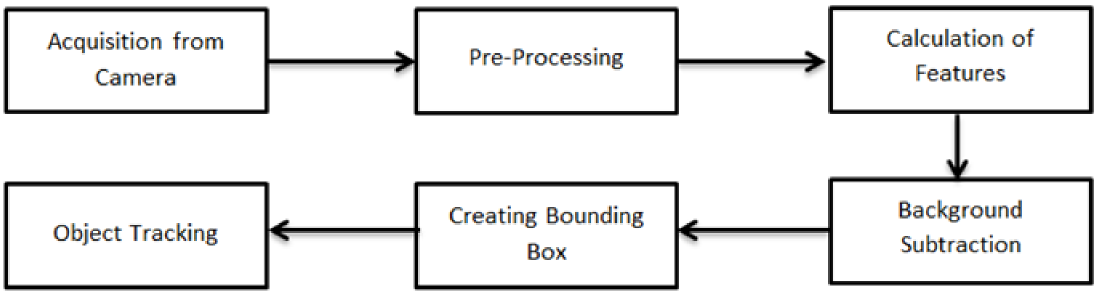


Fig-2.14 Block diagram of object tracking [16]

2.4 In-built data structures on OpenCV :

One of the best things about OpenCV is that it provides a lot of in-built primitives to handle operations related to image processing and Computer Vision. If you have to write something from scratch, you will have to define things, such as an image, point, rectangle, and so on. These are fundamental to almost any Computer Vision algorithm. OpenCV comes with all these basic structures out of the box, and they are contained in the core module. Another advantage is that these structures have already been optimized for speed and memory.
The image codecs module handles reading and writing image files. When we operate on an input image and create an output image, we can save it as a jpg or a png file with a simple command. We are dealing with a lot of video files when we are working with cameras. The video module handles everything related to the input/output of video files. We can easily capture a video from a webcam

or read a video file in many different formats. We can even save a bunch of frames as a video file by setting properties such as frames per second, frame size, and so on.

2.4.A Image processing :

When we write a Computer Vision algorithm, there are a lot of basic image processing operations that we use over and over again. Most of these functions are present in the image processing module. we can do things such as image filtering, morphological operations, geometric transformations, color conversions, drawing on images, histograms, shape analysis, motion analysis, feature detection, and so on.

Her is example of histogram of RGB design robot:

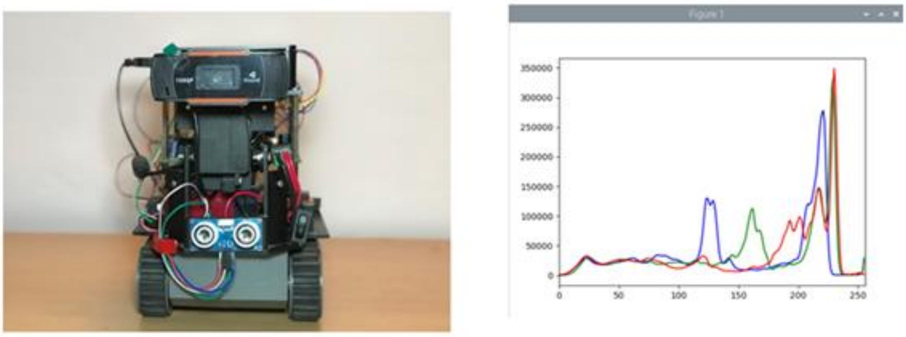


Fig-2.15 Image RGB with Histogram

Example of histogram of black and white design robot:

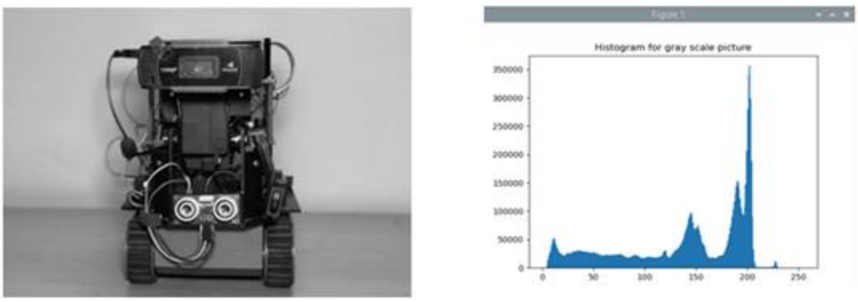


Fig-2.16 Image black and white with Histogram

We can do this transformation with a single line in OpenCV. There is another module called Ximgproc that contains advanced image processing algorithms such as structured forests for edge detection, domain transform filters, adaptive manifold filters, and so on.

2.4.B Object detection application on traffic sign:

Object detection refers to detecting the location of an object in a given image. This operation is not related to the type of the object. If you design a traffic light detector, it will only tell you the location of the sign in a given image. It will not tell you whether the sign indicates that there is a certain danger or something else. Detecting the location of objects is a very critical step in many computer vision systems.

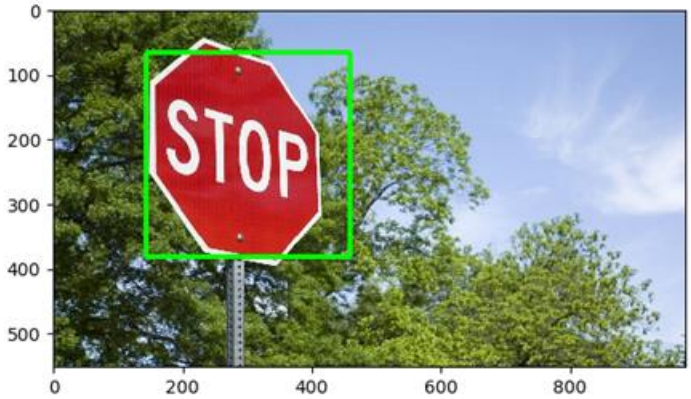


Fig-2.17 Detect traffic signs [18]

2.4.C Image Segmentation:

We can divide or partition the image into various parts called segments. It’s not a great idea to process the entire image at the same time as there will be regions in the image which do not contain any information. By dividing the image into segments, we can make use of the important segments for processing the image. That, in a nutshell, is how image segmentation works. An image is a collection or set of different pixels. We group together the pixels that have similar attributes using image segmentation.

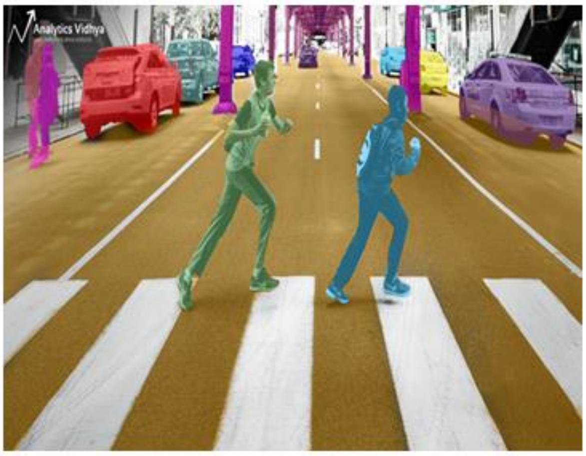


Fig-2.18 Road segmentation to Detect persons and lines [17]

2.6 Conclusion :

Artificial intelligence has become of great importance in human life, as it provides improvements and assistance in performing difficult tasks in all fields and leads to transformative applications within a series of industrial, intellectual and social applications. Artificial intelligence has proven to outperform human decision-making in certain areas.
the next chapter we will do on efficacy mobile robot structure called "webots" to simulate the navigation of Pob-bot in outdoor and get to read traffic signs

CHAPTER N°03 :

Webots

Presentation and Simulation

3.1 Introduction:

Before implementation of prospection sensors and raspberry pi on the Pob-Bot robot we need to simulate the situation using Webots.

Webots is an open source and multi-platform desktop application used to simulate robots. It provides a complete development environment to model and program simulate software for mobile robots.

It has been designed for **a** professional use**,** and it is widely used in industry , education and research. Cyber robotics Ltd. maintains Webots as its main product continuously since 1998 [19].

Furthermore. It helps us to learn programming to avoid many mistakes. Also it's simpler to correct and detect problems before implementing the code in a real robot for a real application.

Finally We simulated a mobile robot navigate outdoors in a university environment. Besides, we will use the camera to avoid obstacles and read the traffic signs.

3.2 The simulation:

3.2.A The environment university :

In this environment, we designed the exact plan for the university of Badji Mokhtar Annaba environment (cars, departments, directional signals, people...), As we can see in these Fig-3.1

Fig-3.1 the center of the university on 3D

3.2.B Design of the Robot:

the tool allows as to define a mobile robot and add sensor on it, we propose a design similar to real robot

- The robot has two distance sensors (right and left) that detect obstacles by calculating the distance between the robot and the obstacle, then by programming we can avoid this obstacle.

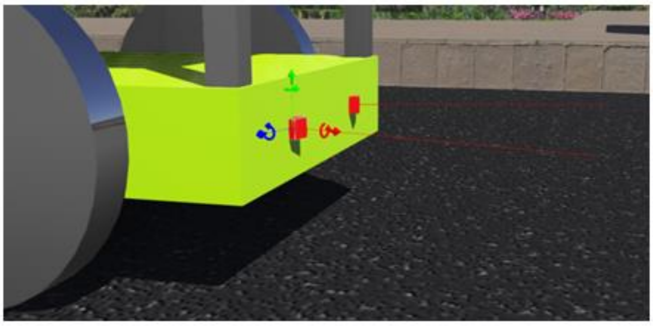


Fig3.2 two distance sensors DS and DS2

- There a cameras installed on the top of the robot ,This camera takes pictures of the traffic signs, after analyzing the image, it will direct the robot according to the traffic signs

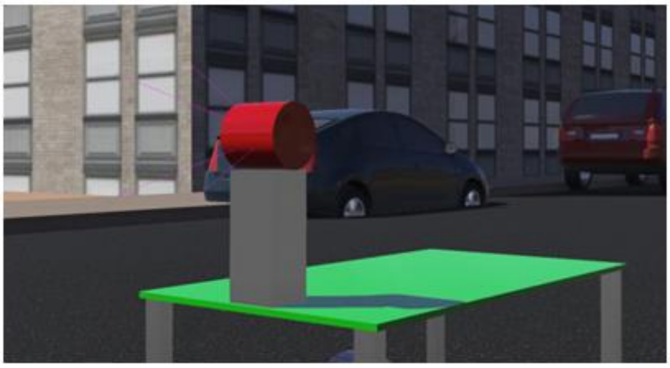


Fig-3.3 web camera installed in the robot

- There are four dc motors installed at the bottom of the robot , These wheels help the robot move through programming on different direction

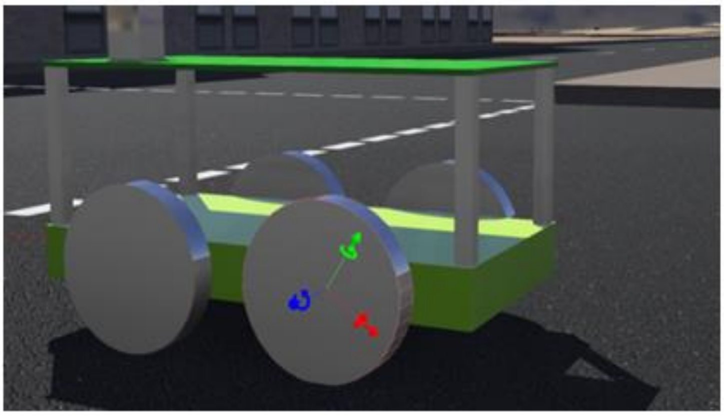


Fig-3.4 tow wheels with dc motor

3.2.C Simulation Phase

- We considered the Department of civil engineering as a starting point , where the robot (POB-BOT) will pass several traffic signs and obstacles that it must avoid and read traffic signs the robot reaches the end line at the physics department .

Fig-3.5 the first point where our robot start navigating is in fron
Of the civil engineering department

As we can see in the picture, there are many cars , traffic signs and obstacles .

- In the middle of the path that our mobile robot will travel, we see how the robot Turn to the left and sensors calculate the distance to keeps the robot on the right path and avoids obstacles .

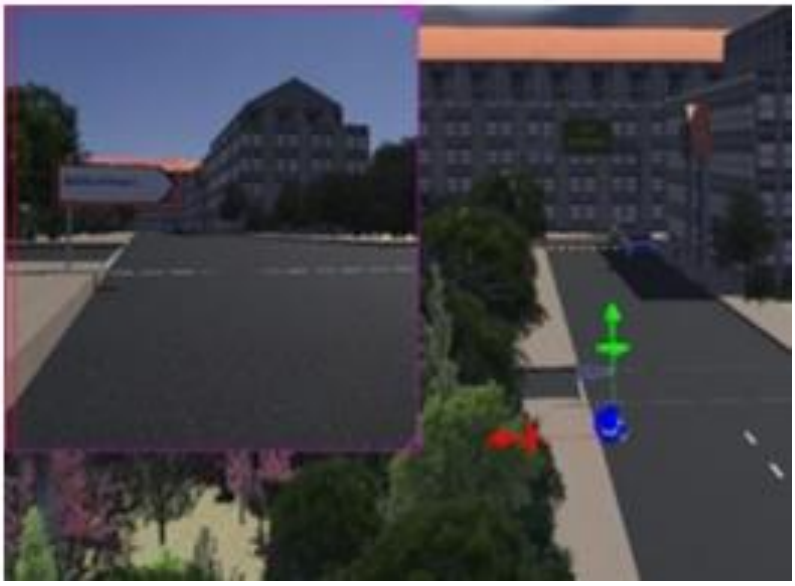


Fig-3.6 robot camera read Library traffic sign

- In the next stage, we see the robot camera have taken picture of the traffic sign ‘stop’ located before the pedestrian lane .

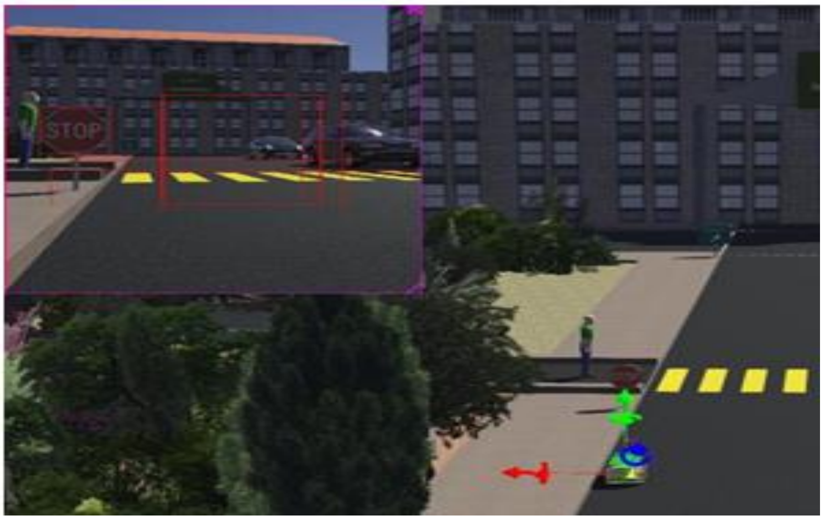


Fig-3.7 robot camera read STOP traffic sign

The robot must stop for 5 seconds and then complete the path without forgetting that the distance sensors avoid obstacles and keep the robot on the right path .

- before the end, we see that the robot takes a picture through the camera installed on it of traffic sign written on it Exit with the arrow .

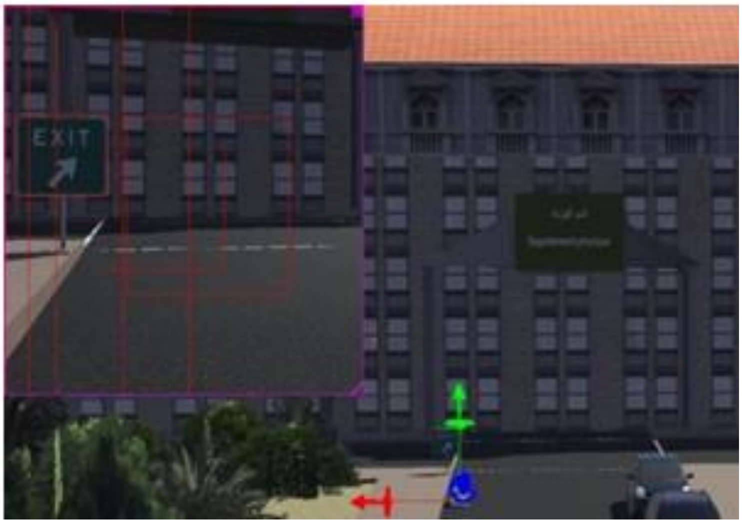


Fig-3.8 robot camera read Exit traffic sign

Here the robot must stop for a few seconds and then turn according to the direction of the signal to exit .

- In the end, we put a cardboard box in the middle of the road , as shown in the picture , to see how the distance sensors work .

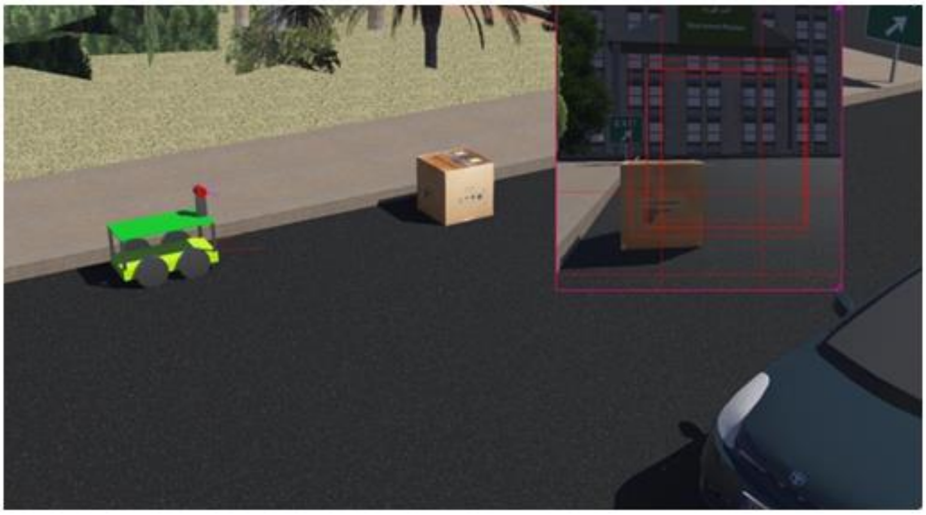


Fig-3.9 the robot sensor avoid Box

In this case, the distance sensors must order the wheels to stop moving when the safe distance is reached to avoid an accident .

3.3 Conclusion :

In this chapter we have seen an interesting Webots 3D simulator that facilitate for us to design and simulate our project.

Besides it have helped us to make the exact plan of our University for the Department of electronics , Department of civil and Department of physics .

Moreover, we have made a robot (POB-BOT) with two sensors that calculate the distances between obstacles and robot , made a body for a robot with camera that help it read traffic light .

Then we have written a program that secure our mobile robot's navigation in University environments and keeps our robot still in the right path and avoids any type of obstacle that it may face along the way.

Finally , the robot travels long distances without the need for assistance , using camera to read traffic light and avoid obstacles through the distance sensor .

CHAPTER N°04 :

Robot design

as we mentioned in the beginning, the POB-bot is limited hardware and process memory, We decided to use the Raspberry pi 4 Model B in this project instead of the POB-EYE for Many reasons

4.1 Raspberry pi presented:

Raspberry Pi is a series of small single-board computers (SBCs) developed in the United Kingdom by the Raspberry Pi Foundation in association with Broadcom.

4.1.A Why Raspberry pi 4 Model B ? [20]

The Raspberry Pi 4 Model B (Pi4B) is the first of a new generation of Raspberry Pi computers supporting more RAM and with significantly enhanced CPU, GPU and I/O performance; all within a similar form factor, power envelope and cost as the previous generation Raspberry Pi 3B+.

This module is available with variants of RAM including 1GB, 2GB, 4GB and 8GB which you can select based on your requirements. The RAM temporarily stores the information and with the removal of the power supply from the module, this memory is also wiped off, the reason it is called volatile memory

.

4.1.B Hardware properties of RPI 4 model B:

- Quad core 64-bit ARM-Cortex A72 running at 1.5GHz
- 1, 2 and 4 Gigabyte LPDDR4 RAM options
- H.265 (HEVC) hardware decode (up to 4Kp60)
- H.264 hardware decode (up to 1080p60)
- Video Core VI 3D Graphics
- Supports dual HDMI display output up to 4Kp60

4.1.C Interfaces:

- 802.11 b/g/n/ac Wireless LAN
- Bluetooth 5.0 with BLE
- 1x SD Card
- 2x micro-HDMI ports supporting dual displays up to 4Kp60 resolution
- 2x USB2 ports
- 2x USB3 ports
- 1x Gigabit Ethernet port (supports PoE with add-on PoE HAT)
- 1x Raspberry Pi camera port (2-lane MIPI CSI)
- 1x Raspberry Pi display port (2-lane MIPI DSI)

- 28x user GPIO supporting various interface options:
- Up to 6x UART, Up to 6x I2C, Up to 5x SPI
- 1x SDIO interface , 1x DPI (Parallel RGB Display) , 1x PCM
- Up to 2x PWM channels , Up to 3x GPCLK outputs

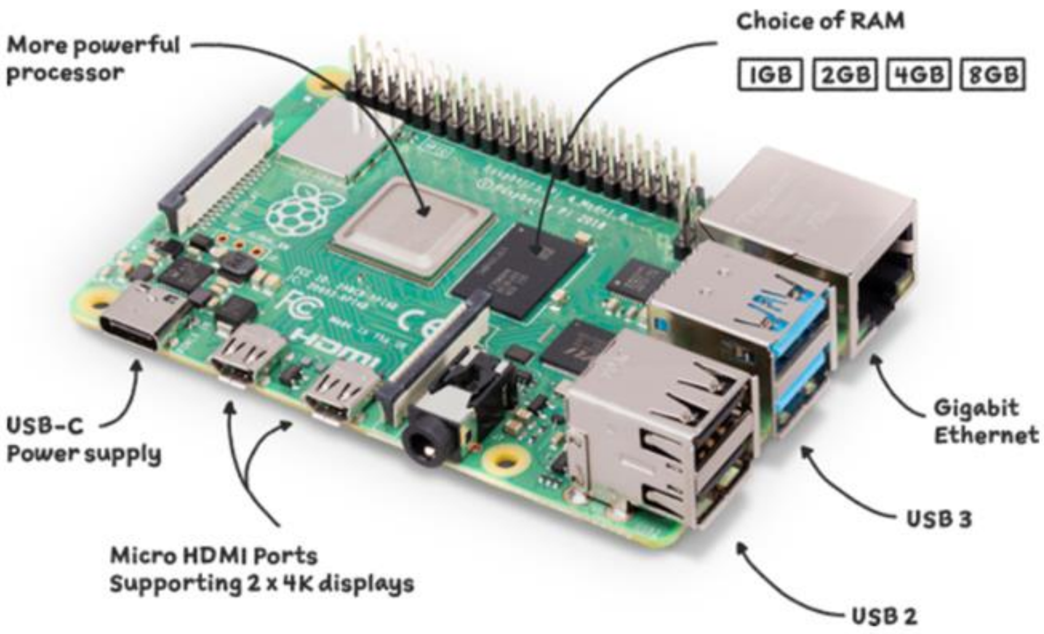


Fig-4.1 Raspberry Pi 4 Model B

4.2 Raspberry Pi OS:

Raspberry Pi OS is a Debian-based operating system specifically designed for the Raspberry Pi Single Board Computer, which was developed by the Raspberry Pi Foundation in the United Kingdom. It is an open-source software project, meaning that it is free to use, and anyone can modify its source code with the proper knowledge.

4.2.A Install Raspberry Pi OS on A Raspberry Pi 4:

We follow these stages :

- Download the Raspberry Pi Imager application on your Windows PC or mac book.
- **Run the Raspberry Pi Imager application**
- connect micro SD card to laptop
- **Choose Raspberry Pi OS Image on the Raspberry Pi**
- **Choose the Storage**
- **Write the Raspberry Pi OS image to the storage**
- connect micro SD card to the raspberry pi 4
- **Raspberry Pi OS is running on the Raspberry Pi**

4.3 raspberry pi application:

there are many application examples of Raspberry in all fields, We mention some of them:

4.3.A IOT based Anti-theft Flooring System

To secure and guard our house in our absence, we propose the IOT based Anti-theft Flooring System using Raspberry Pi. This system monitors the entire floor for movement. One single step anywhere on the floor is tracked and user is alarmed over IOT. This system is secure flooring tile connected with IOT when we go out of house, the system is to be turned on, then whoever comes inside the house it passes the information over IOT [21].

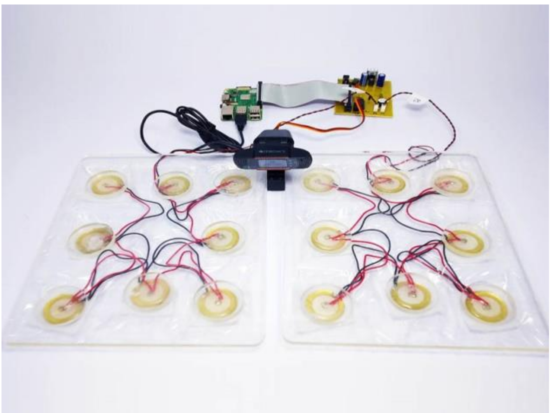


Fig-4.2 IOT based Anti-theft Flooring System

4.3.B Temperature & Mask Scan Entry System For Covid Prevention

The camera is used to scan for mask and temperature sensor for forehead temperature. The raspberry processes the sensor inputs and decides weather the person is to be allowed. In this case the system operates a motor to open the barrier allowing the person to enter the premises. If a person is flagged by system for high temperature or no Mask the system glows the red light and bars the person from entry. Also the face and temperature of person is transmitted over IOT to server for authorities to take action and test the person for covid [22].

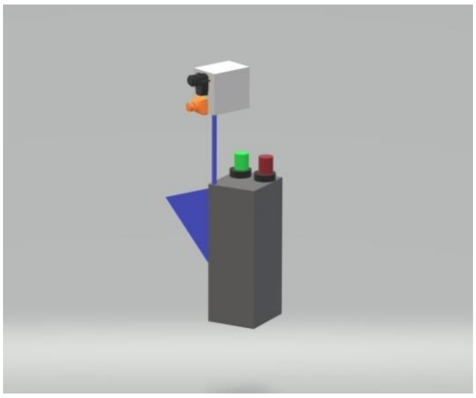


Fig-4.3 Temperature & Mask Scan Entry System
For Covid Prevention

4.4 POB-bot robot presentation [31]:

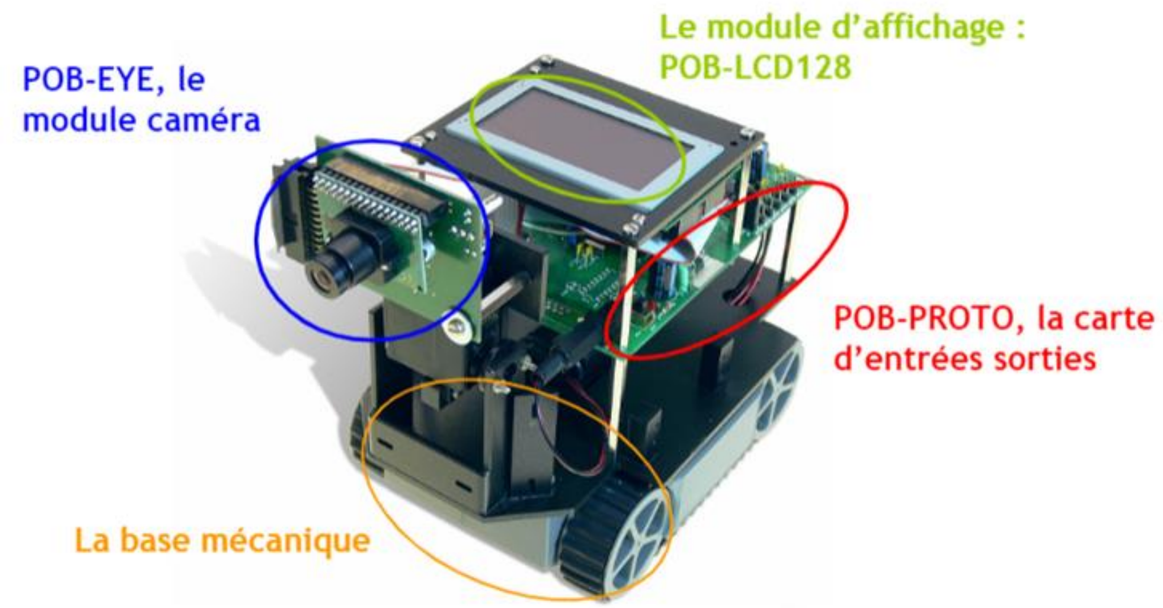


Fig-4.4 Synoptic of the Robot POB-bot

- **A POB-EYE :**

it's the intelligent color camera and a microprocessor type ARM which contains the main program that we're going to execute.

- 32-bit processor
- Color camera
- Address / data bus to control the other cards
- Reprogrammable at will
- Loading of programs by serial link

- **B POB-PROTO :**

It's a large circuit that contains the inputs and outputs such as (wheels motors, turning servomotors, head and grab servomotors and the Joystick) and that circuit allows us to add some other electronic elements such as sensors that we're going to work and manage with.

- **C POB-LCD:**

it's a graphical screen that allows us to visualize both messages and pictureswhich we receive from the camera.

4.4.A Overview about POB-PROTO

POB-PROTO was designed for the POB-EYE in order to build a robot very easily. You will find the following:

- 6 connectors to manage servomotors (Futaba)
- 1 analog joystick and its pushbutton.
- An H bridge to gear 2 DC.

On the CD in POB-PROTO folder you will find examples on how to use the POB-PROTO with all the source code needed.

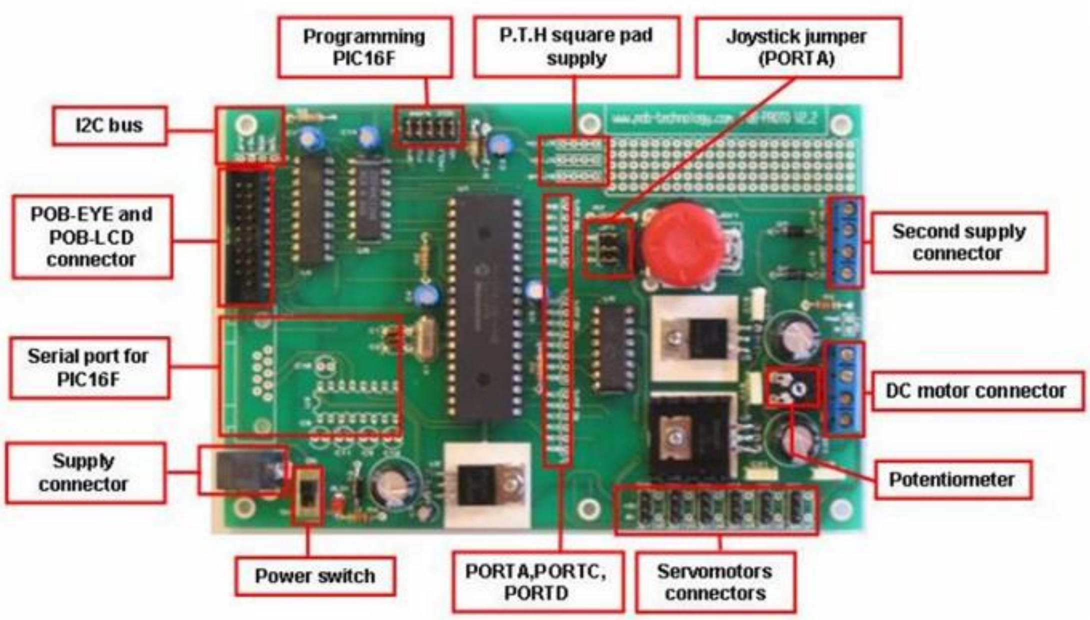


Fig-4.5 POB-PROTO description

4.4.B Board supply :

There is a supply connector on the board, make sure to use the right polarity. This connector can then supply the whole system through the POB-bus

Fig-4.6 Power Outlet

4.4.C H Bridge :

The H bridge is linked to PORTD (RD0, RD1, RD2, and RD3). It gears the 2 DC motors link to the connector block. To adjust the voltage on the motors, use the potentiometer and if needed you can use a multimeter on the test points.

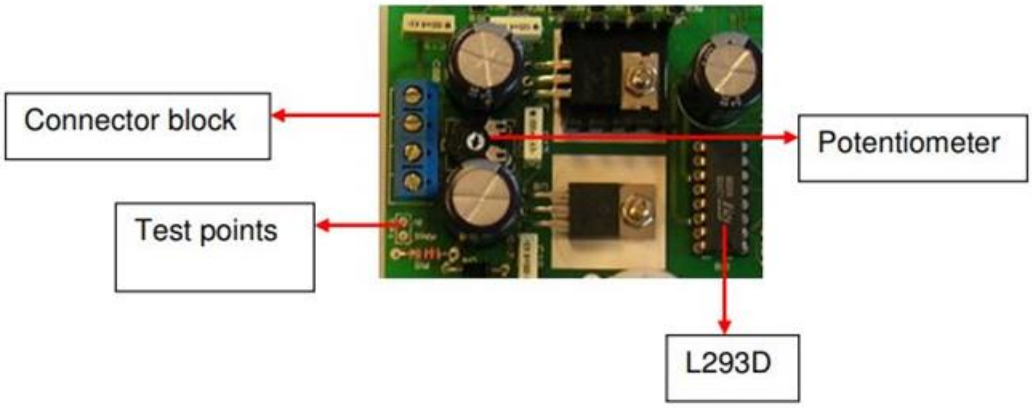


Fig-4.7 H bridge

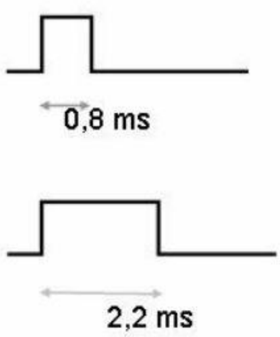
The PORTD pin can be configured independently and pins RD4, RD5, RD6, RD7 used for generic usage .

4.4.D Servomotors connectors :

The connectors are plugged to pin RC0,RC1, RC2, RC3, RC6, and RC7 of PORTC. Because nothing is plugged to these connectors, you can use it for general purpose.

Fig-4.8 Servomotors Connectors

The value to gear servomotors is between 0 and 255 :



Value 0 equal to a pulse of 0,8 milliseconds

Value 255 equal to a pulse of 2,2 milliseconds.

Fig-4.9 value to gear servomotors

4.4.E Ports of the POB-Proto :

All these ports are already used (connectors, H bridge…) by POB-PROTO. Nevertheless it is possible to unplug the existing material and use the port as wanted.

Port A :

PORTA can work in 2 modes:

- Analog input, except for RA4 which is a digital input of 0 or 255.
- Digital I/O, each pin can be configured independently.

Port C :

Each PORTC pin can be configure separately. You can use RC0, RC1, RC2, RC3, RC6 and RC7 to manage 6 servomotors.

Remarks: If the user wants to reprogram the PIC 16F877, he will then be able to use the serial port on PORTC by adding a MAX232.

Port D :

PORTD is an I/O port; every single pin can be configured separately

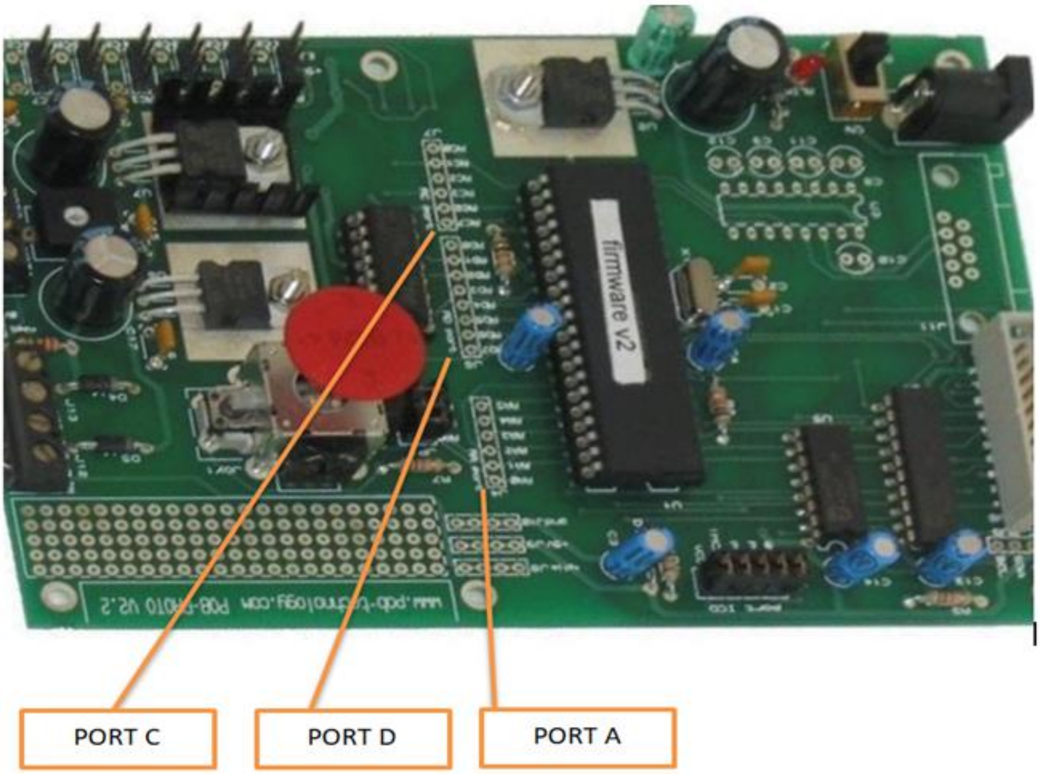


Fig-4.10 Port of the POB-Proto

4.5 Augmentations sensors for navigation:

In our project, we aim to build a self-driving robot that performs several actions without human assistance
So we added in the robot some sensors that will help the robot to navigate and read the external environment
The different sensors that we've added are:

- Ultrasonic sensor hc-sr04 : This element calculates the distance by sending the encounter, and this will help us to avoid obstacles
- MPU 6050 : This element senses movement and acceleration in all axes X,Y and Z , This helps the robot to know which planes it is moving on
- USB web camera : We used the camera to read and recognize the traffic signs, to know which direction to take

All of the previously described sensors are necessary for robot to help him for move safely in environment, we need to find how to connect them with the robot.

4.6 Solutions to retrofit POB-bot with RPI:

First we remove POB_EYE and POB_LCD It remains for us POB_PROTO is the basis We propose two methods of communication between Raspberry Pi and POB_PROTO.

A. **The first method:** using HE10 communication

A.1 HE10 Connector

we wanted to explain he10 connector, In addition to the 0V and supply voltage, the I2C bus and the 15 input/output are on the HE10 connector.

The HE10 bus allows the user to connect an extension board which communicates with the Pob-Eye.

That bus is uses parallel communication protocol. It has twenty pins that give access to the I2C bus in addition to the I/O and the alimentation pins.

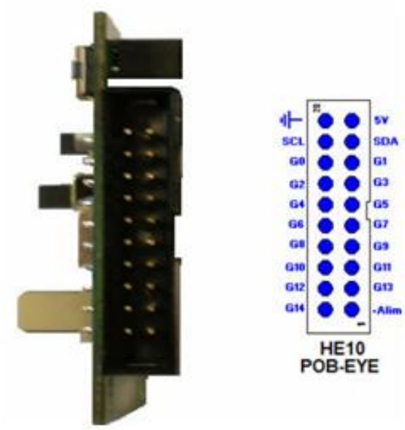


Fig-4.11 HE10 connector

A.2 POB-EYE bus

POB-Technology uses the input/output on the HE10 connector as an address and data bus.

The pins G0 to G7 are the data bus. The pins G11 to G14 are the address bus. This system makes it possible to have 16 addressable cards on the POBEYE bus.

This means it is possible to have on the same bus: cards for direct current motors, card for servomotors management or others such as distance measurements sensors.

Fig-4.12 Pins G0 to G7 of POB-EYE

To complete the bus, there are 3 other signals:

- G8 pin: « R/W » signal indicates a read/write to the peripheral. If G8 is in low state, POBEYE writes data to the extension board. If G8 is in up state, POBEYE reads data from the peripheral.
- G9 pin: « ENABLE » signal, allows signals validation on the bus.
- G10 pin: « ACK » signal, allows to know peripheral states (the peripheral is ready to communicate)

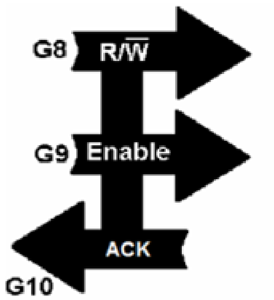


Fig-4.13 Pins G8, G9 and G10

We had to use four pins for address selection and eight for data transmission between the boards that gives the sensors information and transmit them in the bus. We should add some external integrated circuits for the address selection and data transmission.

The daughter board is an electronic circuit that contains the sensors plus other integrated circuitsthat allows us to select reading information from the sensors using one of the HE10 addresses (“74HC245” for data reading and “74HC138” for the address selection) which we’re going to talk about after.

We connect RPI with POB-PROTO via HE10-bus, This is done by connecting the Raspberry ports with HE10 ports As shown in the diagram (Fig-4.14)

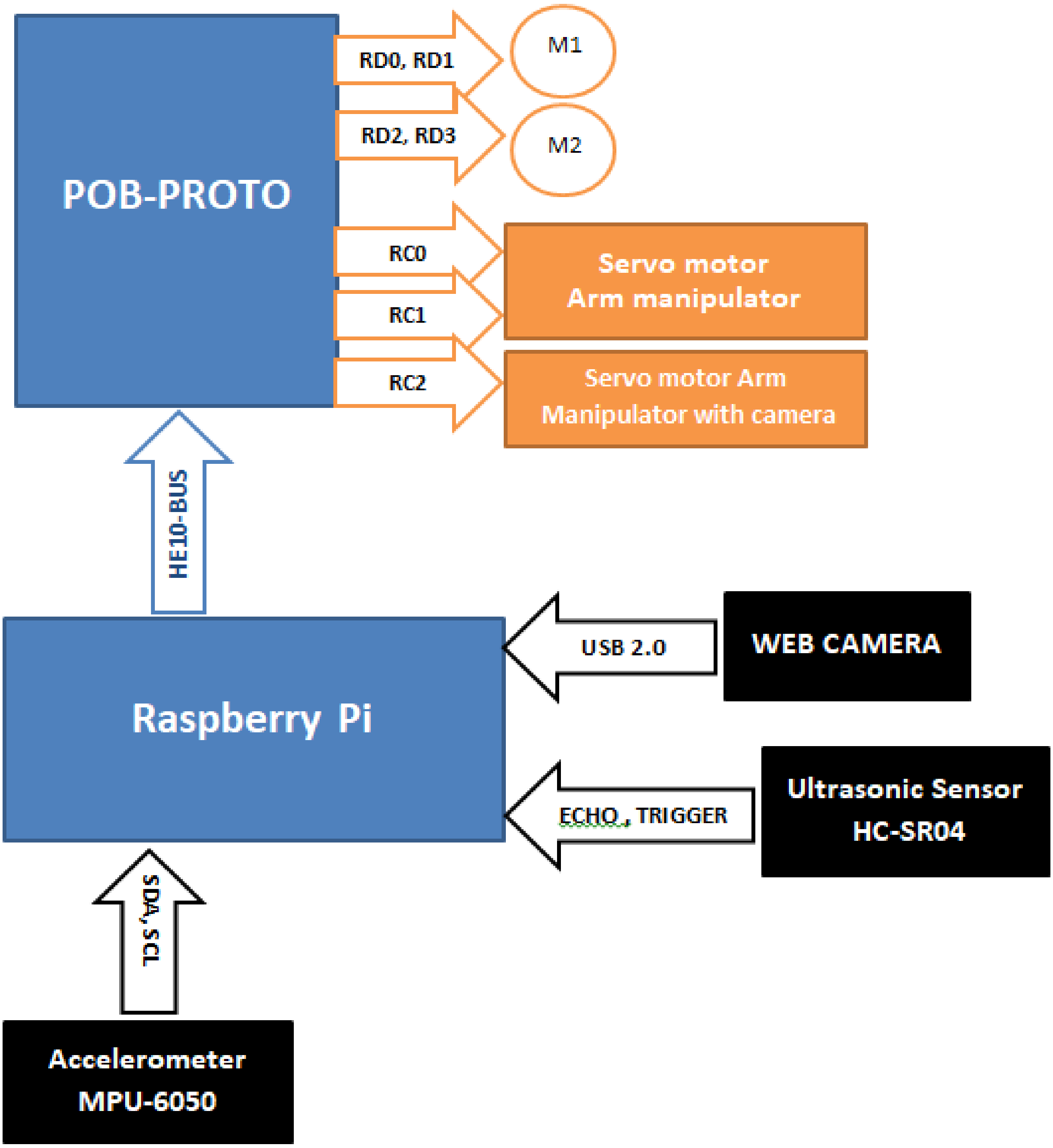


Fig-4.14 Connect RPI with POB-PROTO via HE10-bus

A.3 Conclusion: After suggesting the first method, we found a problem is the Raspberry Pi can't communicate with POP-Proto ports Because there is a mediator between them and he is Pic 16f877 which was set in order to read the data coming from Pob-Eye as we shown in the (Fig-4.12) and (Fig-4.13) , He arranges orders then he applies it according to what is programmed, In this case we cannot change the programming that works on it, For several reasons Including that it will take a long time to get to know his program how does it work and then we change it

B. The second method: After we removed a Pic 16f877 we are relate the robot sensors for Pob-Proto directly with RPI and we change the name of robot for POB-bot to RPI-bot

B.1 Connect RPI with PORT D :

Control block DC motor :

Usually for movements any robots are using 2 DC motors link to a « free » wheel. Motors control requires power electronics.

The assembly needed to POB-PROTO to control DC motors is the following:

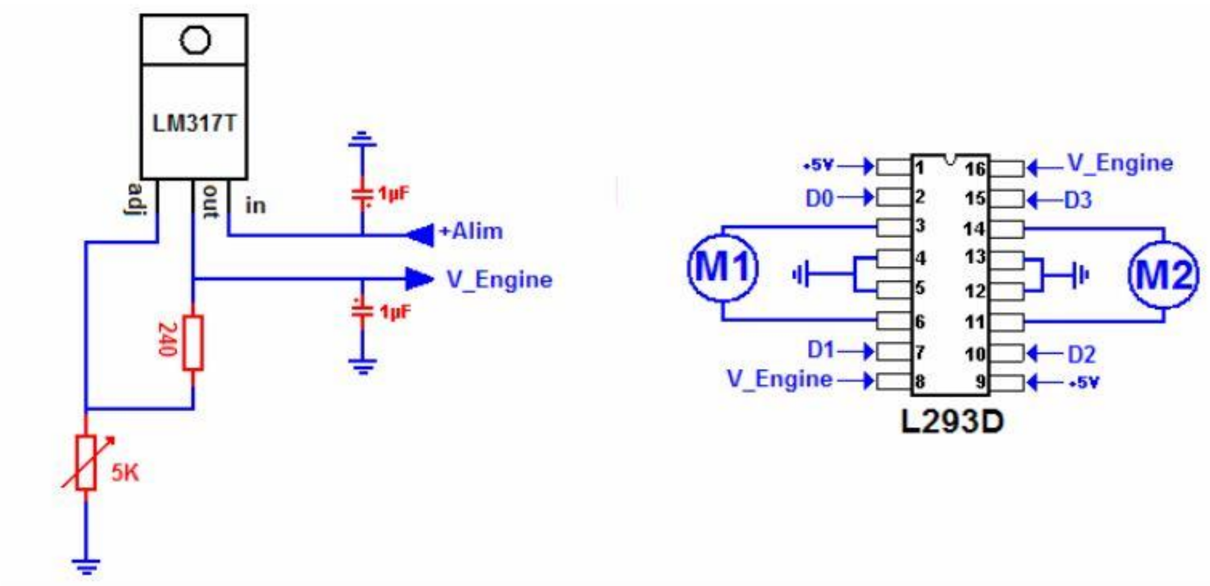


Fig-4.15 Connect RPI with Port D

This assembly was done with a L293D (double H bridge). Each motor is managed by 2 microcontroller pins. Pins D0, D1, D2, and D3 of PORTD are used to control the motors and set to output in your program.

We connects Pins for Port D to Raspberry Pi As shown in the (Tab-4.1) :

PORTD-PIC	GPIO-RPI
D0	**GPIO 5**
D1	**GPIO 6**
D2	**GPIO 13**
D3	**GPIO 19**

Tab-4.1 Connects Pins for Port D to RPI

Change the direction rotation of the wheels :

PINS –L293D				Direction of Rotation
D0	D1	D2	D3	
1	0	1	0	Forward rotation
0	1	1	0	Rotation to the right
1	0	0	1	Rotation to the left
0	1	0	1	Backwards rotation

Tab-4.2 direction rotation of the wheels

B.2 Connect RPI with PORT C :

Each pins of Port C can be configure separately, you can use RC0, RC1, RC2, RC3, RC6 and RC7 to manage 6 servomotors
In our project we need to use one servomotor as shown in the Tab-4.3 :

PORTD-PIC	GPIO-RPI
C1	GPIO 17

Tab-4.3 Connects Pins for Port C to RPI

- We use servomotor 1 connected to the body of the camera to change angle view

B.3 I2C BUS :

On the top right of the POB-PROTO board a layout was designed for the POB-EYE's I2C bus. but we don't need it , because we have I2C port on Raspberry Pi, As shown in the table 4:

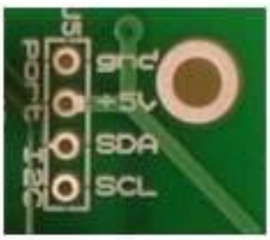


Fig-4.16 I2C Port on POB-Proto

MPU_6050	GPIO-RPI
SDA	GPIO 2
SCL	GPIO 3

Tab-4.4 Connects Pins to I2C Port

B.4 The battery solutions Proposal:

The battery is necessary to power the card of POB-Proto and Raspberry Pi for robot to be free not associated with thread, this helps him for move comfortably. we make scheme with a definition of the devices that we used.

- **LM 2596**

The lm2596 buck converter IC, it is also called a switching regulator because it controls the output voltage by switching on and off the output. the input range is limited to 7 volts to 30 volts due to the 78l05 used in the module. The rated voltage of the 220 micro farad capacitor at the input terminal is 35 volts which is also a limiting factor for the input voltage [23].

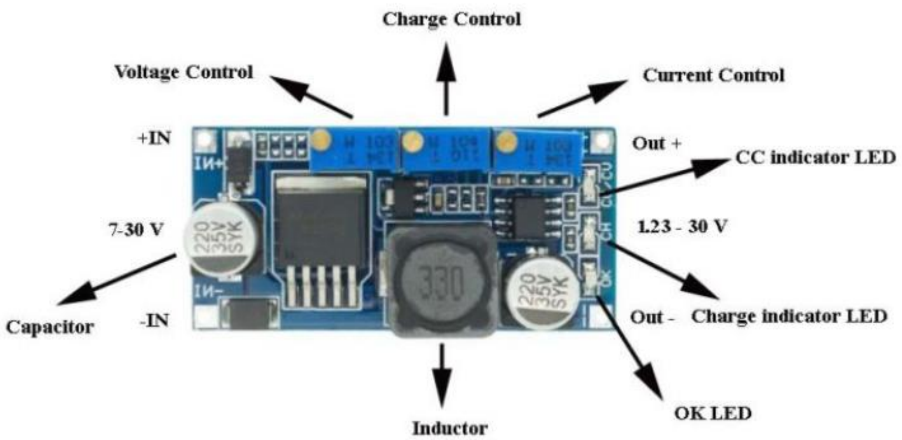


Fig-4.17 LM-2596 buck converter

We connected output of LM-2596 with USB pot, so that we can use a cable USB-USBc To give 5v to a raspberry pi

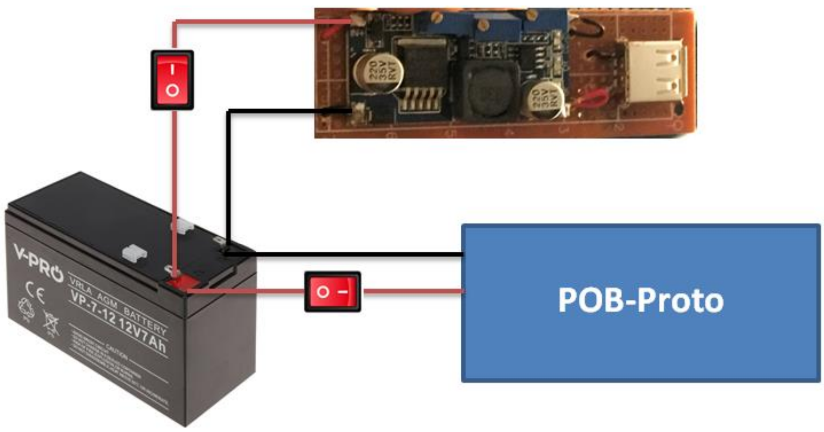


Fig-4.18 LM-2596 buck converter with USB Port

B.5 Conclusion: The problem is that POB-Proto needs 12v to work But RPI 4 needs 5v and 2,5 A to work So we decided to use a switching regulator LM-2596 Instead of using another battery to connect them of the Raspberry Pi 4.

As shown in the (Fig-4.19) we removed microcontroller pic 16f877 and we connect all the robot sensors / actuators of POB-Proto with RPI

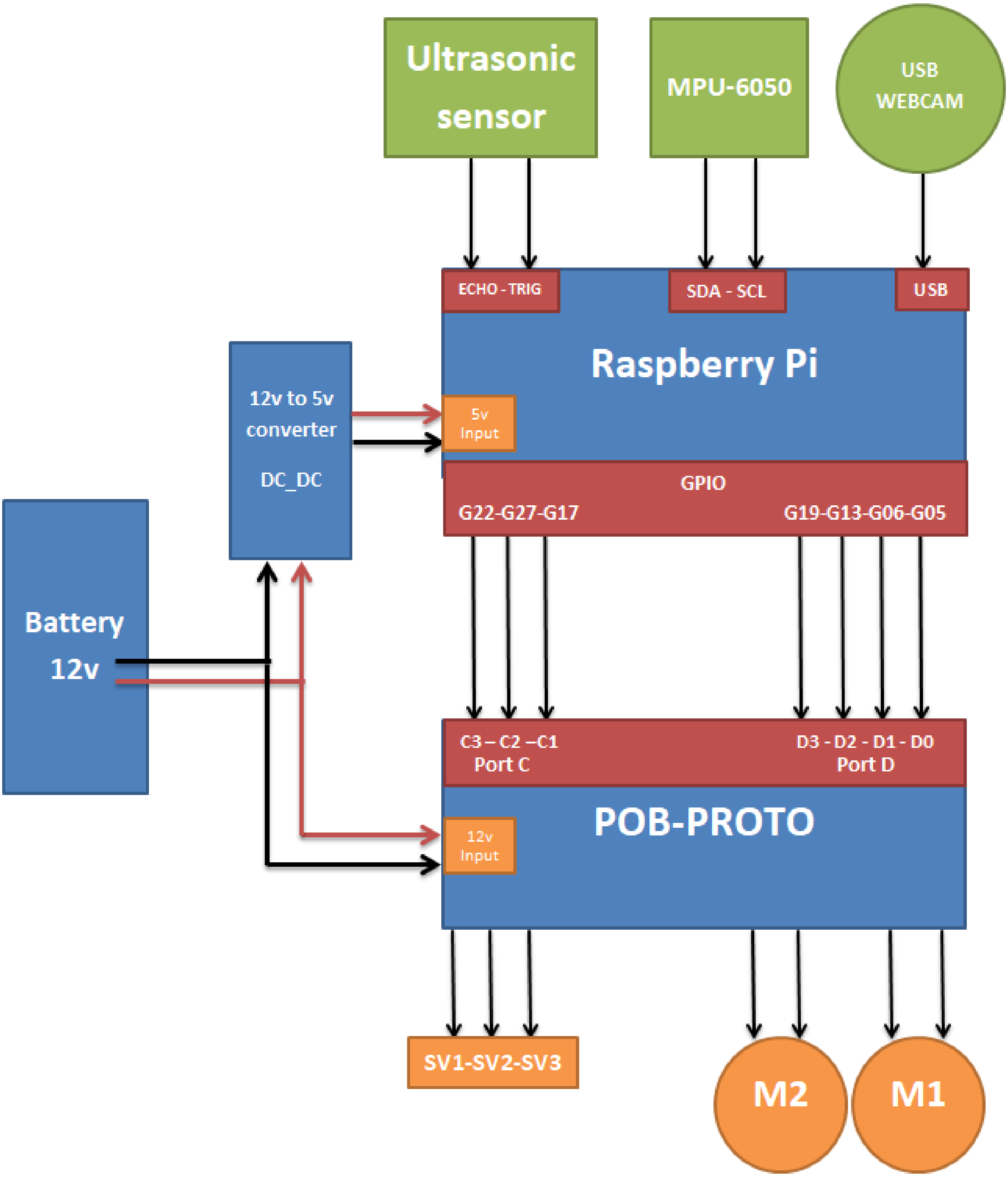


Fig-4.19 Connect RPI with POB-PROTO without pic 16f87

CHAPTER N°05 :

Hardware / Software

Test and Result

5.1 Hardware test

5.1.A DC MOTOR :

We will use L293D motor driver IC to control the motors. L293D is a powerful IC that can control direction and speed of two DC motors running at 4.5 to 12V.

5. L293N Motor Driver IC [24]

L293D motor driver IC is also known as H-bridge IC. It consists of two H-bridge circuits, one for controlling each motor. The use of H-bridge in this IC is to change the polarity of the output so that DC motors can be controlled in both directions.

6. L298N Module Pin out Configuration

Pin Name	Description
IN1 & IN2	Motor A input pins. Used to control the spinning direction of Motor A
IN3 & IN4	Motor B input pins. Used to control the spinning direction of Motor B
ENA	Enables PWM signal for Motor A
ENB	Enables PWM signal for Motor B
OUT1 & OUT2	Output pins of Motor A
OUT3 & OUT4	Output pins of Motor B
12V	12V input from DC power Source
5V	Supplies power for the switching logic circuitry inside L298N IC
GND	Ground pin

Tab-5.1 **L298N Module Pin out Configuration**

7. Features & Specifications

- Driver Model: L298N 2A
- Driver Chip: Double H Bridge L298
- Motor Supply Voltage (Maximum):
- Motor Supply Current (Maximum):
- Logic Voltage: 5V
- Driver Voltage: 5-35V
- Driver Current:2A
- Logical Current:0-36mA
- Maximum Power (W): 25W
- Current Sense for each motor
- Heat sink for better performance
- Power-On LED indicator

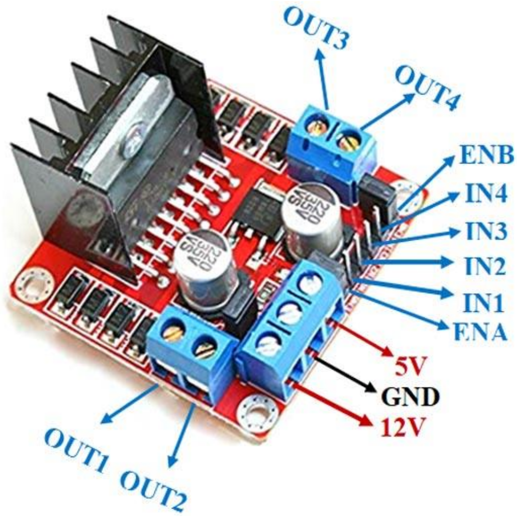


Fig-5.1 L293N Motor Driver [25]

8. Test motor

The way we control the speed of the motor is by using a python module called PWM. That stands for Pulse Width Modulation. What PWM means is just controlling the amount of time a voltage is on by flipping between high and low for a set amount of time. The amount of time the voltage is high is called the 'duty' or 'duty cycle', and whatever percentage that is will be the percentage of power the motor runs on.

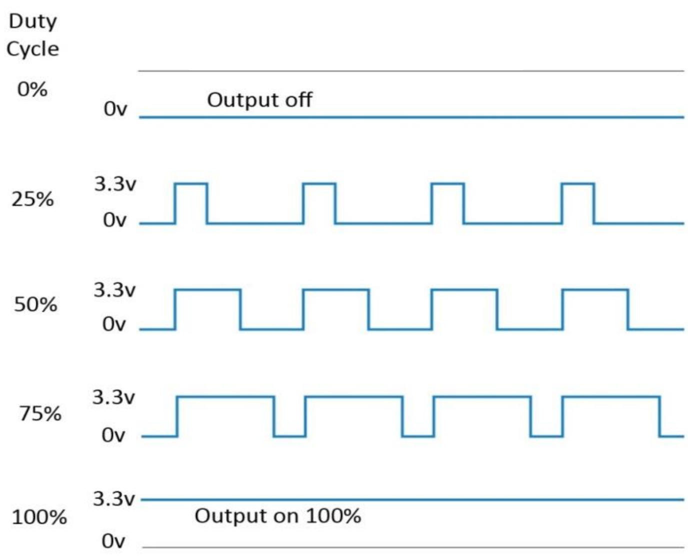


Fig-5.2 Pulse Width Modulation (PWM)

Connect motor input 1 to GPIO 3 and motor input 2 to GPIIO 5. Connect Enable PWM Pin to GPIO 8. The motor driver is provided an external 12V power supply using a 12V battery connected to the VSS pin. Connect GND pin to Raspberry Pi Ground.

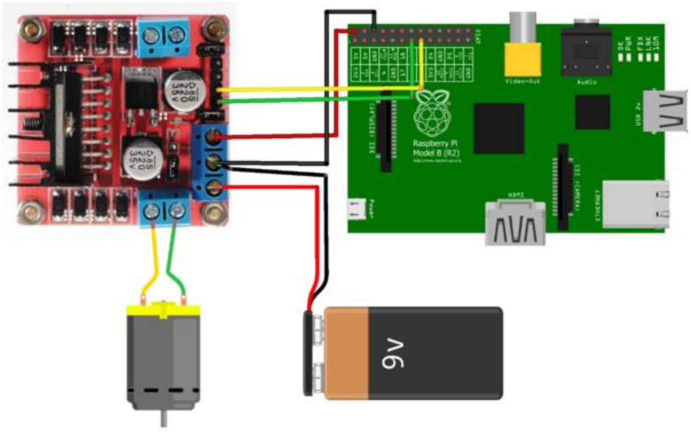


Fig-5.3 test motor with L293D [32]

GIPO 8	GPIO 5	GPIO 3	The result
LOW			whatever he is GPIO 5 and GPIO 3 There is no movement
HIGH	HIGH	LOW	Forward rotation
	LOW	HIGH	Backwards rotation

Tab-5.2 Test Motor

5.1.C Ultrasonic sensor (HC-SR04) on RPI-bot :

The HC-SR04 is an affordable and easy to use distance measuring sensor which has a range from 2cm to 400cm (about an inch to 13 feet).

The sensor is composed of two ultrasonic transducers. One is transmitter which outputs ultrasonic sound pulses and the other is receiver which listens for reflected waves.

The sensor has 4 pins. VCC and GND go to 5V and GND pins on the Raspberry pi , and the Trig and Echo go to any digital RPI pin. Using the Trig pin we send the ultrasound wave from the transmitter, and with the Echo pin we listen for the reflected signal.

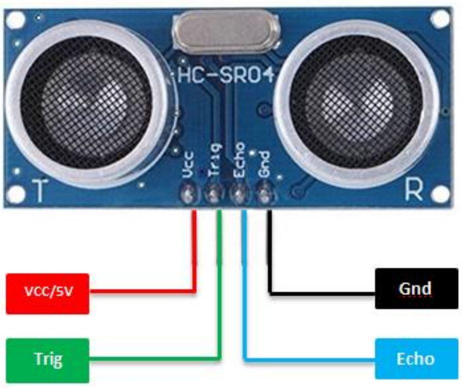


Fig-5.4 Ultrasonic sensor

1. **The method of distance sensor works**

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 [26].

- In order to generate the ultrasound we need to set the Trig pin on a High State for 10 µs. That will send out an 8 cycle ultrasonic burst which will travel at the speed of sound.
- The Echo pins goes high right away after that 8 cycle ultrasonic burst is sent, and it starts listening or waiting for that wave to be reflected from an object.

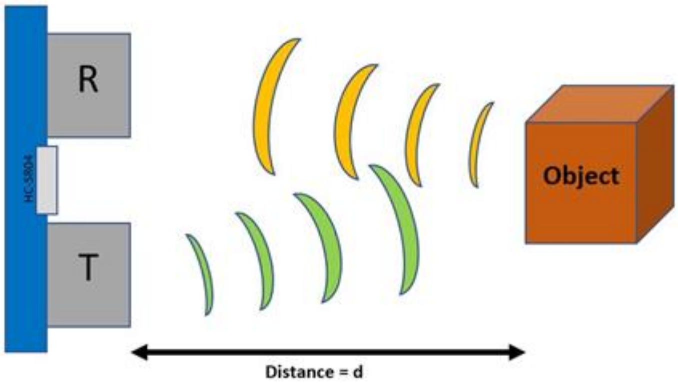


Fig-5.5 The method of distance sensor works [27]

2. **Measure distance**

For that purpose we are using the following basic formula for calculating distance:
Distance = Speed x Time
The time is the amount of time the Echo pin was HIGH, and the speed is the speed of sound which is 340m/s. There's one additional step we need to do, and that's divide the end result by 2. and that's because we are measuring the duration the sound wave needs to travel to the object and bounce back.
Let's say the Echo pin was HIGH for 2ms. If we want the get the distance result in cm, we can convert the speed of sound value from 340m/s to 34cm/ms.
Distance = (Speed x Time) / 2 **= (34cm/ms x 1.5ms) / 2 = 25.5cm.**

3. **Connect HC-SR04 Ultrasonic Sensor to Raspberry PI**

The Ground and the VCC pins of the module needs to be connected to the Ground and the 5 volts pins on the RPI Board respectively and the trig and echo pins to any Digital I/O pin on the Raspberry PI Board.

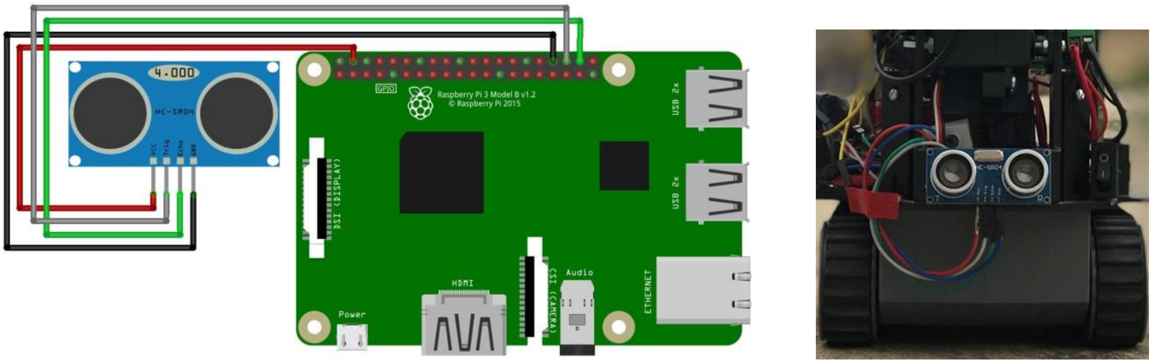


Fig-5.6 Connect HC-SR04 Ultrasonic Sensor to Raspberry PI [28]

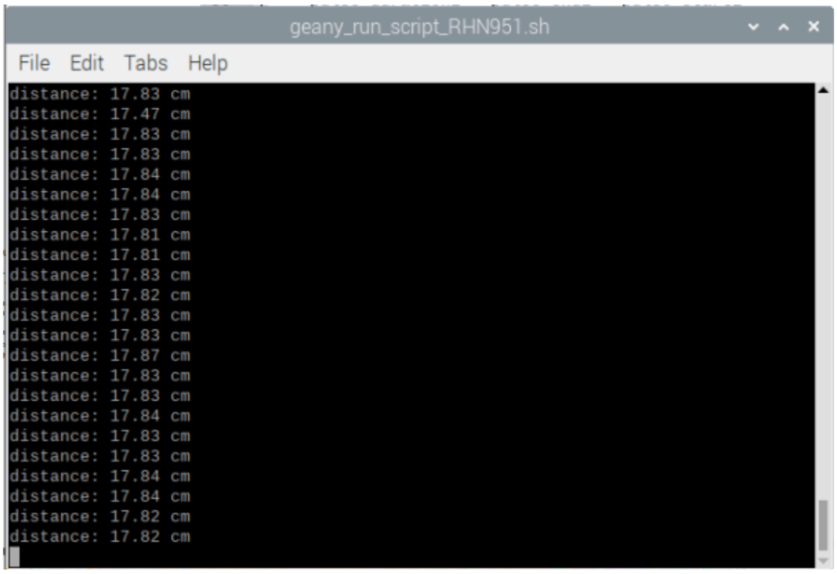


Fig- 5.7 calculating distance

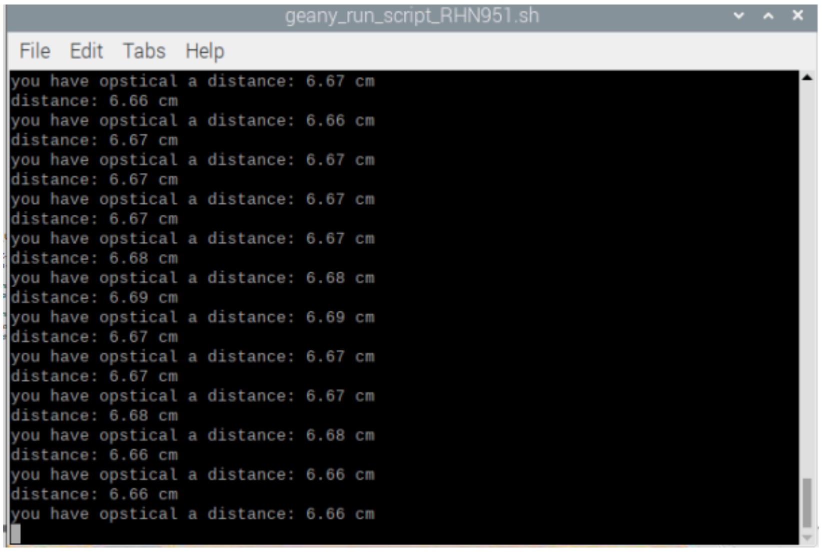


Fig-5.8 The distance between robot and obstacle

5.1.D Accelerometer MPU-6050 :

- The MPU6050 sensor module is an integrated 6-axis Motion tracking device.
- It has a 3-axis Gyroscope, 3-axis Accelerometer, Digital Motion Processor, and a Temperature sensor, all in a single I2C.
- A microcontroller can communicate with this module using the I2C communication protocol. Various parameters can be found by reading values from addresses of certain registers using I2C communication.
- Gyroscope and accelerometer reading along X, Y, and Z axes are available in 2's complement form.
- For precision tracking of both fast and slow motions, the parts feature a user-programmable gyro full-scale range of ±250, ±500, ±1000, and ±2000 °/sec (dps), and a user-programmable accelerometer full-scale range of ±2g, ±4g, ±8g, and ±16g.

Connection Diagram of MPU6050 with Raspberry Pi

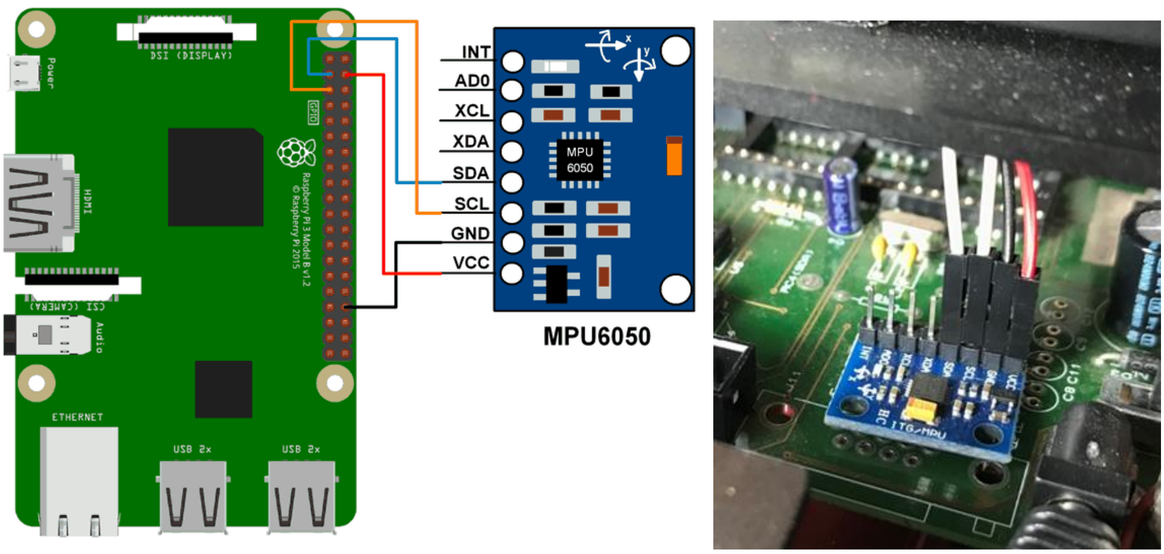


Fig-5.9 Connection MPU6050 with Raspberry Pi [29]

1. MEMS Accelerometer [30]

MEMS accelerometers are used wherever there is a need to measure linear motion, either movement, shock, or vibration but without a fixed reference. They measure the linear acceleration of whatever they are attached to. All accelerometers work on the principle of a mass on a spring, when the thing they are attached to accelerates, then the mass wants to remain stationary due to its inertia and therefore the spring is stretched or compressed, creating a force which is detected and corresponds to the applied acceleration.

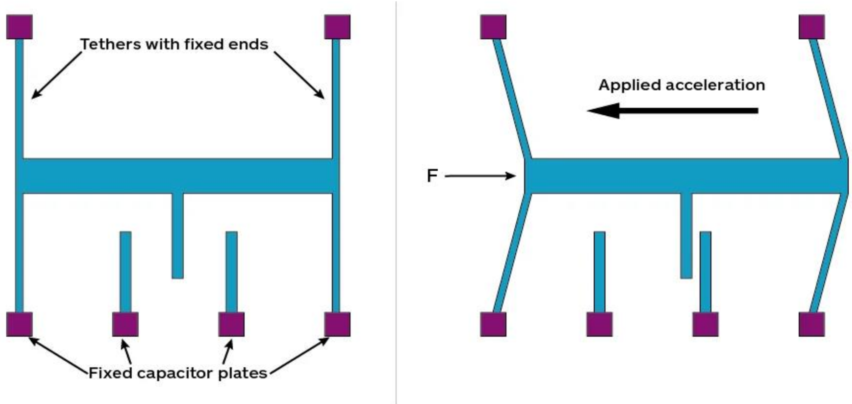


Fig-5.10 MEMS Accelerometer

In MEMS accelerometer, precise linear acceleration detection in two orthogonal axes is achieved by a pair of silicon MEMS detectors formed by spring 'proof ' masses. Each mass provides the moving plate of a variable capacitance formed by an array of interlaced finger loke structures. When the sensor is subjected to a linear acceleration along its sensitive axis, the proof mass tends to resist motion due to its inertia, therefore the mass and its fingers become displaced concerning the fixed electrode fingers. The gas between the fingers provides a damping effect. This displacement induces a differential capacitance between the moving and fixed silicon fingers which is proportional to the applied acceleration. This change in capacitance is measured with a high-resolution ADC and then the acceleration is calculated from the rate of change in capacitance. In MPU6050 this is then converted into readable value and then it's transferred to the I2C master device.

2. MEMS Gyroscope

The MEMS Gyroscope working is based on the Coriolis Effect. The Coriolis Effect states that when a mass moves in a particular direction with velocity and an external angular motion is applied to it, a force is generated and that causes a perpendicular displacement of the mass. The force that is generated is called the Coriolis Force and this phenomenon is known as the Coriolis Effect. The rate of displacement will be directly related to the angular motion applied.

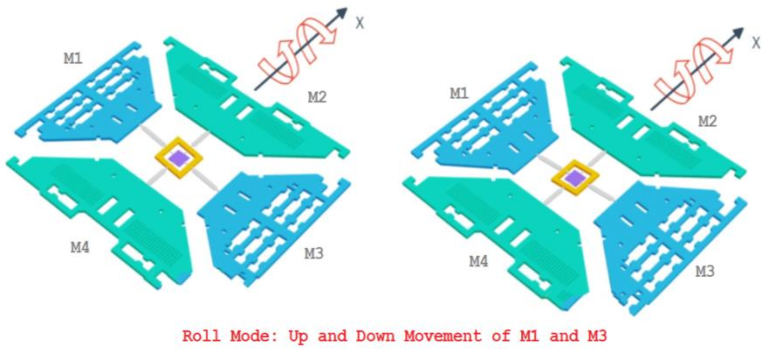


Fig-5.11 **MEMS Gyroscope**

The MEMS Gyroscope contains a set of four proof mass and is kept in a continuous oscillating movement. When an angular motion is applied, the Coriolis Effect causes a change in capacitance between the masses depending on the axis of the angular movement. This change in capacitance is sensed and then converted into a reading. Here is a small animation showing the movement of these proof masses on the application of an angular movement for different axis.

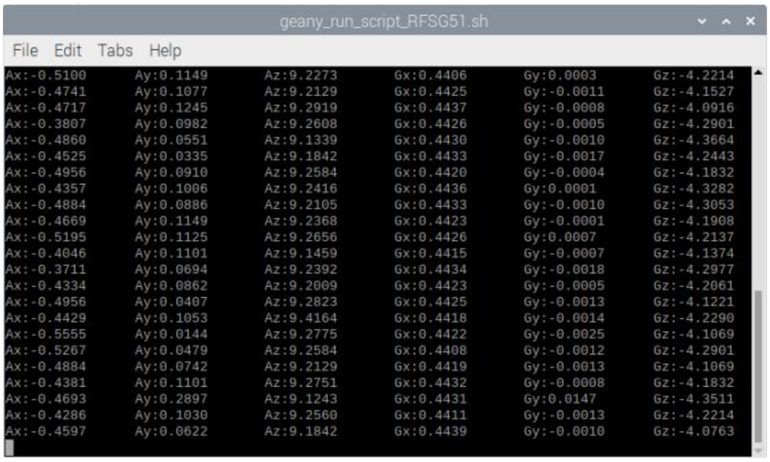
3. Test Accelerometer MPU-6050 :

The output window will show all values mentioned below :

Gx = Gyro X-axis data in degree/seconds   Ax = Accelerometer X-axis data in g

Gy = Gyro Y-axis data in degree/seconds   Ay = Accelerometer Y-axis data in g

Gz = Gyro Z-axis data in degree/seconds   Az = Accelerometer Z-axis data in g



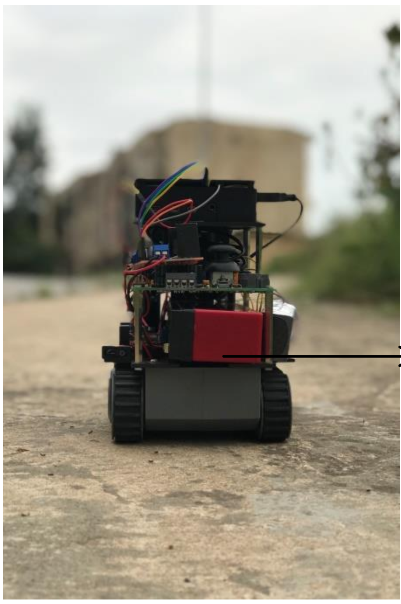
geany_run_script_RFSG51.sh

File Edit Tabs Help

```
Ax:-0.5100    Ay:0.1149    Az:9.2273    Gx:0.4406    Gy:0.0003     Gz:-4.2214
Ax:-0.4741    Ay:0.1077    Az:9.2129    Gx:0.4425    Gy:-0.0011    Gz:-4.1527
Ax:-0.4717    Ay:0.1245    Az:9.2919    Gx:0.4437    Gy:-0.0008    Gz:-4.0916
Ax:-0.3807    Ay:0.0982    Az:9.2608    Gx:0.4426    Gy:-0.0005    Gz:-4.2901
Ax:-0.4860    Ay:0.0551    Az:9.1339    Gx:0.4430    Gy:-0.0010    Gz:-4.3664
Ax:-0.4525    Ay:0.0335    Az:9.1842    Gx:0.4433    Gy:-0.0017    Gz:-4.2443
Ax:-0.4956    Ay:0.0910    Az:9.2584    Gx:0.4420    Gy:-0.0004    Gz:-4.1832
Ax:-0.4357    Ay:0.1006    Az:9.2416    Gx:0.4436    Gy:0.0001     Gz:-4.3282
Ax:-0.4884    Ay:0.0886    Az:9.2105    Gx:0.4433    Gy:-0.0010    Gz:-4.3053
Ax:-0.4669    Ay:0.1149    Az:9.2368    Gx:0.4423    Gy:-0.0001    Gz:-4.1908
Ax:-0.5195    Ay:0.1125    Az:9.2656    Gx:0.4426    Gy:0.0007     Gz:-4.2137
Ax:-0.4046    Ay:0.1101    Az:9.1459    Gx:0.4415    Gy:-0.0007    Gz:-4.1374
Ax:-0.3711    Ay:0.0694    Az:9.2392    Gx:0.4434    Gy:-0.0018    Gz:-4.2977
Ax:-0.4334    Ay:0.0862    Az:9.2009    Gx:0.4423    Gy:-0.0005    Gz:-4.2061
Ax:-0.4956    Ay:0.0407    Az:9.2823    Gx:0.4425    Gy:-0.0013    Gz:-4.1221
Ax:-0.4429    Ay:0.1053    Az:9.4164    Gx:0.4418    Gy:-0.0014    Gz:-4.2290
Ax:-0.5555    Ay:0.0144    Az:9.2775    Gx:0.4422    Gy:-0.0025    Gz:-4.1069
Ax:-0.5267    Ay:0.0479    Az:9.2584    Gx:0.4408    Gy:-0.0012    Gz:-4.2901
Ax:-0.4884    Ay:0.0742    Az:9.2129    Gx:0.4419    Gy:-0.0013    Gz:-4.1069
Ax:-0.4381    Ay:0.1101    Az:9.2751    Gx:0.4432    Gy:-0.0008    Gz:-4.1832
Ax:-0.4693    Ay:0.2897    Az:9.1243    Gx:0.4431    Gy:0.0147     Gz:-4.3511
Ax:-0.4286    Ay:0.1030    Az:9.2560    Gx:0.4411    Gy:-0.0013    Gz:-4.2214
Ax:-0.4597    Ay:0.0622    Az:9.1842    Gx:0.4439    Gy:-0.0010    Gz:-4.0763
```

Fig-5.12 Test Accelerometer MPU-6050

4. Schematic showing different positions of the RPI-bot



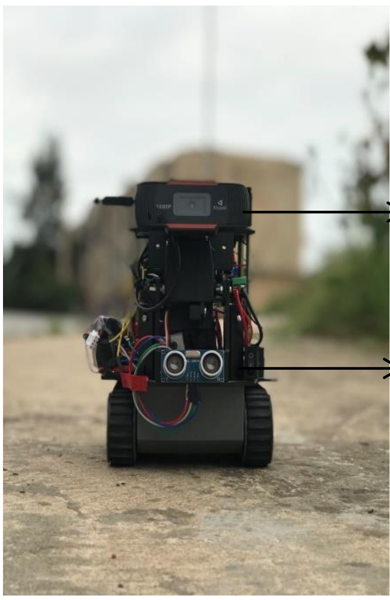


Fig-5.15 Robot flip to the left

Fig-5.16 Robot flip to the Right

ETA	Action a Programmed
Horizon	Si Ax = -0.45 , Ay = 0.09 and Az = 9.17
Robot go UP	Si 1 <= Ax <= 3.19 : increase the speed of the motor
Robot go Down	Si -3.42 <= Ax <= -1 : slow down the speed of the motor And charge a battery
Robot flip to the Right	Si 1 Ay >= 2.34 : stop the movement completely And turn on the warning light
Robot flip to the left	Si Ax <= -2.34 : stop the movement completely And turn on the warning light

Tab-5.3 positions of the RPI-bot with Action a Programmed

5.2 Software test

5.2.A Connect webcam to RPI-bot :

USB Webcams generally have inferior quality to the camera modules that connect to the CSI interface. They can also not be controlled using the raspistill and rasivid commands in the terminal neither by the picamera recording package in Python. Nevertheless, there may be reasons why you want to connect a USB camera to your Raspberry Pi, such as because of the benefit that it is much easier to set up multiple camera's with a single Raspberry Pi .

The Raspberry Pi recognizes most USB webcam and you can use them right away! You just need to add a few applications to run in the background and then it will start right away
There are two methods of use USB webcam :

1. **The first method**

we can control a USB webcam both using bash in the terminal and with Python. First plugin the camera and see if the Raspberry Pi recognises it by entering `lsusb` in the terminal. It should show something like this:

```
(main) pi@jolpi146:~ $ lsusb
Bus 002 Device 001: ID 1d6b:0003 Linux Foundation 3.0 root hub
Bus 001 Device 003: ID 046d:0825 Logitech, Inc. Webcam C270
Bus 001 Device 002: ID 2109:3431 VIA Labs, Inc. Hub
Bus 001 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
```

Fig-5.17 control a USB webcam both using bash

To command the camera in the terminal I suggest to use the `fswebcam` package. To install:

```
sudo apt install fswebcam
```

To take an image with a certain resolution and hide the standard banner:

```
fswebcam -r 1280x720 --no-banner /images/image1.jpg
```

2. **The second method**

We have install Opencv library to read usb camera on the RPI-bot, A number of solutions exist to connect to the USB camera with Python. Unfortunately the picamera software does not work with USB webcams. I suggest to use OpenCV. To help install OpenCV

In the preceding code, cv2.VideoCapture() creates a video capture object. The argument for it can either be a video device or a file. In this case, we are passing a device index, which is 0. If we have more cameras, then we can pass the appropriate device index based on what camera to choose. If you have one camera, just pass 0.

Fig-5.18 test USB webcam

5.2.B How to Read Traffic signs :

The most trending technology the Self-driving car, which has a number of parameters to measure, among that Road sign recognition is also one of the needed parameters to make the car autonomous. Here Raspberry Pi system is used with the camera interface. The system will look onto the road, whenever it detects the sign like slow, stop. It will recognize the sign and confirmed that Road sign as the box [33].

1. **Block Diagram :**

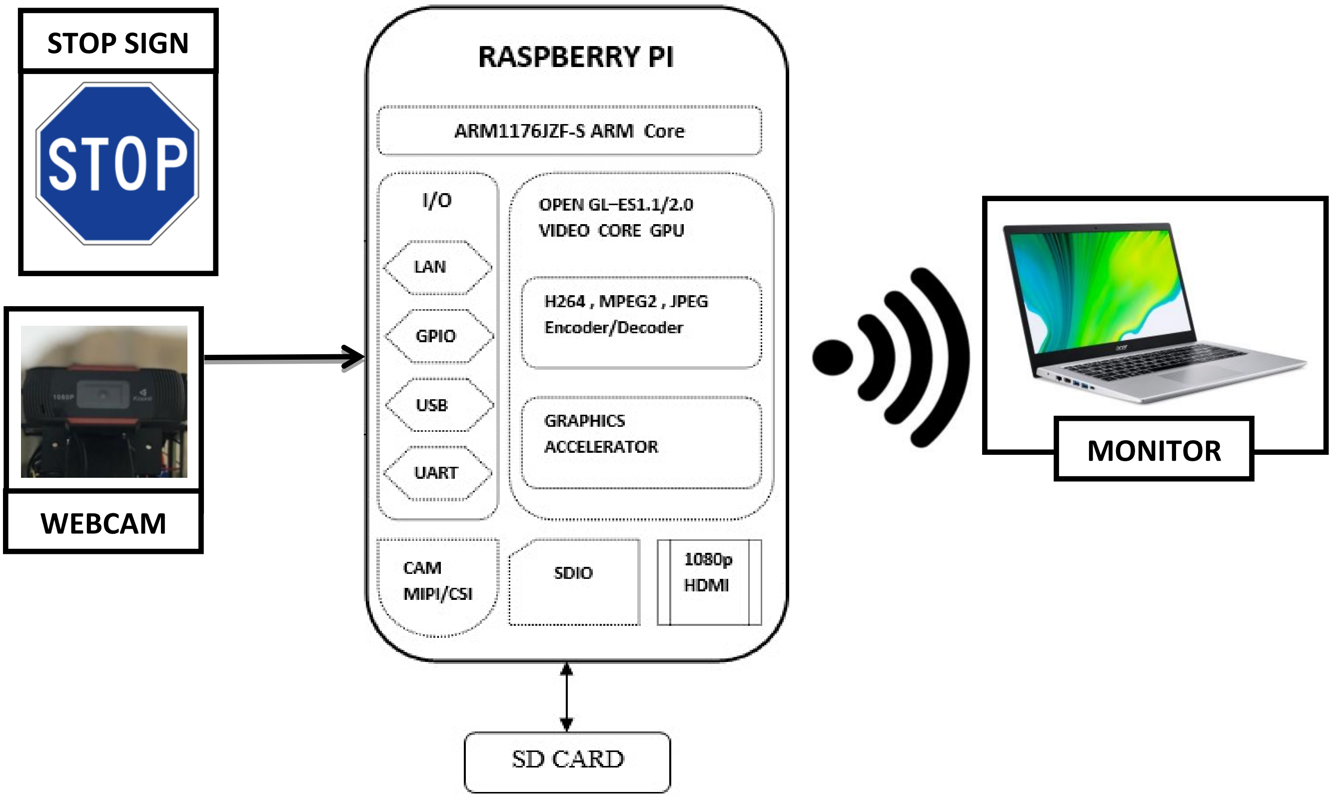


Fig-5.19 Block diagram read Traffic sign

In the above block diagram, USB camera is connected to the Raspberry Pi, which kept constant. To view the detected sign, we connected Monitor to the raspberry via the wireless system.

2. **DESCRIPTION :**

In the self driving car, the parameter like Road sign recognition is one of the main thing to be measured. We are using OpenCV technology with the Raspberry Pi to detect the Road sign like Stop sign, Speed limit sign to make the car as autonomous. The system will look for the sign, whenever it recognize the sign. It stops looking and boundaries the road sign and displays the message of the sign.

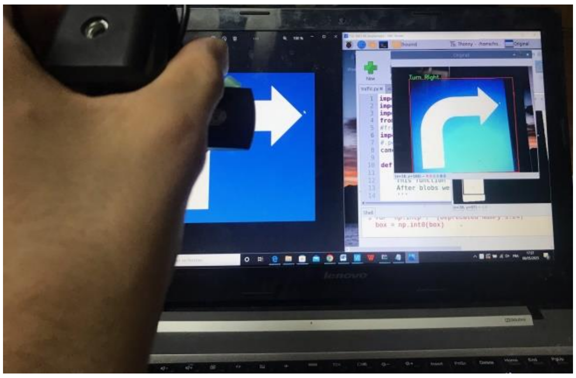
3. LIBRARIES USED :

- Rpi.GPIO as GPIO (To access GPIO Pins of Raspberry Pi)
- Time library (For Delay functions)
- Opencv library
- Numpy (highly optimized library for numerical operations)

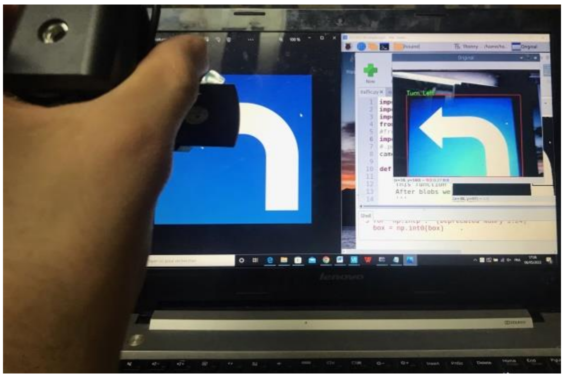
4. Traffic sign classification using Raspberry pi and Opencv :

In experiments we connected a camera to a Raspberry Pi to simulate the traffic sign recognition environment of a smart vehicle. It uses the camera to simulate the computing device inside the robot. It captures video and renders all video frame sizes as 320 x 170 pixels and all patterns are normalized as 50 x 40 pixels. Some example frames are used to show the performance of the proposed scheme, and these typical frameworks are shown as shown in the pictures (1), and they are considered as source images in the proposed scheme.

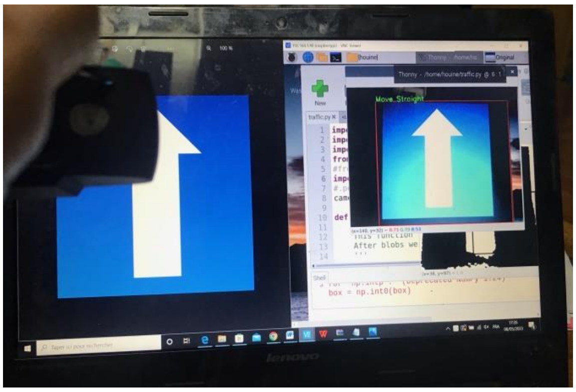
In the first stage, all images are converted from the RGB color space to the HSV color space. Hence, the blue regions of each image are revealed by color and pixel saturation values. The results of the stop sign detection are displayed

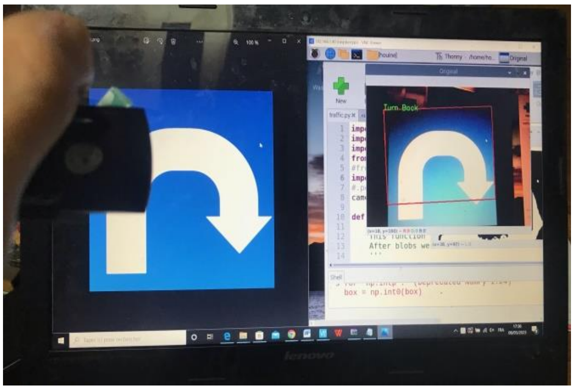


Turn Right



Turn Left





Move Straight	Turn Back

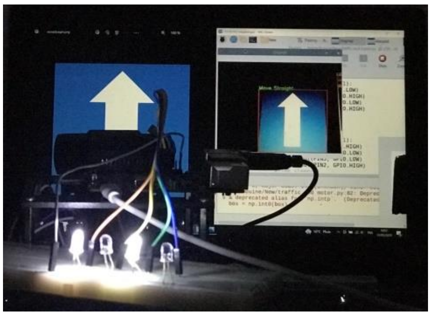
Fig-5.20 test read fourth traffic sign

We did an experiment, which consists of connecting four LEDs on the Raspberry Pi, which represent the motor control ports, and connecting the camera to an USB port to read traffic signs .

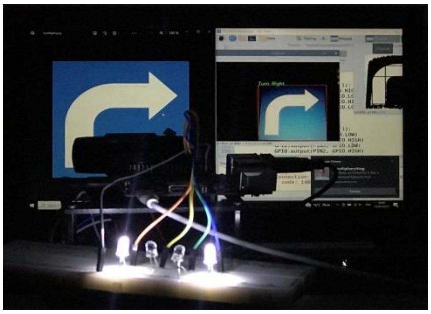
connect leds with raspberry pi :

- Led 1 pin29 (GPIO 5)
- Led 2 pin31 (GPIO 6)
- Led 3 pin33 (GPIO 13)
- Led 4 pin35 (GPIO 19)
- GND pin39

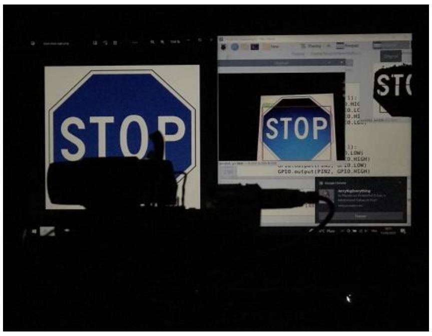
After reading the traffic sings, we send an electrical signal to the LEDS , As shown in the pictures



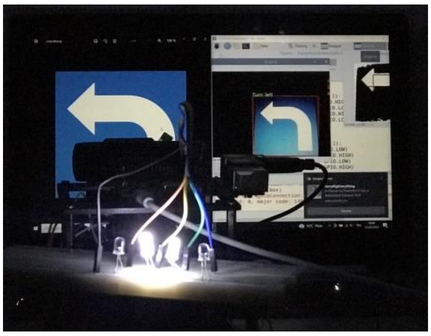
Move Straight



Turn Right



STOP



Turn Left

Fig-5.21 test read fourth traffic sign with LEDs

LED / Traffic sign	LED-1	LED-2	LED-3	LED-4
Turn Right	HIGH	LOW	LOW	HIGH
Turn Left	LOW	HIGH	HIGH	LOW

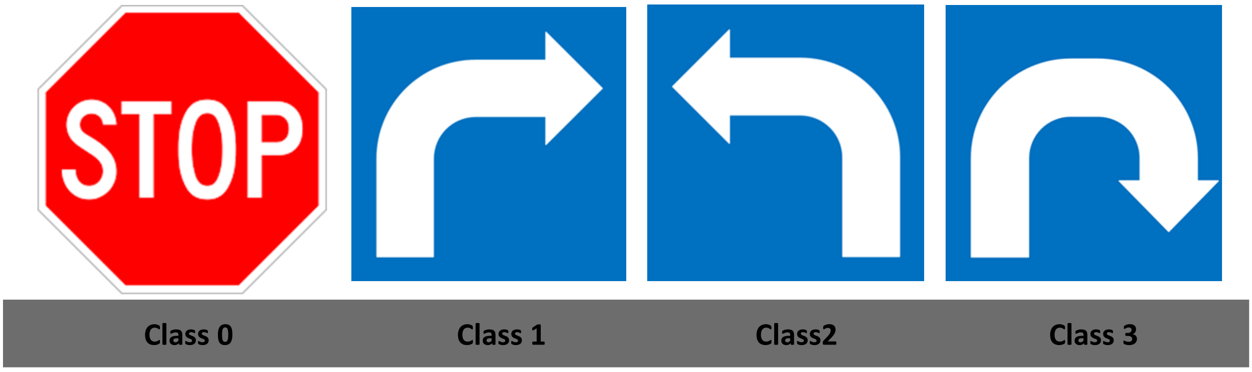
Move Straight	HIGH	LOW	HIGH	LOW
STOP	LOW	LOW	LOW	LOW

Tab-5.4 command led with traffic sign

5. Data Set:

A machine learning dataset is a collection of data that is used to train the model, we selected 4 classes for each class we collected 10 image of traffic signs on differences forms

Class 0 ⟶ Stop
Class 1 ⟶ Turn Right
Class 2 ⟶ Turn Left
Class 3 ⟶ Turn Back



5.2.C Software solutions:

This is a flow chart describing our software solutions for traffic signs detection and recognition to get autonomous driving of "RPI-bot" using OpenCV

General block diagram: main program

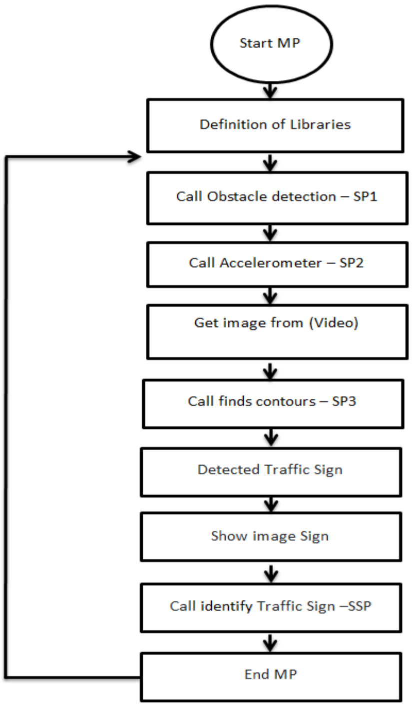


Fig-5.22 General block diagram

Sub-prog1 : Obstacle detection Algo:

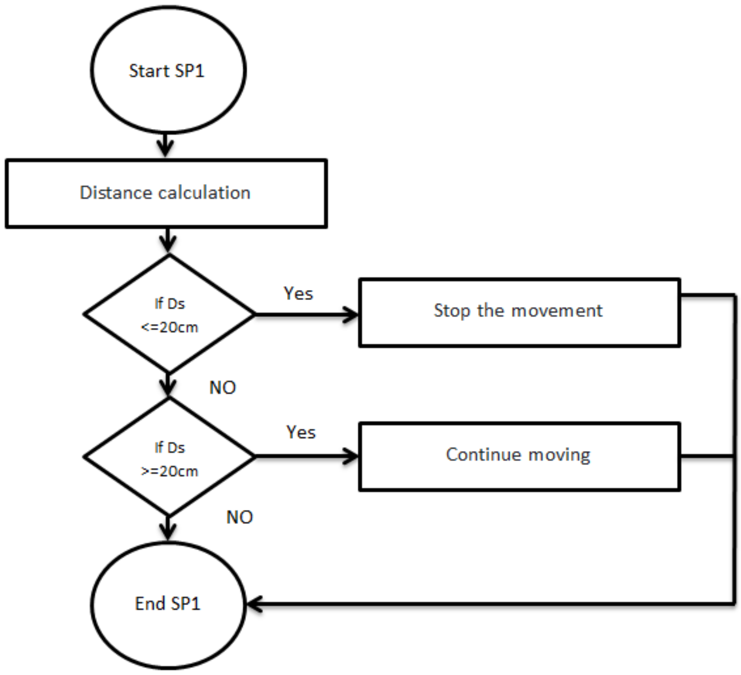


Fig-5.23 Obstacle detection Algo

Sub-prog 2; Accelerometer Algo:

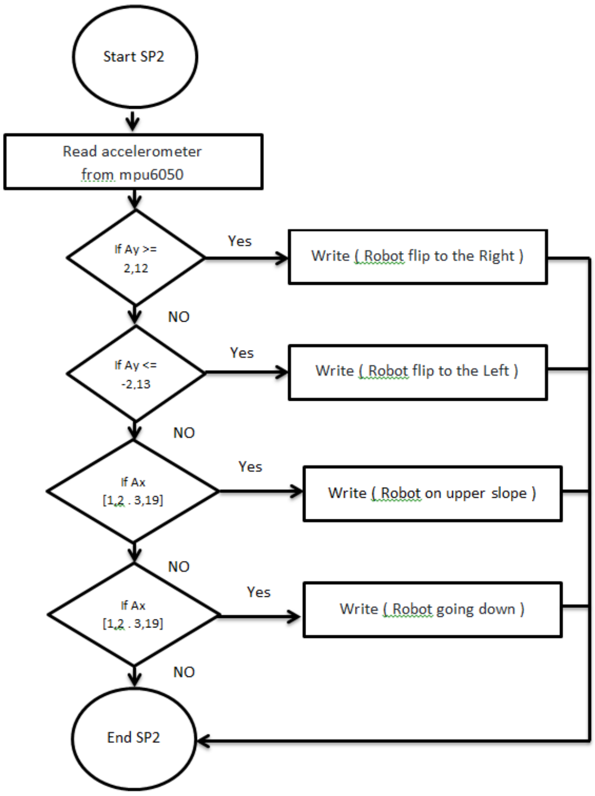


Fig-5.24 Accelerometer Algo

Sub-prog 3: Finds contours Algo:

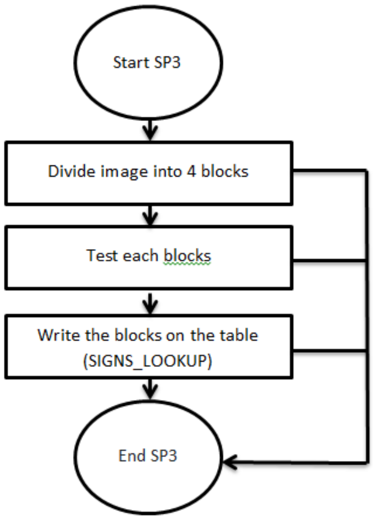


Fig-5.25 Finds contours Algo

Su-prog 4: Identify traffic sign Algo and action on motors:

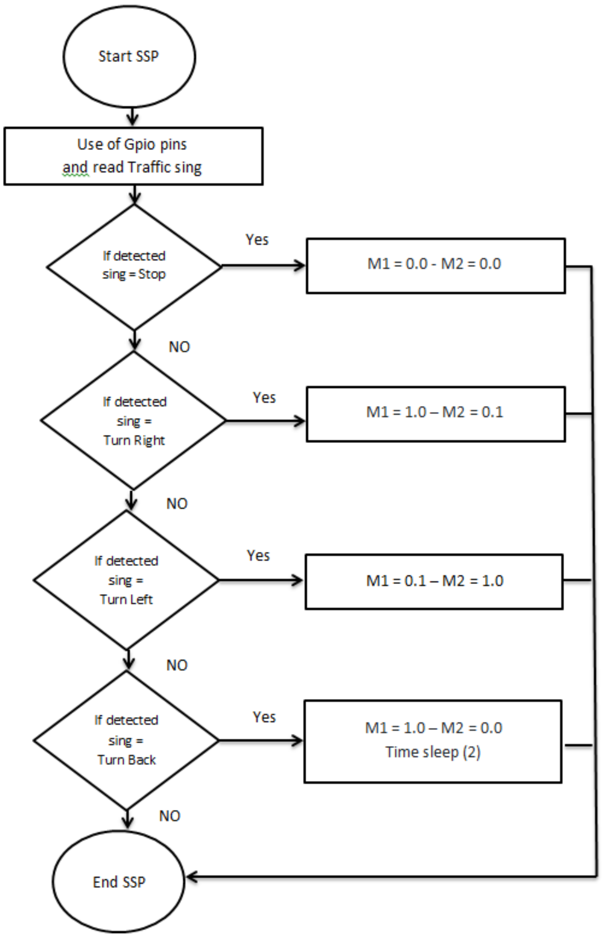


Fig-5.26 Identify traffic sign Algo and action on motors

53. Tests and results

Test were done on robot outdoor navigation and some photos were takn and videos were regisered . They testify on the good results of the navigation as tested on simlator

5.4 Conclusion:

In this chapter we have seen different tools that we used in the implementation and the build of our program step by step (libraries from OpenCv). We have talked in detail about the method we used to recognize the traffic sings by eveloping algorithmes, and we have made the combination of the four sub-programs in one main program:

The first sub-program: It is the program that calculates the safe distance in order to avoid obstacles using US sensor.

The second sub-program: It is a program that measures acceleration and equilibration to control more the robot movements with explanation messages about his position.

The third sub-program: This sub program works to identify the traffic signs with mentioning their names and take the right action for robot navigation.

The fourth sub-program: After recognizing the traffic signs, this program regulates the robot rotation directions by controlling the motors.

Global conclusion:

Despite of the hard work, the low availability of the electronic elements and the unavailability of their documents, this project was an absolutely fascination experience and it fed me the robotic, electronic and embedded systems knowledge due to the rich information and techniques to learn during the whole project.

in this project we learn how to integrate machine learning with robotics, we retrofitted on old robot design "POB-BOT" to new robot "RPI-BOT" with more augmented hardware and software, we integrate the Raspberry Pi 4 with the 'POB-BOT' and added some necessary sensors for autonomous navigation (ultrasonic sensor, MPU 6050 accelerometer and gyroscope).

As a result we have obtained very interesting results and too many information that we've added may help the future works and researches in this area, we can also add a GPS to localize our robots emplacement in the environment and send it to a web site. In addition we can change the wheels type for harsh environment and implement deep learning models for better navigation.

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Husi Géza
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Husi Géza
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