AVERROES

Autonomous, Tele-presence, Object-identifying and Manipulation Robot

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CERTIFICATE OF CORRECTNESS AND APPROVAL

Certified that work contained in this thesis titled "AVERROES (Autonomous, Tele-presence, Object-identifying and Manipulation Robot), carried out by PC Noor ul Hudda, NC Jawad Hussain Kalwar, NC Junaid Ahmed Mohsin and PC Abdullah Munir under the supervision of Asst Prof Mir Yasir Umair for partial fulfillment of Degree of Bachelors of Telecommunication Engineering, in Military College of Signals, National University of Sciences and Technology during the academic year 2019-2020 is correct and approved. The plagiarism is 10%.

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ABSTRACT

Automated Assistance Systems are the main reasons for today's efficient and reliable service in industries and warehouses around the world. These systems help reduce human work load and minimize errors which may be caused by workers. Machines such as robotic arms and monitoring bots have excelled industries to manufacture top of the line products and provide a systematic service to its customers.

The basic idea behind this project being proposed is to design an autonomous and tele-presence robot having the functionality of both a robotic arm as well as a robotic body which would navigate its way through a warehouse and monitor inventory restocking. Sensors on the body would assist the robot in navigating its way avoiding any obstacles it may encounter. Camera mounted on the arm would provide us with a live feed of the area it is used at. That live feed would be monitored by workers through a web application available on most devices. Camera would also scan QR codes on packages checking their correct placement. Motors in both the arm and the body would provide a wide angle of freedom for maximum navigation capabilities.

Different robots were studied and their functionality and hardware components were thoroughly looked through to find the most suitable and efficient parts for our project. Robot designing was done on SolidWorks. Coding of robot will be done on NVidia Jetson Nano. Web application will be designed on WebStorm.

Since our robotic arm will be mounted on the movable robot, it can be used in multiple places without physically moving the arm or having more than one arm in a warehouse. This project may also help prevent injuries to humans as it may replace human labor e.g. lifting and moving packages.

DECLARATION

No portion of work presented in this thesis has been submitted in support of another award or qualification in either this institution or anywhere else.

In the name of Allah, the most Beneficent, the most Merciful

DEDICATION

This research is dedicated to our parents, well-wishers and most importantly to our supervisor, Asst Prof Mir Yasir Umair. A work of this magnitude would not have been possible without their unstinting cooperation and unflinching support.

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All praises for Allah Almighty who gave us the strength to accomplish this mighty task despite numerous difficulties and hardships on our way.

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We revere the moral support and passionate encouragement of Engr. Shoaib Ahmed, CEO Incendio Solutions, throughout the development of our project.

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INTRODUCTION

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INTRODUCTION

1.1. OVERVIEW

AVERROES is an autonomous, tele-presence robot. The proposed project aims at the design and development of an astute, autonomous robot with adjustable wheels. (AVERROES), a self-sufficient robot will easily traverse the wideness and entanglements of its environment using the data gathered from its sensors. It will ensure the mobility and stability in accordance with the surrounding. It will be suited for all sorts of complex and testing conditions. It will also be able to lift reasonable weight. Moreover, it will provide continuous feedback regarding environmental analysis i.e. temperature, pressure, humidity etc. The web application will act as a GUI to control the robot and monitor it using Wi-Fi.

1.2. PROBLEM STATEMENT

Humans have been replaced by the robots to do repetitive and dangerous labor as humans do not want to do those tasks or are unable to do due to impediment of humanely capabilities. Efficiency and feasibility are the need of the modern era. In modern times, robots are made a part of labor force owing to their potential of handling particular, repetitive tasks with proficiency after precise programming. There are many robots being used in workforce but a bulk of labor is still done by humans, which leads to errors. Automated assistance systems have evolved over time, but most of them lack autonomous mobility. They need a team to control and manage them.To get the robot to do something other than what it was designed for, is not only expensive but requires change in the entire algorithm and programming. Robots that are able to multi-task and perform in versatile conditions require that the robot is able to observe and analyze its immediate vicinity. In this regard, the seemingly simple task of detecting an item and picking/placing them at a desired location needs extensive coding, training and testing for that particular item. The required software and hardware for this does not exist commercially yet.

1.3. WORKING PRINCIPLE

We are designing and developing an astute autonomous tele-presence robot that would provide real time info graphics and statistics of inventory by getting product details from user via a web app. The input will then be sent to NVidia jetson Nano system on module in combination with multitude of sensors, motors and actuators to locate scan and then affirm availability of product in the inventory.

In addition to a mobile platform, a manipulator will be mounted on top the body. In this way, the functionality of the arm will not be fixed to a certain location rather it will move in the vicinity with the mobile body and perform the designated tasks. An end effector will be attached to the arm along with a camera. The camera will scan the QR code off the products and the claw will be used for manipulation of products and packages.

1.4. SCOPE

This project will be a productive insight in warehouses, inventories and industries because of its ability to navigate on its own, study the environment and map it and perform the routine tasks more accurately and effectively. It will make the working and management of warehouses easier and more efficient by automating multiple processes.

1.5. LIMITATIONS

The main purpose of robots is to take daily, repetitive task off of the hands of manual labor so that their resources can be used for more creative tasks. Moreover, robots assist humans in tasks such as lifting and transporting heavy object. However, robots need humans for their operation. Robots depend on humans in several ways. Robots are manufactured, fixed and controlled by humans. Robots need humans to interact with them. After a warehouse has been automated using AVERROES, the robot will need a human to direct it to find a particular product and perform the required function. Moreover, robots will be serviced and repaired by humans.

1.6. OBJECTIVES

The primary objective of this project is to design a robot to be used in warehouses, large E-commerce sites, inventories and logistics companies. The robot will be able to navigate buildings while avoiding obstacles and will provide the feature of tele-presence. This robot will be compact, cost-effective and easier to deploy and have a wider scope. It will have an intuitive and minimal back-end user interface that could be operated by someone with little knowledge.

Our end goals or objectives can be broadly identified as:

1. Design and development of wheeled body that will traverse autonomously.
2. Development of web application to control/monitor.
3. Design and development of arm that will detect & manipulate objects.

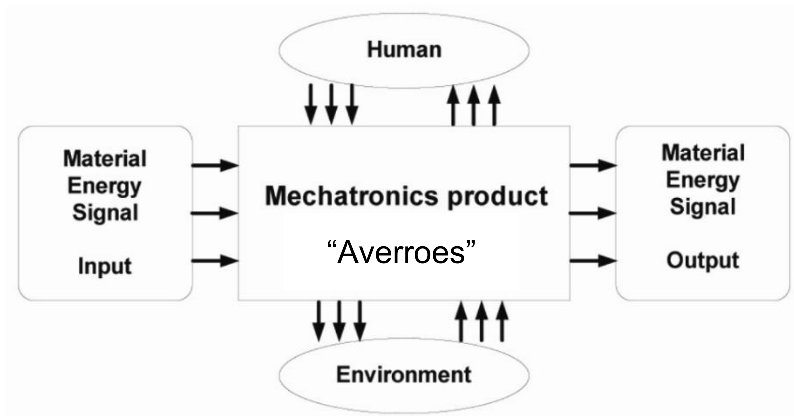

Figure 1-1: Project as a mechatronics system

1.7. ORGANIZATION OF DOCUMENT

This document is divided into six main chapters:

CHAPTER 1:	First chapter is about the introduction and main objectives of the project.
CHAPTER 2:	Second chapter summarizes the literature review and the previous research done on the topic.
CHAPTER 3:	Third chapter lists the hardware and the software requirements of AVERROES including technical specification and setup for working environment.
CHAPTER 4:	Fourth chapter gives overview of AVERROES design and explains in detail the development.
CHAPTER 5:	Fifth chapter is about analysis and evaluation of project.
CHAPTER 6:	Sixth chapter lays down the enhancements and future work.
CHAPTER 7:	Seventh chapter provides conclusion.
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CHAPTER 2

LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.1. PROJECT DOMAIN

In case of this project, mobile manipulator is fundamentally a controller fitted on a moving frame. As the movement of the robotic arm is obscure beforehand, the portable body needs to utilize the data gathered from surroundings to decide the movement of the manipulator. In order to understand the control and coordination of manipulator arm several fields need to be researched. Significant issues identified with this proposition incorporate the controlling a wheeled mobile bot, the tracing of tracks for moving bots and the scheme to manage and synchronize the function of manipulator and mobile body in a systematic fashion. An extensive study of literature has been carried out to investigate and analyze the different concerns and concepts related to movement and utilization.

2.2. MANIPULATOR KINEMATICS

Humans can be supplanted by robots to perform several tasks and functions in industries and warehouses. The robot configuration engineers form several designs to find the perfect arrangement of connections and joints of the mechanically connected framework. The robotic arm is a structure which consists of several links, joints and connections that move to enable the overall movement of the arm. Generally a manipulator provides one degree of portability, either rotatory or prismatic joints. Initially, the mechanical plan for design of a robot arm seems to be really easy but it presents a series of complicated issues. Theories about mechanisms and machines contributed to develop the planar and spatial systems.

Mitrouchev introduced a review about the structural procedure of a modern robot implementation. The strategy permits the production of plane automatic formation with various degrees of portability. The summed up arrangement of controllers, kinematics and elements has been discussed. In order to depict the rotatory and translatory motion of the manipulator arm, a 4x4 homogenous matrix was used. Additionally they formed methods and protocols to solve issues related to motion of robots. A general model depicting the movement of a robotic arm along six degrees of freedom formed the basis of another design that incorporated the concept of in-parallel actuated mechanisms (2). In order to employ a robot with a manipulator arm that will be used for certain industrial applications, three possible solutions were put forth that were likely to remove the limitations and issues regarding the movement. These solutions comprised of

i. movement of the end-effector i.e. clamp
ii. partly-rotatory movement
iii. partly linear movement

Another detailed strategy to tackle the kinematic issues of robotic arm framework for multi-tasks was formed by using screw theory and quaternion algebra. It was introduced by Sariyildiz and Temeltas. A model that incorporates errors related to kinematics have been depicted in a model by mapping design specifications to links angular specs. Dynamic error remuneration technique was additionally talked about in their work by incorporating measures for control in the software. The main advantage of having developed an error model for an industrial robot was that a thorough analysis of the precision and repeatability qualities was obtained.

The precision and exactness of the manipulator arm is determined by using the Denavit-Hartenberg kinematics parameters that makes use of the homogenous matrix and differential change matrix concept. The other measures and calculations related to the arm were also done later using this model. Another low cost model was devised to estimate the movement linked specifications of the robot. The abstract of this concept showed that practical calibration is not fundamental.

The inverted movement model of a sequential robot manipulator map the Cartesian space to the joint space. However, the relationship between Cartesian and joint space is not linear and it requires complex transcendental equations for implementation.

Another important mention in the field of research would be of Pozna. He has been focused on designing of robotic arm that uses several joints and links connected in parallel or perpendicular. This study was supported by the general type of the connection which lies between two progressive joints and the simplification of the connection between joints and links. Aydın and Kucuk also worked on the structural design of a robotic arm that has 6 DOF enabled. They made use of Euler wrist using dual quaternions. The created apparatus displayed the mechanism of rotatory and translatory movement simultaneously.

Pashkevich worked on developing design for inverse transformation of coordinates that was used in industrial supplications. The devised calculations permit end-users to get answers for the endorsed setup, and have great assembly, in any event, for solitary controller areas. Inverse kinematics and dynamic protocols for sequential robots are introduced in references. These bots are controlled by such interconnection of links and joints that produce the required movement by the gripper that is connected as the end-effector.

As the robots become more advanced and complex with time, the problems associated with their control and management also increase. Hence the quest of solution for kinematics problem is difficult and involves complicated calculations and expensive components. Alavandar and Nigam introduced the rakish contrast that is derived and the information anticipated with Adaptive Neuro-Fuzzy Inference System for two and three level of opportunity planar controller. Another three-interface planar controller converse kinematic model has been produced for creating wanted directions in the Cartesian space (2D) by utilizing a feed-forward neural network [3].

2.3. MOBILE STRUCTURE MOTION

This portion discusses the ground work and the past work done for the advancement of mobile robots and to resolve issues regarding it. Extensive research has been done over the past few years to this particular field of technology. Huge number of methods and solutions has been devised trying to take care of this issue yet no single strategy has been generally acknowledged. A review of significant procedures utilized in developing feature of autonomy within robots has been tended to here.

2.3.1. OVERVIEW OF MOTION PLANNING CONCEPT

Each motion planner has a particular problem associated with it for which it provides the most efficient solution. The most significant feature of a movement planner therefore depends on the issue it resolves. This implies that the adequacy of the motion planner relies upon the characteristics of the robot in which it is employed to perform certain functions. When the assignment and the robot framework are characterized the subsequent stage is to develop protocols and algorithms to take care of the particular issue.

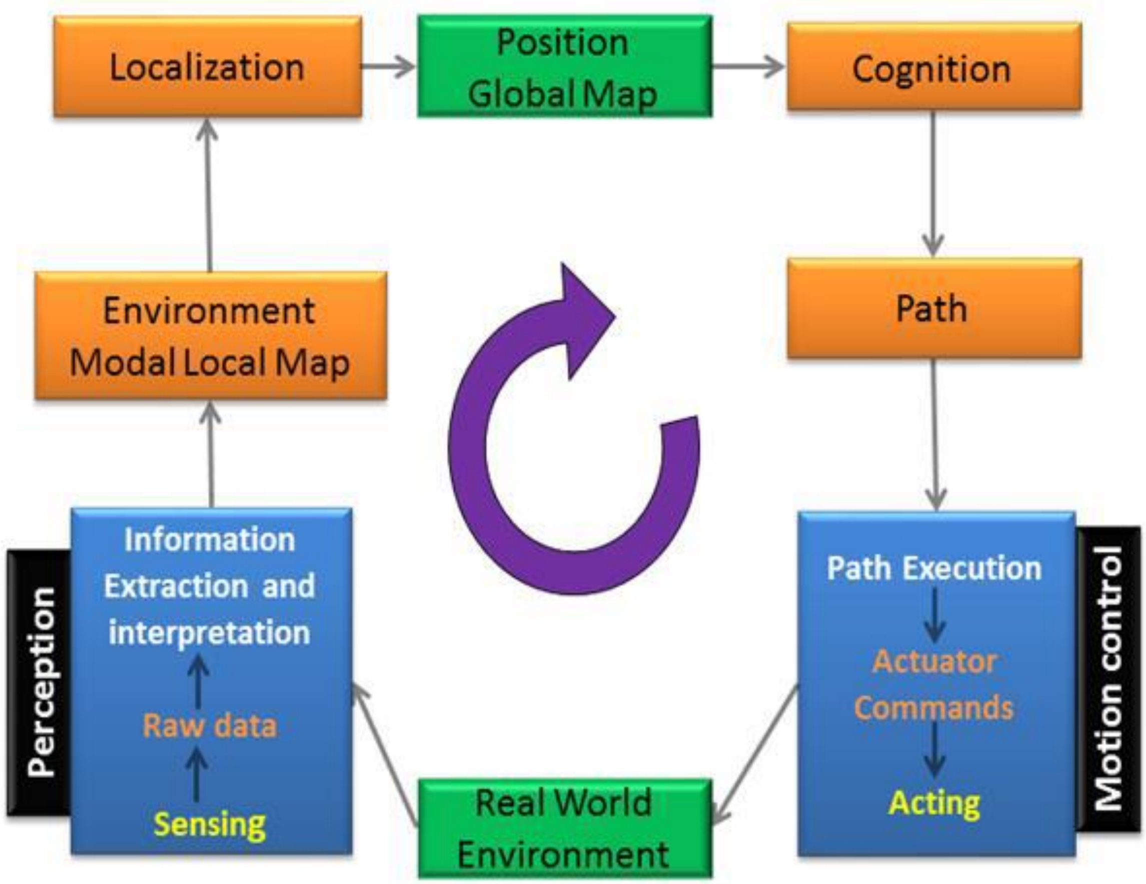

Figure 2-1: Control plan for route trace of a mobile robot

The various angles associated with the robot movement control are shown in the figure above.

The kinematics mechanism issues of autonomous mobile robot/robots include:

1. Robot's ability to move on its own
2. To view (analyze) its environment
3. To locate itself and other objects
4. To adapt and make decisions
5. To control its speed and direction to ensure stability

2.3.2. WHEEL LOCOMOTION

For a robot to be able to move between different locations, it needs a driving force and motion form. There are many possible mechanisms that can be put to use to move the robot. The possible forms of motion include walk (requiring two legs), slide, run (requiring four legs) and jump etc. The mobility method for any robot must be devised inspired from the structure and framework of the bots so that it is able to tread through all sorts of territory. However, to replicate the naturally existing systems of living beings for a mechanical robot for following reasons:

i. Complex mechanical structure
ii. Movement powered by biologically produced energy
iii. Complicated mathematical replication

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On account of these restrictions, it is difficult to recreate the natural motion mechanism for a large number of mechanical legs. Therefore, as of now small number of jointed legs are being used in robots. However, the mechanical designing and development of a legged structure is very complicated as it requires several joints, links, connections, bending property and freedom of movement. As a result, to avoid all these issues and complexities the use of wheels to provide robots a kinematic system is widely accepted.
Using wheels is comparatively simpler, easier and is suitable for flat grounds which are generally laid down in industries. However, this solution is not problem-free. If the surface on which wheels are used is very smooth and soft, the wheels will practically roll over it due to lack of required amount of friction. There must be significant friction between the wheels and surface to ensure a stable and steady movement. Several researches have been done to make the use of wheels well suited to motion needs of robots.

In order to develop a relationship between the frame of the bot and the wheels used we can consider robot to be a flat, fixed surface [4]. The wheels that can be equipped for a robot can be divided into five different categories depending on the geometrical specs of the wheels. The mechanisms of motions and structural design of each robot has been thoroughly studied.

If three individually moving wheels are attached to a mobile robot, the formed framework would provide motion in all directions. Normally, directed wheels are used in robots due to ease of use and durability. Cariou *et. al.* has considered the possibility of robot slipping and deviating from the path traced out by algorithm. The deviation can be either linear or angular. Marcovitz and Kelly have worked on a model that considers all possible degrees of slip that a robot can face. This model was later used to develop skid-steered machines.

As directed wheels have certain restrictions when it comes to moving freely, a new type of wheels called caster wheels are used in machines to have a larger range of motion. The motion of an independent robot having caster wheels is far greater. Chung *et. al.* developed a model of mobile vehicles equipped with all-round wheels. The versatile model of a mobile robot outfitted with fueled caster wheels has been inferred dependent on vehicle elements by presenting contact steadiness condition [5]. Kim and lee have devised ideal symmetric conditions for a mobile robot equipped with caster wheels.

Another wheel that is worthy of mentioning is a Swedish wheel. It is basically a common wheel but has its rollers out on the edge. This particular arrangement of rollers provides the body with full portability in all directions. Hence, Swedish wheel is an ideal choice to manufacture an all-directional mobile robot. *Indiveri* has discussed about the problems that arise in control and management of motion when larger say **n** number of Swedish wheels are used on a robot. Doroftei *et. al.* has put together a robot that used Mecanum-wheels. This comprised of a robot having four Swedish wheels that not only enable the robot to move in all directions but also did not require any interference [6].

In the research of finding the most suitable wheel, another wheel was studied that is the spherical wheel. This wheel offered wider motion and enhanced firmness but the problem of control and management of its kinematics was there. A unique circular wheel was presented in for an Omni-directional portable robot and is successful in stair climbing with its semicircle wheels. After it a new combination of spherical and omni wheel was presented. Its working guideline comprises of a circular wheel driven by two opposite sets of Omni wheels. The 'ball-plate problem' is the kinematics issue of a spherical wheel. Two unique calculations were proposed for reconfiguration of this problem. The primary calculation depends on standard kinematic model and conjures exchanging contributions to get an answer contained round circular segments and straight line fragments. The subsequent calculation depends on the Gauss-Bonet hypothesis which accomplishes reconfiguration through circular triangle moves. The kinematic model of a round wheeled portable robot has been created utilizing quaternions for the depiction of the direction of the robot.

Lauwers et. al. has introduced the general structure of a solitary round wheel portable robot, which can move straightforwardly toward any path.

The conventional wheel is fitted and has no vertical hub of pivot. It is fixed to the frame and has restricted forward and reverse movement and can turn around its contact point to the ground. Any mobile wheeled robot must have three key attributes; mobility, controllability, and firmness. At least two wheels are required for static firmness. Thorough research and several developments have been made that focus on two-wheeled robots that can maintain a stable structure and tread if the focal point of its mass is beneath the wheel axle.

Dhaouadi and Hatab introduced differential drive portable robot elements, which will help specialists in the displaying and structure of appropriate controllers for versatile robot route and direction tracing and tracking.

A nonlinear feedback path controller is introduced for a differential drive versatile robot [7]. Menn et. al. introduced a demonstrating approach for multi-monocycle mobile robots. This approach was later actualized to the RobuRoc robot. Feng et. al. has introduced a model-reference versatile movement controller actualized to a differential-drive portable robot. This controller gives remuneration to outer errors.

2.3.3. MOVEMENT CONTROL PLAN FOR DIFFERENTIAL MOBILE PLATFORM

In order to solve the issues of control of motion of non-holonomic extensive research has been done and considerable solutions and protocols have been developed. A new direction following controller for a mobile robot with non-holonomic wheels has been developed which has obscure boundaries and unsure elements.

Sluný *et. al.* has introduced two movement control designs, transformative calculation and a customary fortification learning calculation dependent on robot's position [8]. Another control strategy for the management and governance of vehicles has been proposed. In this strategy, the locomotion has the data about its own direction, position, interval and azimuth of the main vehicle
Ali has presented the details of design, evolution, execution and trials of a semi-mobile robot. This robot was used for instructive and experimentation purposes.

A measured equipment configuration is utilized to interface various sensors and engine drivers to the ATMEL microcontroller chip (AVR ATmega32). Regarding the kinematical model of a differential versatile robot, a realized way adhering to control law is adjusted to represent actuator speed immersion. The proposed arrangement is confirmed tentatively for fast applications.

2.4. MOBILE MANIPULATOR DEVELOPMENT

Mobile manipulator is an across the board term in these days to allude to robots that consolidate the abilities of movement and control. A mobile operator, in this examination comprises of a mechanical controller and a moving structure bringing about a hybrid system that incorporates a wheeled frame for movement and a controller for control. The assignments designated to these mechanical frameworks are frequently associated with effector development, either in point to point or in persistent movement execution.

Bayle et. al. has introduced a generic methodology of a motion controlled for a mobile robot equipped with wheels. His work described the control of a imitated non-holonomic portable controller, where the function is characterized as a Cartesian direction of the end-effector. A straightforward and general kinematic model for non-holonomic mobile manipulation robot is determined by consolidating the controller movement with the allowed differential movement of the chassis. Another non-holonomic mobile controller was developed with a n DOF joint mechanical arm and a non-holonomic portable platform with two autonomously moving wheels.

Viet et. al. has proposed a trailing control technique for a three-wheeled omnidirectional controller framework considering the impacts of contact [9]. The framework has two subsystems; a four-wheeled mobile stage and a jointed automated controller mounted on the body. Consequently two controllers are planned, each for one subsystem; a motion controller for the manipulator and a sliding controller for moving body.

An omnidirectional moving robot is supplied with three DOF which empowers it to move toward any path which gives it an advantage over the traditional portable robots with two or four wheels. Xu et. al. has proposed a neural system based direction controller of the omnidirectional motion controller with three castor wheels [10]. Hung et. al. has tended to a control procedure for omnidirectional controller framework to follow an ideal direction with a steady speed and an ideal stance of connections.

Datta et. al. has built up an indigenous self-governing portable robot with a controller for completing assignments identified with assembling [11]. The created framework can move on its own in the vicinity and perform transportation tasks in an industry. An incorporated movement planning and control structure for a non-holonomic wheeled moving manipulator is introduced by exploiting the (differential) levelness property [12].

Despite the fact that the kinematic examination of WMM has been dealt with a great attention, yet the focus on dynamic investigation is rare. Another methodology is introduced to decide the payload handling limit of an automated arm in a domain of hurdles and impediments. The recommended technique works out the steadiness of the end-effector i.e. clamp, while keeping the movement of the arm free.

Tchon et. al. has derived an assortment of converse kinematic calculations for movement controller from a typical base of inverse dynamic Jacobian. He characterized the converse elements concerning the disparity that offers an adequate condition for the intermingling of the opposite kinematics calculations. Path tracking of a mobile manipulator has been done by adjusting a fuzzy control and back venturing approach dependent on a powerful model. The recommended control structure thinks about the dynamic connection between the moving body and controller.

Yamamoto and *Yun* have examined the impact of the dynamic association between a mobile body and a portable controller dependent on the execution of the assigned task. *Meghdari et. al*. has studied the dynamic association between a one DOF controller and the body of a mobile manipulation robot of a planar mechanical framework.

2.5. SUMMARY

The above chapter discussed the work done so far related to the mechanical and electrical structure of an ordinary robot arm and its control methodologies as per its kinematic imperatives. After that the discussion led towards the mobile bodies/ robots, its design and movement, speed and direction steering and stages of growth. As the idea of putting mobile robots and robotic arms to work is very much limited, researchers and specialists have now shifted their attention towards infusing mobility and manipulation together in the robots to come. This section also discussed different strategies that have been developed to manage this concept of manipulator on the go. From the literature discussed in this chapter, it had become evident that a mobile robot can definitely be designed that will work autonomously i.e. it will be able to traverse through the complex surroundings and varying conditions of it vicinity with little or no human intervention. However, researchers need to find solutions and strategies that would prove to be efficient for navigation of a mobile robot that will be quipped to perform several tasks.

CHAPTER 3

TECHNOLOGICAL REQUIREMENTS

3.1 Hardware requirements
3.2 Software requirements

CHAPTER 3

TECHNOLOGICAL REQUIREMENTS

This chapter provides comprehensive details about technical requirements of AVERROES i.e. software, hardware and OS requirements. This chapter will provide details about the tools, libraries and packages installation that have been used.

3.1. HARDWARE REQUIREMENT

The hardware components required for this project are:

3.1.1. CONTROL SYSTEMS

3.1.1.1. NVIDIA JETSON NANO

NVIDIA Jetson Nano is a system on module that has a powerful processor that acts as a neural network. NVidia Jetson Nano is well suited for this robot as it provides preferable image classification, object detection, segmentation, and speech processing features, all on a single module which runs at a voltage as low as 5V.

Figure 3-1: NVIDIA® Jetson Nano™ Developer Kit

The Jetson Nano module consists of SODIMM RAM of 4 GB, a processor, Graphic Processing Unit, chipset, heat sink and a Wi-Fi module. It supports the

ROS (Robot Operating System) which is not an OS but a framework present in Linux 2.0.

It has built-in image processing and object identification features which make it a suitable control system for autonomous mobile robot such as AVERROES. In addition to these it is an easy to use control system for AI and machine learning. NVidia Jetson Nano is coded in python for object recognition and image processing using open CV. It is the brain of the AVERROES as all the integrated electronics, sensors and manipulator send their data to Jetson Nano for processing.

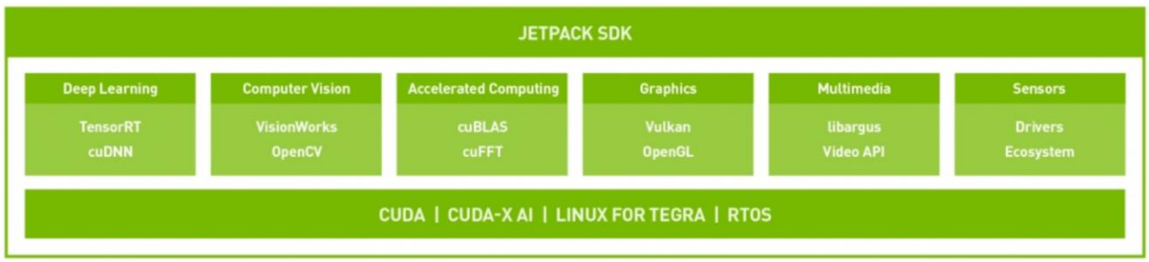


Figure 3-2: NVIDIA Jetson Nano Software kit features.

3.1.1.2. ARDUINO DUO

The Arduino Duo is a microcontroller board based on the Atmel SAM3X8E ARM Cortex-M3 CPU. It has following division of pins:

Digital I/O pins:	54
PWM Output pins:	12
Analog Inputs:	12
UARTs:	4
USB connection:	1
DA converter:	2

It also has a reset and erase button.

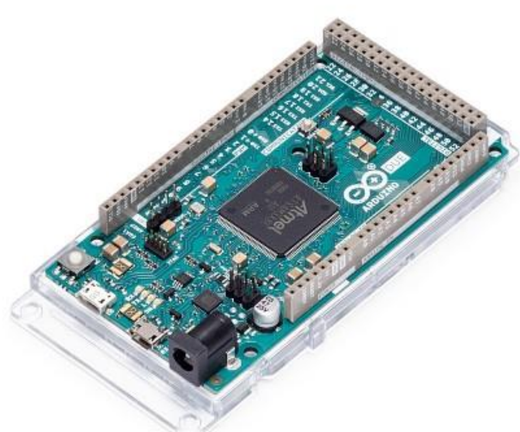


Figure 3-3: Arduino Duo

Arduino Duo will be used for the coding of robotic arm that will be mounted on the body. Arduino is being used for its multiple pins that can be used to input and control various motors at once. It also provides ease of coding. Arduino is the apt choice to code the arm to provide it with 6 degrees of freedom so that it can move in all directions in space and locate the required product.

3.1.2. VISION SYSTEM

3.1.2.1. LIDAR SENSOR

LIDAR stands for Light Detection and Radiation. It is a sensor that is used to measure distance to a target. It works by emitting a laser pulse towards the target. The target reflects the laser i.e. light photons are scattered back from the target and received by the sensor. The sensor determines the time the light pulse takes to proceed from sensor to the target object and back. This time is then used to calculate the distance between the sensor and the object in the path.
The lidar sensor being used in AVERROES provides 360 degree coverage and a range of about 10 meters. It uses triangulation principle to achieve high-precision distance measurements [13].

Figure 3-4: 350 degree, 10 m range LIDAR sensor

This sensor is being used in Averroes to provide it with high-precision distance measurements and awareness of its environment. AVERROES needs to be able to navigate in its environment autonomously. For this it needs accurate environmental analysis. This lidar sensor provides a 360 degree coverage i.e., it scans the environment in all the directions. Moreover it has a range from 0.12 to 10 meters and has a very small distance error. It has a distinguishing feature of not being resistant to light interference.

Specifications and features:

Range Frequency	5000 Hz
Range resolution	< 0.5 mm (Range < 2 m) < 1% of actual distance (Range > 2 m)
Range	0.12-10 m
Scanning angle	0-360°
Supply Voltage	4.8-5.2 V
Starting current	400-480 mA
Working current	330-380 mA
Signal high	1.8-3.5 V
Signal low	0-0.5 V
Laser wavelength	775-795 nm
Laser Power	3 mW
Weight	189 g
Size	102 x 71 x 63 mm

Table 3-1: Features of LIDAR sensor

3.1.2.2. SONAR SENSOR

SONAR or Ultrasonic sensor is a distance ranging sensor. It is used for sensing objects or measuring distance to a target. It works on a very simple principle. The ultrasonic wave is transmitted from the sensor in all directions. When the wave touches an object, it gets reflected back towards the sensor. When the sensor receives the reflected wave, it senses the object and determined the distance using time take taken by the wave to travel from the sensor to the object and back. It is a 4 pin module with pins; Vcc, Trigger, Echo and Ground respectively.

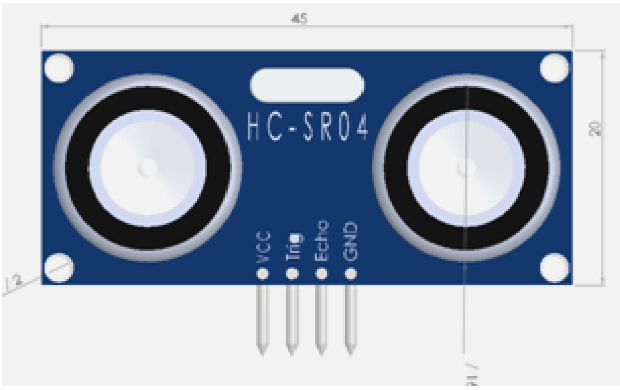


Figure 3-5: Ultrasonic sensor schematic

This sensor is being used for its accurate distance ranging abilities and ease to use. It can sense objects efficiently at a range of 2cm to 10 meters. The ultrasonic wave can penetrate through water and other materials; hence it can be used to measure depth too. The sensor will be mounted at the back of the body to sense the environment at the back. This will prevent the robot from bumping into other robots or racks/ objects in case the robot is moving in reverse.

Figure 3-6: 10 m rage Ultrasonic Sensor

3.1.2.3. CAMERA

A camera will be placed on the mobile body to provide live feed of the area to the staff. This will be used to incorporate the feature of tele-presence in the robot. Using this robot, the manager will be able to look over the ongoing processes without having to be there. This provides an ease to control the environment and other security features.

Figure 3-7: 5 MP, 1080p Camera Sensor

The camera will also be used in robotic arm. As the arm will move along 6 degrees of freedom, the mounted camera will be used to scan the bar codes off of the packages to determine which package is to be lifted.

The camera being used in AVERROES is a 5 Mega Pixels, 1080 p camera. It is a high definition camera that takes high resolution 5 MP images with advanced camera sensors. This camera provides clear images hence the scanning of barcodes will be error free. The camera will also provide clear recognition of various products and faces and can be used for rich details of far off objects.

3.1.3. BODY DESIGN

3.1.3.1. ALUMINUM CHASSIS

The chassis of the robot is a very important part of the entire robot. It ties all the parts together and must be designed meticulously to perform the required tasks. The chassis for AVERROES is made out of Aluminum. The reason to use Aluminum is that it is light weight so it would not add to the overall weight of the robot. The robot will be light and well-balanced.

Aluminum is commonly used to made robot chassis so it is easier to find aluminum-made parts for the chassis or the robot. Aluminum is a soft metal and therefore it can be cut easily using drills and saws. Moreover, aluminum chassis are reliable and they do not rust [14].

3.1.3.2. ACRYLIC STRUCTURE

The structure of the robot is a significant part of the design. It determines the strength and agility of the bot. The structure of AVERROES is made using Acrylic sheets. Acrylic sheets are widely used for robotic structure due to its shiny texture that gives a nice high-tech look to the robot. An important reason for using acrylic for the structure is that it is a cost efficient material that also meets the requirement. It is light weight as compared to alternatives and hence would keep the robot light and well-balanced.

Acrylic is strong thus provides a strong structure to the robot, protecting the internal circuitry from any damage in case of bumps. Acrylic is water-proof, hence it does not rust or get damaged easily.

3.1.3.3. MOTORS

The motor used in mobile platform of AVERROES are geared DC motors. The geared DC motors are basically DC motors with a gearhead or gearbox attached to it. The speed of the motor is measured in terms of rotations of shaft per minute which is termed as RPM. The gear assembly in the motor is added to provide a higher torque.

The gear assembly often known as the speed reducer has two gears; the input gear and the output gear. The output gear has more teeth than the input. The output gear rotates more slowly thus decreasing the speed of the input gear and increasing the torque.

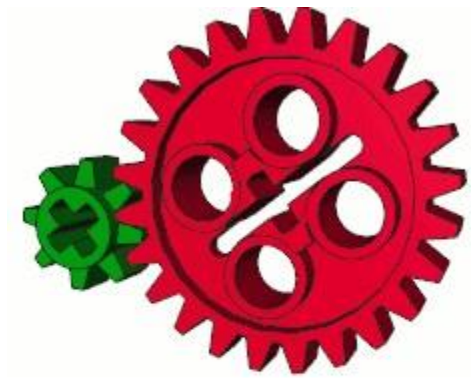


Figure 3-8: Mechanism of gearing down

Geared DC motors are used to lower the speed hence enhancing the torque. Using the correct gear combination, the speed can be reduced to any desired figure so that the robot will be able to move smoothly.

The motor being used in AVERROES is a 24 V motor with a metal geared box, 100 to 1 reduction ratio and an integrated quadrature encoder. The motor provides a resolution of 120 shaft rotations per minute. It has an 8 mm D shaped output shaft. Motor should be used at 24 V but it starts rotating at voltage as low as 1 V. The motor is able to change the direction of shaft rotation depending on positive and negative wiring changes. The motor will reduce the speed to a desirable value so that the robot is able to swift smoothly. It will generate a torque around 35 kgf-cm.

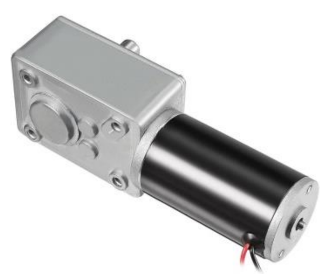


Figure 3-9: 24V, 120 rpm, 35 kgf-cm Geared DC Motor

3.1.3.4. WHEELS

For any mobile robot, wheels are necessary part of the entire design. As an important feature of AVERROES is its ability to move and navigate its environment on its own, the wheels suitable for its design and functionality are an important part of its structure. Wheels are preferred over legs in a robot as they provide a smoother, unobstructed tread and are much easier to control and program. Moreover where a leg needs to be designed and constructed, wheels of various sizes and materials are already available in the market.

A total of four wheels are employed in a robot. There are two drive wheels which control the forward and backward motion and the turns in left and right direction. The other two are idler wheels that control the speed and prevent the robot from falling or slipping. A wheel suitable for the robot design must be chosen and the selected motors must also be considered. The motor speed, torque, diameter of the wheel, material and its resistance are all important factors [15].

For AVERROES, we used a 15 cm diameter, nylon and rubber wheel. As the motor being used is a geared DC Motor with a shaft of 8mm, it is able to support a 15 cm diameter wheel. Nylon is being used to make wheels for a long time now and is very popular for industrial applications. Nylon and rubber wheels are strong and have high load capacity. As AVERROES is to be used for lifting packages, it needs strong wheels which can support the movement with the added load. Nylon and rubber wheels are well-suited for this application as they are cost efficient and have strong tear and wear resistance thus they have a long life span. These wheels add to the strength and reliability of AVERROES.

Figure 3-10: 15cm diameter Nylon and rubber tyre.

3.1.4. ARM DESIGN

3.1.4.1. ARM STRUCTURE

Robotic arms are playing a very important role in field of automation. Robotic arms are being used in different industries to perform routine task with more ease, speed and accuracy. To be able to perform the designated tasks efficiently, the arm must be designed, fabricated and developed explicitly.

The robotic arm of AVERROES will be mounted on a mobile body so that its functionality is not fixed to a location. In fact, the robotic arm will be able to traverse through the motion of body and perform the required task. The robotic arm is to be used for lifting of packages and placing them in the cart on the body. The arm will be able to determine the packet to be lifted via their barcodes. A camera will be attached to the gripper of the arm which will scan the barcodes on the packages.

The robotic arm is made of aluminum as aluminum is a strong metal and supports high load. This enables the arm of lift packages. Moreover, it is inexpensive and can be cut easily. The robotic arm consists of metal base and has a shoulder, elbow and a wrist rotation joint. At the end of the wrist a metal claw or gripper is connected. The gripper is used to grasp objects or perform tasks precisely. This entire structure enables the arm to perform accurate manipulation of pick and place tasks.

The robotic arm is light weight and does not add to the weight on the mobile platform. The arm has 6 degrees of freedom because of 6 motors used in the aforementioned joints. 6 degrees of freedom define the movement in three-dimensional space. The arm can move along the three axis; X-axis (forward and backward), Y-axis (left and right) and Z-axis (up and down). The other three movements are pitch, yaw and roll [16].

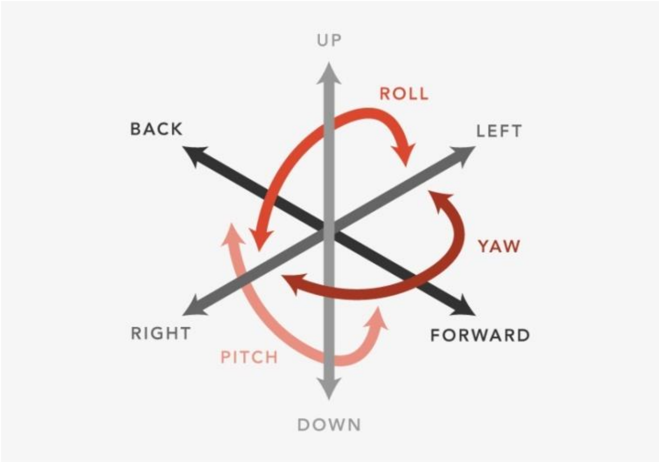


Figure 3-11: Six degrees of freedom

The six degrees of freedom provide the arm with extended reach to access the packages. This adds to the functionality of robot. The firm grip of the claw ensures that the packages are handled carefully and are not damaged in the process. The robotic arm is programmed using Arduino Duo.

3.1.4.2. MG996R MOTORS

The servo motor used to provide the robotic arm with 6 DOF is MG996R motor. It is a high-torque motor featuring metal gearing that provides an extra 10kg stall torque in a small package. MG996R is the improved version of MG995 servo motor with upgraded features and design which makes it more accurate than its predecessor. This upgraded motor provides a rotation of 120 degrees i.e. 60 degrees in each direction.

The MG9965 servo motor is the appropriate choice for this robotic arm as it can be programmed easily to control its movement. Moreover it is small in size and can be fit inside the compact structure of the arm. The motor has only three wires and the connection is pretty simple. The motor generates the required torque so that the movement of the arm is not too fast and abrupt. The motor adjusts the speed so that arm moves smoothly and accurately [18].

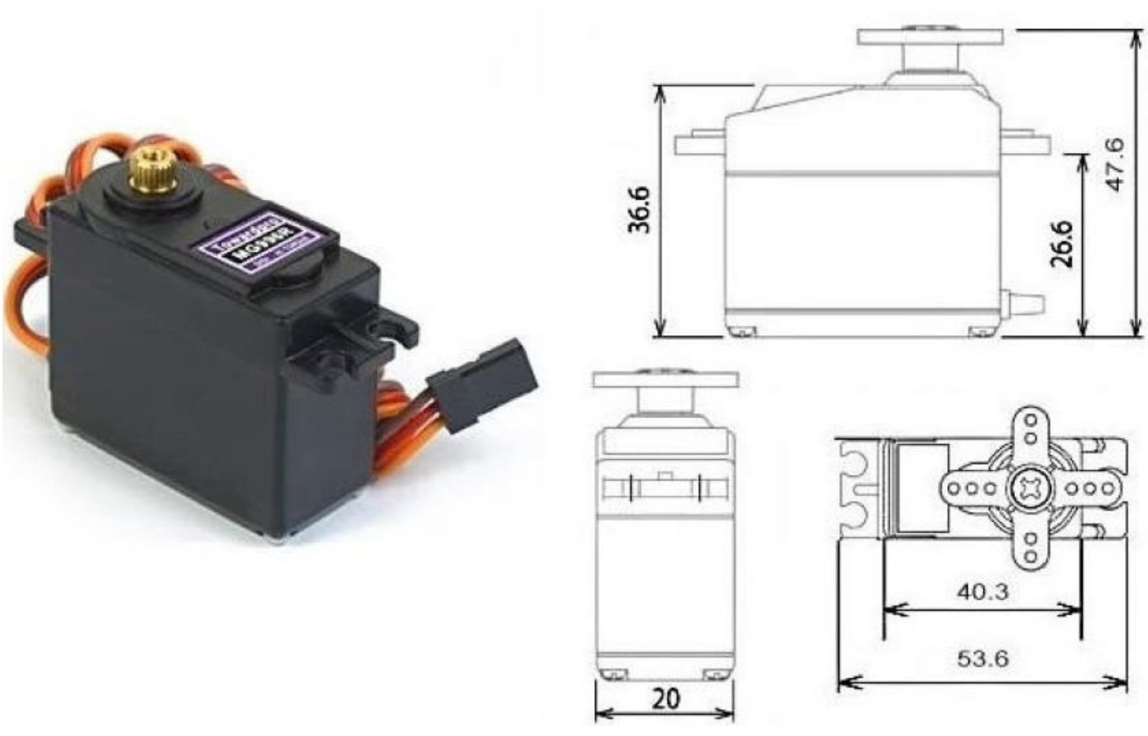


Figure 3-12: MG9965R Servo Motor

Specifications:

Weight:	55 g
Dimension:	40.8 x 19.8 x 42.8 mm approx.
Stall torque:	11 kgf-cm at 6V
Operating speed:	0.14 s/60º at 6 V
Operating voltage	6 V
Running Current:	500 mA–900 mA (6V)
Stall Current:	2.5 A (6V)
Dead band width:	5 µs
Temperature range:	0 ºC –55 ºC

Table 3-2: Specifications of MG9965R Servo Motor

3.1.5. INTEGRATED ELECTRONICS

3.1.5.1. WI-FI MODULE

Different electronics and modules are also integrated in AVERROES to increase it functionality. One of the modules used is the ESP8266 Wi-Fi module. This module allows the control system to access the Wi-Fi network. It works on TCP/IP protocol. Once connected to the network, it can work upto a distance of 500 meters using antenna.

ESP8266 is programmed using Arduino IDE. It is used to connect AVERROES to the Wi-Fi network. This enables the user to view a live feed of the warehouse via internet. This can serve as a security device that navigates autonomously, providing a live feed of the area to the manager over the internet. This feature is also used by Averroes to maintain an online database or inventory of the products in the warehouse.

The ESP8226 is used because it is a low-cost and user-friendly device that provides internet connectivity to the robot very easily which enhances the functionality. It has processing abilities and storage capacity of its own and can be integrated with other electronics.

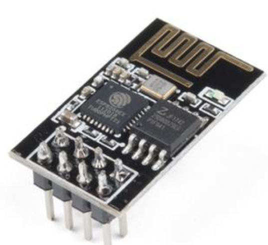


Figure 3-13: ESP8226 Wi-Fi Module

Features:

i.	Power Supply:	3.3V
ii.	Current:	100 Ma
iii.	Microcontroller Unit:	32 bit
iv.	Flash Memory:	512 Kb

Table 3-3: Features of ESP8226 Wi-Fi Module

3.1.5.2. BATTERY AND BMS

AVERROES is also equipped with a 72 Ah battery to power the bot. The battery supplies the power to the bot and the arm required for functioning. The battery used is a kind of Lithium ion battery i.e. $LiFePO_4$. It is a rechargeable and high power battery.

The $LiFePO_4$ battery is popular because of its feature of recharging. Moreover it has a long life and lasts for about 2000 charge and discharge cycle therefore; it is a good choice for the robot. These batteries charge up in around two hour using a 438 watt charger which is about four times faster than the other available alternatives. Thus the robot will be charged and back at job in no time [18].

Features:

i.	Capacity:	72 Ah
ii.	Voltage:	3.3 V
iii.	Cells:	24 cells
iv.	Internal resistance:	<0.45 ohm
v.	Charging current:	72 A
vi.	Discharging current:	216 A
vii.	Charging cut-off voltage:	3.65 V
viii.	Discharging cut-off voltage:	2.5 V

Table 3-4: Features of 3.3 V, 24 cell, 72Ah $LiFePO_4$ battery

Figure 3-14: 3.3 V, 24 cell, 72Ah $LiFePO_4$ battery

A battery monitoring and management system (BMS) of 72 Ah capacity is also used along with the battery. A BMS is a must with every Lithium ion battery. Every Lithium ion battery has a safe area in which it operates and if the conditions deteriorate the battery can get damaged i.e. if the battery is overcharged or completely discharged. The BMS is used to ensure that the battery operates in the optimal conditions. The BMS keeps a check on voltage, current and temperature during charging and discharging. The BMS also ensures that each cell in the battery is uniformly charged and no cell is overburdened. The BMS also determines the charging/discharging end cycles [19].

The BMS basically has three objectives:

i. Protect the battery from any damage
ii. Prolong the work-life/ cycle life of battery
iii. Ensure that the battery is working in optimal conditions so that it is employing its maximum potential.

When the battery is charged, it charges up quickly initially and is slowed down at the end. Same process occurs during discharging but in reverse. The BMS system ensures that the battery charges and discharges linearly which increases the life of the battery. The BMS uses a buck boast module which ensures that a regulated DC power is supplied to the battery. The buck boast module supplies a constant DC voltage output from an input source so that the battery does not receive fluctuating voltage during charging and does not get damaged.

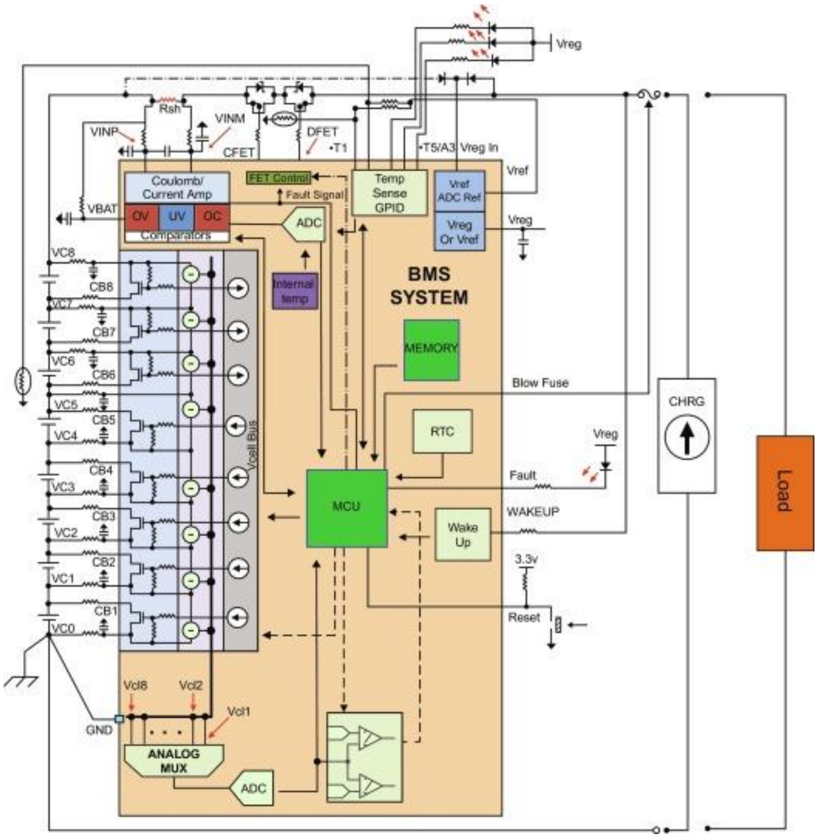


Figure 3-15: Schematics of a BMS

3.2. SOFTWARE REQUIREMENT

AVERROES software requirements have been discussed below:

3.2.1. DESIGN SOFTWARE: SOLIDWORKS

Solidworks is a modeling tool that mainly runs on Microsoft Windows. It is computer-aided design (CAD) tool that enables the engineers and architects to form 3-D models of the required product.

Figure 3-16: Logo of Solidworks

AVERROES consists to two systems; a four-wheeled mobile platform and an articulated robotic manipulator with an end-effector mounted on the body. For accurate fabrication and development of these systems it was necessary to have a precise 3-D model of these systems. Solidworks is used to design and model the mobile platform and the manipulator. Solidworks was used to test and choose the appropriate dimensions to ensure the strength and agility of these subsystems.
Solidworks version 2018 is used which was released on September 26, 2017.

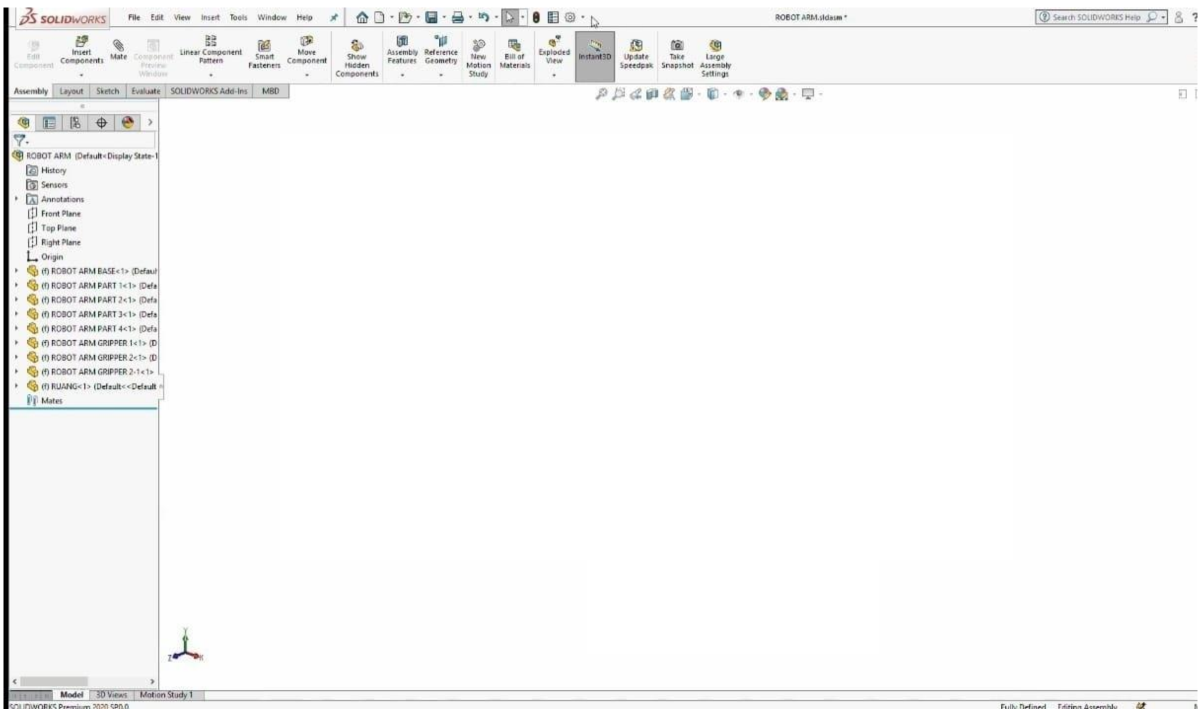


Figure 3-17: Interface of Solidworks 2018

The manipulator has been designed with a flat base and three main joints with rotation i.e. shoulder, elbow and wrist. Next to wrist an end-effector is connected. The end-effector is a gripper that is able to lift objects and packages of significant weight. The arm is made of aluminum. There are six motors used to control the motion and provide arm with 6 degrees of freedom so that it can move around freely in all directions. All the requirements have been focused on while designing arm in solidworks. Keeping in view the aforementioned requirement, manipulator has been designed to have a stable and strong structure.

The mobile platform has an aluminum chassis and the structure is made of acrylic sheets. To provide mobility to the platform, 4 nylon wheels are employed that are controlled by geared DC motors. The design of body is made using solidworks. All the requirements and feature have been kept in mind to design a solid, sturdy and well-built model that will not only support the mounted manipulator but also have high-load capacity.

3.2.2. SIMULATION SOFTWARES

Robots are designed to perform repetitive, specific tasks to reduce human effort or lessen that risk of harm to them. Robots are designed and manufactured to have a close resemblance to human body or parts of it. In order for a robot to work accurately, the parts should be designed and tested precisely.

Before the fabrication and development is started, it is important and useful that several simulations of the designed parts and electronics are done to minimize the risk of error and damage. For human-like parts such as a manipulator with gripper, different softwares are present that provide simulations of human body. These simulations point out the inadequacies in the design which can be modified before fabrication.

MATLAB is a computer aided tool that provides a numerical environment for analysis, plotting, interpretation, implementation and interfacing of data and algorithm. MATLAB also provides different simulation features that are convenient options for testing robot parts.

For simulations and testing of parts and electronics of AVERROES, we have used two simulation tools available in MATLAB that are stated below:

3.2.2.1. SIMULINK TOOL

Simulink is a MATLAB tool used for modeling, analyzing and simulating dynamic systems. It uses graphical blocks and customizable libraries to perform simulations. It is used for analysis and simulations of integrated electronic and components. It enables the user to develop and test algorithms and working mechanisms of different components before they are fabricated. In this way, damage to the components, electronics or the machine can be avoided [20].

In AVERROES, Simulink is used for modeling, analyzing and simulating all the integrated electronics. The battery, BMS and Wi-Fi module were modeled into the design and analyzed. Different simulations were run on these electronics to ensure that the desired results were obtained. After successful testing and simulations, the aforementioned electronics were integrated in AVERROES to get accurate results.

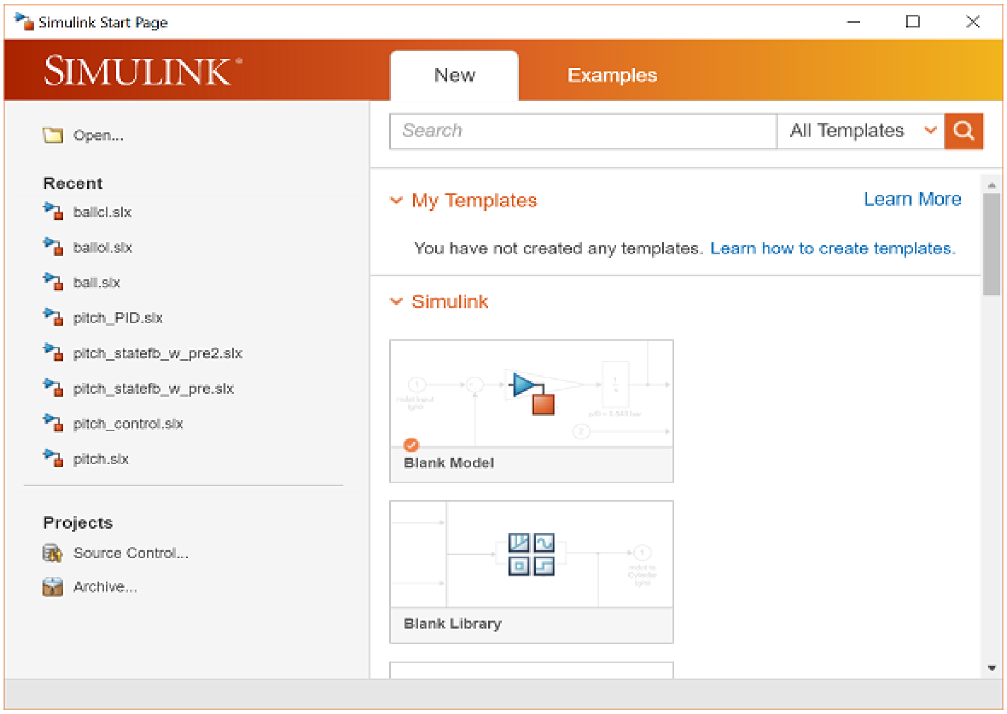


Figure 3-18: Simulink Start Page

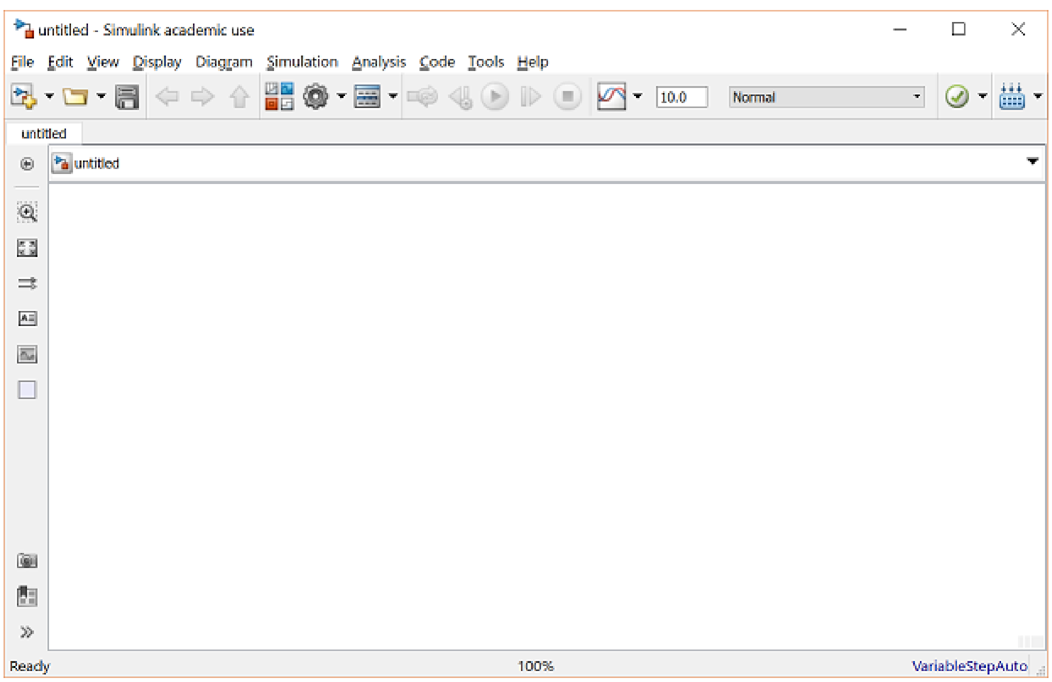


Figure 3-19: Simulink Interface

3.2.2.2. SIMSCAPE TOOL

Simscape is a simulation tool in MATLAB that allows you to form physical models and test them by running various simulations. It provides modeling and analysis capabilities for complex components.

Simscape is used to run simulations on various components, electronics and joints of AVERROES. The manipulator needs to function like a human arm. It has similar joints and is able to move in 6 degrees of freedom. Simscape was used to test the design of manipulator to ensure that it will be able to move smoothly and precisely and lift objects. This was done by testing all joints and motors in arm. The motors were tested to check that they were driven at the right speed so that the arm does not arm abruptly. The claw was tested to check if the tongs moved accurately and had a firm grip.

Similarly, simulations were run on mobile platform. The mobile platform needs to move around the premises autonomously and carry objects. The motors and wheels of body were simulated to ensure that the platform will move at a stable speed and it will not slip, drift or fall. Moreover the wheels were programmed and tested to have controlled rotation and motion while making turns.

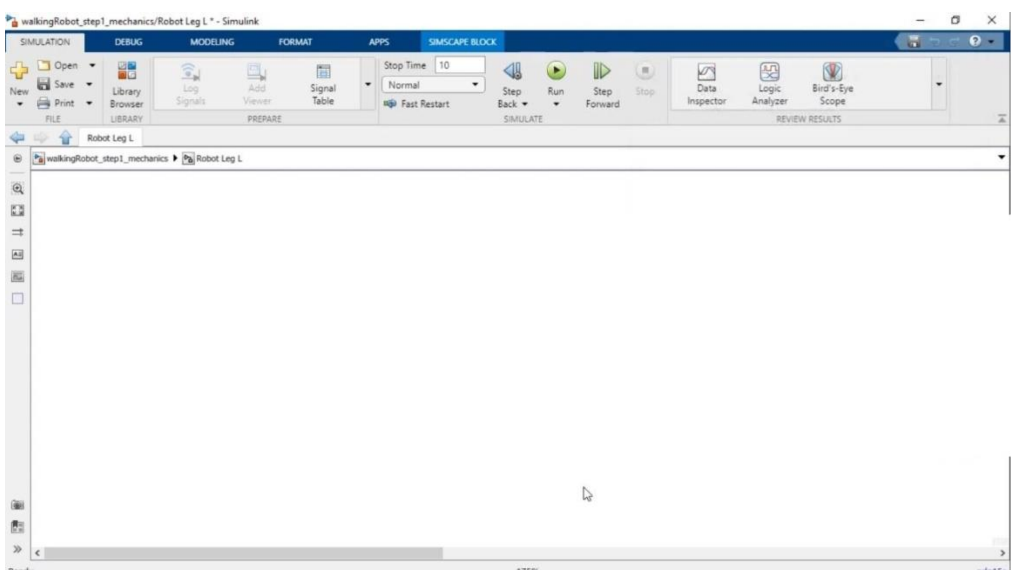


Figure 3-20: Simscape Interface

3.2.3. CODING SOFTWARES

Different coding software / languages are used to code different part of AVERROES to perform different functions. The different software used are listed below:

3.2.3.1. ARDUINO IDE

ARDUINO IDE (Integrated Development Environment) is software that is used to code Arduino board. It is easy-to-use software that runs on different operation systems. It an open-source software and the coding environment is Java based. It can be used with all Arduino boards and is used to program boards for multiple tasks.

Figure 3-21: Arduino IDE Logo

In AVERROES, Arduino board is used in arm assembly and Arduino IDE is used to program Arduino Duo for movement of arm. The Arduino is hard-coded. The Arduino board is coded to enable and assist the arm movement. The arm has three joints and is able to move along six degrees of freedom. The movements are coded in Arduino. In addition to these a claw is attached as an end-effector which is able to grip, pick and move objects of considerable weight. The Arduino board is coded to perform all the movements via Arduino IDE.

3.2.3.2. PYCHARM 3.3

Python is a high level language that is easy to learn and use and has a fairly simple syntax. It is used to develop GUI, web apps and websites. It makes programming easier with the wide variety of built-in libraries that it provides. Pycharm is an integrated environment used for python. For this project, we used Pycharm version 3.3.

In AVERROES, python is used to code Nvidia Jetson Nano, which is the brain of the robot. Jetson Nano is coded for multiple tasks and all the components and integrated electronics are interfaced with it.

Python is used to code Jetson Nano for controlling and monitoring the navigation of mobile platform with aluminum internal structure and acrylic enclosure with 4 wheels individually driven by encoded geared BLDC motors. Interpretation of LIDAR and sonar data on NVidia Jetson Nano and it's processing to compute environmental map and coordinated to be sent to all the actuators is also done on python [21].

Jetson Nano is also coded for image recognition that assists in the autonomous navigation. This feature is incorporated via the interpretation of cameras (2 in number). The camera along with the above mentioned sensors are used for object recognition and Jetson Nano is coded for image processing. The camera is also used to provide live feed of the area and for scanning of QR codes.

Figure 3-22: Pycharm Logo

3.2.3.3. VISUAL STUDIO

Visual studio is an integrated environment that is used for coding and programming in Microsoft. The Visual Studio supports various operating systems. Visual Studio supports about 36 programming languages. For this project, the coding is done in Visual Studio in C Sharp (C#). Visual Studio is an easy to use and fully free coding platform.

C# is used as it is a general-purpose and multi-paradigm programming language. C# is suitable for writing programs for both hosted and embedded systems, ranging from massive and strong operating systems controlling to the very small used for particular tasks probably one at a time. Although C# applications are supposed to be least expensive with regard to reminiscence and computing capacity, the language was never meant to compete immediately on overall capabilities and length with C or assembly language [22].

Jetson Nano acts as a neural network for this robot and must be interfaced with all the components and electronics to take data from them and process it to perform designated tasks. For the interfacing of peripherals and integrated electronics, C# is used in Visual Studio. NVidia Jetson Nano is coded using C# in Visual Studio for the integration of BMS for monitoring battery statistics on the web application. It is also coded for the integration of Wi-Fi module and the other integrated redundant modules [23].

Figure 3-23: Visual Studio Logo

3.2.3.4. WEBSTORM

WebStorm is a JAVA based IDE that provides an intelligent yet comprehensive coding environment to create Graphic User Interface, web pages, web apps etc. It has effective error detection mechanisms.

WebStorm is used to design the GUI of AVERROES. AVERROES will take instructions via it web app. In this project, we have developed a web app instead of a mobile app so that it can be used on any OS easily. The GUI is user-friendly and anyone with minimal knowledge can use it [24].

The GUI allows to user to view the warehouse through the camera mounted on the bot. This provides surveillance and security features. The user needs to enter the product name and ID. The robot will check the database to determine the location of the product. It will then traverse along the determined path to the fetch the product. The GUI also shows the environmental analysis such as temperature, humidity etc. Moreover, the state of robot will be accessible at all times i.e. it will show the battery percentage of robot and notify when charging will be required.

Figure 3-12: WebStorm Logo

CHAPTER 4

DESIGN AND DEVELOPMENT

CHAPTER 4

DESIGN AND DEVELOPMENT

4.1. ARCHITECTURE DESIGN OF AVERROES

This project of "AVERROES (Autonomous, tele-presence, object-identifying and manipulation robot" comes in the category of Hardware -Software Integration. The project can be best understood by flow chart and block diagram. Our project has two subsystems. One system is the mobile platform that has the ability to navigate autonomously using sensors mounted on it and provide a live feed of the environment via camera and Wi-Fi module. The second system is the manipulator mounted on the body. The robotic arm has three joints and is able to move along six DOF. The manipulator has a gripper and is able to scan QR codes off the packages and pick and move objects with the gripper.

4.2. DEVELOPMENT PLAN

Designing and development are the most important aspects of a project especially when it comes to FYP. So the basic timeline which was followed during the development of our project is given below:

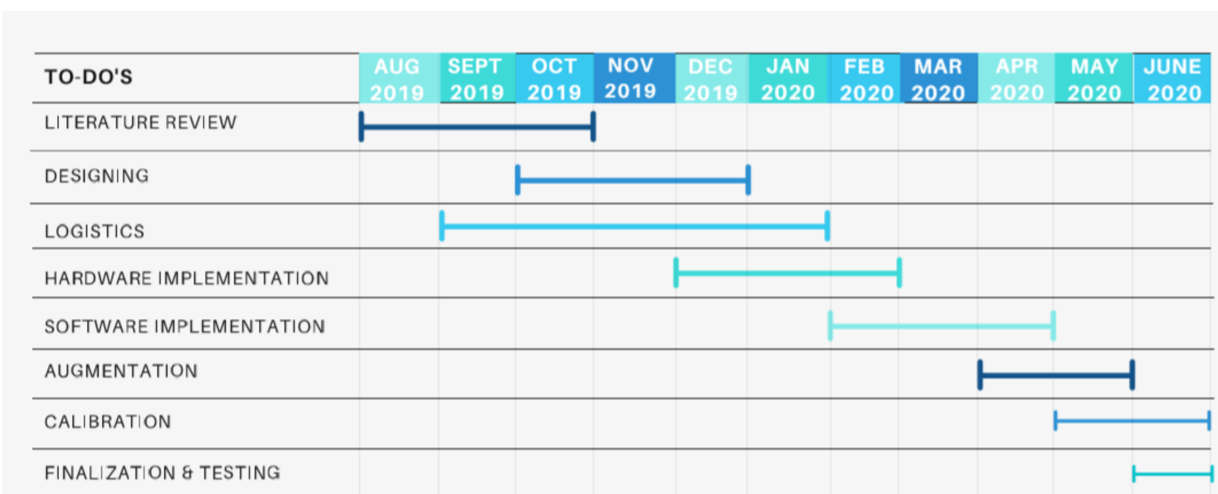


Figure 4-1: Timeline of AVERROS

4.3. COMPARISON OF SENSORS

The most important feature of AVERROES is autonomous navigation i.e. it is able to traverse the environment in which it is deployed entirely on its own without any human intervention. To equip AVERROES with this feature, sensors are used that explored the environment and provided with results to determine the motion. Two sensors were suitable for mention operation; LIDAR and SONAR sensor. Each of these sensors has its advantages and disadvantages and are suited for a particular task. Both of these sensors are used in our project because of their unique functionality and accuracy in results.

The basic working principle for both these sensors and any other object detecting sensor is the same. The transmitter emits a signal. The signal traverses in the environment. When the signal hits an object it is reflected back from the object. The reflected signal is received by a receiver and hence the object is identified. These sensors are also used to determine the distance to a particular object by using the time taken by the signal to travel from the sensor to the object and back. The difference between LIDAR and SONAR lies in the type of signal used by each. A LIDAR uses a light pulse whereas SONAR puts ultrasonic waves (sound echo) to use.

These two sensors also differ in accuracy. The accuracy depends on the frequency, lower the frequency, higher is the accuracy. The ultrasonic waves have a frequency of 20 kHz to 200 kHz whereas the frequency of visible light wave is 430 to 750 THz. As sound waves have lower frequency they are more accurate. Therefore, SONAR is employed for close proximity to avoid bumping into other bots or objects. LIDAR, on the other hand has comparatively lower accuracy but travels a greater distance. It is employed for scanning of the environment and determining the location of other objects or bots.

The two sensors also differ in terms of speed with which they receive and process data. As light travels faster than sound, LIDAR receives the reflected signal sooner than SONAR and hence is able to detect and warn about the object sooner. SONAR is placed at the rear of the robot or autonomous vehicle to provide parking assistance and detect any incoming traffic. In terms of cost, SONAR is a more efficient option as LIDARs are too expensive to make autonomous robots affordable. LIDAR is of the size of a coffee-can and SONAR is even smaller.

The LIDAR is employed on the top of robot to detect objects around the bot. It is used to provide the wider and complete map of the environment to the neural component. SONAR is placed in front and rear bumper area. SONAR is used to detect objects in close proximity to avoid bumping into other bots or objects [25].

The two sensors are compared in a tabular form in the figure below

Quality/Device	**LIDAR**	**Sonar**
Type of a signal	Light pulses	Sound waves
Distance		✓
Accuracy	✓	
Reliability		✓
Data update speed	✓	
Cost		✓
Size		✓

Table 4-1: Comparison between LIDAR and SONAR

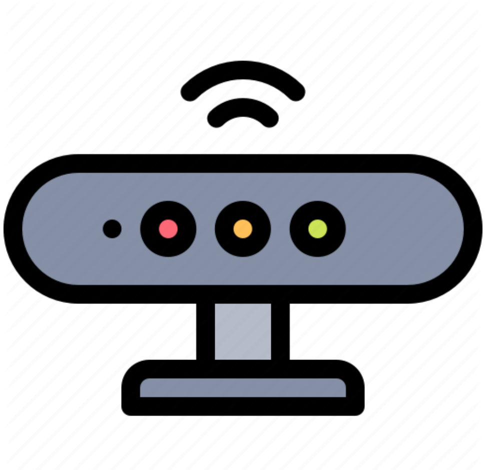


Figure 4-2: LIDAR sensor icon

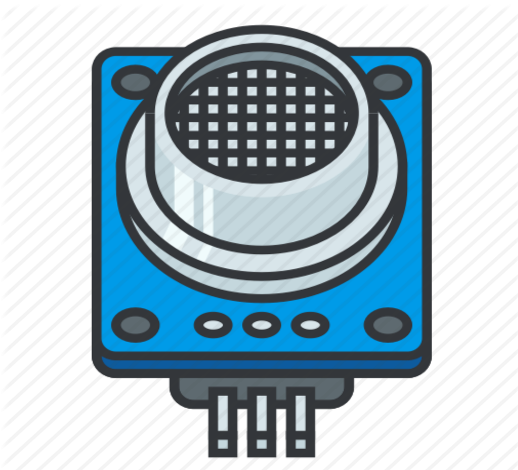


Figure 4-3: SONAR sensor icon

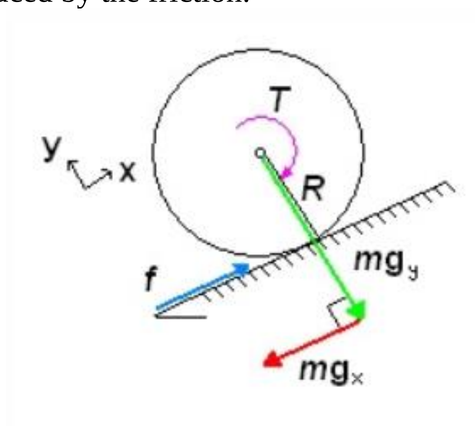
4.4. SELECTION OF SUITABLE MOTORS

To get to the horizontal position, motorized wheel enough torque is important to be produced by the motors so that it will make up for any lacking factor in wheels and in addition to that, it will also aid in avoiding any probable crash between the robots. Hence, it can be stated that the robot, may it be of any size, does not need a large amount of torque, just ‘enough’ torque to have a smooth tread.

In case of larger robots, greater amount of friction and resistance will be produced compared to a smaller robot however, though it is still much lower when the robot meets the cord. For the robot to mount a horizontal open position, it should be able to produce enough torque to curb the gravitational pull o the robot which would cause the bot to slow down. At a sloping surface that is at an angle theta, the robot will be likely to drop only if one half of the weight of the bot i.e. mgx is parallel to the surface. The force applied perpendicularly to the wheels of the bot by the top side of the bot balances out the weight mgy.

In order to avoid the slipping of the robot, there must be a contact between the wheels of the bot and the surface which would cause friction necessary for a smooth movement. Or instance, heavy trucks are known to produce significant amount of power and torque, however there have been multiple instances of trucks slipping o roads and tracks due to lack of necessary friction.

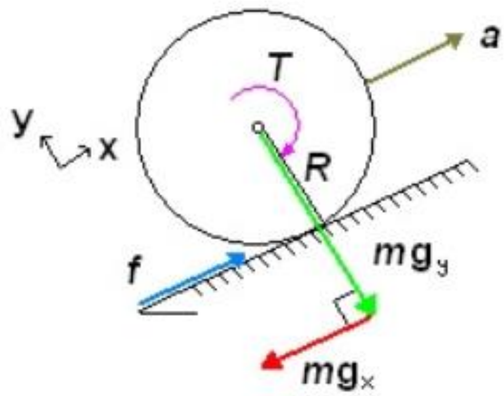
Hence, the torque is produced by the friction.



The required amount of torque is:

$$T = f * R$$

In order to choose the right motors, the ‘worst case scenario’ associated with the motors must be considered, that is that on a sloping surface, the bot not only inclines down it but also catches up more speed during its movement.



Forces are acting along the x and y axes. The force of x-axis i.e. F_x is given as:

$$\sum F_x = M * a = f - m * g_x$$

Entering the above torque equation, as well as the mgx equation, we get:

$$M * a = T/R - M * g * sin(\Theta)$$

Rearrange the equation to divide T:

$$T = R * M * (a + g * sin(\Theta))$$

The above stated equation defines the amount of trque require to move a body up a sloping surface. This is the torque that must be produced by the bot overall. However, as there are multiple wheels that drive the robot, the amount of torque (T) should be divided by the number of wheels (N) on the bot. This would give the amount of torque that each wheel needs to produce to help the body of the robot move up an inclined surface. This amount of torque gives the aggregated torque that is needed to move the robot upward on the inclined surface.

A noteworthy factor is that numbers of passive wheels are not considered as they do not produce torque and only add to the weight of the robot.

$$T = \frac{(a+g*\sin(\theta))*M*R}{N}$$

The efficiency (e) of motor, gearing and wheel slip can be considered as:

$$T = (100/e) * \frac{(a+g*\sin(\theta))*M*R}{N}$$

The efficiency of the system is regarded as the efficiency here. It can be measured as:

• Battery -> Car Control: 95% proficient
• Car Control -> Motors: 96% proficient
• DC integrated vehicles: 92% proficient
• Spur gear (per phase): 93% per phase

The overall performance is affected (reduced) by each step. The calculation of reduction in this particular case will be given as:

$$96\% \times 95\% \times (93)^5 \times 92\% = 58\%$$

$$0.96 \times 0.95 \times 0.95 \times (0.93)^5 \times 0.92 = 0.58$$

It is observed that in most of the cases, use of cheap components reduces system performance and 58% efficiency is high. The energy lost is mainly transmitted by heat and noise.

Considering the performance of the system increases the torque required to compensate for malfunction. Each motor's power can be calculated as:

$$P = T^*\omega$$

From the above equation, the amount of torque T can be calculated and angular velocity (w) is defined by the constructor. By selecting the maximum possible angular speed, relative high power can be achieved. To determine the current required, we can use :

$$P = I^*V$$

Following relationship can be gathered from the above mentioned equations:

$$I = \frac{T^*\omega}{V}$$

The robot will require a battery of size **c** given as:

$$c = I^*t$$

The size/capacity of the battery required may cause some confusion however when the ideal battery is being selected the measurement of hours a battery may serve by amps is not efficient. Moreover, the total charge deteriorates with time. Hence, by choosing a battery with higher capacity ensures that the required current can be drawn at the time of need.

4.5. METHODOLOGY

AVERROES is an astute autonomous tele-presence robot that provides real time info graphics and statistics of inventory by getting product details from user via a web app using NVidia jetson Nano system on module in combination with multitude of sensors, motors and actuators to locate scan and then affirm availability of product in the inventory.

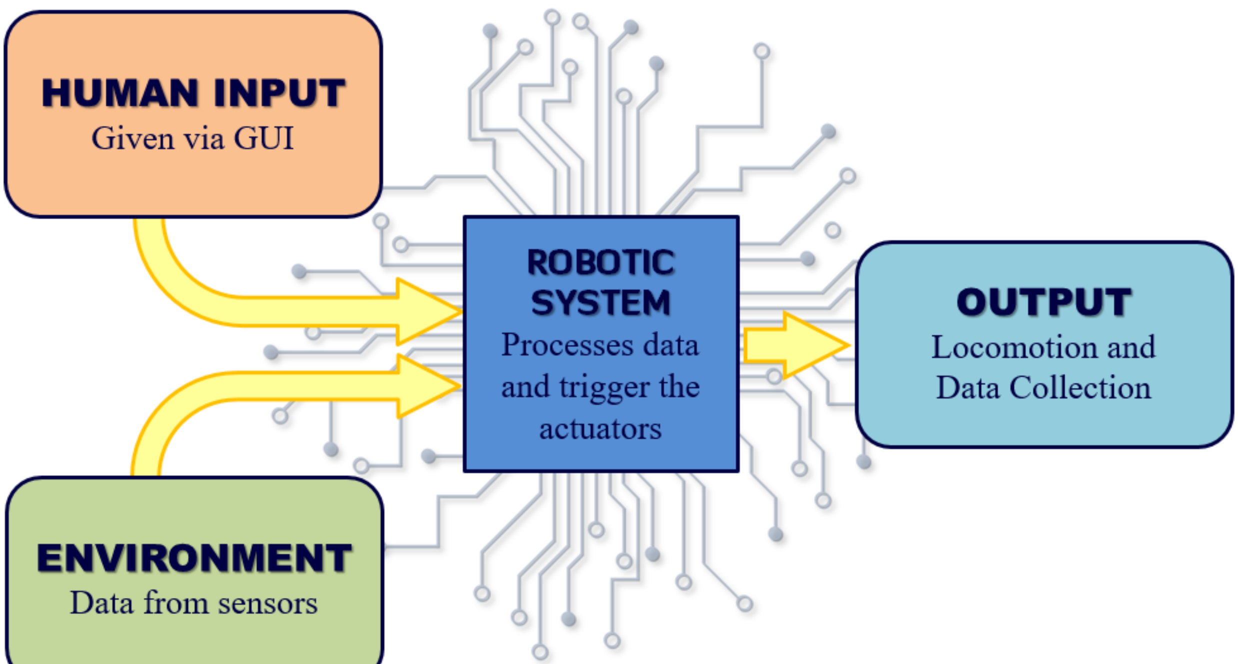


Figure 4-4: Project as a system.

It is able to navigate through aisles of a warehouse, avoiding any obstacles in its way such as boxes people and other robots working in the factory, and scan QR codes and report them back. The system comprises of Vision module, Mobile platform, manipulator arm with gripper and scanner and other integrated electronics i.e. BMS, GPS and Wi-Fi etc.

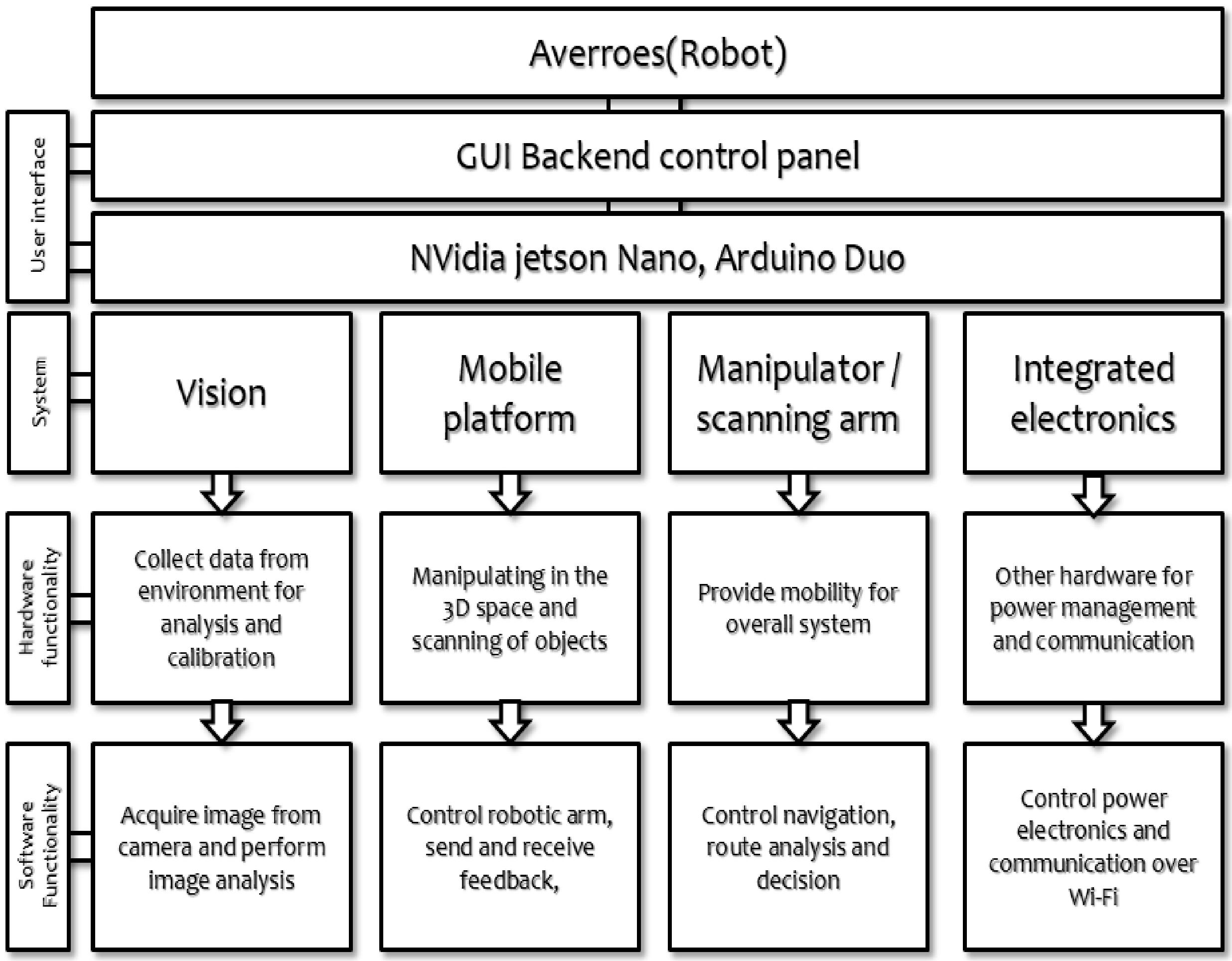


Figure 4-5: Project Functionality Diagram

Vision module allows the robot to "see" and navigate around an environment and avoid any collision. It consists of LIDAR, two cameras (one on the gripper and other on the mobile platform and a sonar at the back of the robot, it provides environment mapping via scanning the surroundings through LIDAR and sonar which connect directly to the SOM NVidia jetson Nano which processes the images through the camera, LIDAR data and sonar data to map the environment around it and calculates the instructions to be given to the mobility module and gives back the live feed on the User end.

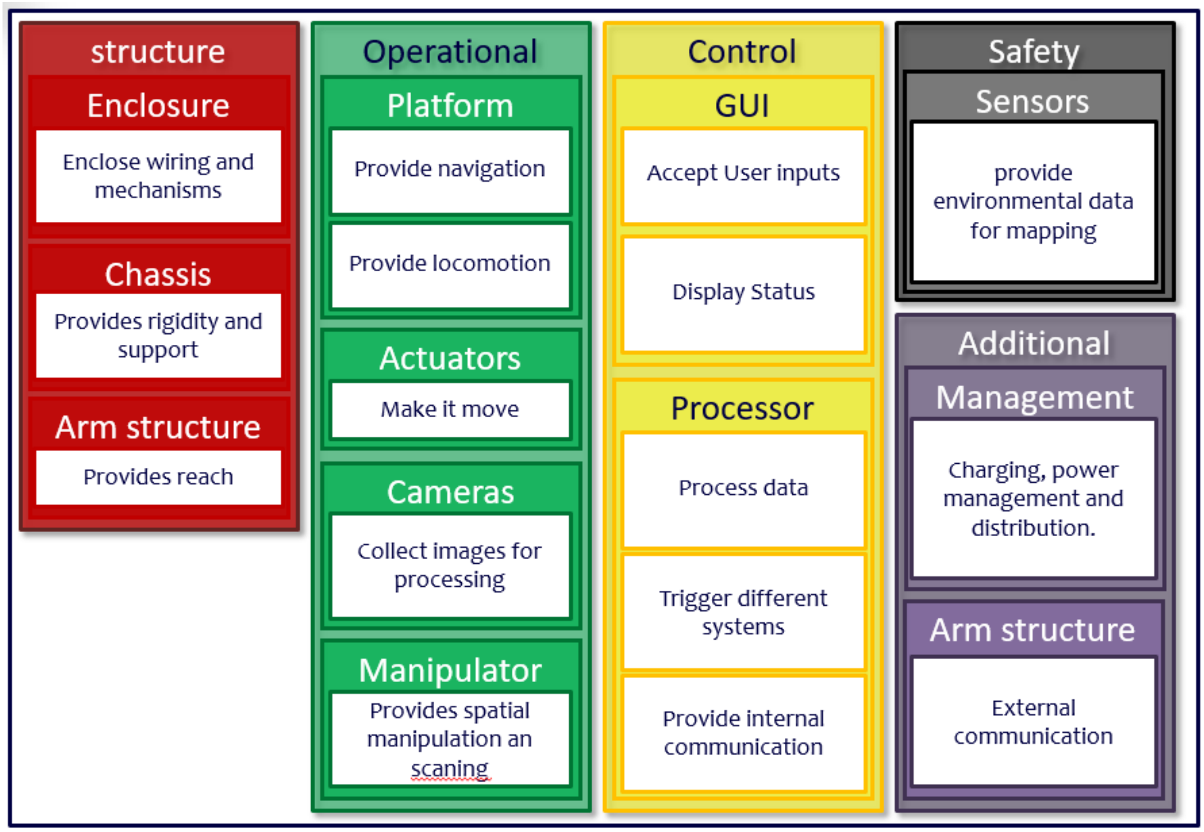


Figure 4-6: Project Functional Modules

Mobile platform is the basically the body on wheels, it comprises of an aluminum internal chassis in an acrylic enclosure that is supported by 4 individually driven, controlled and encoded brushless dc high powered motors specifically 110W 12000 rpm motors, motors shafts are connected to a 100:1 reduction gar box that provide final output of 120rpm with very high torque that can easily push the robot in its entirety.

Manipulator arm is mounted on the chassis that would provide an extra degree of reachability to scan the QR codes on the boxes in the warehouse, it comprises of 6 servo motors that provide 6 degrees of freedom. A gripper is attached to the end of the arm as an extra feature with the main purpose being the camera mounted there.

Other integrated electronics include battery management system for monitoring, charging and discharging of the battery. A redundant Wi-Fi module is also a part of integrated electronics that would increase the reliability just in case the main Wi-Fi on the SOM NVidia Jetson Nano stops working. GPS module provides estimated location of the robot and with the help of encoders attached to the motors and SONAR and LIDAR Data all combined provide position accuracy up to 1cm that is hugely more than enough for such application.

When a product is entered in the inventory database its Product name, Product ID (that's unique for each QR code on the box), category, rack number, aisle number are also added along with it that would give the robot product's location so it can be reached later to monitor stock or to check its availability in the inventory. Robot will learn all the positions in the initialization phase at the time of deployment after mapping the environment.

In case of failure to find the requested product/s the robot will generate a warning that will be sent to the user. That can happen when the product is out of stock or is misplaced in the warehouse.

4.4.1. OBJECT DETECTION

Warehouse robots have been an emerging research area in the field of robotics. These robots are used to automate the working of warehouses and their applications include environment monitoring, mapping and infrastructure inspection. To perform these tasks the robot should be equipped with the ability of autonomous navigation so that it can work without any human help. Considering the highly dynamic and three-dimensional environment of the warehouses, path planning and tracking are important for the autonomous navigation. For these operations, sensors are used to detect and map the environment. The sensors used for object detection are LIDAR and SONAR that work on the same principle but use different type of signals thus have different accuracy. These sensors provide the robot with distance from all the objects at all times. SONAR is used to register all the changes in the environment to avoid collision and LIDAR is used to locate and position different objects and robots moving in the same vicinity.

When the robot is deployed for the first time, it moves around, studies its environment and maps it. The sensors report back the distance from all objects to the central unit of the robot i.e. NVidia Jetson Nano. Jetson Nano commands and controls the movement of the bot. It is programmed to process the data from the sensors and give required commands. Now when a sensor detects a new object or an object/bot in close vicinity, it sends the distance calculation to the Jetson. Jetson then processes the data and sends the command to motor driver i.e. cuts the voltage supply to the motor drivers and tires and the robot stops. Then it uses the data from the sensor to evaluate and analyze the environment to give command to the tires to turn in a particular direction and move along it. The robot continues to move along the new direction until a new obstacle is detected in the determined path.

4.4.2. AUTONOMOUS NAVIGATION

For a robot to be autonomous in its traversal and functioning, it must be able to perform four tasks as discussed below:

i. **Navigation:** The robot must be able to devise a path and then traverse through it.

ii. **Situation Analysis:** The robot must be able to observe, analyze and maintain record of its surroundings and all objects in it, at all times.

iii. **Motion Planning:** The robot must be able to trace out the appropriate path of movement (speed, direction) for a particular pre-set timeframe, so that the bot keeps travelling along the course determined without colliding into any item (static or dynamic) along the path of traversal.

iv. **Trajectory Control:** The robot must be able to keep itself stable and steady in case of turns or change in speed.

These functions require several sensors to work such as visual sensors i.e. camera, radar sensors such as SONAR, ranging sensors like LIDAR etc. The basic reason of using all these sensors is to collect data from the surrounding in terms of distance and images etc to provide continuous awareness to the robot about its vicinity.

Owing to the data collected, the robot then determines via fed protocols its course of action. The neural network i.e. central controller of the robot is programmed to examine and inspect the gathered data and devise a path, movement and other necessary actions. This requires thorough training, testing and experimentation to have an error free feature. Any errors made during the motion planning are usually the cause of robot-accidents.

Especially, when there is a change in speed or direction of the robot, the trajectory control unit performs a comparison between the calculated changes that were to happen and the real-time changes that have happened in order to detect a high deflection and if it exists, the central unit instinctively regulates the changes by either accelerating or braking or steering and restores stability. It can be stated that the trajectory control unit manages all the changes in speed and direction during traversal of the bot.

To sum up, an autonomous robot uses the navigation controls to trace out a path, the situation analysis unit to detect and track objects in surroundings, the motion planning unit to determine movement actions and trajectory control to manage changes during movement. The control unit and the sensor unit are the fundamental components that aid in the decision making.

These units consist of following sensors:

i. Cameras:

Camera sensors are used in self-navigating robots to provide visual/image inputs for the robot to process images and detect objects. The only sensor that can detect colors and shades are cameras, hence they enable the robot to detect different lights and signals that may be used to direct the robot to go or stop from/at a particular station. The camera is infused with a Wi-Fi module to provide a live feed to the area at all times. The disadvantages of a camera sensor include its sensitivity to certain environmental conditions, problem to track dark objects and in low light and lack of distance measurement feature.

ii. Lidar:

LIDAR is short for "Light Detection And Ranging". Lidar utilizes laser pulses and their reflections to discover objects and their certaing characteristics. Lidar sends a laser t an object which gets reflected back. This happens at a very high rate i.e. millions of pulses are transmitted each second. The time taken by the laser beam to travel to the object and get reflected back is measures. The information gathered by the LIDAR sensor is used to form a 3D image of the object/ existence in the path. Lidar has more improved features that assist in formation of 3D images which the other sensors lack. That is why it can be used to detect objects as well as gestures and the direction in which the object is moving. Due to these advanced features Lidar is more expensive. Other disadvantages include shorter range and higher probability of failure.

iii. Ultrasound:

Ultrasonic sensors or SONARs work on the same basic principle as Lidar. SONAR transmits sound waves and detects objects in the path of the transmitted wave when it gets reflected back by those objects. However, ultrasound sensor has slower speed and shorter range, therefore it used to detect object in close proximity and avoid robots from bumping into other bots or objects.

4.6. WEB APPLICATION DEVELOPMENT

A web application has been developed that will be used to control the movement of mobile platform as well as the movement of maniupulator along 6 DOF. The interface of the app is shown below:

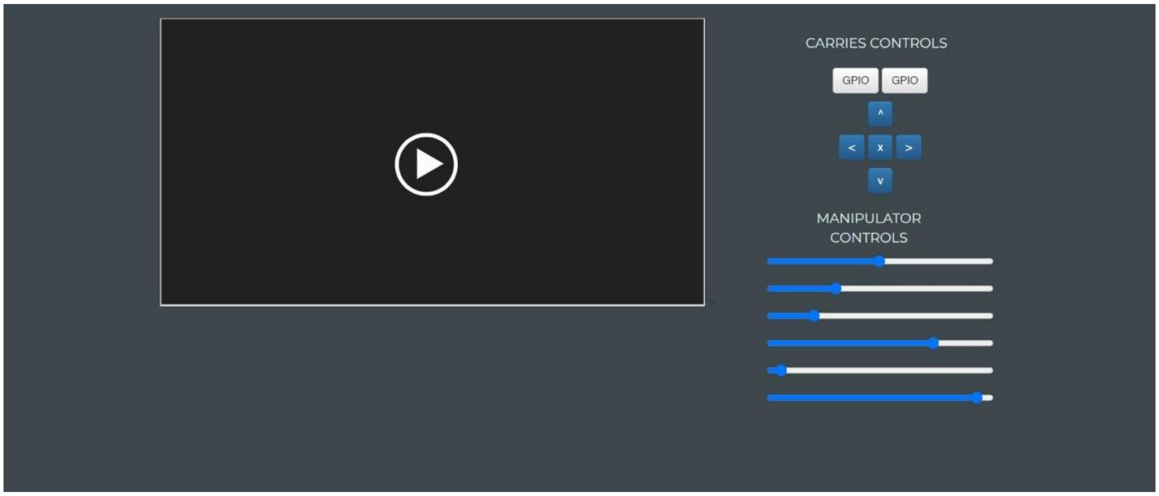


Figure 4-7 Interface of web app

The movement of the wheels to move the body will be done via directional buttons located at he top right corner of the interface.

Figure 4-8: Carrier controls in GUI

The movement of robotic arm along 6 DOF for detection and manipulation of packages will be done via 6 sliders (each for each degree of freedom), located on right below the carrier controls.

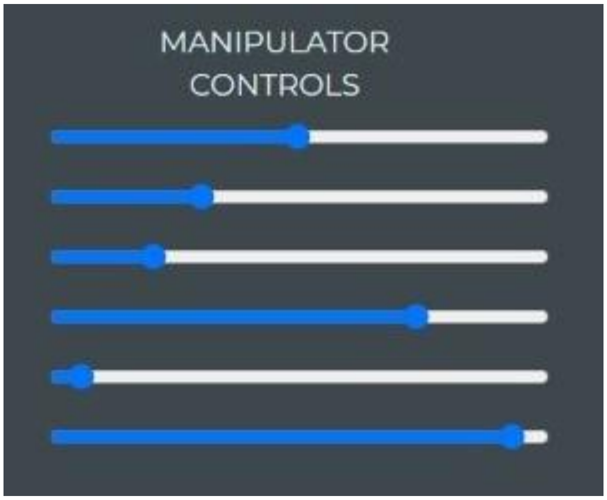


Figure 4-9: Arm controls

The live feed of the vicinity and environmental analysis (temperature, humidity etc.) at all times will be displayed in the screen present at left of the interface.

Figure 4-10: Live feed and environment analysis panel

4.7. MANIPULATOR ARM DESIGN

The robotic arm has been designed to provide it 6 DOF so it can move freely in space to scan QR codes off the packages and then carry the desired products to their respective stations.

The design of manipulator is shown below:

Figure 4-11: Manipulator Design

4.8. QR SCANNING

A 5 mp camera has been mounted on top of the gripper of manipulator arm. This camera will be used for scanning QR codes off the product packages to detect required packages and perform manipulation as directed.
The code for QR scanning is explained below:

```
# loop over the frames from the video stream
while True:
    # grab the frame from the threaded video stream and resize it
to
    # have a maximum width of 400 pixels
    frame = vs.read()
    frame = imutils.resize(frame, width=400)

    # find the barcodes in the frame and decode each of the
barcodes
    barcodes = pyzbar.decode(frame)
```

In this section a loop is started which collects and then resizes the frame from the live stream video to gather the barcode portion.

The command '**pyzbar.decode(frame)**' is used to detect the bar code in the cropped frame and then decode it to numbers to be matched against the database.

```
    # loop over the detected barcodes
    for barcode in barcodes:
        # extract the bounding box location of the barcode and
draw
        # the bounding box surrounding the barcode on the image
        (x, y, w, h) = barcode.rect
        cv2.rectangle(frame, (x, y), (x + w, y + h), (0, 0, 255),
2)

        # the barcode data is a bytes object so if we want to draw
it
        # on our output image we need to convert it to a string
first
        barcodeData = barcode.data.decode("utf-8")
        barcodeType = barcode.type

        # draw the barcode data and barcode type on the image
        text = "{} ({})".format(barcodeData, barcodeType)
        cv2.putText(frame, text, (x, y - 10),
            cv2.FONT_HERSHEY_SIMPLEX, 0.5, (0, 0, 255), 2)

        # if the barcode text is currently not in our CSV file,
write
        # the timestamp + barcode to disk and update the set
        if barcodeData not in found:
            csv.write("{},{}\n".format(datetime.datetime.now(),
                barcodeData))
            csv.flush()
            found.add(barcodeData)
```

In this section a loop is started over the detected barcodes. The bounding box (x, y)-coordinates are extracted to limit the area of the frame in which the barcode exists. A bounding box is then drawn the detetcted barcode area and the barcode is decoded in the 'utf-8' format to determine the type.

The commands **barcodeData** and **barcodeType** is used to format the image. Then it is checked that a unique QR code has been detected.

The csv file is time-stamped. The database is also updated to manage duplicates.
The rest of the code in QR script incorporates commands for displaying frame, checking if the quit key is pressed and performing the cleanup.

4.9. MOBILE PLATFORM DESIGN

4.9.1. ILLUSTRATIONS

The desired design illustrations are presented below:

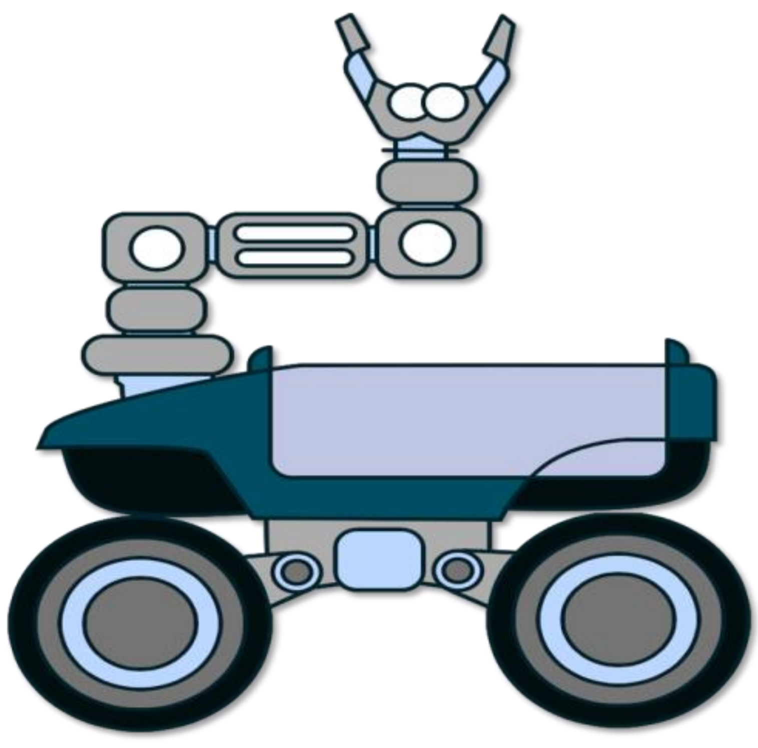


Figure 4-12: Project Mock-up Illustration

Another illustration made using Fusion 360 is attached:

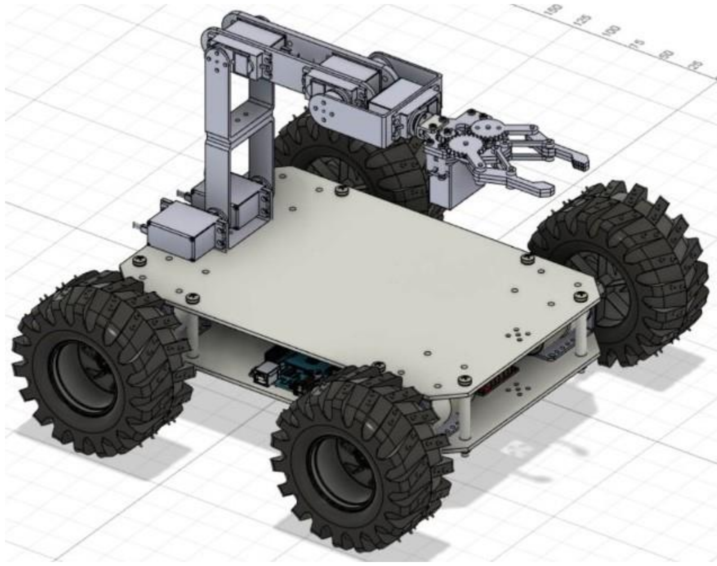


Figure 4-13: Project Illustration

4.9.2. INTERNAL CIRCUITRY

The internal circuitry has been shown in the following images:

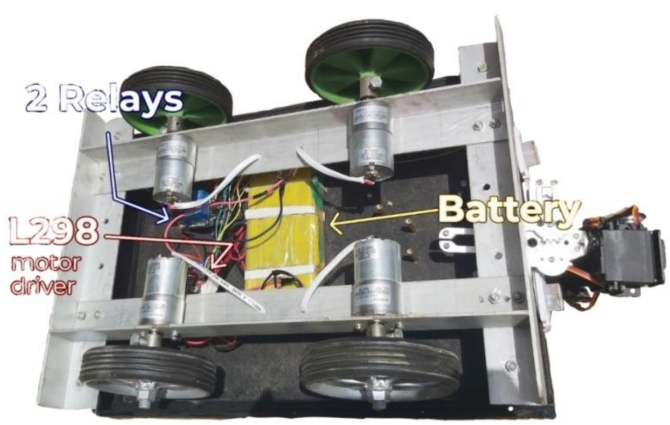


Figure 4-14: Components attached beneath platfor

4.9.3. BODY STRUCTURE

The body structure is shown below:

Figure 4-15: Mobile Platform Design

4.10. LIVE VIDEO STREAMING

A 5 mp camera is placed on the robot that will stream the live video of the vicinity where robot will be employed. This is added to incorporate the feature of tele-presence.

The extracts from code for live video streaming are attached:

```
while(True):
    # Capture frame-by-frame
    ret, frame = cap.read()
```

Cap.read () statement always provides a bool value that can either be true or false. If the value returned is true that indicates that the frame was comprehended accurately.

```
# Our operations on the frame come here
gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
```

This function takes two vales as input; one is the actual image whereas the other is a code for color conversion. As the original image has **BGR (BlueGreenRed)** color palette we must convert it to **gray** as per our requirement. To do so, the command **COLOR_BGR2GRAY** is used.

```
    # Display the resulting frame
    cv2.imshow('frame',gray)
```

This function takes two inputs; first one is a string that contains the name that is given to the window, the second one is the variable that refers to the image that needs to be displayed.

4.11. CONTINUOUS FEEDBACK

Different sensors such as DHT 11 and DHT 23 are integrated in the circuitry to provide continuous feedback about environmental conditions and robot. These are temperature and humidity sensors that will report back these conditions. These sensors will collect and compile data and send it over Wi-Fi which will appear on the GUI. It will be used to ensure that robot has suitable circumstances to work efficiently in.

4.12. POWERING OF ROBOT

AVERROES is powered through 3.3V, 24 cells and 72 Ah $LiFePO_4$ battery. Buck converters are used with the battery to regulate the voltage supply to all the components in the circuitry. Buck converters are used with the battery which converts the input supply to provide 5V supply to the central controller (Nano) and 6.7 V supply to the servo motors. The battery used is rechargeable, hence the robot will charge up completely in 3 to 4 hours.

4.13. FINAL ROBOT

The final robot looks like:

Figure 4-16: Final Robot

CHAPTER 5

CONCLUSION

5.1 Summary
5.2 Discussions
5.3 Objectives Achieved
5.4 Artificial Intelligence & Machine Learning Integration

CHAPTER 5

CONCLUSION

5.1. SUMMARY

This thesis presents an overview of the ongoing patterns in automated warehousing, particularly the utilization of robotic advances and technologies to satisfy orders. The benefits of mechanization are fundamentally space saving, work cost saving, around the clock accessibility (it isn't easy to discover unqualified faculty ready to accomplish warehouse work), and reduction in funds on other operational expenses. Moreover, robotic advances give versatility and throughput adaptability, which is basic in e-commerce business situations where the interest inconstancy is high. Automation of capacity, stock check and request picking requires impressive scale and a drawn out vision as the expenditure can be earned back in the medium and longer term. Subsequently, it is significant to create apparatuses to help owners locate the right answers for their stockroom. Consequently, studies have been completed to display and streamline the working and features of the different automated frameworks.

5.2. DISCUSSIONS

We present the kinematics of the robot, as well as its mobility and efficiency in its work. We also illustrate how the models are used in long-term and short-term decision-making processes (structure, operational control and drafting). We evaluate the literature that identified the different structure and control issues in these frameworks, for example, ideally molding the framework, route calculations, image processing and obstacle avoiding procedures, and storage task. Every one of these frameworks is diverse as far as infrastructural prerequisites, operational conventions and hardware developments are concerned however, the frameworks are basically common and models should be tweaked to suit each organization’s distinguishing needs and qualities. We also talk about rising advancements and perspectives that have not gotten enough (or any) consideration in the writing. Human picking in combination with AGVs is one of the latest advancements that is getting popular practically owing to its simplicity and adaptability, however it has not yet been sufficiently examined. Additionally, computerized renewal and sequencing, integrated systems, human-machine communication and distribution center supportability are domains that require more consideration from analysts and researchers.

5.3. OBJECTIVES ACHIEVED

The objective of a rigid body is achieved by using aluminum to build the chassis which is lightweight and acrylic sheets are used for the basic structure of robot. It has four wheels along with geared motors that control the movement of the wheels to help the robot to move around without losing its balance hence fulfilling the criteria of mobility as well. The motors provide feedback to the central controller.

Web application is designed to give commands to the robot and also to receive the feedback from the sensors. Sensors are integrated with the robot to give a continuous feedback about the environmental conditions of the surrounding area. Live video stream is achieved by integrating a 16mp camera. Live feed is also received on the web application.

Distance and ranging sensors (LIDAR and SONAR) study the environment and provide data to the central network to map the environment. NVidia Jetson Nano is coded for object recognition and image processing. A mobile manipulator is mounted on the arm. It is made of aluminum and has a reach in six DOF. The arm fulfilled the objective of product picking and manipulation.

5.4. ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING INTEGRATION

A major and critical role in our future prospects is played by the Artificial Intelligence and Machine Learning integration with our robot. AI and Machine Learning is the future of technology and is the front runner for creating a more automated lifestyle and work style. Combined with a strong and powerful AI module, nVidia Jetson Nano, our robot will be able to map a warehouse and navigate through it without any human control. This will lead to more advanced and efficient monitoring of warehouse inventory.
Integration of more scripts in the algorithm will enable AVERROES to further create a more methodical system where human input is at its minimum. These scripts will further aid in analyzing the training data in a more comprehensive manner and thus create an even more reliable system than it was before.

CHAPTER 6

Future Work and Enhancements

6.1 Overview
6.2 Electrical Design
6.3 Mechanical Design

CHAPTER 6

FUTURE WORK and ENHANCEMENTS

6.1. OVERVIEW

AVERROES is designed to traverse the environment on its own with the help of its rigid body and the mounted sensors that analyze the surroundings. It is also able to determine the location of the product and carry it around. The applications of the robot can be enhanced in different aspects to improve its performance and to broaden the horizon of its usage.

6.2. ELECTRICAL DESIGN

Future improvements in the electrical design could include an efficient network of communication. AVERROES provides an efficient battery feedback about its voltage and current to monitor charge level and power draw. It can be improved to sense the voltage and current of each motor. As each motor has almost the same bus voltage, current sensors can be used to determine and analyze the amount of torque produced by each motor individually.

The stepper motors can be used instead of the dc motor which will provide a greater control over the motors and hence a precise rotation and movement can be achieved.

Encoders can be used with each wheel that would provide accurate calculations of degree of rotation. This will enable us to move the exact required distance. The degrees of rotation multiplied with the diameter of the wheel will give the distance covered.

Furthermore, as all other electrical components and sensors will get improved they can be incorporated in the design to make it more efficient.
Battery that is used to power the bot can be improved as stronger and longer lasting batteries are made.

6.2. MECHANICAL DESIGN

The body of the robot can be enhanced to make it more suitable for the environment so it can perform more efficiently. Stronger material can be used for the chassis and the body so that the structural rigidity can be increased. The payload of the robot can be increased so that heavier packages can be lifted.

Moreover, individually adjustable wheels can be added to the design. The degrees of rotation in arm can be increased so that it has a smoother movement and greater reach.

CHAPTER 7

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APPENDIX A: CODES

- **Code for QR Scanning:**

```
# python barcode_scanner_video.py

# import the necessary packages
from imutils.video import VideoStream
from pyzbar import pyzbar
import argparse
import datetime
import imutils
import time
import cv2

# construct the argument parser and parse the arguments
ap = argparse.ArgumentParser()
ap.add_argument("-o", "--output", type=str,
default="barcodes.csv",
   help="path to output CSV file containing barcodes")
args = vars(ap.parse_args())

# initialize the video stream and allow the camera sensor to
warm up
print("[INFO] starting video stream...")
vs = VideoStream(usePiCamera=True).start()
time.sleep(2.0)

# open the output CSV file for writing and initialize the set of
# barcodes found thus far
csv = open(args["output"], "w")
found = set()

# loop over the frames from the video stream
while True:
   # grab the frame from the threaded video stream and resize it
to
   # have a maximum width of 400 pixels
   frame = vs.read()
   frame = imutils.resize(frame, width=400)

   # find the barcodes in the frame and decode each of the
barcodes
   barcodes = pyzbar.decode(frame)

   # loop over the detected barcodes
   for barcode in barcodes:
      # extract the bounding box location of the barcode and
draw
      # the bounding box surrounding the barcode on the image
      (x, y, w, h) = barcode.rect
```

```
        cv2.rectangle(frame, (x, y), (x + w, y + h), (0, 0, 255),
2)

        # the barcode data is a bytes object so if we want to draw
it
        # on our output image we need to convert it to a string
first
        barcodeData = barcode.data.decode("utf-8")
        barcodeType = barcode.type

        # draw the barcode data and barcode type on the image
        text = "{} ({})".format(barcodeData, barcodeType)
        cv2.putText(frame, text, (x, y - 10),
            cv2.FONT_HERSHEY_SIMPLEX, 0.5, (0, 0, 255), 2)

        # if the barcode text is currently not in our CSV file,
write
        # the timestamp + barcode to disk and update the set
        if barcodeData not in found:
            csv.write("{},{}\n".format(datetime.datetime.now(),
                barcodeData))
            csv.flush()
            found.add(barcodeData)

    # show the output frame
    cv2.imshow("Barcode Scanner", frame)
    key = cv2.waitKey(1) & 0xFF

    # if the `q` key was pressed, break from the loop
    if key == ord("q"):
        break

# close the output CSV file do a bit of cleanup
print("[INFO] cleaning up...")
csv.close()
cv2.destroyAllWindows()
vs.stop()
```

- **Code for Live Feed:**

```
import cv2

cap = cv2.VideoCapture(0)

while(True):
    # Capture frame-by-frame
    ret, frame = cap.read()

    # Our operations on the frame come here
    gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)

    # Display the resulting frame
    cv2.imshow('frame',gray)
    if cv2.waitKey(1) & 0xFF == ord('q'):
        break

# When everything done, release the capture
cap.release()
cv2.destroyAllWindows()
```

APPENDIX B: SYNOPSIS FORM- AVERROES

Extended Title: AVERROES: Autonomous general purpose tele-presence robot

Brief Description/Thesis with Salient Specifications: This project aims at the design and development of an astute, autonomous robot with adjustable wheels. AVERROES, a self-sufficient robot will easily traverse the wideness and entanglements of its environment using the data gathered from its sensors. It will ensure the mobility and stability in accordance with the surrounding. It will be suited for all sorts of complex and testing conditions. It will also be able to lift reasonable weight. Moreover, it will provide continuous feedback regarding environmental analysis i.e. temperature, pressure, humidity etc. The web application will act as a GUI to control the robot and monitor it using Wi-Fi.

Scope of Work: This robot will prove to be an innovative breakthrough in field of robotics owing to its compressed size, stability and autonomous mobility. It is going to be helpful in guidance and delivery. So, through this project we wish to integrate our theoretical knowledge with practical experience to gain further insight and redefine our skills.

Academic Objectives: This project will provide hands-on experience in the following courses:

- Control Systems
- Microprocessors Systems
- Programming Techniques
- Structure Designing
- Robotics

Application/ End Goal Objectives: This project will provide following objectives:

- To develop a robot that can navigate autonomously in all buildings and environments.
- It can be used for guiding unfamiliar people in an building
- Delivery of consumer products
- Helping out employees in an office
- Reasonable weight lifting capacity
- Object tracking

Previous Work Done on the Subject: Different variants of the robots have been designed in the past years. They include

- Roomba (September, 2002)
- SoFi (February, 2016)
- Amazon Delivery bots (2013)
- Asimo (2000)
- MonsterBorg
- ROSbot
- Turtle Rover (June 2018)

Material Resources Required: We will require

- RF Controllers
- Mobile Application
- Machine Learning
- Microcontrollers
- Different sensors
- Motors and actuators

No. of Students Required: 4

Group Members:

- PC Noor ul Hudda
- NC Jawad Hussain Kalwar
- NC Junaid Mohsin
- PC Abdullah Munir

Special Skills Required:

- Machine Learning
- Embedded Systems
- Robotics
- Programming

Approval Status

Supervisor Name and Signature

Asst Prof Mir Yasir Umair ___

Assigned to: ______________________

HoD Signature: ____________________________

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APPENDIX C: LIST OF ABBREVIATIONS

i.	**IDE**	Integrated Development E
ii.	**QR**	Quick Response
iii.	**OS**	Operating System
iv.	**DOF**	Degrees Of Freedom
v.	**LIDAR**	Light Detection And Ranging
vi.	**SONAR**	Sound Navigation And Ranging
vii.	**PCB**	Printed Circuit Board
viii.	**GUI**	Graphic User Interface
ix.	**IR**	Infrared
x.	**USB**	Universal Serial Bus
xi.	**IOT**	Internet Of Things
xii.	**DC**	Direct Current
xiii.	**ML**	Machine Learning

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