# Human Following Robot

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**ABSTRACT**

The main purpose of this project is to develop a robot that can follow a human to help their activities easy in a well-planned manner. The first implementation of this project is to detect a human and follows the human in a single human environment. The last implementation is to upgrade this into a robot that can detect humans in a busy environment. When designing a robot to work as a human follower it must fulfill some requirements. The issues which are more focused to resolve in here are, the size and mobility while tracking the humans and obstacle detection of the robot. There are many human assistant robots that manufacture small scale in size, but they are not capable of well-assistance and also most of the physically large robots find it hard to assist and handle some activities. Most of the humans following robots are designed for single work, therefore people tend to spend more money on buying robots to fulfill various work. Usually, the components that are used to develop human detection robots are expensive and it is one of the reasons why these types of assistants are expensive. Here, one of the problems which is mobility of the robot while tracking was resolved by developing a more suitable structure, improving the motor-control method, and adding a step-climbing mechanism to the robot. As the robot is manufactured to follow a human, a method to identify a human using image processing is implemented. Also, a method of detecting the position of human is also implemented. And also, the power plan design and all the electronic developments including the power supply unit development and also the power level checker as well has been implemented. Finally in order to make it less complex the circuit has made on PCB.

Keywords: *Fuzzy Logic, PID, Structure, Image Processing, Boost Converter, Object Detection, Human Tracking, PCB*

## 1 INTRODUCTION

Robots were created to assist humans in industrial and day-to-day activities. Typically, robots are created to accomplish tasks that humans might not in certain industrial applications. In addition to industry, the robot can assist and direct humans by working as an assistant. Human assistant robots come in a variety of shapes and sizes to assist people with various tasks. The definition of a person following a robot can also be applied to the human assistant category. This paper is about to build a human following robot by solving the above abstract mentioned global issues. This project is doing in charge with three undergraduate students in Sri Lanka Institute of Information and Technology. In this robot project there were many parts to complete to have a success full and accurate robot.

This robot`s structure is mainly dependent on the step climbing purposes due to that it had to make some changes for the last implementation of the structure. In this paper it was giving big focus for the wheel placement and structure of the robot because the whole robot accurate is depending on them. Another interesting part of this paper is motor controlling of the human following robot. Human following robots' main tasks is to follow the human with accurate manner it should be track the human with precise gape and speed with the follow's human. As a solution for the accurate of any system, in the history of the engineering they were invented several control systems to make the accuracy of the system. Among these control systems there are very common accurate two controllers they were PID controller and fuzzy controller. In this robot project PID controller is used to control the obstacle avoidance part and fuzzy controller for control the turns.

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In recent days, capturing images with high quality and good size is so easy because of rapid improvement in quality of capturing devices with less costly but superior technology. Object detection and tracking is one of the challenging tasks in computer vision. Mainly there are three basic steps in video analysis- Detection of the object of interest from moving object, tracking of that interested objects in consecutive frames and analysis of object tracks to understand their behavior. In order to detect the object first take the necessary and relevant steps together, information from the many computer vision applications. This implemented method can be used for surveillance purpose in many security applications. So, deep learning basics, Image annotation, Object identification and Object tracking is being discussed in this document. After detecting the human, reacting to human movement also identified and moving according to humans' speed also discussed.

The obstacle detection is one of the main parts in the robot since it can detect the obstacles in the environment and interrupt the robot about them to avoid. This is a main part when it is considered the protection of the robot. In this robot, the obstacles were detected using the ultrasonic sensors. The ultrasonic sensor uses a natural phenomenon, which is the sound reflection to detect things. To detection part, mainly the length dimension had been used. And this length was given by the ultrasonic sensor not as a length. Therefore, the calculations need to be done using the output that is being gained by them. And also the development of the power supply and the localization of this robot will be discussed. Power supply is one of the most important units in any kind of an electronic. There are several considerations as such as power distribution, power source selection and power converters. And in the PCB finalizing section, the PCB of the voltage indicator circuit was done. The process of all of these sections will be discussed in the following parts.

### 1.1 Objectives

- Develop a structure for the robot.
- Configuring the structure for different scenarios.
- Arranging the motor controlling using the inputs.
- Development of obstacle avoidance unit.
- Development of the Power supply units.
- Circuit Integration and PCB designing.
- Human detection using several methods.
- Integration of the programming units.

## 2 BACKGROUND READING

### 2.1 Structures of Robots

Yoonchang Sung and Woojin Chung's research demonstrates the need for the robot's construction to be planned in accordance with the human body parts that will be detected by algorithms that follow the human. The width of the structure should match that bodily part's width, as they state. The product's accuracy will thereafter improve (Yoonchang Sung, 2011). Since their robot is built on the robosoft robulab10 robotic platform and has a robust construction, Guillaume Doisy, Aleksandar Jevtic, and Sasa Bodiroza claim that it can hold a maximum payload of 4 kg. They also said that the robot may use a laptop as its central processing unit. The path is clear, they simply need to follow a predetermined path, and they do not need to worry about their wheels because they can only have two motor wheels and one free wheel for their robot (G. Doisy, 2013). The mechanical framework of a robot at Pakistan's Institute of Space Technology has designed for two levels, which are used to arrange the parts. In order to collect superior visual data, the top base is built with the idea that the robot's camera must be set above a particular height off the ground. This camera's height is also adjustable to match different body sizes. The finest achievement is having a camera that can be adjusted, but components that are on the top base of the design shouldn't guarantee that it's bad for a robot that follows humans (M. Hassan, 2015). A project for a three-wheeled omnidirectional mobile robot was completed by Mohanraj, Elango, and Reddy. To travel and make several directional turns, this robot simply needs three omni wheels.

Additionally, the angle between the two chosen wheels may be adjusted by the robot as desired. The angle variable chassis is the primary responsibility for this project (A. Mohanraj, 2016).

## 2.2 Motor Controlling Methods for Robots

In this proposal, Caroline Queva stated that the pan and tilt motor allows cameras to move in practically all directions. The robot will not want to rotate at that point, and the human will not be missed by the camera. As a result, this technique gives this robot extremely accurate real-time operations. However, there is one problem to this approach. A human may not be followed by the mobile base if they move quickly and perpendicular to the robot (CAROLINE, 2013). The human following robot does not need to have a camera on it as Kazuyuki Morioka showed in the project because he created a concept called "ISpace" with a better arranged, set of cameras. The power that wants to control the camera's motors is then released. However, there is a limitation to this concept: it can only be used indoors. This idea is more accurate because the human subject is not lost to the camera. (2002) K. Morioka As Hosein Marzi explains in the study, robots uses AC motors. They contend that ac motors do not react more quickly than dc motors. This paper applies fuzzy control to flux vector inductor motor performance. Another justification for using fuzzy logic is that it has excellent balancing abilities and can handle several inputs (Marzi, 2007). Research on servomotor modelling and control for secure robots has been conducted by Song and his four project collaborators. This study demonstrates how the nonlinearity of the permanent magnet synchronous motor is decoupled here using the field-oriented control theory (J. Song, 2015). On autonomous underwater vehicles, the lifting control system is implemented using fuzzy logic. Using ADC conversion, fuzzy logic was used in this case for ultrasonic sensors. And this section discusses how precisely to sense distance (A. ZARKASI, 2019).

## 2.3 Power management and obstacle avoidance

Kazuyuki Morioka demonstrated multiple strategies for identifying items in Fumiaki Hoshino's research. As stated in the project "Human Following Robot based on Control of Particle Distribution with Integrated Range Sensors," accurate ways for identifying objects include LRF, the Likelihood method, and the use of a kinetic sensor (F. Hoshino, 2011). In the essay "Energy Modeling and Power Measurement for Mobile Robots," Linfei Hou, Liang Zhang, and Jongwon Kim explore the power management of mobile robots. And they have recommended using low-power devices whenever possible. And they have developed an algorithm for the power consumption of each robot component (L. Hou, 2018). In the essay titled "UB Robot Swarm - Design, Implementation, and Power Management," the group discusses various strategies for obstacle detection. In addition, they have been used a camera and a mapping system to create a more precise method for detecting obstacles. Even though noted previously, this is an excellent solution, but it consumes more system resources and is a much more complex system (M. Patil). The robot created by the Engineering UG group is a human-following robot that can photograph adjacent objects when it is following a person. It was created using a straightforward technique that employs ultrasonic sensors for detecting. The ultrasonic sensors have been positioned higher on the robot, allowing this strategy to be effective. However, this may still cause some uncertainty on the robot, making the robot less clear (M. Kumar, 2017). The project "Follow Me: A Human Following Robot Using Wi-Fi Received Signal Strength Indicator" conducted by a group of university undergraduates has been powered using a 12V power supply. They have been using significantly more power-hungry components. In addition to applying a mapping system to detect and avoid obstacles, they were required to devise a more effective method for supplying energy (V. Geetha, 2020). Michael Burke's "Gain-scheduling Control of a Monocular Vision-based Human-Following Robot" study uses a LIDAR sensor, which is a Light Detecting and Ranging sensor, as the detection method, according to Willie Brink. A vision-based detection system employing a complicated algorithm has been created. This can provide some data on precision if better LIDAR sensors are developed (M. Burke, 2011). Wei Peng, Jingchuan Wang, and Weidong Chen's study titled "Tracking Control of Human-Following Robot with Sonar Sensors" deployed an ultrasonic sensor ring for both obstacle identification and human detection. They have been creating a particular algorithm for the system to identify between an obstacle and a person when both are identified at the same time. This technique is simpler and more reliable. When the system is used for both cases, however, there may be instances in which the robot is unable to detect the barrier precisely (W. Peng, 2017). In the article titled "Power

Optimization in Mobile Robots Using a Real-Time Heuristic," the power source for robots has been explored. In addition, they recommended using Li-Po batteries rather than other types of batteries. And they have been implementing a power monitoring system that may be put on a robot that follows a human to provide a more accurate technique of measuring the power. However, Li-Po batteries cannot be used in most robots due to their rapid discharge rate (T. Abukhalil, 2020).

### 2.4 Human detection and tracking

Most variable presentation aspects managed by incorporating the YOLO framework. YOLO's input size and velocity flexibility makes an obvious choice in the RCNN family, when dealing with a diverse set of tiny input images. Research done on object detection using YOLO, the applicable YOLO network trained a portion of 2007 PASCAL VOC data and 2012, focusing on the classes of humans, vehicles, and motorcycles (Koskowich, 2016). Another object tracking research done on event-based tracking learning detection. e-TLD is the name given to their event-based object tracking technology. This paper presents a general method for tracking object using event cameras that implemented rapidly in software, rather than neural networks that requires a lot of training for learning. The incremental SVM update stage of the e-TLD online learning process is well-documented as efficient technique. Although the online TLD's learning capability, the fundamental training procedure is the codebook learning step, which takes less than a minute on a normal PC utilizing efficient sampling algorithms for 500ms worth of data. To account the changes in object appearance during tracking process, online learning also required. When the region-of-interest (ROI) used as an object, binary classifier utilized by the tracker updates. This drifting problem mitigated by updating the tracker, only when the confidence is more than a portion of mean tracking score and the tracking fails, the tracker must reactivate with a higher confidence value. To put it another way, the target will only track if it passes both the detector and a “stricter” tracker (Ramesh, 2015). The application created with the idea that video sequence was captured by camera and that it could be used with offline video. First phase is using motion segmentation, which involves subtracting moving objects by the updated backdrop by performing the morphological processes. This produces binary masks, using white pixel color by corresponding to the foreground and black pixel color corresponding to background. Second phase is tracking the object, which involves assigning detections to tracked objects. Every track's next location is predicted by the current detection's assigned positions, or using the position of previous frame allocated if nothing was assigned to present frame. This application generates a video with each monitored object's bounding rectangle and identity number. It has shown around 92% accuracy in finding humans in collisions (Sadura, 2012).

## 3 METHODOLOGY

In this section the development of each unit will be discussed. This unit is consisted with several units since the development taken place in several steps. Each part is guaranteed as the pure effort of the group mates. Since this robot mainly has 3 components to be worked, and several objectives to be fulfilled, group members came up with their own way of development steps, which made this project a success.

### 3.1 Structure Implementation of the Robot

Robot structure was first starting to implement to design as a 3D drawing. Figure 1 shows the fully complete solid work implemented 3D model of the robot. This robot used a chain wheel as the actuator. It used a rubber belt as the chain of the robot. These rubber belts run on a pulley. One side of this robot has five wheels for running the belt. It has ten wheels robot when it used a chain wheel mechanism the robot works as a two-wheeled robot. Of these five pulley wheels two of them were connected to the motors and rest of other three wheels are mounted as free wheels for the robot. The wheels which are connected to the motors are not going to contact the ground. When fixing the motor's connected wheels from this much ground clearance then it can reduce the friction that generate from contacting the wheel with the floor.

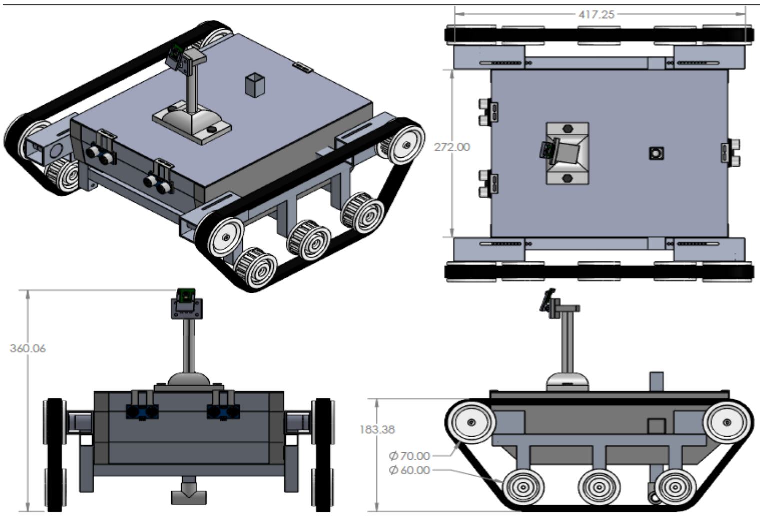


Figure 1. 3D model of robot

Implementing a step-climbing method was a main objective of this project. For this mechanism, it required a two-servo motor, one T joint of PVC pipes, aluminium bars, rubber belts, and MPU-6050 sensor. The mechanism of this function when the robot moves forward and detects the first step by using the front wheels robot can climb half of the first step and the MPU 6050 sensor detects the orientation of the robot gets changed. When the sensor gets the orientation change the method for step climbing activates and motors stop. When robot climb the step again step climbing method deactivate and motors start. Figure 3.15 shows how the step climbing method applies to the structure and how it works.

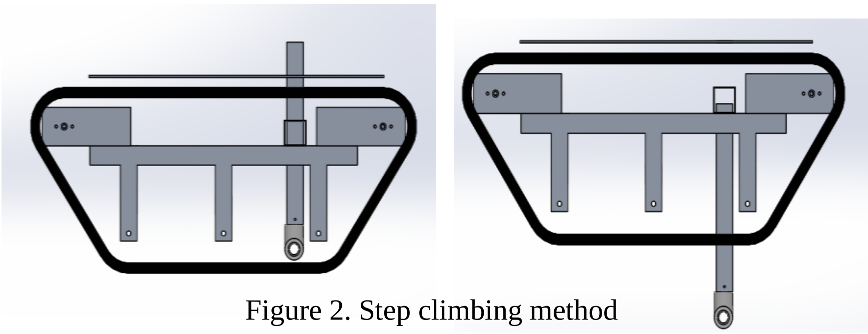

Figure 2. Step climbing method

In figure 3 shows the final hardware implementation of the robot with all the motor placements, step climbing method and sensor mounted.

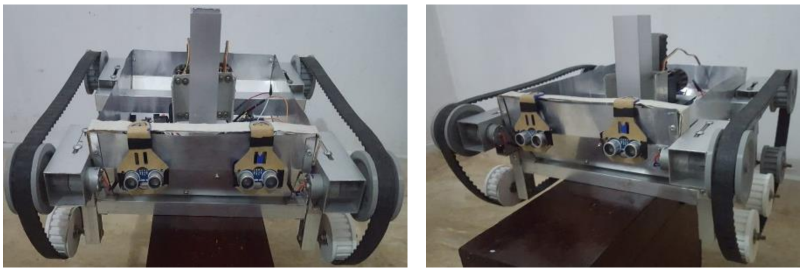

Figure 3. Final structure hardware implementation

When selecting a motor, it has to do some mathematical calculations for select better suitable motor. Due to this robot have to follow humans we have to find the average speed of a human. After having the average speed, it can calculate the test of other parameters. Then the obtained the calculated result we have to compare the result with suitable motors data sheets and select one.

Table 1. Humans` walking speed according to the ages (Cronkleton, 2019)

| Age | Meters/second | Miles/hour |
|---|---|---|
| 20 to 29 | 1.34 to 1.36 | 3.0 to 3.04 |
| 30 to 39 | 1.34 to 1.43 | 3.0 to 3.2 |
| 40 to 49 | 1.39 to 1.43 | 3.11 to 3.2 |
| 50 to 59 | 1.31 to 1.43 | 2.93 to 3.2 |
| 60 to 69 | 1.24 to 1.34 | 2.77 to 3.0 |
| 70 to 79 | 1.13 to 1.26 | 2.53 to 2.82 |
| 80 to 89 | .94 to .97 | 2.10 to 2.17 |

$$Total\ of\ the\ speeds = (1.35 + 1.38 + 1.41 + 1.37 + 1.29 + 1.19 + 0.95)ms^{-1}$$
$$Average\ speed\ of\ a\ human = \frac{(8.94\ ms^{-1})}{7}$$
$$Average\ speed\ of\ a\ human = 1.27ms^{-1}$$
$$Average\ speed\ of\ a\ human \geq 1.27ms^{-1}\ for\ worst\ case.$$
$$Then\ average\ speed\ of\ a\ human = 1.5ms^{-1}$$

For motor selection it has to follow some more calculations as follows. Required data for the calculation; M = Robot weight =4Kg | r = Wheel diameter = 0.07m | μ= Coefficient of friction on roughly rubber or wood = 0.9

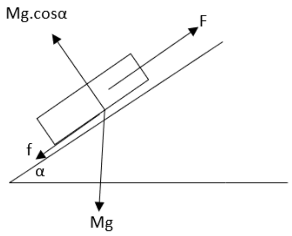


Figure 4. Motor selection calculations

$$F = Mg(sin\alpha + \mu\,.\,cos\alpha) \quad (1)$$
$$F = 4 * 9.8(sin0 + 0.9cos0)$$
$$F = 35.28N$$
$$For\ one\ motor\ required\ for = \frac{35.28N}{4} = 8.82N \quad (2)$$
$$For\ one\ motor\ required\ force$$
$$Torque = F * r \quad (3)$$
$$Torque = (8.82 * 0.07)Nm$$

$$Torque\ for\ one\ motor = 0.617Nm, \qquad Torque\ for\ full\ robot = 2.469Nm$$

According to the calculations the selected motor was RK-370CA-14445 12 v gear motor.

### 3.2 Motor Controlling

This project camera input signals are going to control by fuzzy logic controller and ultrasonic sensors are going to control by using PID controlling method. In this design it selected a fuzzy controller for the camera input signals. This method was selected for the camera inputs because fuzzy logic method is accurate for the one output function and PID is accurate when it has several inputs for control. The Fuzzy controller for the camera signals was built by using matlab software. First, we have to decide which output signals are going to use for designing the fuzzy controller. Fuzzy controllers basically use extensions of some boolean logic scenarios, but this controller just provides the output according to the input due to it having one input source. Here we are going to use mandani method. Mandani method is controlling the PWM signal so that it can control the speeds of the motors then the robot can have smooth bends.

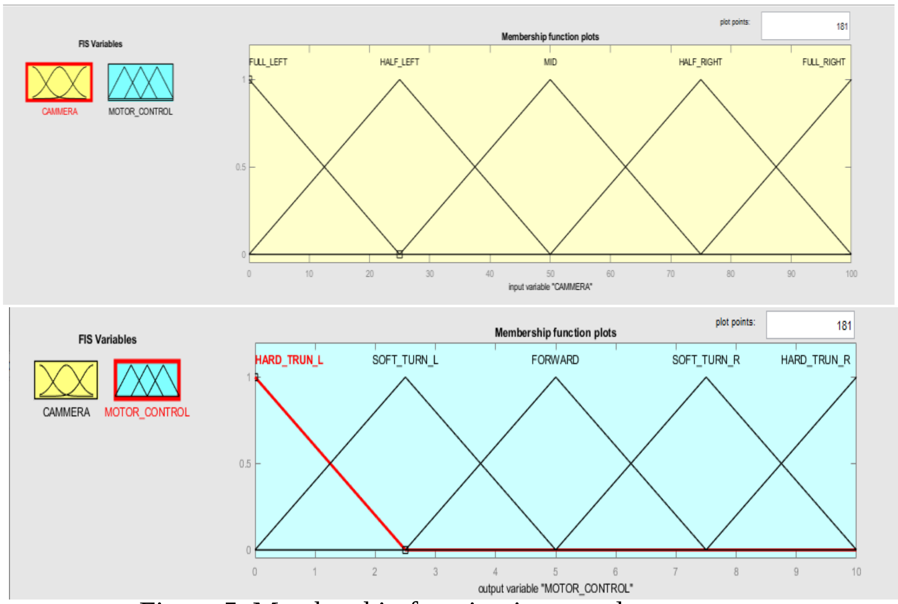


Figure 5. Membership function input and output

In second its implementation is the PID controller for three ultra-sonic sensors. In here this PID controller implemented according to the graph shown in figure 6 step by step.

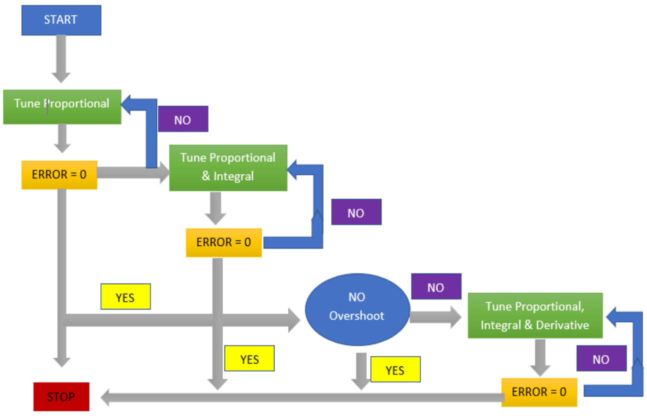


Figure 6. PID control implemented step graph

PID implement calculation.

$$70: X_{PWM}$$

$$[OUTPUT = ERROR]: Y_{PWM}$$

$$\frac{70}{ERROR} = \frac{X_{PWM}}{Y_{PWM}}$$

$$Y_{PWM} = \frac{[X_{PWM} * ERROR)}{70} \quad (4)$$

$$X - (\pm Y) \quad (5)$$

In the above equation calculated for obtain an algorithm for PID controller which going obtain from Ultra-sonic sensor inputs. seventy is known distance X also know the PWM. X can vary according to the user requirement. when we have you got to know the set point distance PWM and the output error value that occur from the error signal and when the equations one shows Y PWM value can calculated. in the equation two it explains the new PWM value should be add or substitute to the set point PWM value. When the error has a negative value PWM should be add to the setpoint PWM and when the error gives a positive error the set point PWM should be deduct from the Y PWM. For the equation it used for when X negative the value it will happen what we need from PID controller.

### 3.3 Power unit development

The main part in power management is to share the power to all over the circuit in an efficient manner as shown in Figure 7.

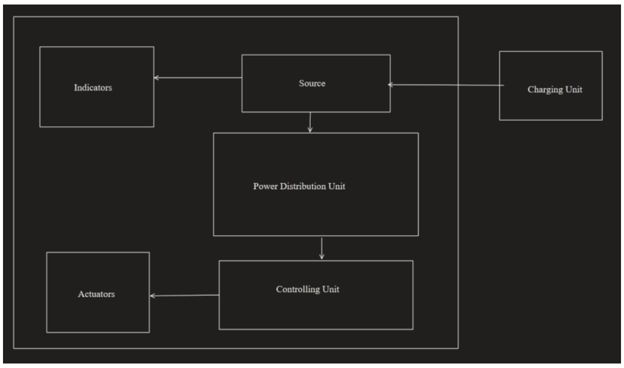


Figure 7. Basic Power Plan

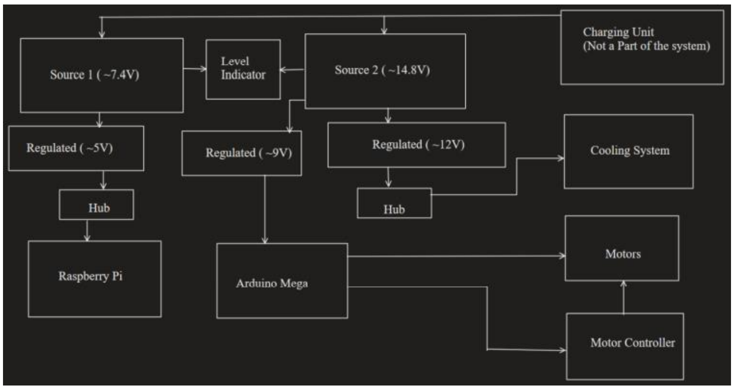


Figure 8. Power Distribution

Power distribution is becoming one of the main parts that control the relevant power needs in the circuit as shown in the Figure *8*. The Power is distributed as follows as in the Table *2*.

Table 2. Voltage and Current Needs of active components

| Component | Voltage Needs | Current Needs |
|---|---|---|
| Raspberry PI | 5V (4.8V – 5.1V) | 1.2A to 2.5A |
| Arduino Mega | 7V – 12V | 200mA |
| Ultrasonic Sensors | 5V | 15mA |
| Motor Drive (Motors) | 12V | 1A to 2A |

In here the ~7.4V (2 x 3.7V) Li-Po batteries – 2800mAH have been used to power up the Raspberry PI 3 board only. Since it draws maximum current or 2.5A, the single power source was used for it. And this source was used for multiple components, whereas the Arduino Mega, the motor controlling and for the cooling system. The most suitable power supply this is the Switch Mode Power Supply (SMPS). So, in boost converter was selected. When making the circuit of the boost converter, the simulation circuit as in was done and the following Figure *9*, PCB was done on the Ultiboard software.

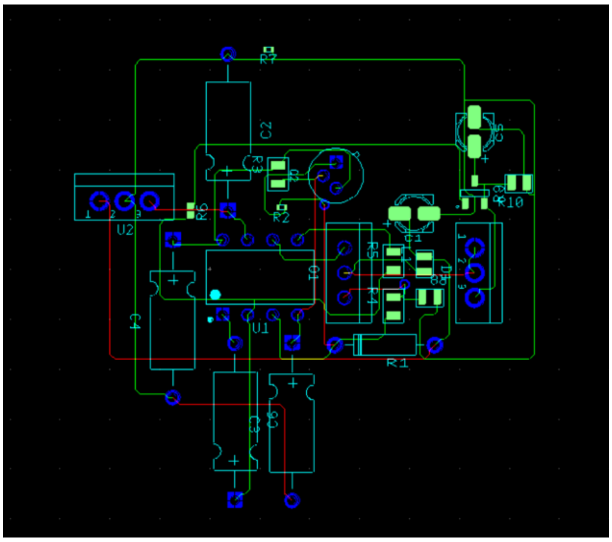


Figure 9. Boost Converter PCB

The voltage indicator was made which gives the voltage level in the batteries, that indicates the low and high levels. This was an important part for the circuit since when the indication comes the users gets to know when to charge the batteries or not. And it was designed as can be seen in the Figure *10*. The PCB of it designed and finalized as in the Figure *11*.

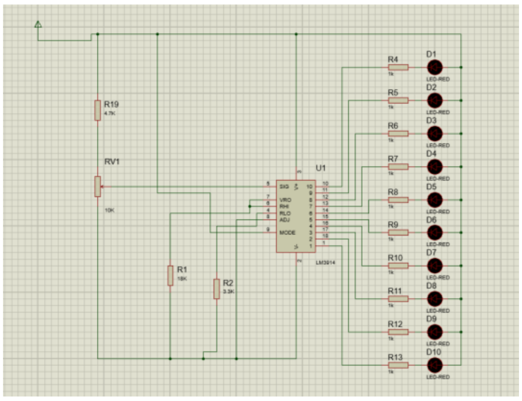

Figure 10. Voltage Level Indicator Simulation

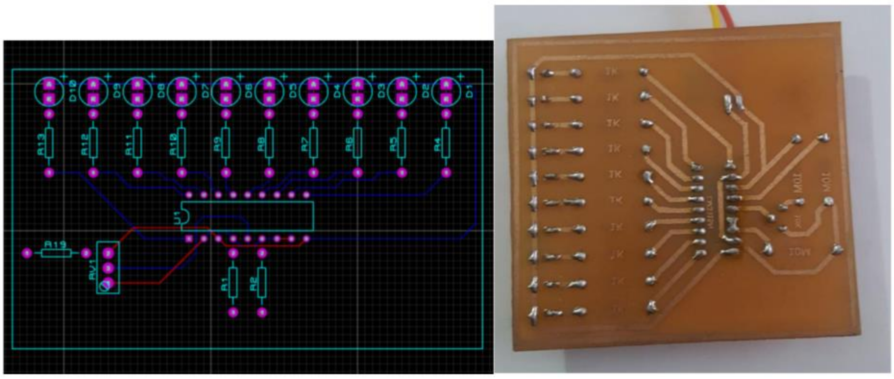

Figure 11. Final PCB

### 3.4 Obstacle Detection

When detecting an obstacle, it is very important to have several sensors mounted on the robot. Since the ultrasonic sensor (HC SR-04) is being used as the main sensor the sensor placement and number of sensors that are being used is very important. To detect the occurrence of an object, according to the size of the robot the sensor placements are also can be changed. In this human following robot, the robot was designed to have the width of the human walking path. Then the sensors were placed in the robot, that it can have the maximum output from the outside to detect the obstacles as in Figure *12*.

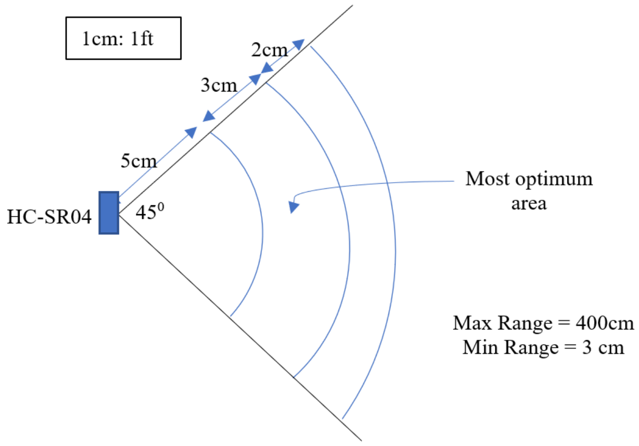


Figure 12. Sensor Coverage

Using these characteristics, there are for ultrasonic sensors have been placed in the robot as follows and the sensor coverage of the robot can be identified like in the following figures, Figure 13, and Figure 14.

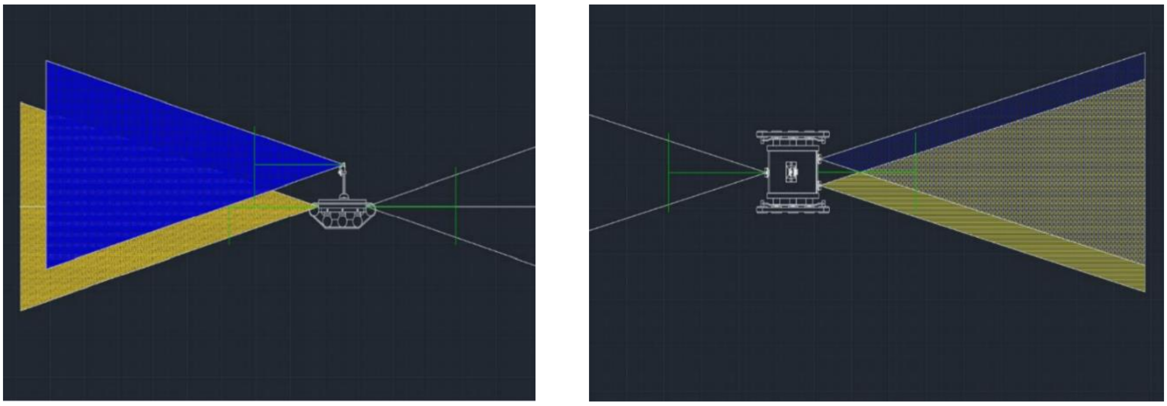

Figure 13. Sensor Coverages

### 3.5 Human Detection

The first stage is to collect high-quality training data for the model. Therefore, have taken approximately 500 photographs of several people from a variety of angles, clothing types, poses, positions, etc. Then, each image is precisely labelled and created bounding boxes for each. In this instance, chose to annotate only one class, however several classes can be annotated by the software. It will generate an XML file (in format of Pascal VOC) with all bounding boxes and annotations for each image. In order to facilitate the translation to TF.record format (below), the aforementioned program's XML was converted to two CSV files and already generated data are segregated into train and test (80 percent -20 percent). These files have nine columns: width: image width, height: image height, class: Image, xmin: the smallest x value of the bounding box, ymin: the smallest y value of the bounding box, xmax: the highest x value of the bounding box, ymax: the highest y value of the bounding box. Using labelimg software makes it simple to make images in the aforementioned format. TensorFlow 2's Object Detection API simplifies the development, training, and deployment of object detection models. This project utilizes this API to train the model using a Google Colaborative Notebook. Transform the input into a sequence of binary records to feed it to object detection API of TensorFlow. Then, based on selection of an object detection model, generated a specialized file to instruct the training operation done later in this notebook. Chosen among possible training models by altering the selected model variable. I've implemented the first few models of the EfficientDet series for exploration purposes. Each model is assigned a model name, a pretrained checkpoint, a batch file and a base pipeline file. The makers of the TF2 OD repository made available the base pipeline file, which has a specific training configuration for each model type. The pretrained checkpoint is the location of the saved pretrained weights file from the object identification model on COCO dataset by adjusting custom dataset based on these weights. Due to the utilization of pretraining, model did not have to start from scratch when determining which attributes can be used for object detection. Once having the custom data, pretrained checkpoint, and training settings in place, can update the initial pipeline file. In order to train more quickly, can increase batch size to point where the GPU can handle it, and the number of steps to train for. Then needed to remember to decrease by the same number of steps amount as raised the batch size if wanted to keep the training time constant. In the training command, specified both the pipeline file and the directory in which to save the model. Training in Colab will take a long time even if had access to a free GPU. Colab's kernel session will time out after a while of inactivity (around 45 minutes).

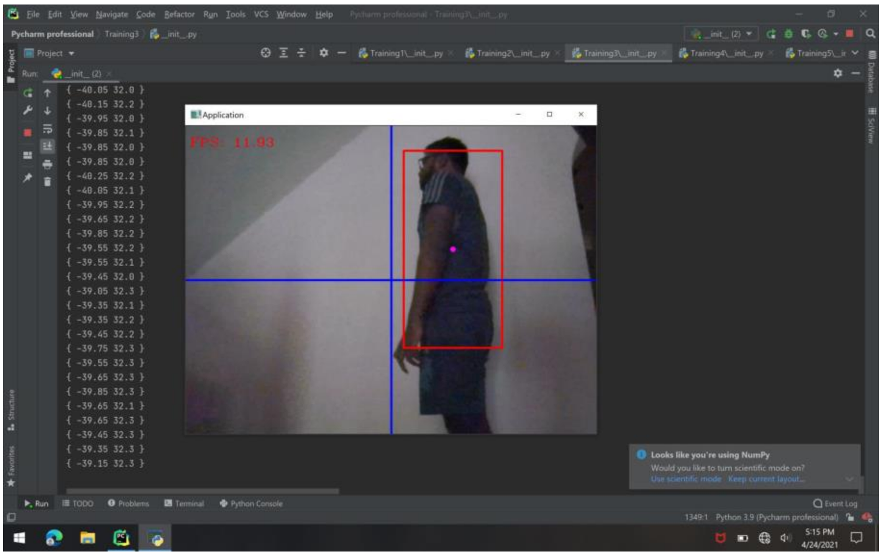

Figure 14. Detection of a person

## 4 CONLUSION

The future of the world will reconstruct with robotics. Every industry will be automated with robotics. Among them there are robots that are available to help human. In this project also to develop a human following robot that it also a one type a human helping robot. As a future improvement this project can add more features like up to a self-assistance robot. This robot is about following a one human and upload a map to the sever, as in advance future update the team discuss improve this robot up to a rover by using more efficient cameras motors and well as better communication engineering side; or self-assistance robot with more actuators to help human to the day today things more accurately by using an Artificial Intelligence.

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