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Electronic Group Project

EE 2314

Automated Guided Forklift

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Assignment

SECTION A – TO BE COMPLETED BY THE STUDENT

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I confirm that:

- I have been given a copy of the assessment criteria relating to this test
- I understand the meaning of the terms Cheating, Collusion and Plagiarism

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SECTION B – TO BE COMPLETED BY MODULE LEADER/TEAM

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1. ABSRACT

This engineering project presents the development of a smart forklift capable of autonomously navigating a white surface following a black line using IR sensors. In addition, forklift lines incorporate an ultrasonic sensor to detect objects along the path. After detecting an object, the robot stops near it, positions its forks underneath, and uses a servo motor to lift the object. Then, the forklift continues to following the line until it reaches the end point, where it stops and reverses the servo motor to unload the object. Arduino mega board uses to control all the operations done by the robot and 12V battery uses to powered the whole system.

The purpose of this project is to demonstrate the integration of IR sensors, ultrasonic sensors, servo motors, and the Arduino Mega board to create an intelligent forklift. The ability to follow a designated line while detecting and manipulating objects presents practical applications in various industries.

The Arduino Mega board serves as the control hub for the project, facilitating sensor integration, decision-making, and actuator control. Its enhanced capabilities, including increased I/O pins and memory, make it suitable for managing multiple sensors and actuators simultaneously.

The implications of this research project are significant for industries that require automated material handling. The smart forklift demonstrates improved efficiency and safety in tasks such as object detection, lifting, and unloading. The integration of the Arduino Mega board and the chosen sensors provides a reliable and cost-effective solution for implementing autonomous robotic systems in similar applications.

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3. INTRODUCTION

Since the Stone Age, people have been inventing new things to make life easier for people. In the past, the best invent was the wheel. First people are inventing things to make their work easier with inventing machines with the human involvement. On that case they able to doing things with machines with less time. For an example if a man does a work within a week, then with the machine, he can do it within a day or less. After when people get used to do things the machines even though people wanted to do things with less effort. As a result of this robot science began.

Forklift is a machine which can use to lift heavy weights which cannot lifted by a man. In the past it uses the hydraulic systems and then it comes to the electric systems and eventually it comes to the hybrid system which is use both hydraulic and electric systems. But even though it is man involve. Then comes the robot technology for the forklift and uses for it. Then the forklift can work fully automatically for given command. It's a big leap in terms of technology.

Warehouses is a place where used store cargo prior to their distributions. In the past used manual forklift and eventually it becomes automated.

In manual cargo handling in a warehouse will be inconvenient with many difficulties. Such as in manual cargo handling the time waste is high since the handling process is done by workers, Labor costs will be high since in the handling process involvement of workers is high and Lots of documentation will be involved in a manual handling process. As a solution to overcome the above problems, a fully automatic forklift Robo vehicle that can be operates in a warehouse to faster the cargo handling process. Which includes the following key features,

- L shape mechanism arm that moves vertically to lift the cargo to a certain height from the ground.

- Three wheel programmed line follow Robo vehicle which can move the cargo from one place to another.

- A sensor system to detect the line path of the road and to detect and identify the object that is needed to pick up or drop off at a relevant point.

Basically, this project can be divided into sub projects.

1. Line follow Robo vehicle.
2. Object loading and unloading forklift.
3. Object detecting and identification system.

In this report there will be an explanation of above 3 areas of this project.

3.1. Aim and Objective

In this project aims and objective as follows.

3.1.1. Aims

To develop a fully automated Robo forklift that can be operated in a cargo warehouse and to fulfill

the below requirements,

- The programed line follows Robot forklift vehicle that works without any human involvement.

- Smart object detecting and identification system to identify a specific cargo in warehouse
- Object picking and loading forklift arm to handle the cargo.

That will be fast the cargo handling process overall.

3.1.2. Objectives

- **Line follow Robo vehicle,**
  - The vehicle must be able to follow the line in a specific pathway.
  - Tracking the various degrees of turns in the line path.
  - The vehicle sensors should be able to clearly identify the black and white color path line of the track.

- **Forklift arm,**
  - Pick and place an object from/to any specific place.
  - Balance the object with the two arms and take it to a distance.
  - Ability to lift the object while balancing the object with the two arms.

- **Object detecting system,**
  - Identify the object and its place that is needed to pick.
  - Identify the drop-off place of the object.
  - Stop the vehicle at the correct position when it needs to load or unload the cargo to the forklift arm of the vehicle.
  - Identify any foreign objects that are on the road taken and stop the vehicle without any collision on it.

4. LITERATURE REVIEW

Line following robot is widely use in present day since it can expand into the several paths. In this project also it's a expand version of a line following robot.

1)So that line following is used in our project as well. We had to categorized line following robot into two parts. Those are,

1. Line following track
2. Line following robot

When comes to the line following track used a 4.5cm width track since we are using 4 IR sensors. Two of them in the black line and two of them are in the white surface. With the width of the IR sensor have had to goes with the 4.5cm width track. Since this is a forklift, it uses in widely in warehouses. So that didn't want a track which has sharp curves. Its only having straight lines and 90-degree curves. For better path planning can have given an algorithm which can identifying which line should go (Xinyi Huang, 2022).As future work better go through that. For now, main purpose is load and unloading in a L shape track.

Then comes to the line following robot firstly got a question about what type of chasse need to use for this project and how about the simplicity of the controllability of the chasse. So that use a two-wheel chasse with Casper wheel. When comes to the forklift it should be move easily in any direction since the track has 90-degree angle curve (Mohammed Abdul Kader, 2018).Then use a L298 motor driver which is used to control the speed and direction of the two DC motors, that drives the robots' wheels. Also uses 4 IR sensors instead of two IR sensors, the line following robot can detect the line more accurately and make more precise movements. The outer sensers help to keep the robot centered on the line while the inner sensors provide feedback to adjust the robots speed and direction. After then a control unit which can control all our inputs and outputs. For that uses an Arduino uno microcontroller which can easily program and control (Prof R.P.Onkare, 2017). Then for power up the system uses a lithium-ion battery system which is the widely uses in present as our power source. It because lead acid batteries have some issues and it has developed in the lithium ion like cost, efficiency, environmental impact (Mingyue Jiao, 2021).

2)In the forklift part we had to focus several things.

1. Design
2. Mechanisms
3. Design complexity
4. Center of gravity
5. Reduce overturn accidents

Those are the parts which we consider when selecting a forklift. When it comes to the design we try goes with some simple designs. Firstly, we build the two forks which can use easily when loading and unloading (Anon., 2021). Then we want some the track which can goes up and down. After that saw a frame that on some internet source (Anon., n.d.). Then we sketch a rough forklift getting both ideas and check the strength of our frame throughout the calculations and it gives us a good result. Therefore, we go through that frame. Then we come to the mechanisms we had basically two systems to use.

1. Hydraulic forklift systems
2. Electric forklift systems
3. Hybrid forklift systems

With those systems the better system is the hybrid system which is a combination of both hydraulic and electric systems Which electric forklift has no emission, pollution and other characteristics (K. Baša, n.d.) (Conte M., n.d.) while hydraulic forklift systems have and also while hydraulic can work many hours while electric forklift systems can't (Liu Panpan, 2020). Therefore, later on we'll try our project get to that level as future works. For now, we'll use the electric forklift system. In here also have 2 sub categories. Those are remote control and Automated Guided. Within those use automated guided in those systems. Since it can work without any human involvement. Then it works for only given command (Moh. Nasyir Tamara, 2018) (A.Z. Arfianto, 2019) (Florentinus Budi Setiawan, 2021). After that have to look after some mechanisms which can going up and down through the ditch min the frame. So that use a wrapping up and down system for our project (Anon., 2019).Then focus better method and a low complexity to implementation. Then found screw rode which can directly do the mechanism. It only needed to power up. (Florentinus Budi Setiawan, 2021).But then have to rejected it since it is steel rode and it gives a lot of weight to the forklift robot. If get that steel rode then it gives a momentum towards the forks. It couldn't control through the counter weight.

Then study how the center of gravity changes while the always changing the center of gravity when loading and unloading. So that have to use counter weight at the back end (Ashik Sarker, 2017). And also, there are two main groups of forklift counterweights. Those are Bulk type: Specifically designed body part at the back end. It is rather a single metal casting or a hollow metal container with mix of concrete and metal. Other type is Stack type: Flame-cut cast metal plates stacked onto a base plate or an existing bulk. Stacking or removing plates enables weight change (Anon., n.d.).For the prototype going with bulk type is good then can developed to the stack type. When comes to overturn accidents happens a lot. Mainly it happened when forklift is loaded. It is happened because when get an overturn then there occurs a centrifugal force. There are many facts to occurs a centrifugal force. But the mainly it's because of the velocity of the vehicle and the center of gravity goes high respect the ground level (Mori, 2017).To reduce overturn accidents can lower the object to the ground level and can tilt it a small number of degrees towards the forklift truck. Then the center of gravity is near to the ground level and can reduce some sort of accidents (Anon., 2012) (Nisar, 2012). And better can reduce velocity through the motor drivers. Later on, can develop to that level. And also, can build a safety system the forklift which when the forklift is overloaded can detected through a buzzer or something and can do the same for tilting angle and other stuff (Pratiksha R. Patil, 2019).

For object detection part of our project, we had divided into two categories. Those are,

1. Object Detection Methods
2. Implementation.

Then we go through those categories.

We had mainly three ideas. There are use a camera module, LIDAR or ultrasonic sensor. Then we have to decide which method is useful and easy to implementation for our purpose. Then we go one by one through datasheet and research papers. First of all, we go through the camera module cause if we were able to program it then it has lot of advantages such as, using artificial intelligence to object detection. Then we can develop our project pick the object only for given command. And also place the same color object to same place. Likewise, we can develop that to the next generation

level (Nitesh Funde, 2019) , (Forero & Julián Ávila-Navarro, 2020) , (Yeong-Hwa Chang, 2022), (Bekti Khona'ah, 2019), (Rahul Kumar, n.d.).This method is too useful but when comes to the implementation this is hardest method. Hence, we had to reject that method. But we can use this method for our future works. Then we focus to use LIDAR sensor. The long term of the LIDAR is light detection and ranging sensor. It emits a LASER light and the standard detector is based on a Si PIN diode, but optionally, could support a Si Avalanche Photo-Diode (APD) for greater sensitivity and range. (BEND, n.d.).Since it is surrounded through the source it is unnecessary for our project. Therefore, we reject that too. The last option we had is get an ultrasonic sensor. Then we go through the data sheet and other stuff to collect data to be sure the sensor is compatible to our purpose. The sensor is getting the inspiration from how the bat knows the barrier. Then the sensor is very well compatible for our project. It gives us a short range which is 2cm- 400cm while working with low supply voltage which is 5v and current draw is 20mA. It uses the 40kHz frequency and it working temperature is -15C to 75C (Borison Ningthoujam, n.d.).Therefore we choose ultrasonic sensor for our purpose.

5. METHODOLOGY

5.1. System Design:

The smart forklift robot is designed to mainly perform line following, object detection, cargo lifting, and unloading operations. The system consists of several main components, including IR sensors for linear tracking, an ultrasonic sensor for object detection, a servo motor for lifting objects, an Arduino Mega board for control, and an L298N motor driver for motor driving.

The specifications and requirement of the fork lift can be categorized into three parts.

1)Line Following - The robot must be able to accurately follow a black line on a white surface. The width of the line is approximately 3 cm. IR sensors are used to detect the line and provide feedback to control the motion of the forklift.

2)Object Detection - The system should be able to detect objects in its path using an ultrasonic sensor. When an object is detected on the line following track, the forklift should come close to it by 2cm and stop.

3)Lifting and Unloading - The system should be capable of lifting and landing objects. This is achieved by using a rotating servo motor to lift the forks of the forklift under the object. After lifting, the forklift should start again following the linear path, and at the end of the line, the servo motor should reverse to unload the object.

Based on these specifications and requirements, the overall system layout is designed as follows:

When connecting the IR sensors to the Arduino mega board, the digital output pin of the IR sensor is connected to the digital input pin of the Arduino Mega board. These sensors provide input signals indicating the presence of a black line. The Arduino Mega board processes the sensor data and accordingly controls the movement of the forklift.

The ultrasonic sensor is connected to the digital input pins of the Arduino Mega board. The trigger pin sends a pulse to the ultrasonic sensor which emits an ultrasonic wave. The echo pin receives the reflected wave and calculates the distance to the object based on the wave's time of flight. When an object is detected on the line following track, the Arduino triggers the stop action by moving 2cm closer to the object.

The servo motor is connected to a digital output pin on the Arduino Mega board. The servo motor is controlled to rotate and lift the forks under the object. The Arduino mega board sends appropriate signals to the servo motor to perform the lifting and unloading operations of the forklift robot.

The L298N motor drive is used to control the speed and direction of the motors that drive the forklift. The Arduino Mega board sends PWM signals to the motor driver to control the motor speed and digital output signals to control the motor direction.

By integrating these components and establishing the necessary connections, the Arduino board provides the commands for the smart forklift system to automatically follow black lines, detect objects, and lift and unload objects.

5.2. Hardware Implementation:

In this project hardware implementation can be divided into these main stages,

5.2.1. Chassis and the Forklift

The chassis is playing a major role of smart forklift by providing stability, support and ease of handling to the overall system. In this project, a two-wheeled chassis with Casper wheels is chosen for its simplicity and effectiveness to navigate the track and carry the forklift mechanism. The 2 wheels used here are powered by 2 motors with 5V input with associated gear wheels.

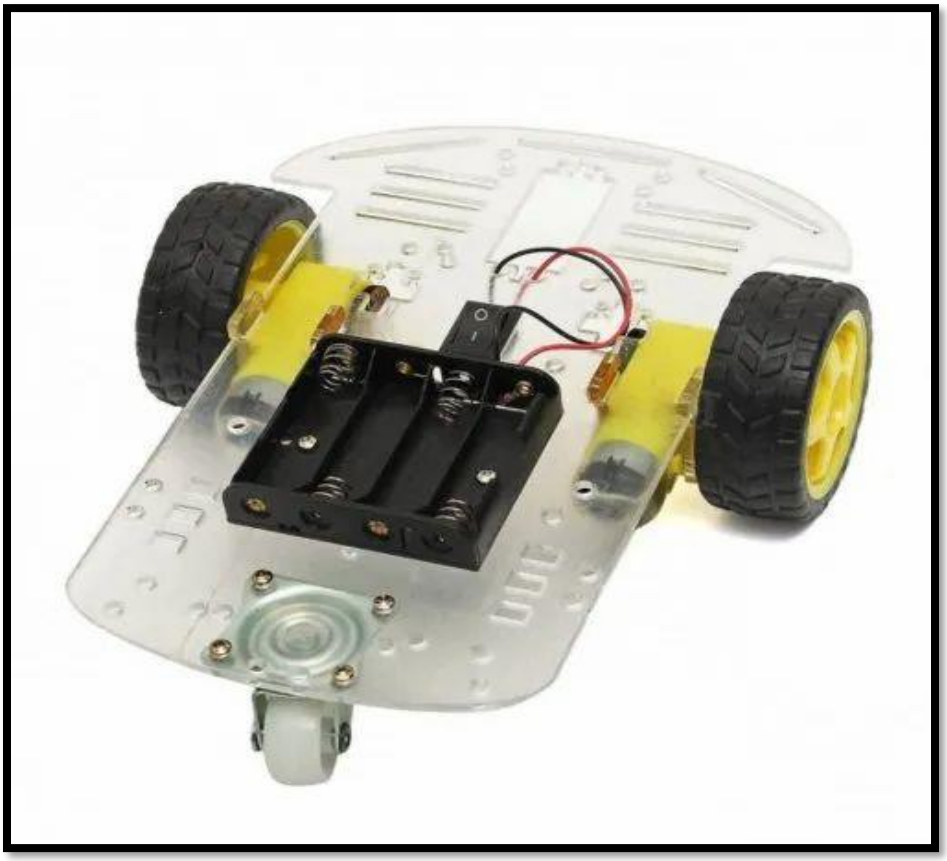

Figure 1:Chassies and the forklift

The two-wheeler chassis consists of a sturdy frame that holds the forklift's components, including the Arduino Mega board, L298N motor driver, power supply batteries, and necessary wiring connections. For this, a chassis made of plastic with good strength and good durability has been used.

The Casper wheel is used for this robot because it has a smooth and effortless movement. Also this wheel is suitable for navigating the straight lines and 90 degree curves of the track which gives stability to the chassis and also reduces friction and ensures efficient operation of the forklift.

Forklift design focuses on the lifting and unloading mechanism. Forklift Robot's forklift parts are 3D printed and designed for safe handling and transport. Here, while obtaining the size and dimensions of the forks, they must be carefully obtained so that they can be attached to the chassis of the line following robot and ensure that they can accommodate the various types of objects commonly found in the warehouse environment. In here solid works software was used to do the 3D design of the forklift part.

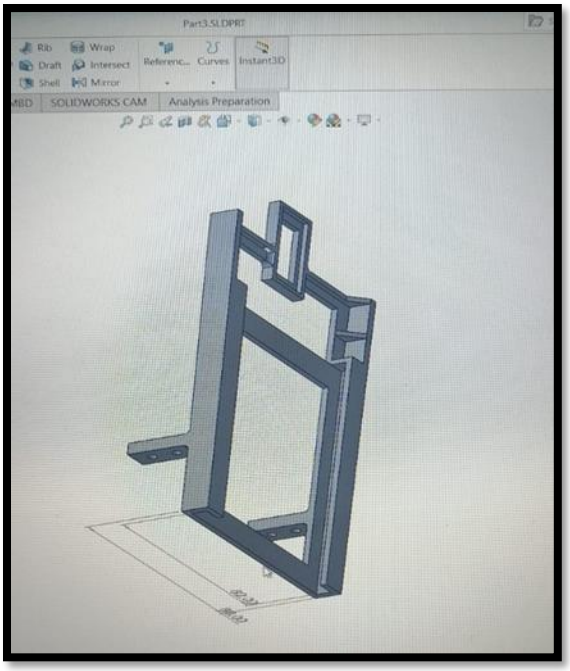

Figure 2:Forklift frame design

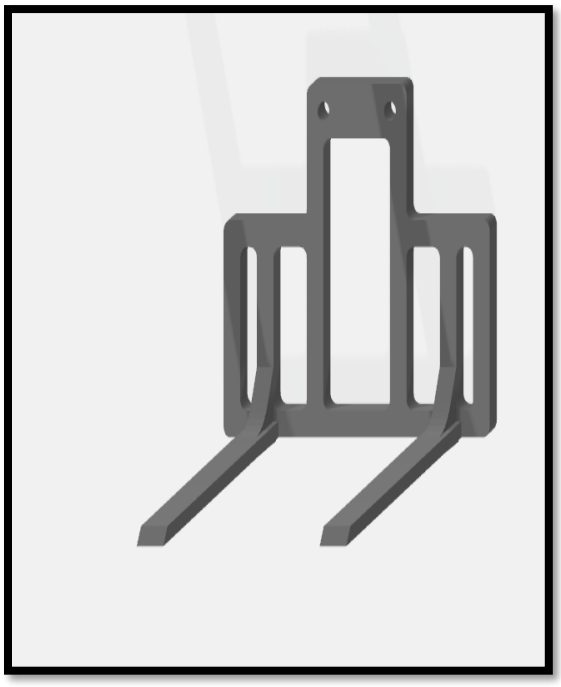

Figure 3:Forklift arm frame

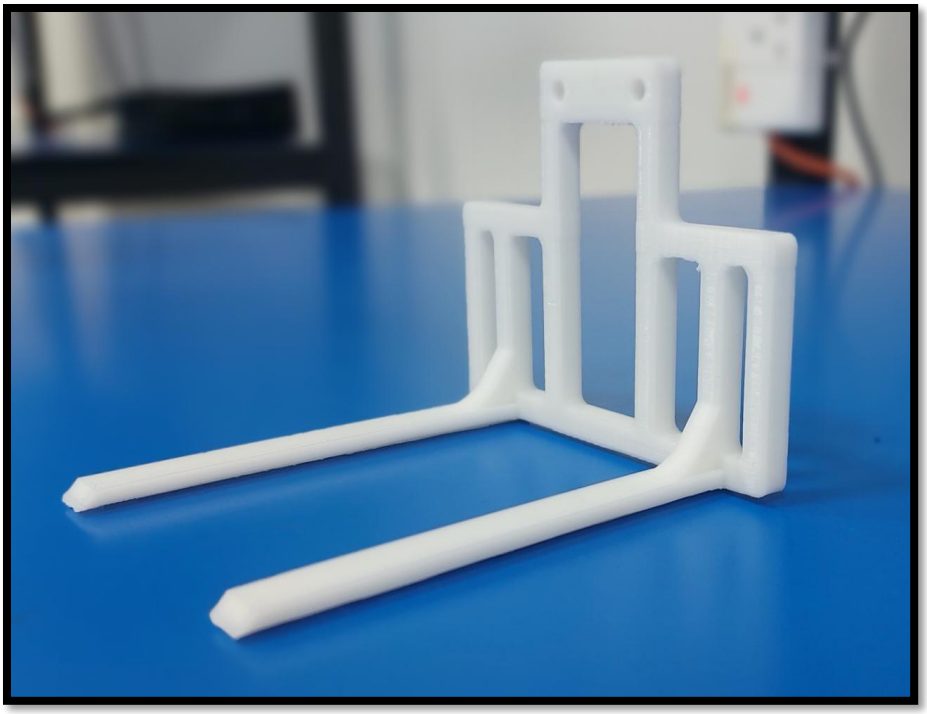

Figure 4:3D printed forklift arm frame

For successful loading and unloading operations in this smart forklift, the forks are positioned at the front of the robot. When the robot detects an object using the ultrasonic sensor, it stops near the object, aligns the forks under it, and activates the servo motor. Servo motor rotation lifts the object and allows it to be transported by forklift. It is designed so that the fork can safely lift objects of varying weight without compromising the balance and stability of the forklift. The forks are attached to the robot, also focusing on the center of gravity to avoid tipping accidents.

5.2.2. IR Sensor Connection

IR sensors are an integral part of this smart forklift for line detection. IR sensors are connected to the Arduino Mega board which enables the robot to follow the black line on the white surface.

3 IR sensors are attached to a 3D printed plastic plate attached to the front underside of the robot. The sensors are attached to the plastic plate using small screws.

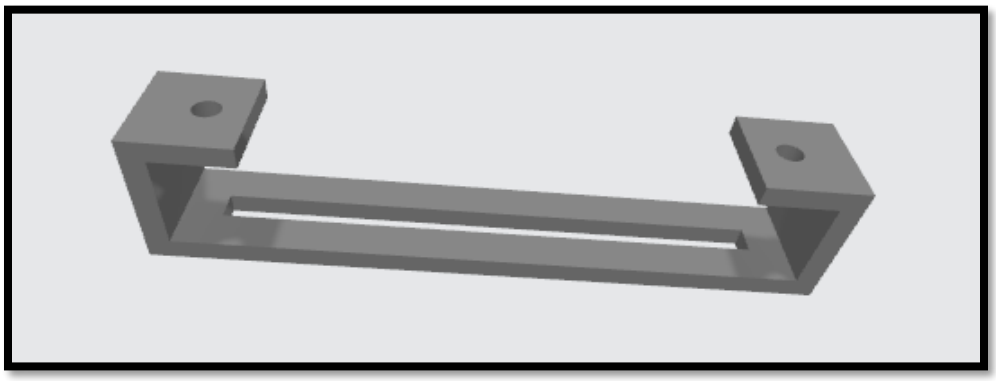

Figure 5:Special design for fixing IR sensors

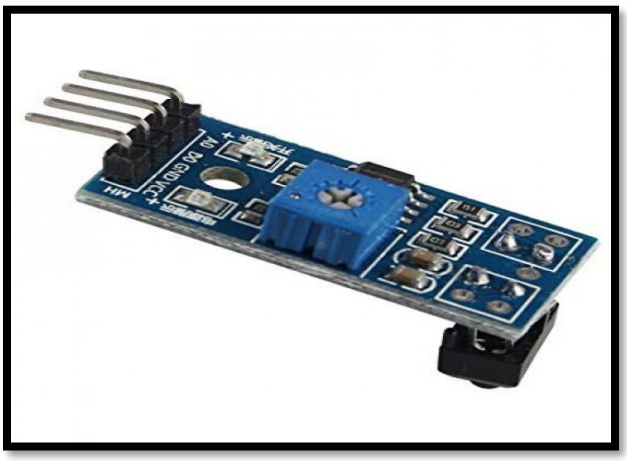

Figure 6:Digital IR sensor

Each IR sensor has four pins: VCC(power supply), GND(ground), DO(digital Out) and AO(analog out). Connect the VCC pin to the 5V pin on the arduino mega board to power the sensors. And connect the GND pin of each sensor to GND pin on the arduino board to complete the circuit.

This ir sensor has 2 output pins. Here, the DO(digital output) pin is used for the smart forklift. Next, the digital OUT pin of each IR sensor was connected to the corresponding digital input pin of the Arduino Mega board specified in the programming code section used. Once the IR sensors are correctly connected, the Arduino Mega board will be able to receive signals from the sensors and process them to detect the black line on the white surface.

5.2.3. Ultrasonic Sensor Connection

When connecting the ultrasonic sensor module to the robot, its data sheet was carefully studied. The Ultrasonic sensor used here usually has four pins: VCC(power supply), GND(ground), Echo pin and Trig pin. The VCC and GND pins are connected to the circuit as previously connected in the IR sensor.

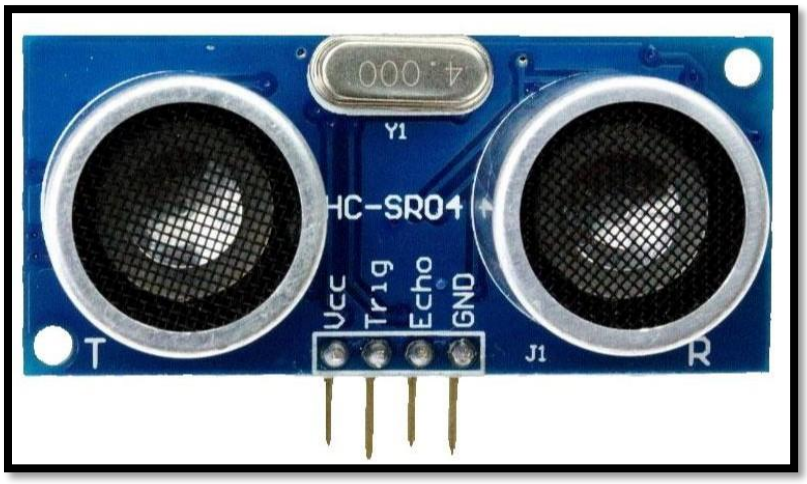

Figure 7:Ultrasonic Sensor

Next, the trigger pin and echo pin of the ultrasonic sensor should be connected to the Arduino Mega board. Here the trigger pin is connected to a digital output pin on the Arduino board. This pin will be used to send a trigger signal to the ultrasonic sensor. Then the echo pin of the ultrasonic sensor was connected to a digital input pin on the Arduino board. This pin will receive the echo signal from the ultrasonic sensor. By connecting the ultrasonic sensor to the Arduino Mega board, the forklift robot will be able to send trigger signals and receive echo signals to measure the distance between the sensor and objects in its vicinity.

5.2.4. Servo Motor Connection

Servo motor use in smart fork lift project to controlling the rotation and lifting of the forks. It is connected to the Arduino Mega board to precisely control the movements of the forks. The servo motor is mounted on the top of the forklift. The forklift frame is designed to fit it.

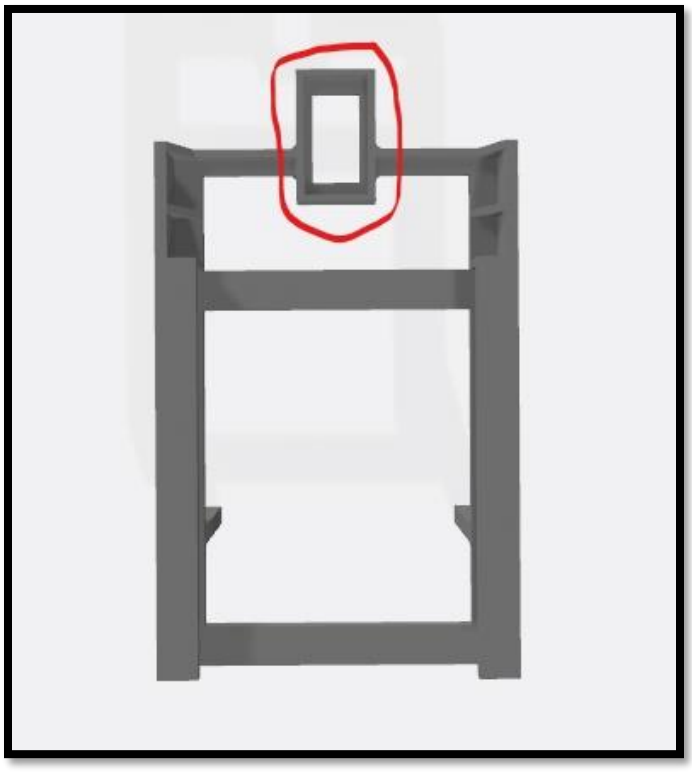

Figure 8:Special design for fix servo motor

The servo motor typically has three wires: power (usually red), ground (usually black or brown), and control signal (usually yellow or white). The VCC and GND pins are connected to the circuit as previously connected in the IR sensor.

Next, the servo motor's control signal wire is connected to a digital output pin on the Arduino board capable of PWM (Pulse Width Modulation) to control the rotation and lift of the forks. This pin will be used to send control signals to the servo motor to determine the angle and position of the forks.

Connecting the servo motor to the Arduino Mega board enables precise control of the rotation and movement of the fokllift's forks.

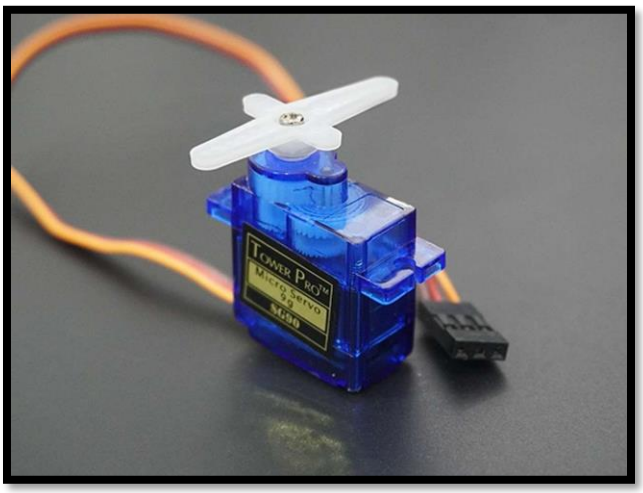

Figure 9:Servo motor

One end of a string is connected to the axis of the servo motor and the other end of the string is connected to the fork part of the forklift that can move up and down. When the servo motor is

turned on, it rotates and wraps the thread around its axis. As a result, the string pulls the fork part upwards, lifting the object placed on the forks. This mechanism allows the lifting process to occur.

Likewise, during the landing process, the servo motor runs in the opposite direction, and the string is loosened from the axis. As a result, the fork part moves down, unloading the object from the forklift.

5.2.5. L298N Motor Driver Connection

In the hardware implementation of the smart forklift project, the L298N motor driver is used to control the movement of the forklift. It allows control of the motors that drive the wheels of the forklift.

The L298N motor driver normally requires a separate power supply to drive the motors. Connect the positive terminal of the power supply to the "+12V" terminal of the motor drive and the negative terminal to the "GND" terminal. A 12.6V battery is used to supply this power.

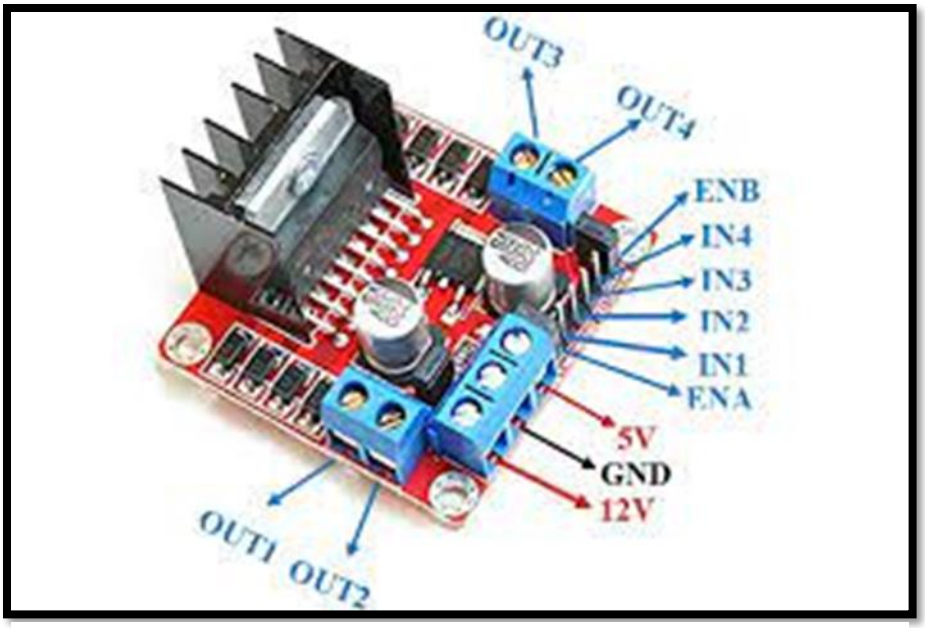

Figure 10:L298N Motor Driver

Next, connect the control pins of the motor driver to the Arduino board. The motor driver has control pins for each motor labeled "IN1", "IN2", "IN3" and "IN4". This control pin determines the direction of rotation for each motor. Connect the motor driver's control pins to the appropriate digital output pins on the Arduino Mega board.

- IN1 , IN2 pins are used to control the direction of Motor 2
- IN3 , IN4 pins are used to control the direction of Motor 1
- ENA used to Enables PWM signal for Motor 2
- ENB used to Enables PWM signal for Motor 1
- OUT1 ,OUT 2 Output pins of Motor 2
- OUT3 , OUT 4 Output pins of Motor 1
- 12V - 12V input from DC power Source
- 5V - Supplies power for the switching logic circuitry inside L298N IC
- GND - Ground pin

5.2.6. Power Supply Unit

To power the smart forklift robot, a combination of lithium-ion batteries and a battery management system (BMS) was used. Three 3.7V lithium-ion batteries were connected in series to obtain a total voltage of 11.1V. To ensure proper charging and protection of the batteries, a 3S (3-series) BMS with a voltage rating of 12.6V and a current rating of 20A was used. A BMS regulates battery charging and discharging, preventing over-charging, over-discharging and short-circuiting.

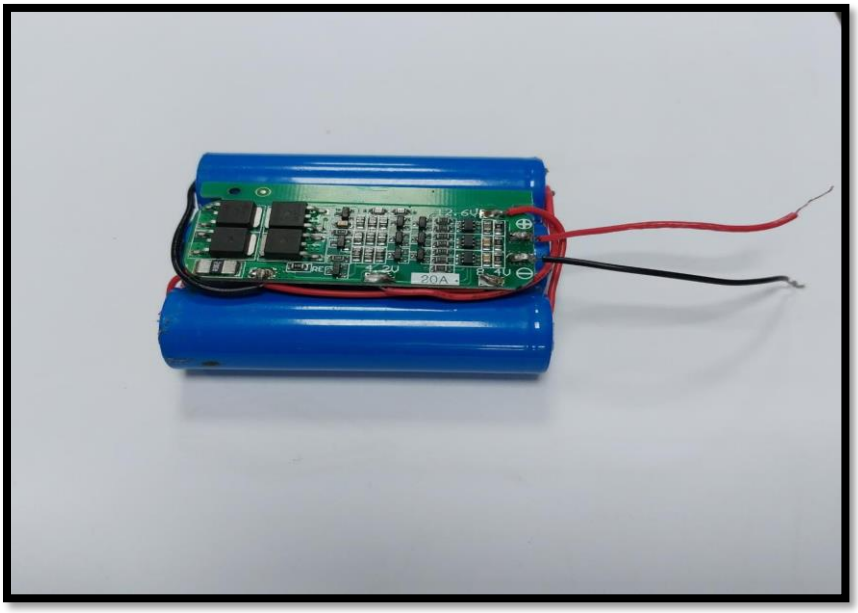

Figure 11: 11.1V Battery pack

The 12.6V output from the BMS was fed directly to the 12V pin of the L298N motor driver, which controls the forklift's motors. This enabled the motor driver to provide a stable and consistent power supply, ensuring smooth operation and control of the forklift's movement.

To power the Arduino Mega board and various sensors, a separate power supply unit was created. This power supply unit used voltage regulator integrated circuits (ICs) to step down the voltage of

the lithium-ion batteries to the required level. Specifically, 7805, 7809, and 7803 ICs were used to regulate the voltage to 5V, 9V, and 3.3V, respectively.

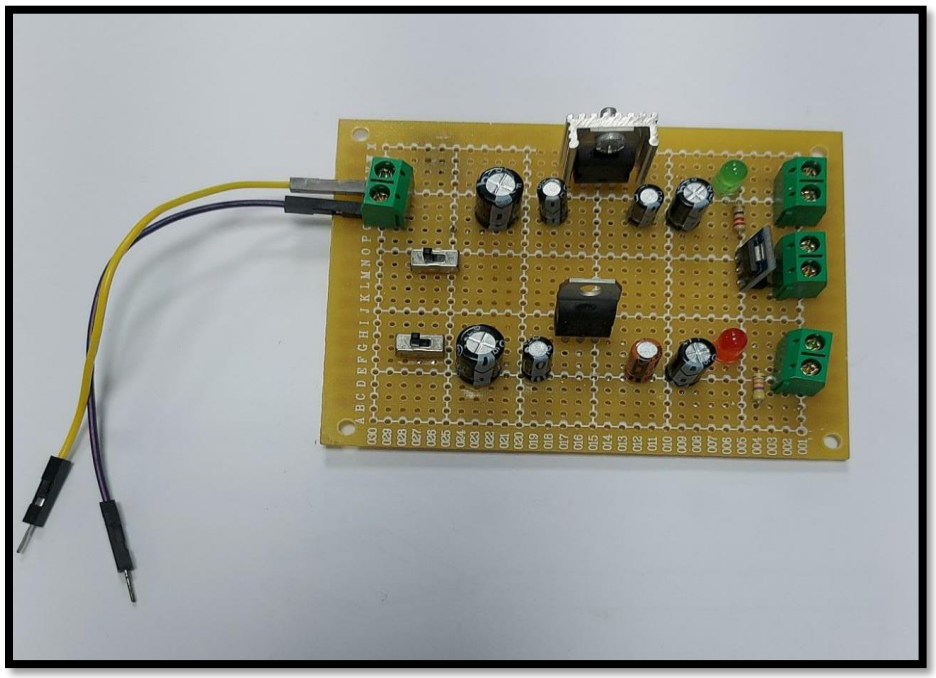

Figure 12:Power supply

The power supply unit is used to provide a stable and suitable voltage to the Arduino Mega board and sensors for their operation. This approach allowed for efficient power distribution, avoiding any voltage fluctuations or inconsistencies that could affect the performance of the electronics.

5.3. Sensor Calibration:

In creating this smart forklift robot, three IR sensors were used to follow the line. These 3 IR sensors are mounted in a row under the front of the robot. Considering these sensors Arduino board is programmed to always middle sensor to follow the black line and other both side sensors to follow the white surface. When any sensor detects black line, it gives Binary ‘1’ signal to the Arduino board and when any sensor detects white surface it gives binary ‘0’ signal to the Arduino board.

The figure below shows the different situations where the 3 IR sensors used by the smart forklift robot are located on the lines following track.

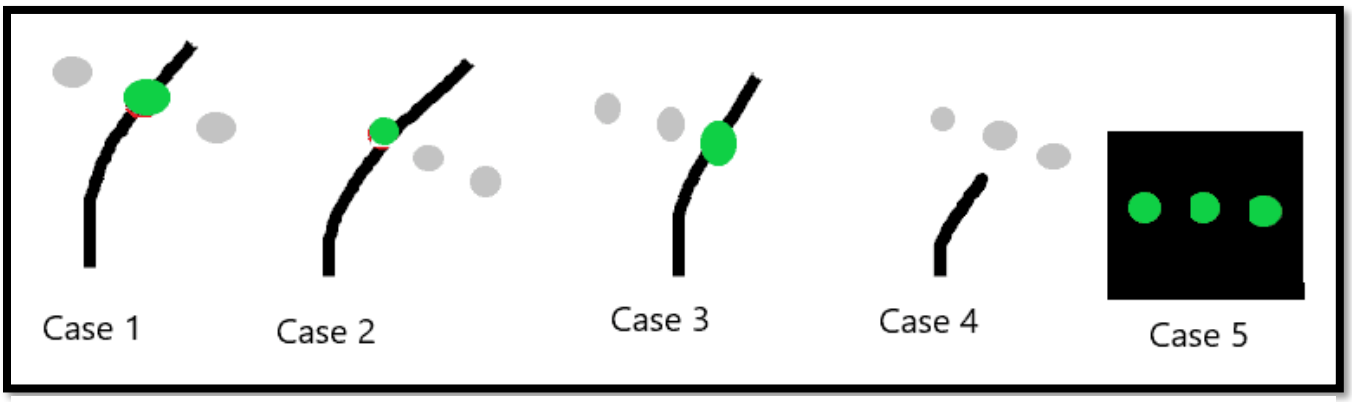

Figure 13:Sensor calibration

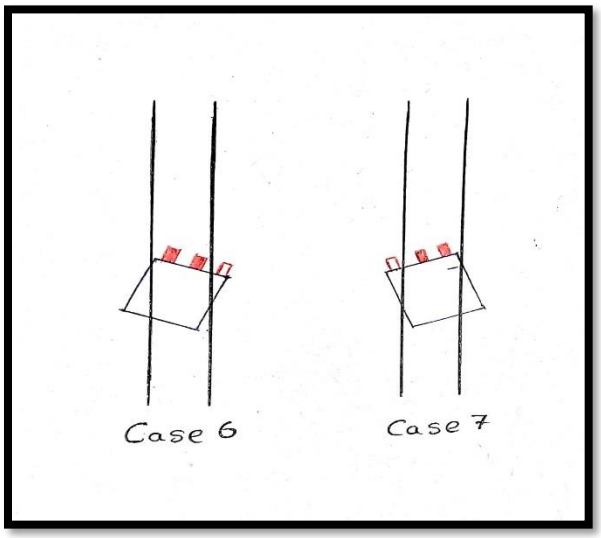

Figure 14:How sensors work when following line

Case No	How the sensors are located on the track	Motion of the robot
Case 1	Only Middle Sensor on the Black line and other both side sensors on the white surface	Robot move Forward
Case 2	Only Left sensor on the black line and Middle & Right sensors on the White surface	Robot turn Left
Case 3	Only Right sensor on the black line and Middle & Left sensors on the White surface	Robot turn Right
Case 4	All the sensors on white surface	Robot Stop
Case 5	All the sensors on Black Line	Robot Stop
Case 6	Left & Middle sensors are on the Black Line	Robot turn Left
Case 7	Right & Middle sensors are on the Black Line	Robot turn Right

Table 1:How the sensors locate and motion for that

5.4. Testing:

5.4.1. Line Following Track

The following track of this project is designed for testing purposes of the Smart Forklift Robot. The track consists of a white surface with a black line made using black tape. The black line is 3cm wide, and IR sensors provide clear visual contrast against the white background for easy line detection.

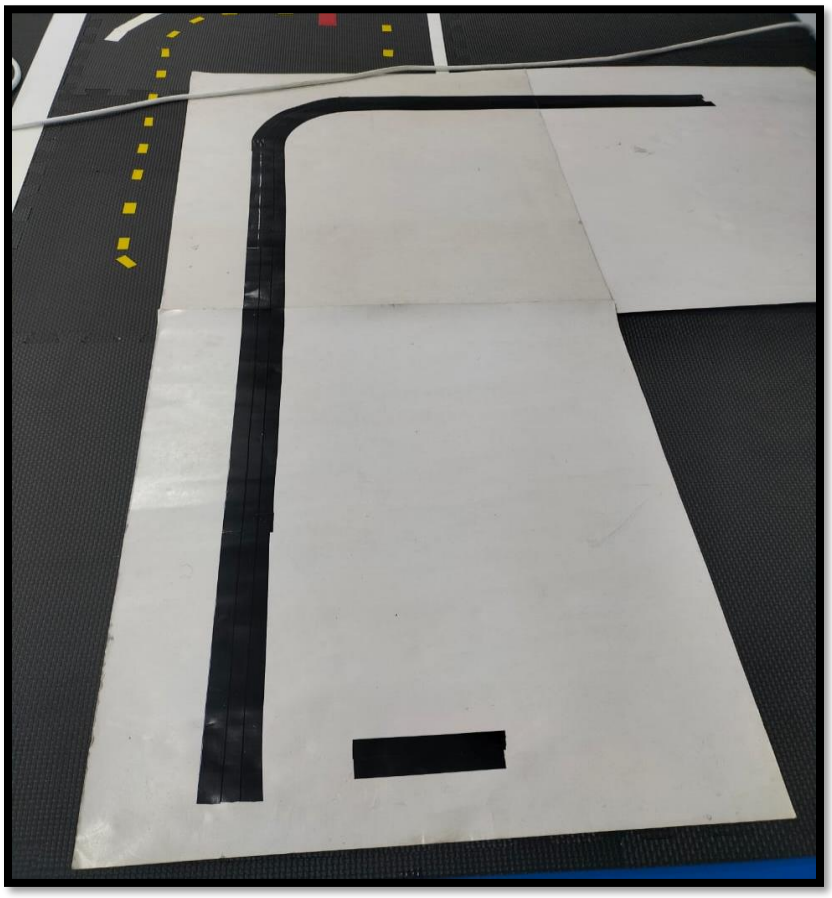

Figure 15:Line following track

The purpose of the track is to simulate a real-world scenario where the smart forklift robot needs to navigate along a prescribed path. By following the black line, the forklift can demonstrate its ability to accurately track and follow a predetermined path.

Black tapes were used strategically on white surfaces to create straight sections and 90-degree curves. This design allows for precise movement and maneuverability of the forklift.During testing, the forklift's IR sensors detect the black line and provide feedback to the arduino board, which acts as the control circuit, enabling the robot to make necessary adjustments in speed and direction to stay on track.

5.4.2. Cargo Box design

A specially designed cargo box is used in this project for the loading and unloading process. The cargo box is constructed using cardboard material with dimensions of 5×5×5cm units and its weight is between 20-40grams. It is placed on a small frame that allows the forklift's forks to go under and lift the cargo box safely.

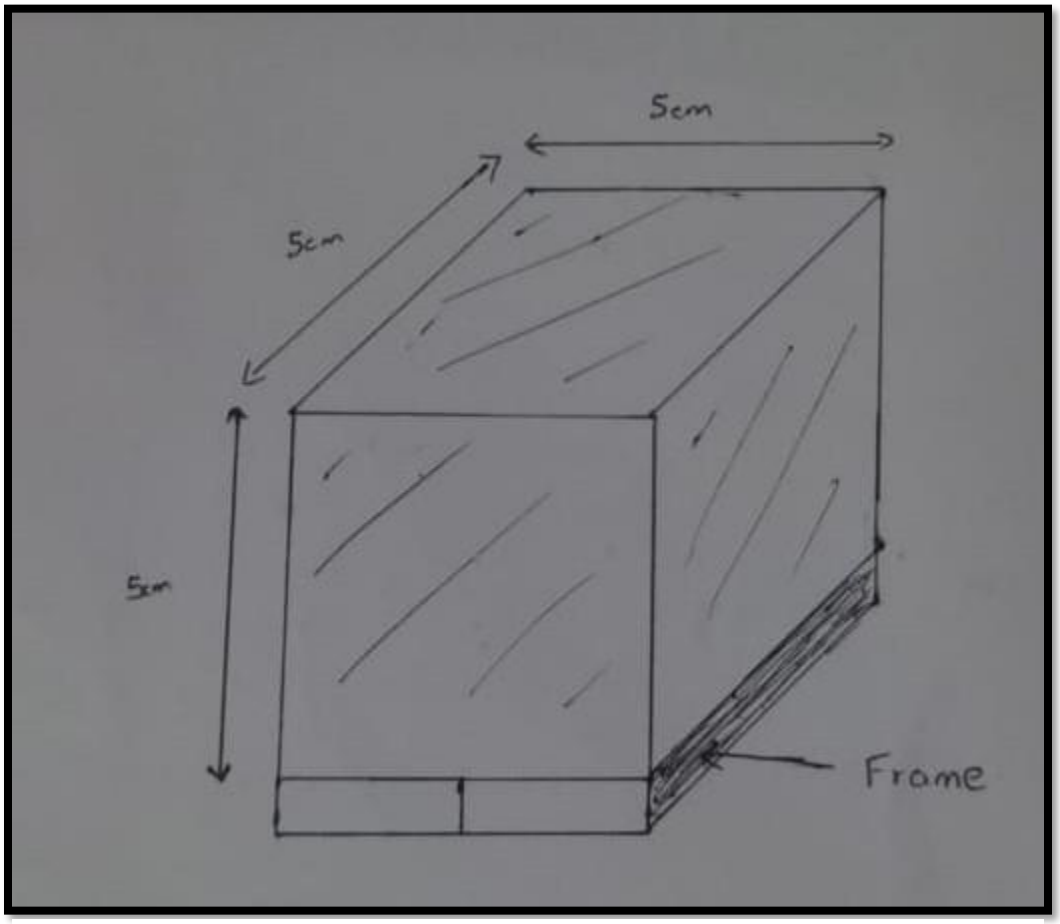

Figure 16:Cargo Box

This loading and unloading process simulates real-world cargo handling scenarios. It demonstrates the forklift's ability to accurately lift and transport cargo boxes, highlighting the practical application of the Smart forklift in warehouse and logistics operations.

6. RESULTS AND DISCUSSION

As mentioned above this project can categorized into sub projects basically.

1. Line follow Robo vehicle.
2. Object loading and unloading forklift.
3. Object detecting and identification system.

- **Line follow Robo vehicle**

In line following Robo vehicle first categorized into two fields.

1) Line following path
2) Line following robot.

1)Line following path

In this section first we have to decide the path what we want. Firstly, we decide a path with including v shape ,90 degree shape half circle shape and s shape. Then we got lot of issues with the robot when passing these line segments.

When passing these line segments Robo is not going through some of them. Specially v shape segment and 90-degree segment. Then with the basic purpose we remove v shape and 90-degree segment from our line following path.

2)Line following robot

After set the line following path then we use 2 IR sensors to detect the line firstly. On that time, we got lot of oscillation and sometimes it is not getting curves and edges and sometimes it didn't go continuously. Hence then we use 4 IR sensors to detect the line following path. Then this time robot goes continuously. But in this time sometimes there has a oscillation and some times it goes as we want that means without a oscillation. In this time robot gets curves and edges sharply.

In line following robot overcome this oscillation issue we observed the width of the line following track is high. Hence, we have to reduce the line following track width from 4.5cm to 3cm.After reducing the line following track width then we observed the robots' oscillation is also got reduced. But even though still there had a small oscillation.

To overcome this issue further then we adjusted the distance between the sensors. But then oscillation got increased again. Therefore, we reduced our 4 IR sensor array to 3 IR sensors. Then there had a negligible oscillation. This oscillation is typically don't affect this project. But better use PID controller to overcome this also as the future work.

When comes to the power up the robot we needed batteries. For that we used three 4300mah batteries connected series to get 11.1V which is need to power up the motor driver. We used that much battery capacity because the line following robot getting nearly 1 Ampere current too. With

the forklift the current is get high. We got 4300mah the lithium-ion rechargeable battery perhaps If the robot gets more current and we needed to power up this forklift a considerable time. But we got a issue regarding the battery. It had to charge many times. Then we calculate the power we need again. There is no wrong with the calculations. Then we checked the battery then the problem is there. There has not that much capacity in the battery as mention.

In this robot is also not work with the lower motor speed. It didn't work for the below 70 motor speed. So, we use appropriate motor speed since even high motor speed it is not suitable hence the object can be fallout and will be damage.

- **Object loading and unloading forklift**

  In this section we had some issues in several categories. We can categorize these issues into 2 sections.

  1. Forklift design
  2. Changing center of gravity.

1)<u>Forklift design</u>

In this section we had several issues such as how to fix ultra-sonic sensor with the forklift, how to fix forklift to the chasse while there has IR sensors in front without affected. And how the strength of the fork how much of weight can be lifted.

When considering the ultrasonic sensor and IR sensor fixing, we had made a very special design as follow.

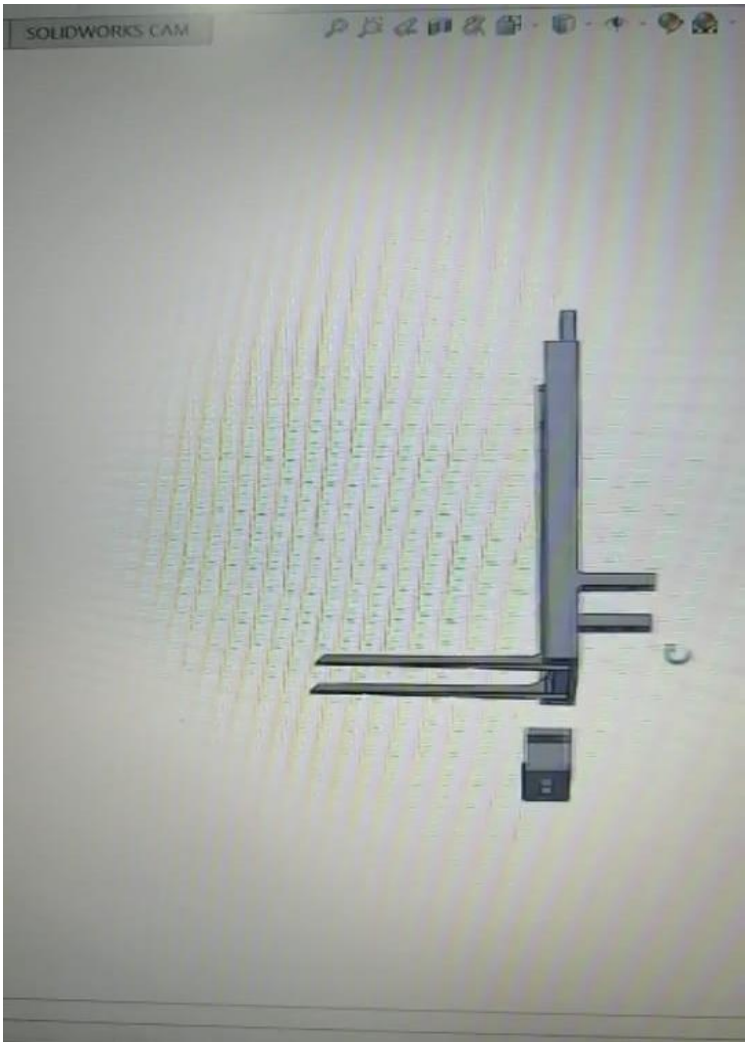

Figure 17:Special design for forklift

This can overcome these two issues.

Then we had to checked the strength of the forklift. It gives us a good understanding about how much it can lift. Since we used a 20-40g 5*5*5cm box we need to checked strength for that. With the safety factor we checked it for 100g. That means 1N. In there we got 1.4mm bending over. To reduce that we used a web through the two forks. Then we checked it again with 1N force. Then it bending over 0.8mm. That is very small amount and it is negligible.

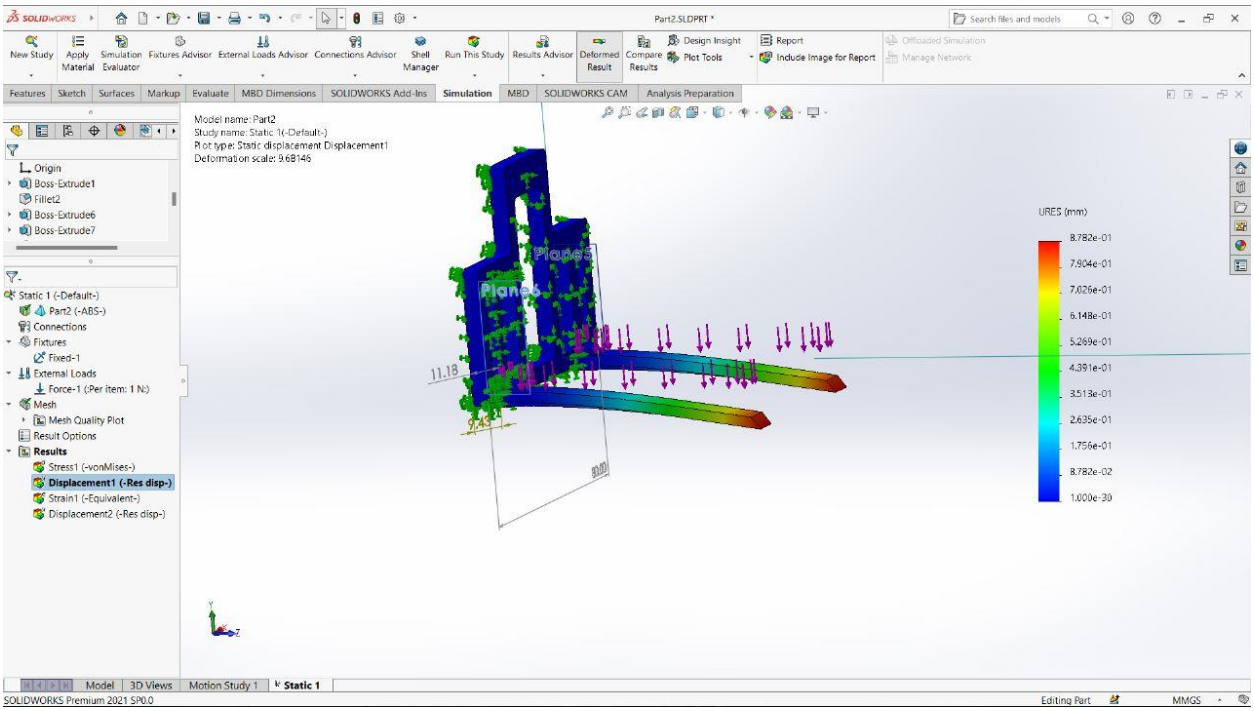

Figure 18:Bending over for 1N without web

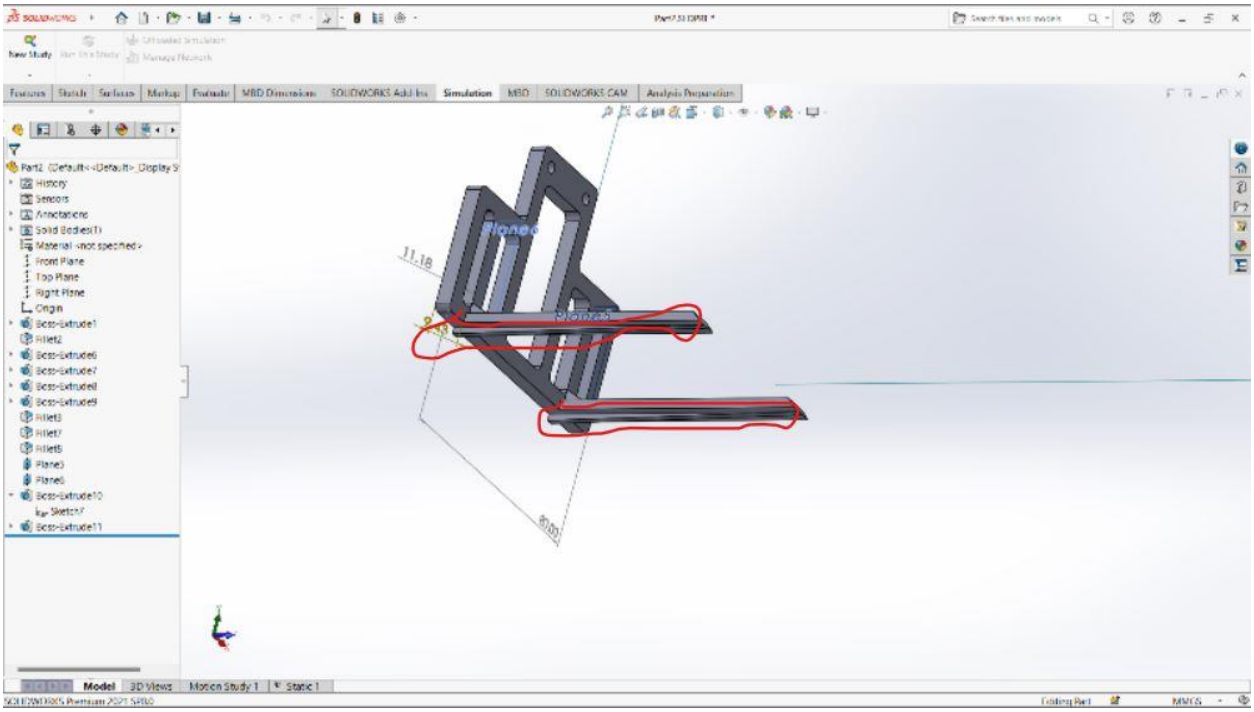

Figure 19:Webs for increasing strength

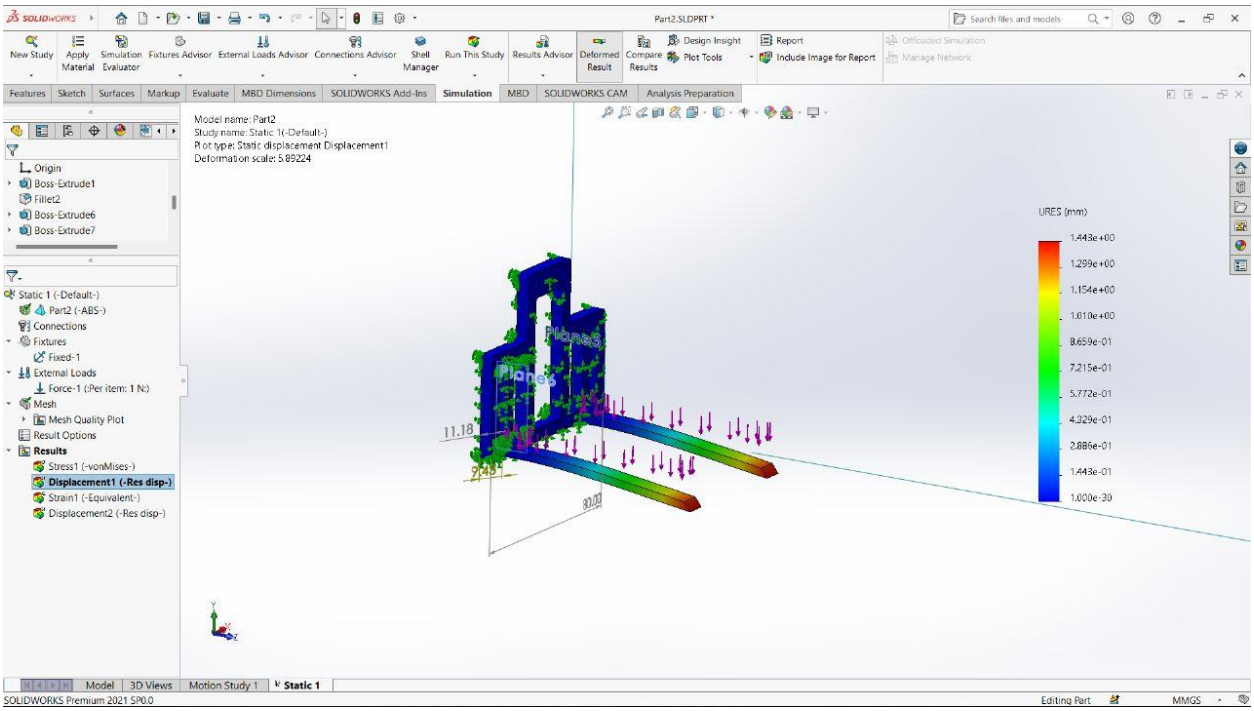

Figure 20:Bending over for 1N with web

In here we had some issue regarding the changing the center of gravity while after the pick the load, the center of gravity changed. But in here we lift 50g 5*5*5cm box. Hence it is not affected too much for the center of gravity since the battery pack is heavy as enough for handle that.

- **Object detecting and identification system.**

In this part we have gone with the simple object detection and identification system. That is using an ultrasonic sensor. But in here we got an issue with the where to fixing the sensor when after the loading sensor is blocked by the load. In that scenario we used black line to stopped the Robo and by reversing the Robo vehicle.

7. CONCLUSION

This report is based on a smart forklift which is useful for cargo handling. This automated forklift we can categorized into 3 parts.

1) Line following Robo vehicle
2) Object loading and unloading
3) Object detecting and identification system.

In here we got the basic result what we want and it can develop further in future in several areas. In object detection part we can use a camera module and AI technology to object detection.

In the forklift part we can use hybrid system which is used both electrical and mechanical forklift system and also, we can use a system to reduce overturn accidents since there are lot of accidents when using forklifts as future works.

When comes to the line following robot we can use more IR sensors to go through the v shapes segment and 90-degree segment. We can create a design to lift more than 1N s and then it can be occurring a momentum while changing the center of gravity. To overcome this, we can use a gyro sensor and stack type (flame-cut cast metal plates stacked onto a base plate or an existing bulk) forklift counterweight.

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