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AUTONOMOUS FLOOR CLEANING ROBOT

COLLEGE OF
ELECTRICAL AND MECHANICAL ENGINEERING
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COLLEGE OF ELECTRICAL AND MECHANICAL ENGINEERING

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PROJECT REPORT

AUTONOMOUS FLOOR CLEANING ROBOT

Submitted to the Department of Electrical Engineering
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in
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Sponsoring DS:

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CERTIFICATE OF APPROVAL

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This project is submitted to **Department of Electrical Engineering**, College of Electrical and Mechanical Engineering (Peshawar Road Rawalpindi), National University ofSciences and Technology, Pakistan in partial fulfilment of requirements for the degree of Bachelor of Electrical Engineering.

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ABSTRACT

This project titled "Autonomous Floor cleaning Robot" is aimed at delivering a smart, self-navigating and efficient cleaning mechanism that is capable of performing domestic Cleaning with minimum human supervision. The catalyst behind this project stems from the inherent problems in the traditional cleaning processes which are often time and labor intensive, and fail to offer consistent results.

This project focuses on the development of an autonomous floor cleaning robot that employs Visual SLAM, a technique which enables a system to understand its surroundings and seamlessly navigate through them without the need of pre-installed maps. This technique is centered on utilizing the raspberry pi, integrated with a web cam to capture a stream of images in real time. The images are fed into the Raspberry pi for processing subsequently outputting key features to create an accurate map of its surroundings and successfully able to pinpoint its relative location within the map. The robot's navigation and obstacle avoidance capabilities are further augmented by integration of ultrasonic sensors thereby avoiding collisions and ensuring smooth cleaning process.

The project encompasses both the development of hardware and software. A hardware system utilizing the Raspberry pi as the central processing unit integrated with motion sensors and a webcam carefully mounted within a 3D printed exoskeleton. Deployment of Visual SLAM and motion control algorithm lied under the software domain to facilitate a comprehensive coverage and systematic cleaning of the space.

In conclusion, the deployment of Visual SLAM technology along with motion sensors demonstrates a significant step in integrating computer vision techniques to further advance the capabilities of autonomous robotics. With its compact design and sophisticated functionality, our project underscores the potential of robotics to revolutionize traditional domestic methods, offering smart and convenient alternatives.

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

In our fast paced modern lives, where time is precious commodity, the demands for automated solution for daily life chores has subsequently sky rocketed. Among these, automated floor cleaning robot stands out as a testament to the fusion of robotics, machine learning, computer vision and artificial intelligence.

Secondly, considering household chores, cleaning can also be considered as a health risk to some citizens who cannot do dusting and cleaning by themselves as they face health issues such as "Dust Allergies". Around 10% of the population in the world faces this issue. While cleaning themselves, this sensitivity can also aggravate the asthma and can become a serious lifetime health issue in some cases.

This research seeks to provide an automated solution for such problems faced by the people in their lives. In this fast paced life, it contributes in lowering the laboras well as satisfying health care demands.

1.2 Objectives

The unfolding of autonomous floor cleaning robots mirrors the persistent march of technological innovation. These robots have undergone a astounding transformation, from early prototypes with essential navigation systems to revolutionized machines equipped with modern fused sensors and a variety of algorithms. This project aims to present presents an innovatory solution for these revolutionizing technology.

The central processing unit and technological backbone of this project is "Raspberry Pi", an adaptable, multifaceted, economical, credit card sized computer. It serves to control the actions and decision making process of the robot. This micro controller serves as the nucleus of the robot that is the alloy of hardware and software allowing enhanced efficiency in this task.

Complementing this with the gyroscopic sensor which is embedded within MPU6050, which is fundamentally used for its latest and up to date tracking capabilities, that empowers unambiguous and error free navigation and control.

Furthermore, to strengthen the functionalities and working of the robot, innovatory technique of Kalman filter is employed. This filtering technique is known for its potential to detect the noisy data produced within the sensor and approximate the actual state of the system. Kalman filter plays a crucial role in securing flawless and well regulated movement within the cleaning vicinity.

Moreover the project is integrated with the technique of Visual SLAM (Simultaneous Localization and Mapping). This technique allows robot to steadily move as well as reform the depiction of its cleaning vicinity. This enables robot to know its original location, identify the obstacles and how to manage the path in the presence of these obstacles.

While taking into account the techniques of computer vision, ORB (Oriented FAST and Rotated BRIEF), brute force matching, affine estimation, hamming distance are considered. These techniques help in feature extraction and feature matching which in return helps in robust localization an mapping in cleaning vicinity.

To further improve the output of the robot, sensors such as ultrasonic sensor are utilized to efficiently detect not only the obstacle, but also the robot's distance from that specific obstacle. This contributes in shielding the robot from unnecessary smashes. It also enhances the robot's perceptual capabilities.

Throughout this report, we will thoroughly understand the complexities of all the components, applied techniques, implementations, methodologies and design parameters. In addition to this, this project report summarizes the challenges that we encountered and also the measures that were taken in order to nullify them. Moreover, it also encapsulates the amalgamation of hardware, software and algorithmic revolutions.

1.3 Significance

The importance of floor cleaning robot not only limits itself for household chores, it can also be used in offices and commercial places for small areas of cleanings. This endeavor represents advancements towards robotics and intelligent systems with implications in the following domains:

- **Efficiency Enhancements and Comfort:** This automated technology aims to significantly reduce physical work and manual labor and so saves time and effort. Human intervention is appreciably reduced and so can clean a designated space effortlessly.
- **Improvement in Hygiene and Sanitation:** The major principal for wellbeing and healthy lifestyle is maintaining "Tidiness". This robot guarantees efficient cleaning, damping the risk of allergens, microorganisms and dust mites etc.
- **Technological Transformation and Revolution:** The amalgamation of raspberry pi, machine learning algorithms, computer vision techniques and sensors

integration including gyroscopic sensor, ultrasonic sensor and camera is the evidence of human creativity in technological domain.

- **Health Care:** The people suffering from sensitivity to dust significantly contributes to the population of the world. Cleaning household space is a daily chore and needs to be done consistently. For these sensitive people, this robot will bring so much ease in their lives as they won't be dusting or cleaning the space on their own. This will nullify their interaction to dust and so they won't face asthma or any other such health care issue.
- **Economic Advantage:** As compared to other robots, this floor cleaning robot is pocket friendly and less expensive for daily use if commercialized. This technology has the potential to make its place in this saturated market as it is the significant need of the day.

CHAPTER 2

BACKROUND AND LITERATURE REVIEW

2.1 Introduction

Diving into this chapter, extensive view of all the existing content is dished out. This chapter will be summarizing the research papers, articles and methods previously used in this technological domain.

2.2 Historical Background

The adaptation of Autonomous Floor Cleaning Robot can be tracked back early explorer who were keen to learn and advance in the domain of automated technology. Early designs of 1956, comprised of Robovacs with two functionalities i.e remote control and self-drive operation. Perceptions of set and forget solution may deceive sometimes. IRobot launched its two renowned models of robot vacuums; Roomba in 2002 and Scooba in 2005. Scooba 5900, the first one from its family of floor scrubbing robots, included dirty and clean water tanks along with cleans solutions. Later on, Scooba 200,300 and 450 with small sized capabilities included internal clean water bladder with bristle cleaning up to 150 sqft, 250 sqft and 3 stage cleaning processes of sweeping, soaking and scrubbing respectively.

On the other hand, Roomba/Dust puppy of September 2002, a famous vacuum cleaner with powerful vacuum had 3 buttons of clean, spot and max in its first two generations with standard dustbin size and charging abilities. Implanting squeegee vacuum, reduced impact speed feature and Forward looing IR sensor in next generation in addition to WIFI connectivity and aerovac bin, Roomba prospered. Later on in 5th Generation HEPA Filter was introduced in vacuums plus its scheduling features added up to its commercial value. Camera was later incorporated for simultaneous mapping and localization. APP control feature was also installed. Currently 10th generation Roomba are equipped with both LIDAR and camera with sensor fusion implemented for better response.

In early 1990’s, the first milestone was achieved and a robotic vacuum cleaner named "**Electrolux Trilobite**" was introduced in market. The major disadvantage of this robot was that it couldn’t properly detect obstacles and so frequently collisions were observed. It also faced issues while turning of the robot around the obstacle. Secondly, it’s navigation of the cleaning vicinity was quite weak so it often left some areas uncleaned. As a result this robot was discontinued in the market.

But this innovation laid a strong core for the upcoming advancements in this domain. The early market robots include the following;

2.2.1 1st Generation Scooba Robots

The two models of the 1st generations are explained below:

- **Scooba 5800:** In early 2005 Scooba 5800 was introduced by iRobot. In early 2006, it was produced on large scale for commercial purposes. But it’s sale were not as much as were initially expected mainly because it was costly for normal domestic people. Secondly, this model started to face some battery health issues and so its demand in the market certainly dropped.
- **Scooba 5900:** This failure of Scooba 5800 didn’t stop the pioneers of technolog-

ical advancements and they released Scooba 5900 in the second half of 2006. In this model, the software was revamped and the battery efficiency was much improved. Secondly, the navigation was improving and obstacle detection became more efficient.

2.3 Importance of Autonomous cleaning

As seen in previous years of pandemic, where traditional cleaning methods failed to address the need of patients effected with transmissible disease, robot vacuums serve best in this regard. Around 20 million people i.e about 12% of adult population in Pakistan suffers from asthma and many of them are allergic to dust and daily brooming can cause a serious health risk to such people, Therefore, it is helpful for allergic adults.

Realtime screen surveillance helps keep track of robot locations as well as necessities of old people can be easily monitored on screen. App control feature allows in accessing all robot features on a single click without utilizing any external energy.

2.4 Role of AI in Robotic vacuums

Robot utilizes common ML algorithms from OpenCV for implementation of VSLAM. In this section all the algorithms will be discussed used in key point descriptor extraction, matching of two consecutive frames and distance calculations.

2.5 Visual Simultaneous Localization and Mapping

This Visual simultaneous localization and mapping is achieved by Monocular vision camera along with 4 most common libraries OpenCV, SMBUS, Rpi.GPIO and NumPy. 30 fps webcam with 720P resolution is used for this purpose. Images from Webcam are fed to the microprocessor Raspberry pi 4B+. Debian Bookworm is installed in

Raspberry pi as the operating system.

2.5.1 OpenCV

OpenCV stands for open source computer vision library. It can easily access camera, extract keypoints from images based on their shapes and size etc. Difference can also be computed per frame and based on this difference trajectory can be estimated.

2.5.2 Algorithms in OpenCV

OpenCV is a notable library with a wide range of machine learning and deep learning algorithms used in many computer vision tasks such as object detection, face detection, VSLAM implementation. Among those the most common Algorithms are YOLO, Mobilenet SSD, OFAST, rBRIEF, KNN, CNN, SIFT, SURF, Adaboost, HOG, Filterpy, Brute Force matcher and Haar cascade.

2.5.3 Libraries

Numpy is the basic library used. NUMPY stands for Numerical python library. This library is widely used for matrix and array calculations. Normally it is used in python codes for basic mathematical operations, computing target location and position different according to trajectory coordinates.

2.5.3.1 Algorithms in NUMPY

Like OpenCV, NUMPY is enriched with many complex algorithms like e.g FFT (Fast Fourier Transform) used mainly in DSP applications and image processing. Random number generation algorithm can be used when hardcoding sensor results. Array Manipulation for incrementing new values according to changed results per frame. Interpolation algorithms can be helpful in inserting different nature variables.

2.5.3.2 SLAM related NUMPY algorithms

- **Array Manipulation:**
  - Manipulating Trajectory and map points.
  - Stores key points and descriptors.

- **Mathematical Operations:**
  - Computes Target position
  - Computes position difference according to trajectory and odometry

- **Rpi.GPIO:** For controlling robot motors for different kinds of movements, Rpi.GPIO serves the purpose. Rpi.GPIO can be used to move robot either forward, back- ward, rotation about its fixed axis, left, right and stop.
- **SMBUS:** It stands for System Management bus library for MPU/ gyroscopic sensor. It communicates with raspberry pi using i2c interface, and can either send or receive signals in a very minimum delay. This library is used when incorporating MPU6050 for correct angular rotation, monitoring z axis values.

2.6 Robotic Vacuum and Efficient floor cleaning

Robotic Vacuums like Roomba, Scooba and Braava are enriched with obstacle avoidance sensor like infrared. Latest models also incorporate gyro along with a sensor of SLAM and Lidar based distance measurement results. This section discusses concept, benefit and challenges during entire building process.

2.6.1 Concepts

Our robotic vacuum possesses the capabilities of room mapping, autonomous navigation, obstacle avoidance, precise rotations with zigzag motion. Recent robotic vacuums use Lidar + SLAM technology, however incorporating Lidar for slam implementationis way too expensive, therefore an alternative approach is addressed here, using Sonar sensors with ultrasonic distance estimations and utilizing webcam for detecting key points, mapping, locating robot's exact location and roaming freely.

Ultrasonic sensors launch ultrasonic waves for 5ms when trig pin is high and the reflected waves provide the distance measurements.

Distance Formula:'

Distance = (duration * speed of sound)/2

- Ultrasonic sensors are used for obstacle avoidance via distance threshold, if distance is less, robot moves a little backward, rotates for 180 degree and continues with its SLAM target position tracking process.
- MPU sensor can be used as both either accelerometer or gyroscopic sensor. For this robot, only gyroscopic part of this sensor is used.

```
MPU 6050/ Gyroscopic/ IMU sensor
  // Convert raw gyro data to degrees per second
  float gyroX_degPerSec = gyroX / 131.0;
  float gyroY_degPerSec = gyroY / 131.0;
  float gyroZ_degPerSec = gyroZ / 131.0;

  // Integrate gyro data to get angle change
  angleX += gyroX_degPerSec * 0.01;  // 0.01 is the time interval in
seconds
  angleY += gyroY_degPerSec * 0.01;
  angleZ += gyroZ_degPerSec * 0.01;
```

Figure 2.1: Parameters for MPU-6050

Gyroscopic sensor picks up raw x,y and z values and converts its readings into degrees per second by dividing it with its sensitivity factor.

Next the angles in degrees per second after sensor working can be converted to pure degree values by multiplying with 0.01s. Then the conditions of 180 degree are continuously monitored by the sensor and hence desired characteristic is achieved.

Gucee Webcam with 30 fps and 720p resolution is used for capturing frames within slam loop. Performance parameters are as follows:

- **Focal Length Adjustment**

  focallengthx = 600

  focallengthy = 600

- **Principal Point Adjustment:**

  principalpointx = 320

  principalpointy = 240

- **Radial Distortion Coefficients adjustment:**

  k1 = 0.1

  k2 = 0.01

  k3 = 0.001

- **Tangential Distortion Coefficients adjustment:**

  p1 = 0.001

  p2 = 0.001

Cleaning portion: Robot is equipped with a central 11.3cm high vacuum container of around 7.8cm outer and 7.3 cm inner diameter with a suction hole of 3cm diameter providing suction pressure of 500Pa along with two sweeping brushes attached to two DC geared brushed motors operated at 24V each in opposite directions.

Unlike Scooba it doesn't use any liquid or bleach for cleaning and scrubbing floors, instead it uses powerful vacuum suction and a cost plus energy effective approach.

2.6.2 Benefits

Robot vacuum with autonomous navigation capabilities can be at times, time saving when preparing for meeting and left with only 2-3 hours. Its compact size enables and enhances its ability to penetrate to every corner of room and ensure an efficient clean area. Compared to generic vacuum cleaners, it is light weight and thus more convenient for usage. Most commonly thought of as set and forget solutions. Recharging features contribute to least consumption of resources. At normal cleaning modes it is less noisy compared to typical vacuum cleaners. Recent linkages with apps and Alexa has made it much convenient and user friendly.

2.6.3 Challenges

Maintaining a well precise motion involves incorporating several sensors among which Lidars and night vision camera can be too expensive. Such gap is taken into consideration and a new approach of monocular webcam SLAM with Sonar technology is utilized. Although Zigzag motion has helped achieve a faster cleaning response but still it takes time as compared to manual labor. Rechargeable batteries, though contributing to sustainable development still come up with a price to pay. Replacement of parts contribute significantly to high operating costs.

2.7 IOT and sensor technologies

So far advancements in VSLAM has lead and encouraged towards fusion of different sensor technologies along with camera for accurate and efficient results. Each sensor has its own dedicated role whether its Sonar for obstacle avoidance, gyroscopic sensor for zigzag rotation or webcam for key point detection and mapping.

2.7.1 Challenges with sensor

Dealing with sensors especially in microprocessors like Raspberry pi is not a straight-forward task since sensors normally operate at 5V and 0.4mA while raspberry pi is incapable of empowering these sensors, so a different approach of designing circuits has to be used for this purpose.

Sensors no doubt being quiet helpful in precision of desired results, can still be deceptive. Sensors like MPU6050 often have accuracy and reliability problems.

2.8 Communication Protocols

2.8.1 WiFi

This section provides an overview of commonly used protocols used in this project i.e WIFI. WIFI provides high data rate access. For our project it can be easily linked to IP which not only enables its app connection feature but also enables live monitoring via VNC.

2.8.2 Challenges and Limitations

Although WIFI protocols help in making it more user friendly, however it is limited to only specific range with frequency of 2.4 GHz and range can only reach up to 150 indoors.

2.9 Designing and Analysis

Each component in our circuit demands its own power rating, while sensors work at 5V 0.4mA, brush motors require 24V and wheel motors require 6 V for an optimum operation. Vacuum is constructed using DC brushless motor fan acquiring 12V and 1.68A.

For such difference of power in components, two circuit PCBs were designed, first was buck converter in order to manage power for sensors and relay. The other circuit was of boost converter for power handling of motors rotating brushes. A re- lay is added in between so that whenever raspberry pi turns on, vacuum and brushes automatically start on their own.

2.10 Trajectory and Mapping

Robot uses 3D affine estimation algorithm in order to mark coordinates of next target position. FAST algorithm is first applied on Image captured to check intensities of lighter and darker pixels. Further rBRIEF is applied on same image to produce binary string and compute hamming distance. Now the image is processed at translational and rotational aspects and a final coordinate, let's say (x1, y1 is computed).

Robot's present position is initialized at (xo, yo), where;

xo = 0 and yo = 0.

Now the position difference is calculated and new coordinates (x2,y2 are com- puted) where;

x2 = x1-xo

y2 = y1-yo.

If y2 is positive, robot will move forward

If y2 is negative, robot will move backward

If x2 is positive, robot will move right

If x2 is positive, robot will move left

2.11 Sensor Fusion

Compared to Lidars, ultrasonic sensors also act upon distance computation however, the two differ in their method of computation. Lidars use laser which reflects back and distance is computed, while Ultrasonic sensors throw ultrasonic waves which re- flect back and distance is computed. Obviously lasers have a much faster speed than ultrasonic waves therefore efficiency of Lidar is much greater.

Here in this section we are discussing about Implementation of Visual SLAM, single camera based SLAM along with ultrasonic sensor instead of Lidar and night vision camera in order to produce a cost-effective and more convenient product.

Lidars have an ability of rotating 360 degrees about their own axis, mapping room throughout, however ultrasonic sensors are single faced, therefore 3 ultrasonic sensors are connected, two at 45 degrees and one at 90 degrees purely at front.

For mapping Webcam serves the purpose by detecting key points and computing hamming distance. Trajectory lines are plotted accordingly and results in 2D + 3D map building.

2.11.1 Working

Each sensor continuously checks out for obstacles. If either one of these sensors detect an obstacle distance below its specific threshold, Robot moves backward for 1 second and makes a U-Turn rotatory movement. Simultaneously frames are being captured and robot moves according to same SLAM algorithm and computed target position whenever obstacle distance is greater than threshold. While Rotating robot keeps tracks of its angular position and once 180 degrees rotation is achieved robot continues with slam instead of rotating further.

2.12 Drawbacks of Robot vacuum

Due to a low suction pressure of only 500 Pa, robot vacuums lack efficiency in cleaning larger surface area where generic vacuums may serve better. Robot vacuums may face wireless connectivity issues at times due to limited range.

Robot vacuums are equipped with container as well as brushes. Regular usage results in dirt capture across brush edges and container has to be made empty, therefore it requires regular maintenance. Recharging feature no doubt helps in maintaining a sustainable environment but on the other hand there’s a heavy price to pay.

Rechargeable Lithium-ion batteries are more expensive than older batteries, so once they are drained out, There’s no other way than exchanging them, so depth of discharge factor has to be considered of great importance while using these batteries in robot for a long lasting performance.

CHAPTER 3

METHODOLOGY AND IMPLEMENTATION

3.1 Introduction

This chapter enlightens the basic methodology used for design, development and analysis of Autonomous Floor Cleaning Robot. It serves as a beacon that illuminates the system's architecture, techniques and the procedures used to optimize performance of the robot. Diving further, this chapter has two basic aims.

- To provide transparency regarding the components utilized.
- To clarify the methodologies used to integrate all the components.

Through multiple iterations, simulations and a set of experiments on each sensor, we validate the efficacy of the methodologies used.

3.2 Block Diagram

The system architecture of the Autonomous Floor Cleaning Robot serves as a blueprint that outlines how the entire system works. It provides an overview of how data algorithms such as visual SLAM gathers data within the system and how different components interact with each other reacting to the gathered data.

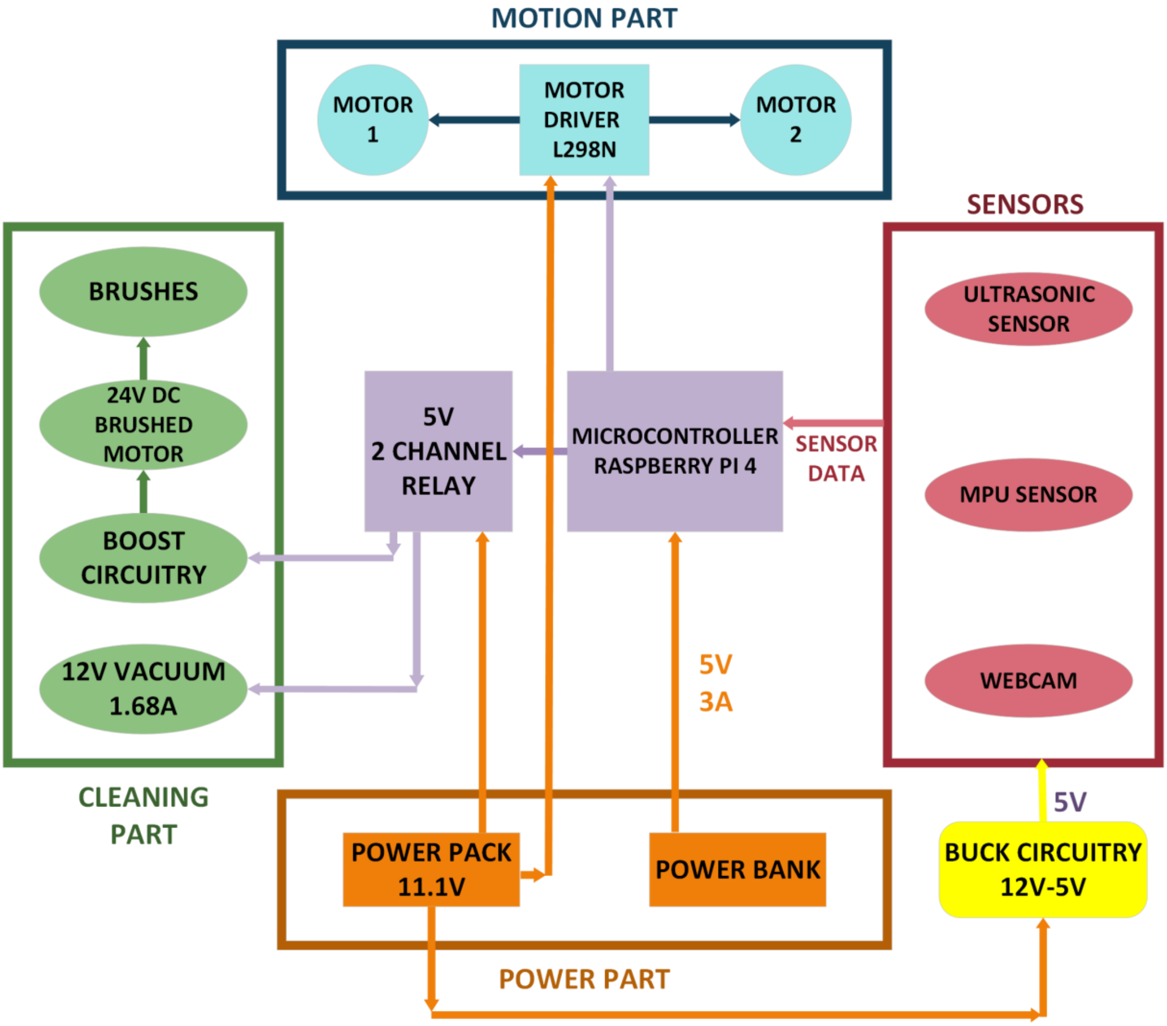

Figure 3.1: Block Diagram of Autonomous Floor Cleaning Robot

3.3 General Architecture

Raspberry Pi used in the project acts as the heart of the project. The general layers of the architecture will be further discussed. Each layers of the architecture is responsible for the perception, control, capturing data, decision making and navigation etc.

3.3.1 Mapping and Localization

The navigation system of the robot is the basic backbone of the robot's movement. This robot follows monocular vision i.e a single camera is used for the vision and mapping. For this purpose, Visual SLAM (Simultaneous Localization and Mapping) comes into ground. To implement Visual SLAM, following techniques of machine learning under the library of OpenCV are used.

3.3.1.1 Oriented FAST and Rotated Brief

ORB is the technique of computer vision that is used for feature extraction. It's foundation is based on the concept of "Fast Corner Detector" and "BRIEF Descriptor" that helps improve the performance in navigation. By using these two technique, ORB has greater efficiency compared to other feature extraction techniques. The overview of technique is as follows:

- **Corner detection:** The working of this algorithm begins with Fast algorithm. The basic purpose of this logarithm is corner detection and identifying the keypoints in the image.
- **BRIEF Descriptor:** BRIEF stands for "Binary Robust Independent Elementary Features". After the detection of keypoints in an image, BRIEF Descriptors is used to make comparison between the intensity of pairs of pixels that lies within the vicinity of each keypoint. After the comparison, it leads to a binary string as

the descriptor.

The traditional BRIEF descriptors is not able to tell the inclination of the keypoints. However, ORB as whole is able to compute the orientation of the keypoints based on the difference of intensity of the neighbourhood pixels of each keypoint, making sure that the descriptors are steady to the rotation.

3.3.2 Planning and Decision Making

This layer encloses analytical modules. Algorithms for the planning of the paths, perfecting the routes, are employed for the proper optimization of cleaning paths and simultaneously encountering the constraints that includes avoidance of obstacles and coverage of the entire cleaning vicinity. For this purpose, sensors such as ultrasonic sensor(for obstacle avoidance) and gyroscopic sensor(for the rotation on a specified angle from the obstacle) is employed.

3.4 Hardware Components

The essential hardware components, according to their functionalities, used in the construction of the robot are as follows:

3.4.1 Visual Perception and Sensing

For the purpose of the sensing of the surroundings, following sensors are integrated.

- **Ultrasonic Sensor:** The basic function of ultrasonic sensor is "Obstacle Detection". the following are the major components of the sensor that helps it to accurately perform its operations. Ultrasonic sensor operates from a voltage of 5V that it receives from the power pack through buck converter.

– **Transducer:** It is used for the conversion of electrical energy into ultrasonic sound waves that are to be transmitted towards the obstacles infront. Secondly, it receives the reflected ultrasonic waves(echoes) that are coming from the obstacle surrounding the robot.

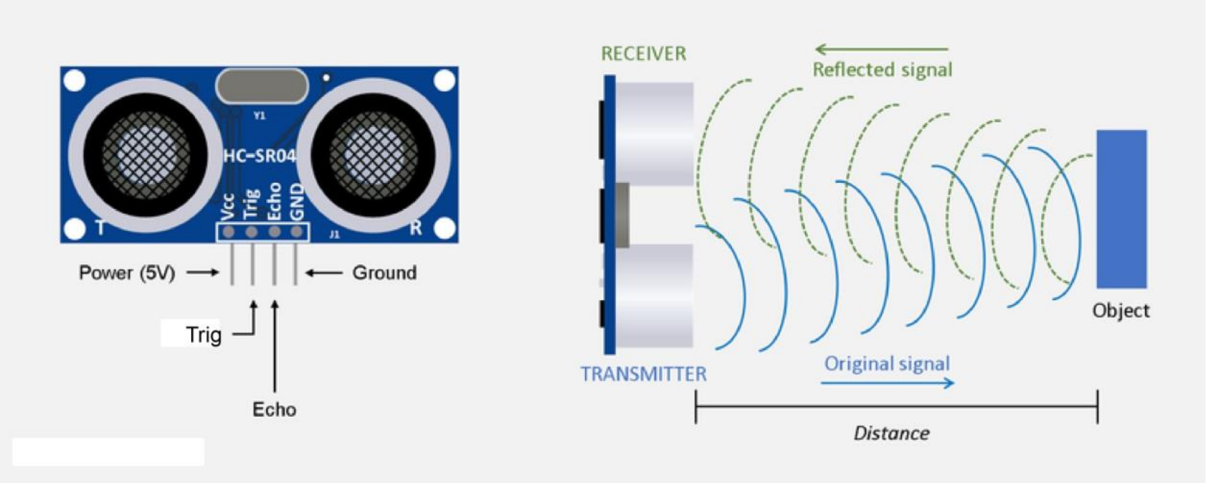

Figure 3.2: Ultrasonic Sensor

– **Basic Circuit Design:** The circuit is designed for the purpose of distance measurement of the sensor from the obstacle. This is calculated using the time taken by the echoes to reach back to the sensor. Externally the sensor is connected to the microcontroller which programs it to detect the obstacle as soon as it enters the specified range of distance.

- **MPU-6050:** MPU-6050 is an integrated circuit(IC) 6-axis sensor incorporating 3-axis gyroscope and 3-axis accelerometer within a single chip. Its basic function is to provide efficient motion sensing. In this project, we are only need the gyroscopic sensor from the IC. The gyroscopic sensor is powered from the power pack passed through buck converter producing a voltage of 5V.

– **Gyroscopic sensor:** Gyroscopic sensor is highlighted for its ability to tell precise orientation and motion data that is required for the efficient movement of the robot. It encloses nanostructures which deflect in response to the angular motion i.e rotation. This gyroscopic module consists of MEMS, which shows deflection in result of tiny angular rotation across the axis. It generates electrical signals that are corresponding to the rate of rotation around each axis. The purpose of this sensor in this project is for perform-

Figure 3.3: MPU-6050

ing controlled rotations around the obstacle at the certain specified angle.

- **Webcam:** This project uses a webcam with a frame rate of "30 fps". It captures the local vicinity and transmits the data to the microcontroller that processes the images further.

3.4.2 Power Management

- **Power Bank:** A 10000 mAH of power bank is utilized that supplies 5V and 4.5A. This power bank is used to power the microcontroller. This power bank can provide continuously for 6 hours of work.
- **Power Pack:** A 2000 mAH lithium ion battery is used. this battery is used to power the DC motors used for the brushes and wheels. This power pack provides with 12V of voltage that is further passed through buck and boost converters as per the requirements. This power pack can be used non stop for around 1.5 days.

3.4.3 Micro-controller

The building block of the project is the micro-controller that is discussed below:

- **Raspberry Pi-4:** Raspberry Pi-4 integrates a quad-core ARM Cortex-A72 processor embedded with 8GB of RAM. It's strengthened processor, USB interface, display ports and Ethernet makes it a perfect solution for our project.

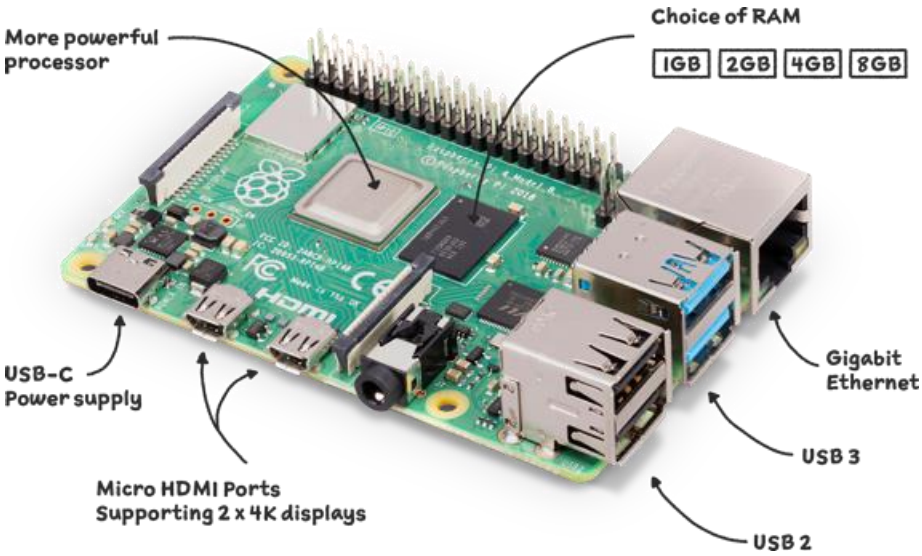

Figure 3.4: Raspberry Pi-4

referring to the fig3.4, the following port connections are made:

  - **Camera:** Pi-4 can be can integrate visual sensing through an external lens/webcam attached to it. The camera can be connected to the pi through the USB port and the images captured by the camera are then passed through many computer vision techniques for feature extractions.
  - **Sensors:** The three ultrasonic sensors and the gyroscopic sensor are connected to the GPIO pins of raspberry pi to navigate the vicinity and detect all the hurdles in the way.

Other than these ports, the powerful processor enables the execution of different computer vision algorithms for the image processing that helps in the mapping of the cleaning area.

Moreover, the GPIO pins enables to make connections with the DC motors for the operation of the wheels and the brushes. The commands for the movement of wheels according to the keypoints is provided by the microcontroller. According to these commands, the wheels takes turns, execute forward motion or reverse itself from the obstacle. On the other hand, the motors attached to the brushes are continuously in motion so that the brushes can gather the debris towards the vacuum and so the cleaning process becomes more efficient.

3.4.4 Motion of the Robot

The motors are the main hardware component enabling the movement of the robot. The details are explained below:

- **Motor Driver:** The motor driver acts as a conciliator between the microcontroller and the motors controlling the motion of the robot. They play the significant role in the control of the robot's movement. It's operating voltage is 12V that comes directly from the power pack used.
  - **Function:** The basic function of motor driver is the regulation of current and voltage according to the motor's needs. It protects the motors from irregular voltage spikes that in return saves the motors from any internal damages.
  - **Integration with Micro-controller:** The motor driver module is connected to the controller through the GPIO pins. Through this connection, it sendsand receives commands from the controller and sends the to the motors thatin return perform the desired action.
- **DC Gear Hobby Motors for Wheels:** These motors are used to control the motion of wheels. These motors operate through the motor driver module that provides it with its desired voltage input. Furthermore, the motors operate the wheels that allows forward, backwards, left or right movement.
- **DC Gear Hobby Motors for Brushes:** These are the motors used for brushes and are operating on 24V at the speed of 142rpm. On the other hand, the power pack used is of 12V. To solve this issue, a "Boost Circuitry" is designed that steps up the DC voltage and fulfills the requirement of the motor.

3.4.5 Suction and Vacuum

Suction is the major and the most essential function of the project. The CPU Fan is used in such a manner that it acts as a vacuum. The characteristics of the CPU fan that it operates on 12V DC. This voltage is provided through the 12V power pack through a relay.

3.5 Applied Algorithms

For the images, "feature extraction" and "corner detection" play crucial role in the navigation of the robot. To implement Visual SLAM the following algorithms are deployed. These algorithms includes:

- OFAST Keypoints Extractor
- Harris Corner Detection
- RBRIEF
- Brute Force Matching
- Affine Estimation
- Hamming Distance

The details of all the algorithms are explained below.

3.5.1 OFAST Keypoint Extractor

OFAST stands for Oriented and Fast Corner keypoints extractor. This algorithm is used for the purpose of defining the distinctive features and keypoints in an image. These are the features that make the two images different from eachother.

The selection of this algorithm for our robot is done keeping in view our need to define the keypoints in the cleaning area. These keypoints increases the perception abilities of the robot to detect between the obstacles and navigate itself according to them.

- **Working:** The features of this algorithm are as following:
  - **Keypoints Detection:** The webcam continuously transmits the images of the vicinity to the processor of the microcontroller. This algorithm identifies the salient features of the image and mark the necessary keypoints including edges, corners etc. It operates by matching the keypoints of the consecutive images and plan a path in accordance with those keypoints.
  - **Efficiency:** This algorithm is well known for its good efficiency and speed in detecting the keypoints in image. If the response is delayed and is less efficient, it can cause the robot to collide with obstacles in the cleaning vicinity as the path planning is not executed on time. Due to this ability, it suits the best for our project because no latency can be affordable in the floor cleaning robot and allows the robot to move efficiently and dynamically in the cleaning space.
- **Implementation:**
  - Select a pixel ’p’ from the image.
  - Construct circle of 16 pixels with 9 units radius each.
  - Compare the intensities of the pixels.
  - Collect all the string values.

Figure 3.5: Captured Image for OFAST

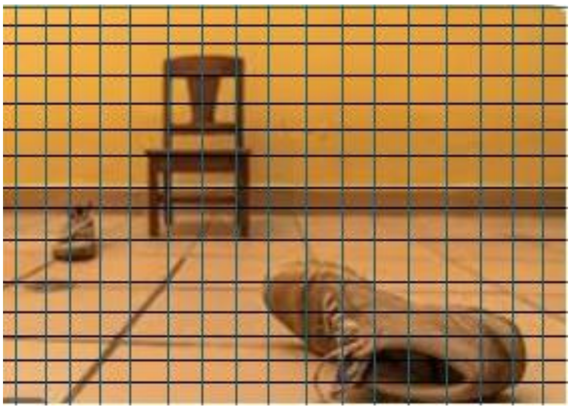

Figure 3.6: Partitioned Image for Operating Algorithm

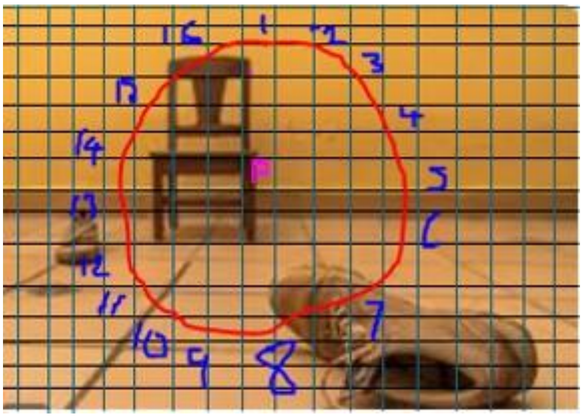

Figure 3.7: 16 pixels selected from neighbourhood

3.5.2 Harris Corner Detection

This algorithm is a well-known method for the detection of corners in an image that is transmitted to the processor. It functions by detecting the changes that occurs in the intensity and identifies those points as "corners". It is widely used for its precision, accuracy and its robustness towards noise.

- **Significance in Floor Cleaning Robot:** Corners are the points where intensity varies in all the directions. Due to this, it is the crucial feature in an image for localizing and navigating purposes. The features detected by this algorithm are invariant to the effect of changing lightening conditions, translation and rotation of the image. This feature makes it perfect for the choice of this project because it will enable the robot to mark the corners whether it’s rotating or is present in varying illumination.

  Secondly, the main factor of its significance includes **"motion estimate"**. By the detection of the corners in the consecutively received images, the robot will be able to make its path by computing the displacement of the obstacle.

- **Working** The working includes the following steps:

  – Calculation of Gradient: First of all, the gradients are calculated at each point to detect changes in intensity.

  – Structure Tensor: A structure tensor matrix is formed using the intensity variations in x and y directions respectively.

  – Response to Corner: After the creation of matrix, the algorithm computes the function based on the eigen values. The points with the highest response are detected as corners.

  – Non Maximum Suppression: To refine the location of the corners already identified, non maximum suppression is used.

3.5.3 RBRIEF

RBRIEF is abbreviation of Binary Robust Independent Elementary Features (BRIEF) algorithm. This algorithm also serves for the purpose of efficient feature selection. This algorithm is an extension of BRIEF algorithm.

- **Significance:** RBRIEF is significantly used for the extraction of compact feature descriptors from the images transmitted through the microcontroller's camera module. It plays a vital role in the implementation of the Visual SLAM.

  Secondly, its very efficient to both build the features descriptors and then match them. This means it's highly efficient and so its a perfect solution for better performance in recognition.

- **Working and Implementation:**

  Binary Test: Take a pixel of 3x3 neighbourhood and compare intensity with all other pixels.

  $T(p:x,y) = 1\ p(x) < p(y)0$

  $p(x) >= p(y)$

  fn(p) = sum($2^i - 1T(p : x, y)$)

  - If intensity is similar, binary output '1'.
  - If intensity is different, binary output is '0'.

Figure 3.8: Simple Image taken for applying algorithm

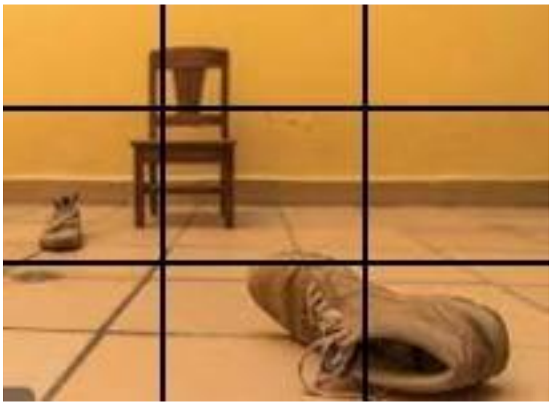

Figure 3.9: Image partition for rBRIEF

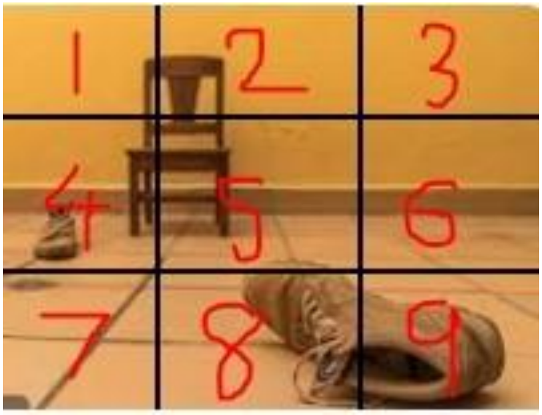

Figure 3.10: rBRIEF pixel numbering to compare intensities and produce string data

3.5.4 Brute Force Matching

Brute force Matching is a significant algorithm of computer vision. Its fundamental function is to match and make comparison between the descriptors of continuously taken images.

- **Working and Implementations**

– **Feature Extraction:** This is done through the techniques described above.

– **Descriptors:** For each extracted feature, descriptors are created.

– **Distance Calculation:** This algorithm finds the distance between each descriptor using hamming distance. This tells the similarity between the two consecutively captured images.

Figure 3.11: Pattern String of Brute Force Matching

3.5.5 Affine Estimation

Affine Estimation is a computer vision algorithm that is used to calculate translational image coordinates. These transformations include rotation, scaling, translation etc of the image.

Working:

- **Detection of Feature:** Like all the algorithms, the first step for. this algorithm is also the extraction of features that can be done using any technique.
- **Equations:** For the keypoints that are matched with their respective coordinates (x,y), a system of linear equations is created that helps in creating the transformation matrix.
- **Application:** To finally apply the transformation of the image, the estimated matrix is then multiplied with the image that gives the desired transformed image as an output.

3.5.6 Hamming Distance

Hamming Distance is a technique that is used to calculate the similarity between the binary descriptors of the image. These binary descriptors are obtained using the techniques of ORB in our case.

Working:

- **ORB:** Through this technique, firstly the binary descriptors are generated for the images that are captured by the robot's webcam.
- **Matching:** One by one, each descriptor is compared to the the descriptor of other image in order to match them. The basic aim is to find the pairs of descriptors that are the most similar in every aspect.
- **Distance:** By the operation of XORing, the distance is calculated. The result of '1' defines the point where the image differs from each other. Greater is the hamming distance, farther is the robot from the origin.

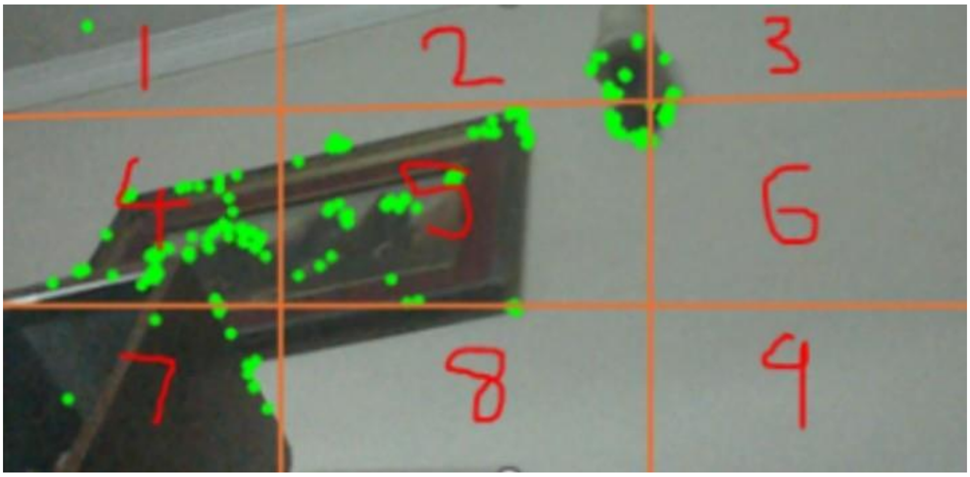

Figure 3.12: Main String for Hamming Distance Calculations

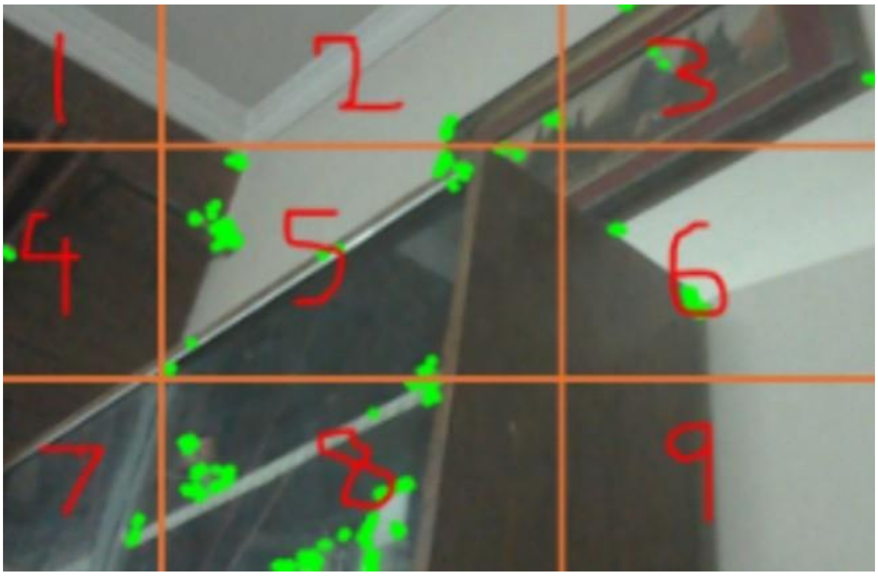

Figure 3.13: 2nd String Data

3.6 Circuitry

The major circuitry involved in this project are:

- Buck Circuit
- Boost Circuit

3.6.1 Buck Circuit

In the field of electronics, power management is the key to make everything work properly. Improper power management can lead to the damage of the electronic components. For example, if a device operates on 5V of DC voltage and the supply provided is 12V, this will internally damage the device and burn it at last.

To cater this issue in our project, we designed a buck circuit. The sensors in our project operates on 5-6V, and the power pack provides 11.1V. So the buck circuitrysteps down the DC voltage from 11.1V to 5V that is perfect for operation

Design Parameters:

- Inductor: 9mH
- Capacitor: 0.5uF

Circuit Simulation:

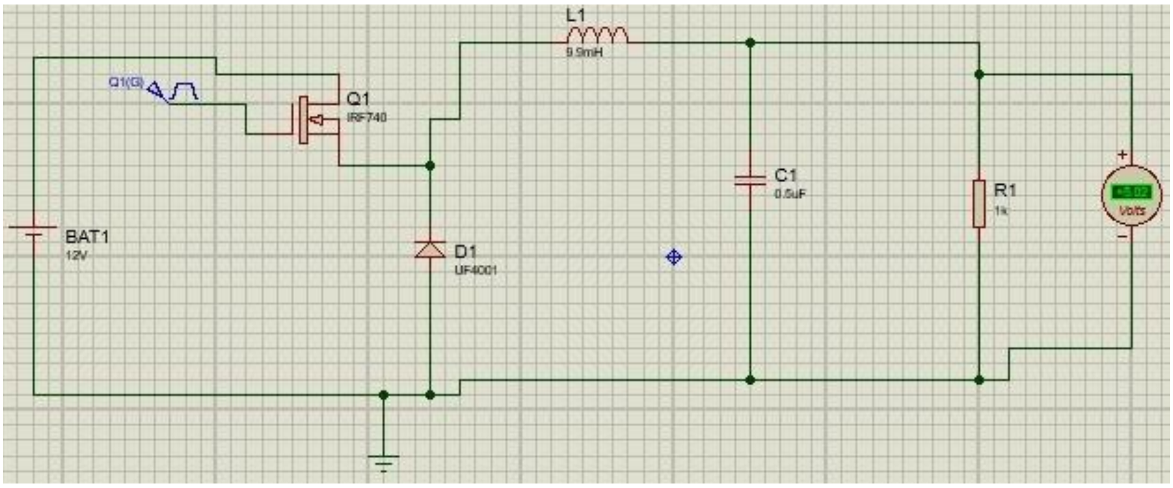

Figure 3.14: Buck Circuit

3.6.2 Boost Circuit

Some components in our project operates on 24V of DC voltage. This includes the DC Gear Hobby Motors that are used to0 operate the brushes. The power pack provides 11.1V that is stepped up and converted to 24V and so it operates perfectly.

Design Parameters:

- Inductor: 6mH
- Capacitor: 0.5uF

Circuit Simulation:

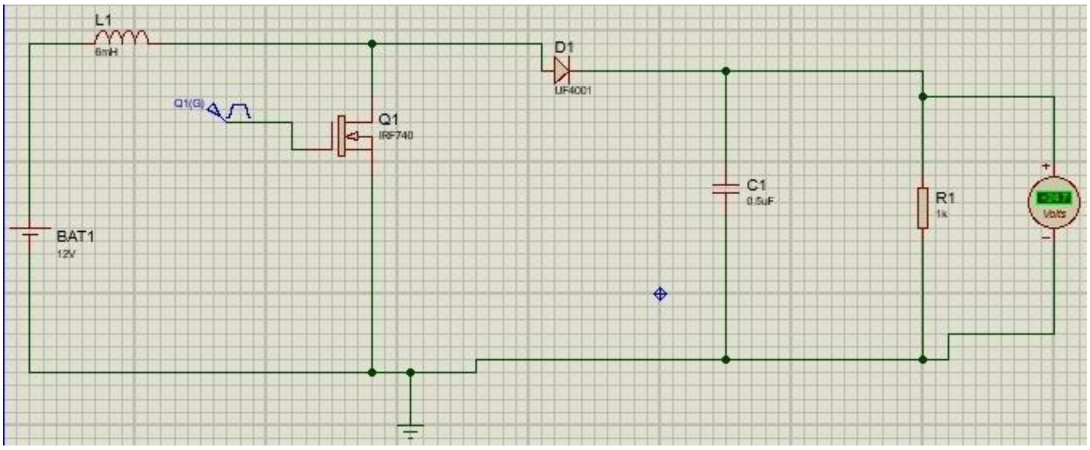

Figure 3.15: Boost Circuit

3.7 Conclusion

In this chapter, we deeply explored all the techniques and methods that formed the basis of our project. These includes all the hardware components, software algorithms and the circuitry designed for the implementations of the project. These technologies collectively helps the robot detect the obstacle, mark the keypoints and then plan a path in order to avoid obstacles while simultaneously cleaning the area.

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

This chapter portrays the results, analysis, and designing techniques involved in our robotic vacuum and provides a dense evaluation of the system's key point generation, 2D Mapping, 3D Mapping and user feedback. The section aims to provide details of effectiveness, reliability and usability of robot in real world scenarios. It presents results and interpretation of camera field of view, generation of key points according to different shapes of diverse and irregular objects. All the data acquired is presented in a well organized form.

First portion of this chapter delivers quantitative and qualitative results of applying ORB algorithm. Second portion deals with Performance indicators and Peak Signal Noise Ratio (PSNR) charts. Higher the PSNR, higher the quality of image. Next, results at different focal lengths and distortion parameters are shown. Results of sensor measurements on both Atmel and Raspberry pi are set forth. Final section deals with error in sensor measurements and entire image processing results are compared and summarized.

4.2 Description of Experimental setup

4.2.1 Initial camera testing

Initially we tested SLAM with laptop camera 0.9 MP 16:9(1280 x 720) with following parameters and distortion coefficients on Thonny Desktop App

- **Camera calibration parameters**

  focallengthx = 600,

  focallengthy = 600,

  principalpointx = 320,

  principalpointy = 240,

- **Radial distortion coefficients:**

  k1 = 0.1

  k2 = 0.01

  k3 = 0.001

- **Translational distortion coefficients:**

  p1 = 0.001

  p2 = 0.001

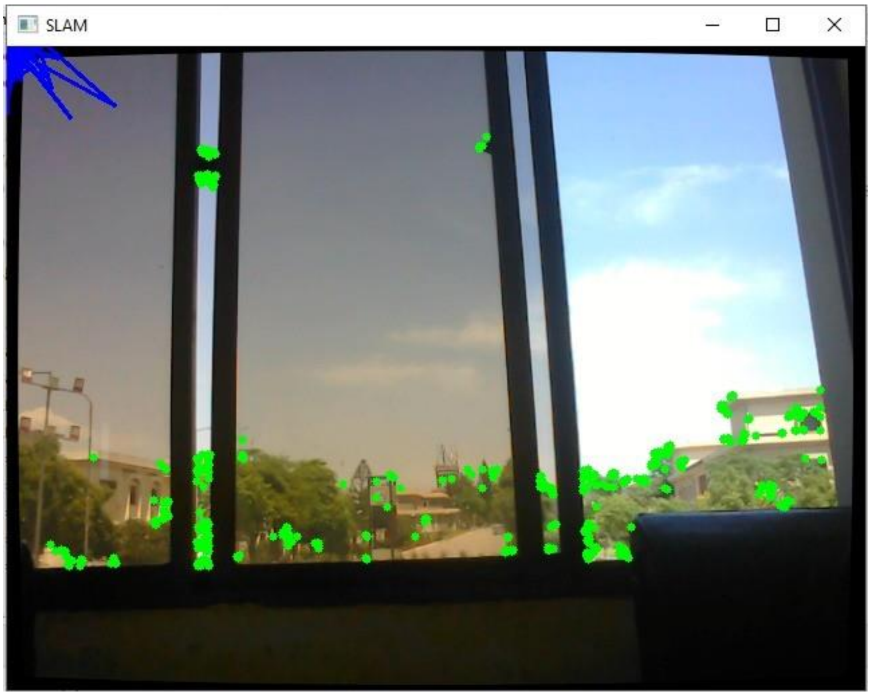

Figure 4.1: Keypoint Detection through ORB

Radial distortion is caused when straight line images appear to be curved while translational distortion occurs when lens and image is not exactly parallel and appears as skewed.

4.2.2 Sensor testing

- A total of 4 sensors were used in tuning this robot vacuum for efficient performance; i.e. Ultrasonic sensor, Webcam (optical sensor), IMU/Gyroscopic sensor and BMP180.
- Each Sensor was first individually tested on Atmel and readings were noted. Refinements were made until they get precise.
- Ultrasonic/Sonar sensor works by throwing ultrasonic waves for 5s and estimates the distance. After the waves bounce back and given input through echo pin.
- IMU, a combination of Accelerometer and Gyroscopic sensor helps robot keep track of its linear and angular rotation while moving and simultaneously estimating its position. For our robot we have used just gyroscopic part and similar to

ultrasonic sensor, IMU's gyroscopic axis was first tested with Atmel for MVP and then on raspberry pi for final product rotation precision.

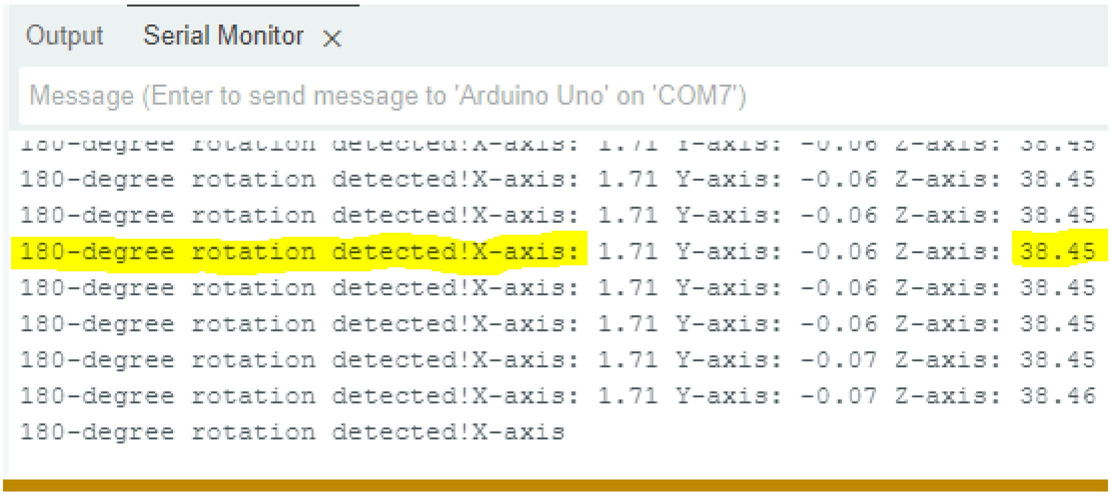

Figure 4.2: Results for Rotation Detection

- BMP 180 sensor is used to calculate exact suction pressure of our self created vacuum. BMP180 like IMU is equipped with multiple sensors i.e. Barometric sensor, Temperature sensor and Altitude sensor. Vacuum was created using CPU centrifugal fan with brushless motor 12V and 1.68A operated in reverse manner. Vacuum was tested at different heights and the corresponding table was created.

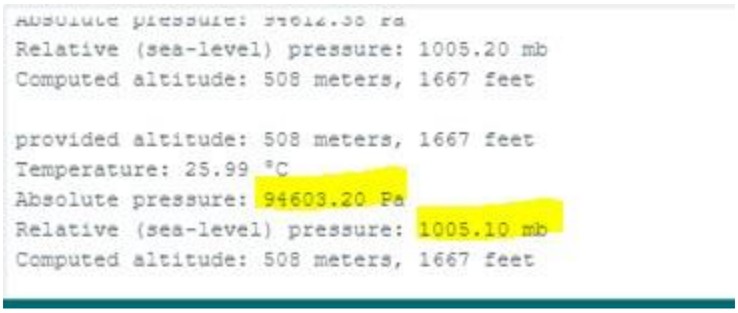

Figure 4.3: Pressure Calculation for Vacuum

Container Height	Sucked Debris Range	Atmospheric pressure/Pa	Absolut pressure value by sensor	Pressure asserted by vacuum
0.5 cm	Square 2.2 cm butter paper, Paper piece, Tissue pieces Peanut crap	94,666	94281	385
1 cm	Square 2.2 cm butter paper, Paper piece, Tissue pieces Peanut crap	94,666	94580	180
1.5 cm	Square 1 cm butter paper, Paper piece, Tissue pieces Peanut crap	94,666	94589	100
2 cm	Paper piece, Tissue pieces Peanut crap	94,666	94588	77
2.5 cm	Tissue pieces Peanut crap	94,666	94588	78
3 cm	Tissue Piece	94,666	94590	76

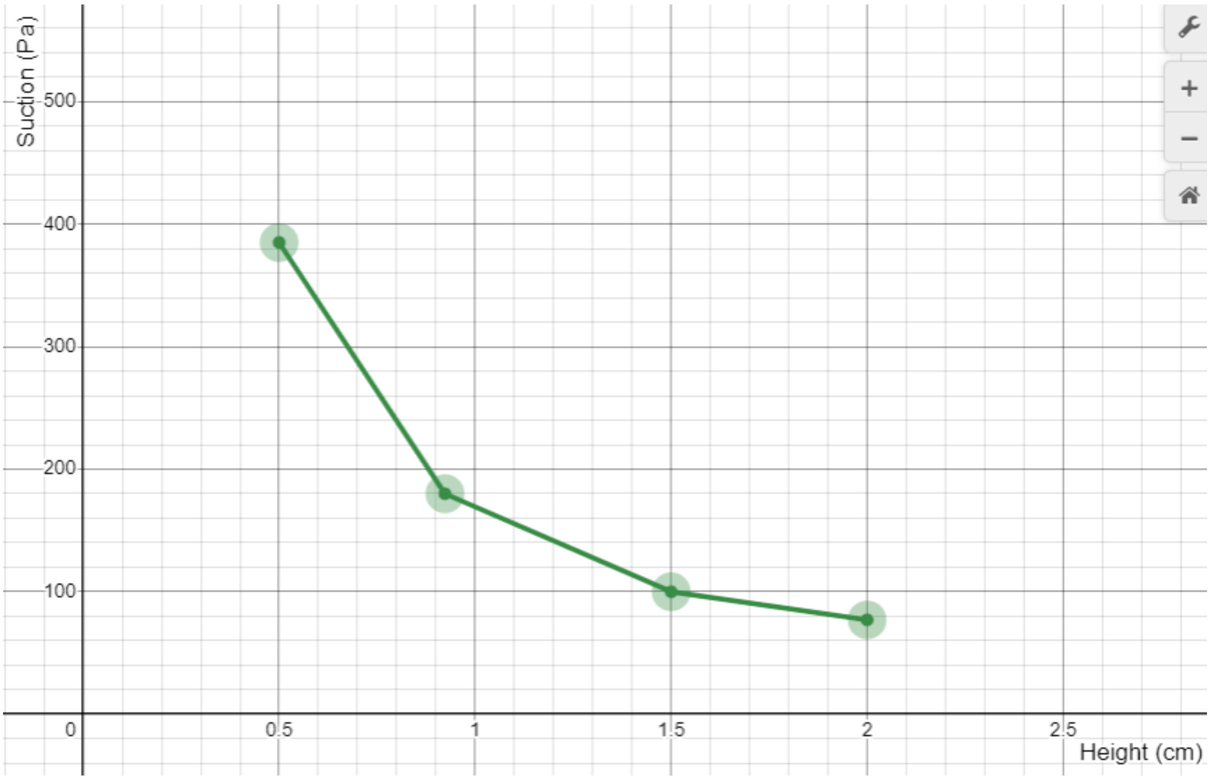

Figure 4.4: Suction Power

At first vacuum fan propeller was directly faced to the dirt/debris. Later filter net was placed before vacuum fan and the suction pressures were compared. Even after placing filter net, suction remain unchanged.

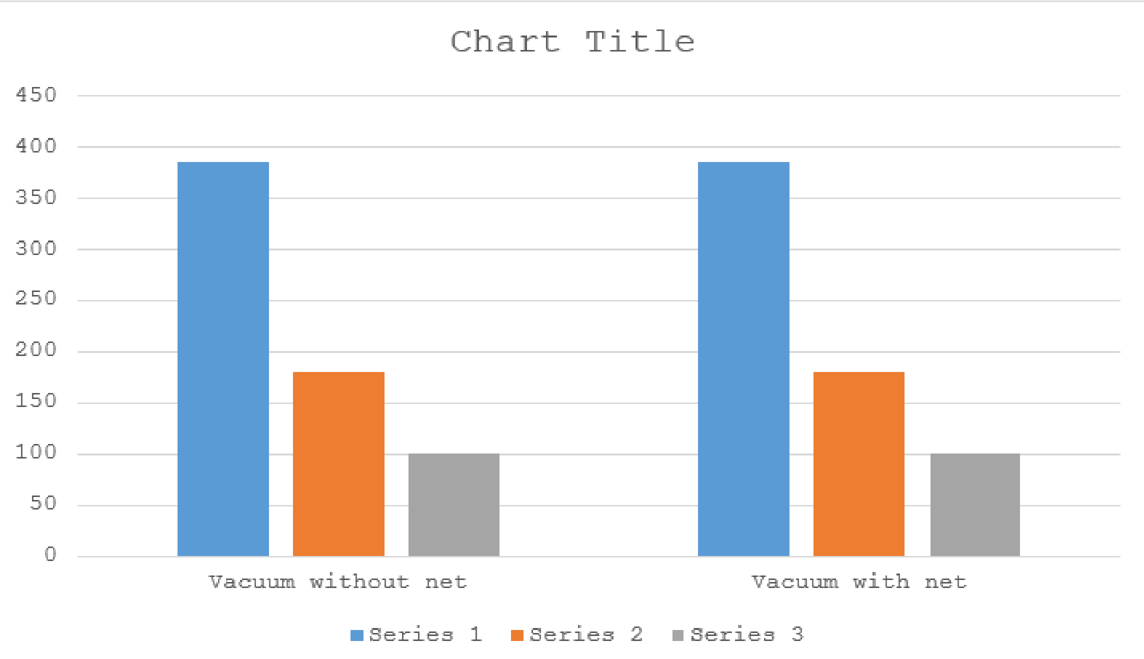

Figure 4.5: Vacuum Suction Testing through filters

4.3 Experimental Procedure

This section discusses about the steps we carried out in order to achieve this autonomous product. Our robot is actually built around webcam which extract features, generate 2D and 3D map and estimates its target position. The robot is equipped with a central vacuum container with a removable lid accompanied by similar but oppositely rotating brushes which push the debris inside, sucked up by vacuum. In order to enhance its obstacle avoidance behavior, multiple sensors are integrated for an efficient obstacle avoidance movement in zigzag manner with high suction pressure.

4.3.1 Techniques for key points extraction

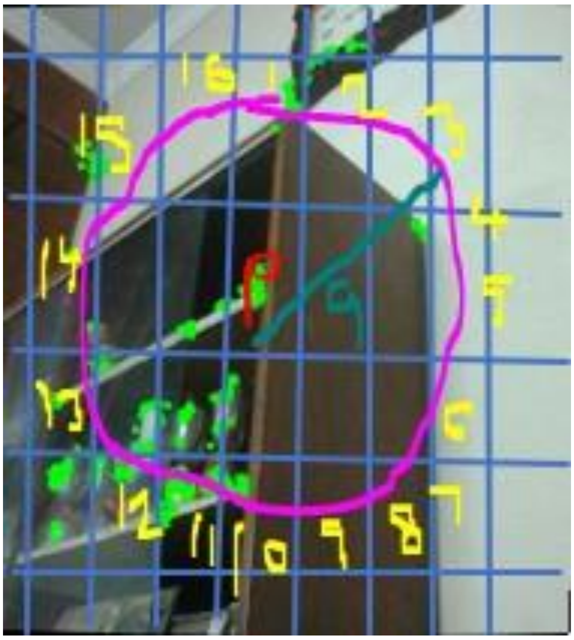

Figure 4.6: Keypoint Extraction through FAST

There are a number of algorithms for feature extraction like SIFT or SURF but FAST and rBRIEF provide a faster response between consecutive frames and also work even if the image is rotated. After the key points are extracted string values are computed according to intensities. Based on different string values, hamming distance is calculated and these key points further allow to create 2D and 3D maps

- **2D Map:**

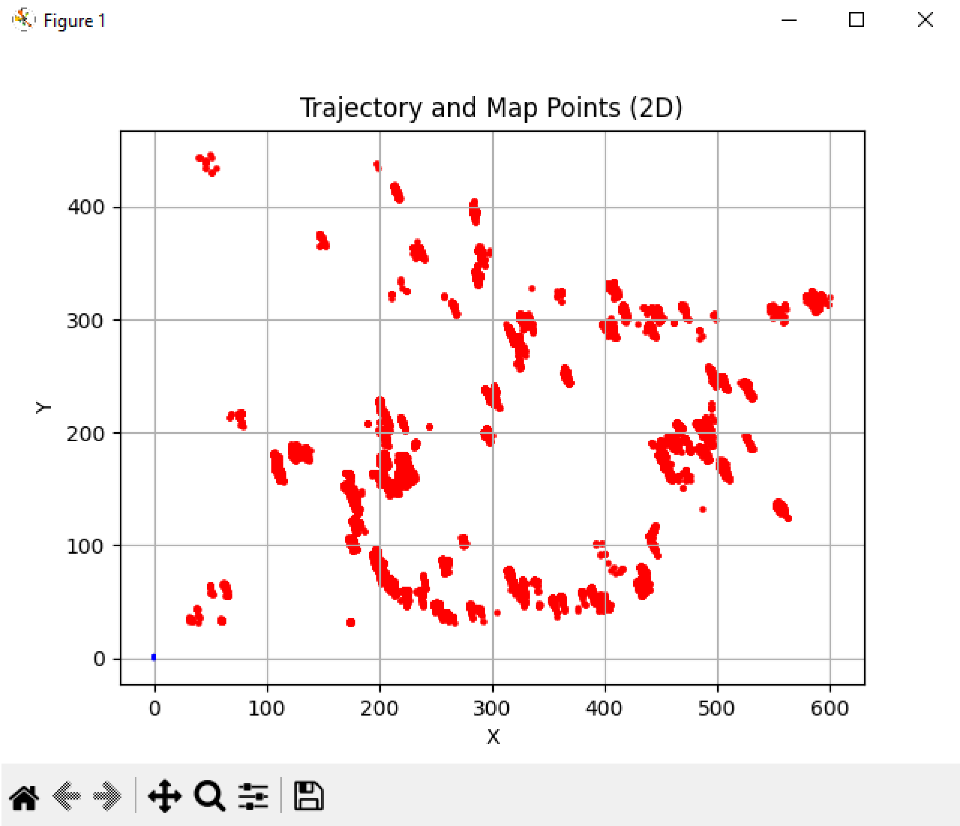

Figure 4.7: Trajectory and Map Points in 2D

- **3D Map:**

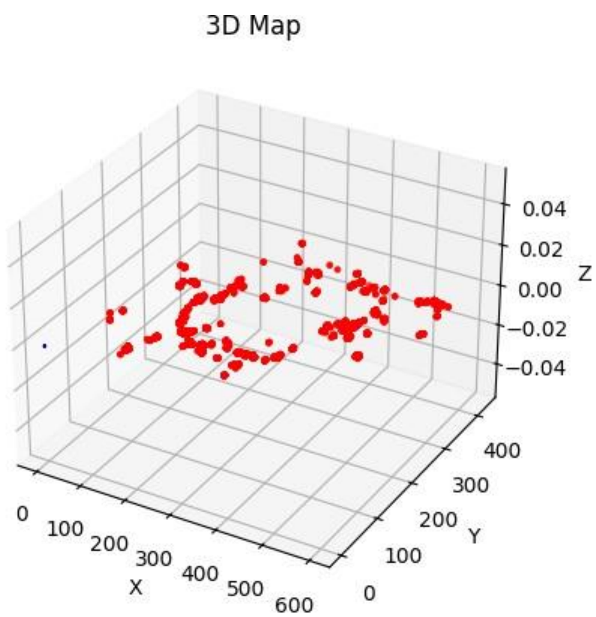

Figure 4.8: Trajectory and Map Points in 3D

For each new step, a new position difference is computed;

"position difference = target position – initial position"

```
Robot position: [ 0.13427457 -0.06670006]
Position difference: [-0.01912092  0.22159864]
moving forward
turning left
Number of map points: 17
Number of trajectory points: 17
```

Figure 4.9: Results of Robot Motion Estimated through Trajectory and Target Position

4.4 Robustness of system

Sensor no doubt, provide a much better estimate of obstacle and help maintain a precise 180 degree turn in this robot however sensors are too sensitive and may give out garbage value sometimes. For a robust system positioning of sensors was important. Since ultrasonic sensors have to detect front and sidewise obstacles, it is important to place 2 ultrasonic sensors at 45 degrees and 1 ultrasonic sensor at 90 degrees. IMU has to be fixed at a specific location otherwise it may cause errors in correct estimation of angular position.

4.5 Performance Evaluation Methodology

4.5.1 Criteria for Evaluation

Structural Similarity Index Model was considered while obtaining consecutive images from camera on still location. This Index varies from -1 to +1. +1 means maximum similarity between two consecutive frames of still camera.

4.5.2 Processing time calculation

Processing time depends on frame rate. For this robot webcam of 30 fps was used, which means it can captures 30 frames per second making it more suitable for consecutive frame change during motion.

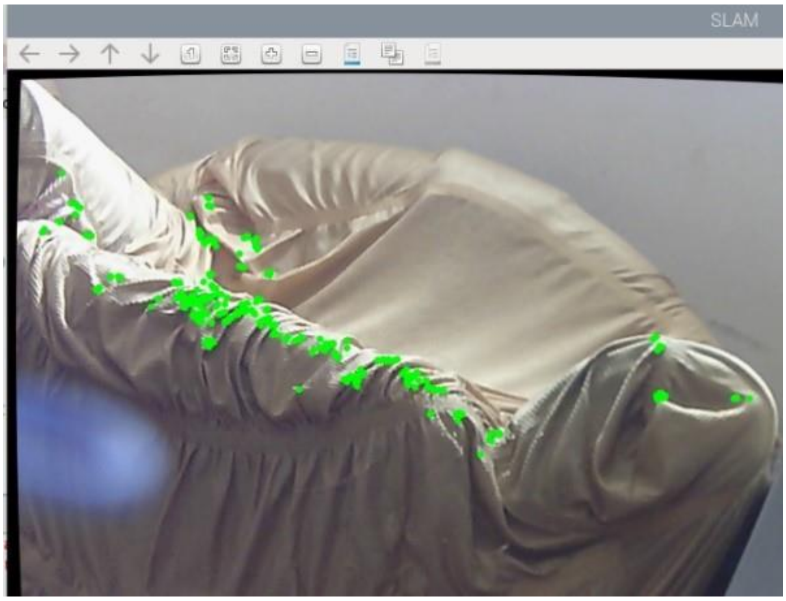

Figure 4.10: Visual SLAM using 720p 30fps COMS Sensor

Figure 4.11: Slam Implementation using HIFI Tone Webcam

4.5.3 Power consumption

Raspberry pi consumes 5V 3A, which is supplied by power bank of 10,000 mah, Vacuum motor needs 12V, Brush motors need 24V, Sensor require 5V and wheel motors need 3.3-6V based on their desired speeds. At first efficiency was tested with individual components and finally they were integrated/ fused. The Pie chart shows the power consumption by each component in this robot.

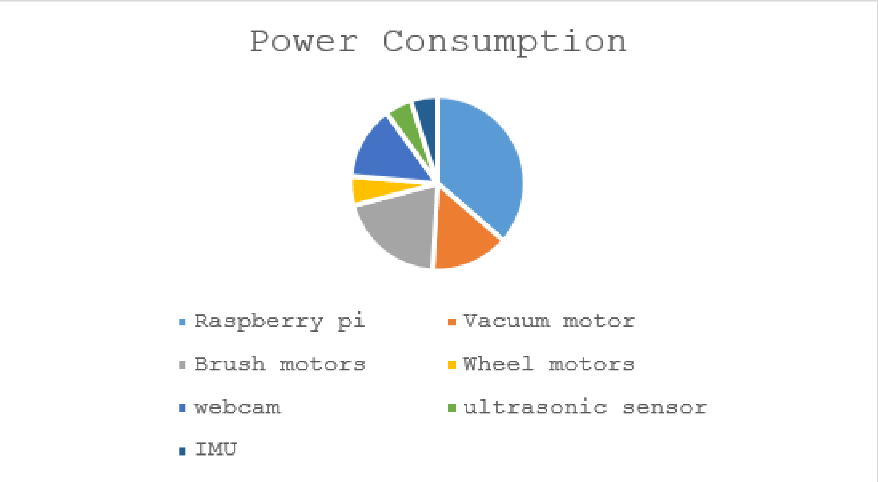

Figure 4.12: Power Consumption

4.5.4 Performance testing with changing of tyres

At first Simple DIY tyres were used at which robot motor could only rotate till almost 90 rpm i.e half of the full value due to friction. Later with Mecannum wheels rpm improved.

Due to this change height of robot increased and thus lead to change in AutoCAD design. The new proposed design is as shown in figure 5.2

4.6 3D Designed Models

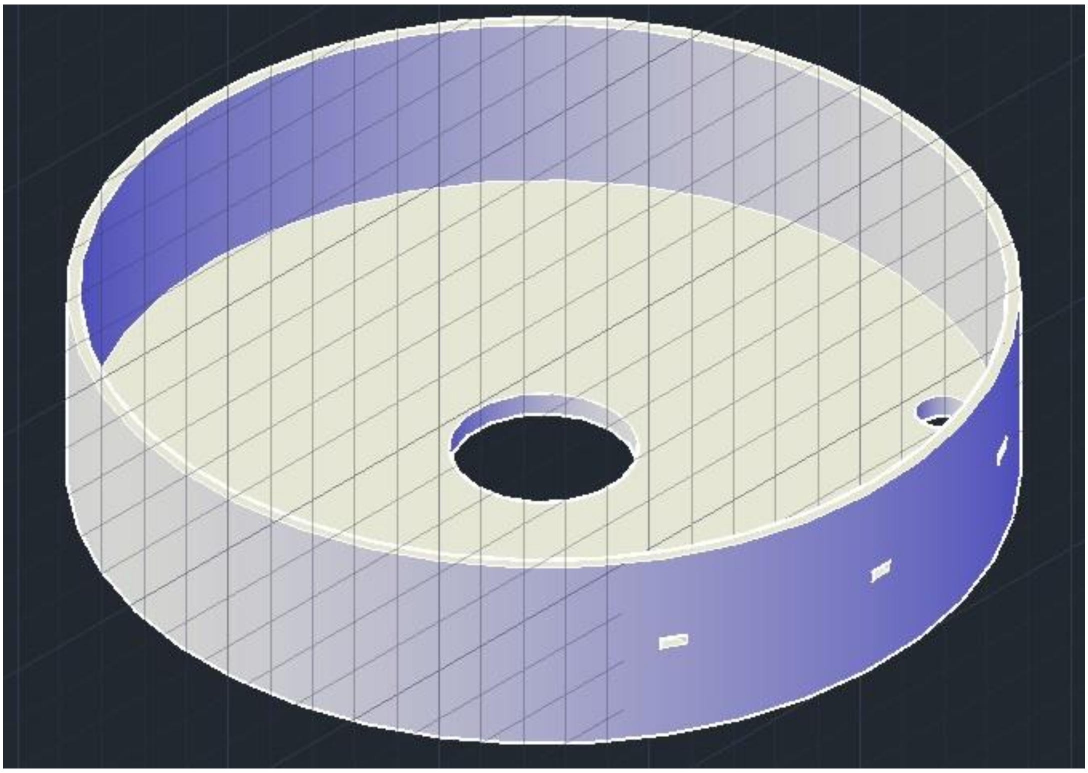

Figure 4.13: 3-D Model of Base

The central hole is for the container that will fit in the CPU fan inside it.

Figure 4.14: Container for Collection of Debris

Referring to fig 4.14, the container has a threaded cap at the bottom and hole. The threaded cap is designed so that after the collection of the dirt, the container can be opened and the waste can be discarded easily without any hustle. The hole is of 3cm diameter that is enough to take in debris easily.

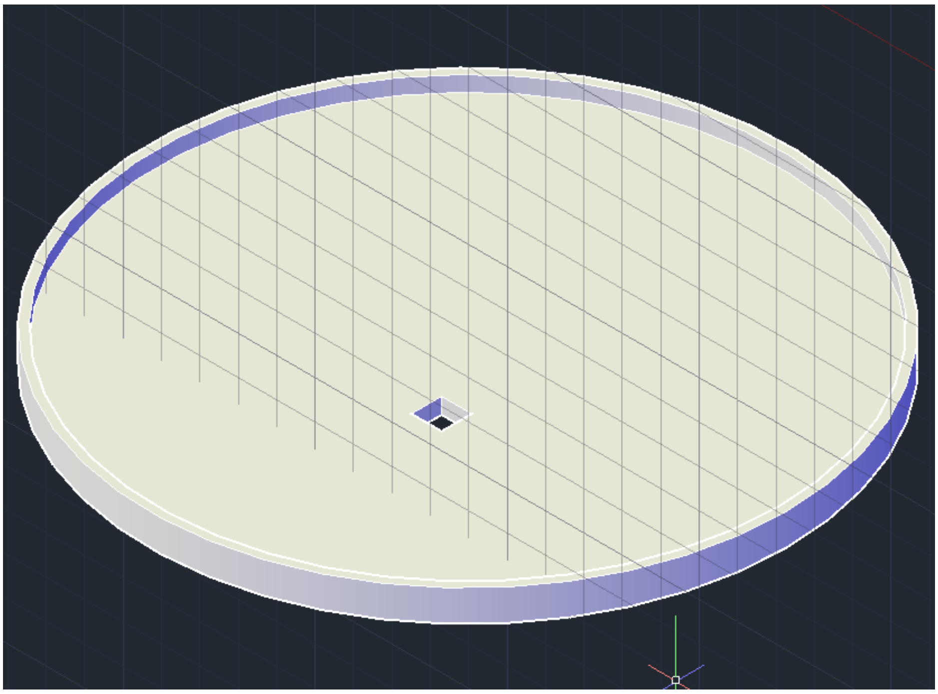

Figure 4.15: 3D Model of Lid

Referring to the fig 4.15, the hole in the LID is designed to give a connection for the camera to the micro-controller directly.

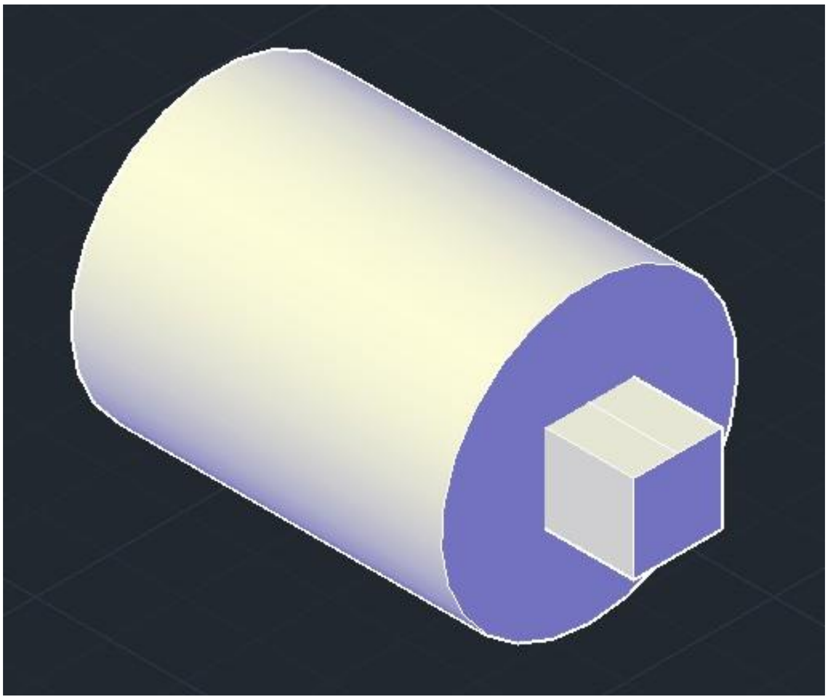

Figure 4.16: South West Isometric View of the Sleeve designed for the Shaft of Motor and Brushes

Referring to the fig 4.16 and 4.17, the sleeves are designed to solve the issue of fitting the shaft of the motor into the hole of the brushes. As the shaft of the motor doesn't exactly fit into the brushes, so it detaches easily. This sleeve has a circular hole to fit in the shaft of the motor and at the other en it has the rectangular shaft that fits inside the brushes thereby perfectly fitting both the things with each other.

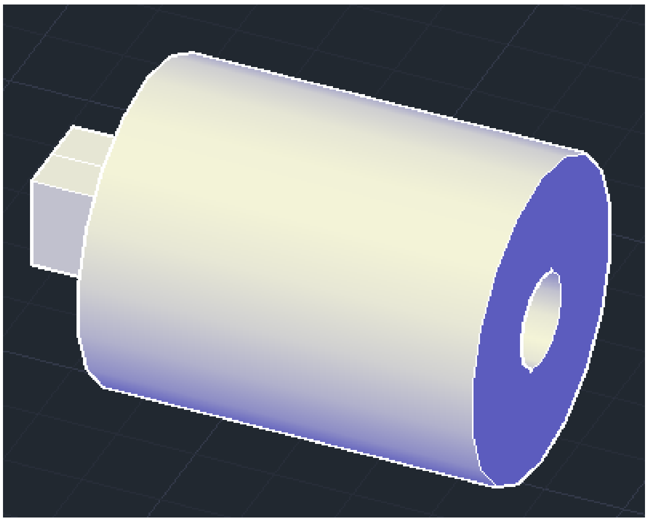

Figure 4.17: North West Isometric View of the Sleeve designed for the Shaft of Motor and Brushes

4.7 Comparison with existing research

Currently robot vacuums in market use Lidar plus Camera for efficient mapping process, the one which we made uses monoslam single webcam and multiple ultrasonic sensors.

First we made run a simulation for checking performance of ultrasonic sensor in real time software proteus with raspberry pi.

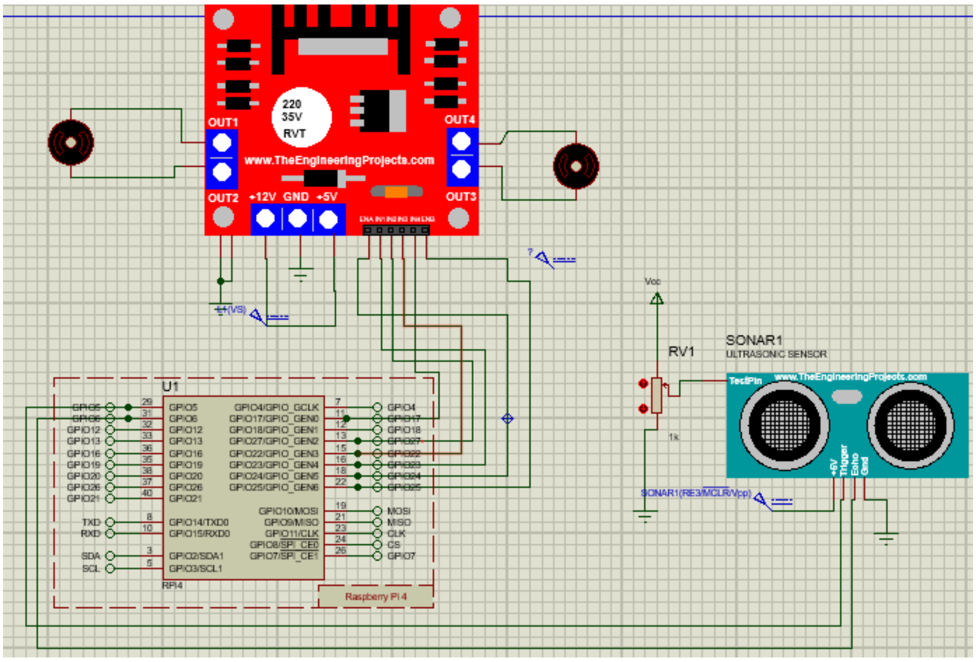

Figure 4.18: Proteus Simulation for Ultrasonic Sensor

Secondly different resolution cameras were used while testing upon which 30 fps, 720p webcam gave better results.

4.8 Challenges

Even though we achieved accomplishments, we still faced some hindrance during the process.

Register and IMU; IMU's first 8 bit data is stored in register1 while 2nd 8 bit data is stored in register2. During this process, we experienced some overwrite problems. Autonomous nature requires set and forget mechanism, however we r using two power supplied, Therefore relay had to be added, Many resources had to be managed with 40 cm diameter of robot. Efficient 3d design required a vast learning of AutoCAD, critical thinking and problem solving skills.

CHAPTER 5

CONCLUSIONS AND FUTURE WORK

5.1 Outline of Findings

This robotic vacuum has been thoroughly examined and following checkpoints are monitored to validate results; accurate brush movement: Proper push debris operation was maintained using two DC brushed motors with an optimal rpm of 142. Left motor was made to rotate clockwise, while right motor was forced to turn in the opposite direction.

Obtaining an improved navigation was never easy, results were obtained individually at first assuming an optimum zigzag movement of robot would be achieved however every method had its pros and cons.

	Ultrasonic sensor robot	Gyro-based robot	Camera based slam implemented robot	Combined version vslam wih fused sensor results
Obstacle avoidance	✓	✗	✓	✓
Accurate navigation	✗	✗	✗	✓
Good rotation	✗	✓	✗	✓
Leaving uncleaned spaces	✓	✓	✓	✗

Figure 5.1: Results of Integration of different Sensors

5.1.1 Suction Preference

Maintaining high suction was not so straightforward and proved to be a challenging part of our project. While testing BLDC 960 KV motor was used along with CPU fan propeller. However this method failed. Next a CPU fan with 12V and 0.45A rating was considered but after measuring the suction pressure using bmp 180, a higher current rating vacuum fan was selected which operates at 12V 1.68A.

5.2 Contribution of Study

- **SLAM Implementation:** We learned about different algorithms present in OpenCV. Learning topics included FAST, BRIEF, Harris corner detection, Affine 2D and 3D estimation.
- **Sensor fusion:** Sonar, gyro, optical sensor(webcam) were integrated and fused

results were obtained. We learned how ultrasonic sensor works and acknowledged how its distance is computed using it's prescribed formula.

- **Raspberry pi connection:** Unlike Atmel and esp32, raspberry pi is a single board mini computer. It needs a monitor display, however our robotic vacuum is a standalone project, therefore for an accurate testing, it had to be linked with VNC server. So IP address configuration step proved to be a challenging situation while in testing process.

5.3 Future Prospects and Enhancements

5.3.1 Staircase Avoidance using Infrared Sensors

Infrared sensors detect heat radiations from the object and according to its screwed sensitivity as shown in Figure 1, helps avoiding nearby obstacles. Such sensors can be placed beneath the robot vacuum to sense steps of staircase, and avoid its fall.

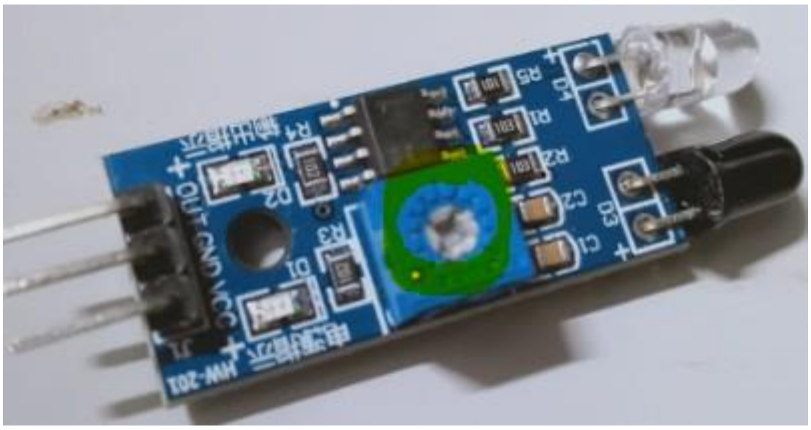

Figure 5.2: Infrared Sensor

5.3.2 Developing a Self Competent Lidar using multiple Ultrasonic and Laser sensor

Ultrasonic sensor provides distance information, fusing multiple of these will help create 360 degree distance estimation system. Considering the concept of speed of light faster than sound, laser sensor can be integrated and thus lidar like results will be obtained.

5.3.3 Introducing protective bump mechanism

A couple of bump sensors may be used along with deep learning reinforcement algorithms to make its movements more precise and accurate.

5.3.4 Surveillance feature enhancements

Consulting and obtaining feedback from multiple researchers and field oriented officers made us realized that its video recording capability can further improved for the purpose of home surveillance. The recorded video can be linked to iCloud, hence providing a real time inspection simultaneously cleaning room.

5.3.5 Collaboration with robotic vacuum companies

Robotic vacuum companies like Dyson and iRobot have 21+ years of experience in such area. Collaborating with these companies can lead to internships, job opportunities and partnerships. Not only robot vacuum companies but also armed forces are in search of people with knowledge about SLAM, Radars and unaided vehicles for army projects. Therefore, partnerships for goals can lead to permanent stabilizing positions.

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APPENDICES

APPENDIX A

SUSTAINABLE DEVELOPMENT GOALS FOR FYP

FYP TITLE:

“Autonomous Floor Cleaning Robot”

FYP SUPERVISOR: Assistant Professor Sobia Hayee

G RO UP MEMBERS:

	REGISTERATION NUMBER	NAME
1	339315	Muhammad Saad Khan
2	345947	Sara Khan
3	332980	Taiba Azam
4	339151	Abdul Moiz Lodhi

SDGs:

	SDG No.	Justification after consulting
1	3	10% of world population are allergic and can’t mop regularly so it becomes a serious health issue thus it achieves target 3.9 i.e. reduces illness and death from hazardous chemical and production.
2	9	Supports domestic technology development and industrial diversification.
3	11	Supports least developed countries in sustainable and resilient building and reduces environmental impact of cities by paying special attention to air quality and municipal and other waste management.
4	12	It uses rechargeable batteries, so it achieves target of sustainable management and use of natural resources.
5	17	Since our estimated cost of this locally assembled product is less than same imported product therefore it promotes sustainable technologies to developing countries.

FYP Advisor Signature: _

UN website: https://focus2030.org/Understanding-the-Sustainable-Development-Goals#:~:text=The%20Sustainable%20Development%20Goals%20(SDGs,life%20for%20all%2C%20by%202030.

APPENDIX B

Autonomous Floor Cleaning Robot

ABSTRACT

Traditional cleaning processes, while effective to some extent, often fall short in addressing specific needs such as allergic cleaning and daily maintenance. They tend to be time-consuming and labor-intensive, posing challenges for individuals with busy schedules. Our project focuses on advancing vacuum cleaner technologies, exemplified by the Roomba, through integration of Embedded systems, Computer vision, AI, Visual SLAM Implementation, Power Electronics, and Control systems. Utilizing the Raspberry Pi 4B+ platform with a webcam, sonar sensor, and IMU. visual SLAM, a cost-effective alternative to Lidar SLAM, enables precise localization and mapping, enhancing adaptability and effectiveness.

Our robot targets small spaces, serving pet owners, allergy sufferers, and venues. We tackled challenges like power optimization and sensor fusion, starting from market surveys to final model printing in AUTOCAD, providing a precise and affordable cleaning solution.

This project presents a complex engineering problem with several characteristics outlined in the WP1 to WP7 framework:

1. WP1 - Depth of Knowledge Required: (WK3, WK4, WK5, WK8)

   The project requires in-depth engineering knowledge at the level of WK3 (engineering fundamentals), WK4 (engineering specialist knowledge), WK5 (engineering design), WK6 (engineering practice), and possibly WK8 (research literature engagement) to integrate various technologies like Embedded systems, Computer vision, AI, Visual SLAM Implementation, Power Electronics, and Control systems into a cohesive solution.

2. WP2 - Range of Conflicting Requirements: The project involves integrating various technologies and addressing conflicting requirements such as effectiveness, adaptability, affordability, and precision.

3. WP3 - Depth of Analysis Required: To create a novel solution, the project necessitates abstract thinking and originality in analysis, particularly in areas like sensor fusion, power optimization, and visual SLAM implementation.

4. WP4 - Familiarity of Issues: Many of the issues encountered in the project, such as power optimization and sensor fusion, may be infrequently encountered in traditional engineering practice.

5. WP5 - Extent of Applicable Codes: The project may involve developing solutions outside the scope of existing standards and codes of practice, particularly in integrating advanced technologies like visual SLAM into consumer products.

6. WP6 - Extent of Stakeholder Involvement and Level of Conflicting Requirements: The project involves addressing the needs of diverse stakeholders, including pet owners, allergy sufferers, and venues, which may have conflicting requirements regarding cleaning effectiveness, noise levels, and cost.

7. WP7 - Interdependence: The project is a high-level problem involving the integration of multiple component parts or sub-problems, such as Embedded systems, Computer vision, AI, Visual SLAM Implementation, Power Electronics, and Control systems, to create an effective cleaning solution.

In summary, this project represents a complex engineering problem that requires a deep understanding of engineering fundamentals, integration of various technologies, and innovative problem-solving to address conflicting requirements and develop a novel cleaning solution.

	WP1						**WP2**	**WP3**	**WP4**	**WP5**	**WP6**	**WP7**
	WK3	**WK4**	**WK5**	**WK6**	**WK7**	**WK8**						
PLO1 (WA1)	X											
PLO2 (WA2)		X						X				
PLO3 (WA3)			X									
PLO4 (WA4)									X			
PLO5 (WA5)				X					X			
PLO6 (WA6)												
PLO7 (WA7)											X	
PLO8 (WA8)												

APPENDIX C

AUTONOMOUS FLOOR CLEANING ROBOT

by Sobia Hayee

Submission date: 20-May-2024 02:49AM (UTC-0700)
Submission ID: 2383920012
File name: AUTONOMOUS_FLOOR_CLEANING_ROBOT.txt (53.62K)
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