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Project Report part-1
Application of the Cambridge EDC Inclusive Design Methodology

Robot LUNA the Restaurant Robot

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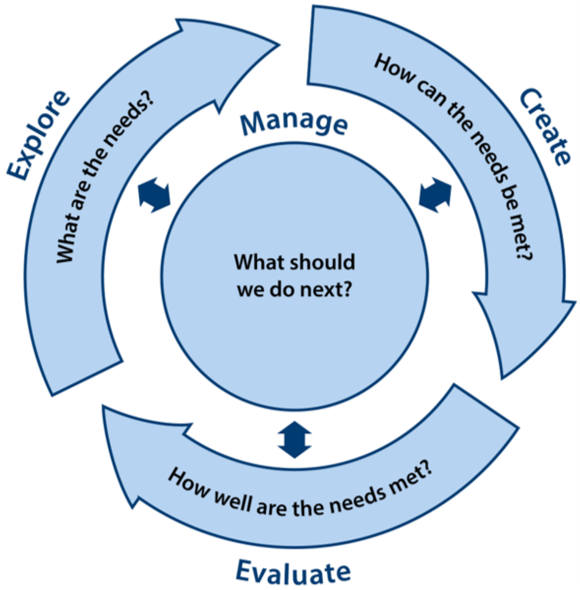
Submitted in partial fulfillment of the requirements for the module
EN2160 Electronic Design Realization

Date: 2023.06.21

Contents

Abstract

This document covers the Application of cambridge EDC model for the design of "Robot LUNA", a Restaurant waiter robot. It describes about manage, explore, create and evaluate phases related to the restaurant robot.



1 Review Progress and Plan Next Steps

A comprehensive analysis of the work done by numerous companies and universities in the area of restaurant automation was conducted to evaluate the current state of restaurant robots. Understanding current approaches, innovations, and technologies provided the basis for our project. Information sources included YouTube videos, product brochures from relevant manufacturers, and research articles.

- **Bear Robotics:**
  - Known for their Servi robot, which automates food delivery and bussing tables in restaurants with features like autonomous navigation, tray detection, and multi-robot coordination.
  - Reduces wait staff workload, enhances customer experience, and improves efficiency.
  - YOUTUBE: Bear Robotics at the National Restaurant Association Show 2024

- **Keenon Robotics**

  - Offers robots, which are designed for food delivery and customer service with interactive touch screen, autonomous path planning, and obstacle avoidance.
  - It streamlines service, engages customers with interactive features, and supports staff.
  - YOUTUBE: KEENON DINERBOT — Tokyo — Cute Serving Robot with Great Customer Service

- **Pudu Robotics**
  - Known for their BellaBot and PuduBot, which focus on efficient food delivery with precise positioning, user-friendly interface, and voice interaction.
  - It enhances service efficiency, reduces staff workload, and improves customer interaction.
  - YOUTUBE: BellaBot delivers food & drinks in restaurant in Malaysia — Pudu Robotics

Plan Next Steps

The initial phase of our project involves developing a restaurant robot system to automate repetitive tasks such as food delivery, order taking, and customer interaction.

To achieve this, our first subtask focuses on identifying the optimal system architecture and features for this specific application. This section describes the planning and execution of this required initial step and decide the essential steps to be taken in the project.

Project Management and Collaboration

We have developed a project management along with knowledge linking base in obsidian ecosystem along with a GitHub repository to manage and collaborate on code and documents with team members. We will assign sub-tasks to each member with an equal workload to ensure that everyone contributes to the project's progress efficiently.

Evaluation Criteria

To determine the most suitable system architecture, we will employ a set of predefined evaluation criteria. These criteria include efficiency, reliability, and user-friendliness. Each concept will be rigorously tested to ensure its effectiveness in real-world applications.

Experimental Setup

- Found an suitable robot chassis
- We are using gazebo simulation environment to test and simulate algorithms related to navigation, obstacle avoidance.
- We are using SBC with camera and microphone for experiments related to customer interaction algorithms.
- Design and integrate necessary sensors and control systems.

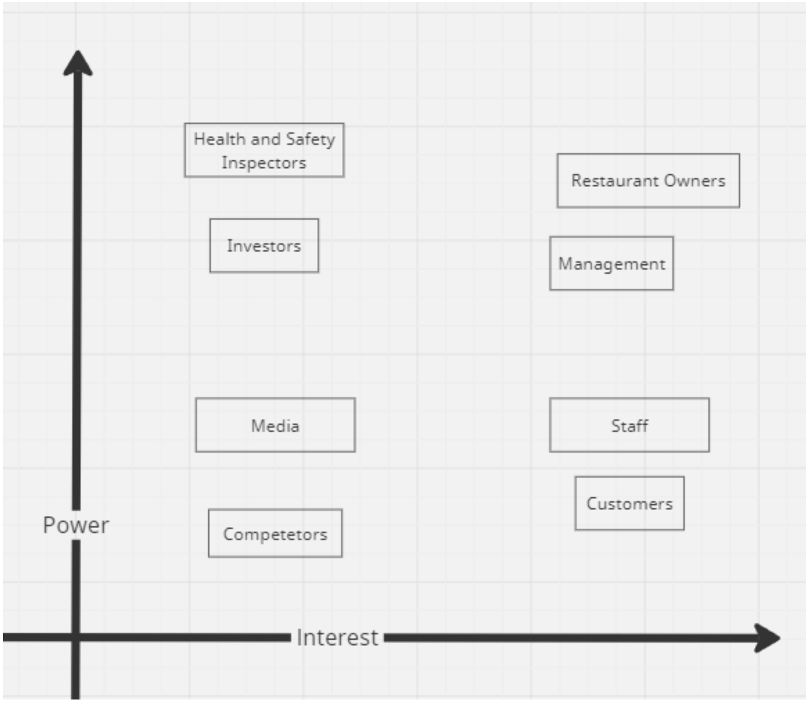
Testing and Validation

- **PCB Testing**:For PCB testing we are planning to carry out bare-board testing after soldering has done.
- **Stability Testing**: Conduct tests about the stability of the robot and food items when robot carrying them at different conditions.
- **Power Testing**: Validate the power consumption of the robot with different settings and time it takes to run on a full charge.
- **Environmental Testing**: Test the robot's adaptability to different environmental conditions such as lighting, floor types, and obstacles.
- **Safety Testing**: Ensure that all safety features like emergency stop functions and obstacle detection are reliable.
- **User Feedback**: Collect feedback from restaurant staff and customers to refine the design.

Final Implementation

- **Optimization:** Fine-tune the robot's functionalities based on test results and feedback.
- **Deployment:** Roll out the final version of the robot in a real restaurant setting for a pilot run.

2 Identification of Stake Holders



High Power, High Interest

- **Restaurant Owners/Management**: They are the decision-makers who would decide to implement the robot in their restaurant. They would be concerned about the cost, efficiency, and customer satisfaction the robot can provide.

High Power, Low Interest

- **Investors**: They provide the necessary capital to purchase and implement the robot. They would be interested in the return on investment.
- **Government and Safety Regulators**: They ensure that the robot complies with all health and safety regulations in a restaurant environment.

Low Power, High Interest

- **Customers**: People who would interact with the robot in the restaurant. Their experience and satisfaction are crucial for the success of the robot.
- **Restaurant Staff**: Work alongside the robot and may also need to troubleshoot the robot.

Low Power, Low Interest

- **Media**: They can influence public opinion about the use of robots in restaurants.
- **Competitors**: Other restaurants that are using or not using robots can influence the decision and implementation process.

3 Observe Users

User observation is about get to know what people really want, what they really need, and what they really do. To gain deep understanding of the needs and behaviours of potential users we use the following techniques.

- **On-site observations:** We went to restaurants and tracked customers from entry to exit observing their interactions and also followed about restaurant staff while observing customers. Also we interviewed restaurant customers and staff from different levels.
- **Research:** We used youtube to see videos about deployment and food delivering of robots in real restaurant settings and use internet to study articles about restaurant owners, managers, staff, and customer experiences and expectations.

Few examples for such observations are

- **Bear Robotics in Restaurants**
  - The Bear Robotics SERVI robot specializes in automated food service solutions for restaurants. The robot offers a range of options to perform various tasks in the food service industry, such as delivering beverages and food to tables, retrieval of dirty dishes, and more.
  - YOUTUBE: Bear Robotics Restaurant Deployment

- **Food Delivering Robots in Marriott Marquis Hotel**

  - In Marriott Marquis Hotel robots specializes in automated food delivering solutions for restaurants. The robot offers a range of options to perform various tasks in the food service industry, such as delivering beverages and foods to the rooms, automatically plugged in to charging, and more.
  - YOUTUBE: Robot "RUN" work in JW Marriott Marquis Hotel

Key Insights,

- Staff spend considerable time on repetitive tasks such as taking orders, delivering food, and processing payments, which could be automated.
- Personal interaction with staff is important, especially in full-service restaurants where personalized service is expected.
- Order Accuracy: Errors in order taking and fulfillment can result in customer dissatisfaction and reduced loyalty.
- Visual and Auditory Accessibility: Customers with visual or auditory impairments require additional support, such as large print menus or visual indicators for order readiness.
- Ease of Use: Any technological solution must be intuitive and easy to use to ensure adoption by all user groups.

4 Need list

After the observation of users we come in to the following need list

- As a restaurant manager, I need a robot that can deliver food efficiently so that I can reduce the workload on my staff and improve service speed and easily integrate to existing system.
- As a investor, I need the robot to be cost-effective so that the return on investment is maximized.
- As a marketing manager, I need the robot to enhance the customer experience so that our restaurant gains a competitive edge and attracts more customers.
- As a customer, I need the robot to deliver my food accurately and quickly so that I receive the correct order without any mistakes.
- As a staff member, I need the robot to assist in delivering quickly with easily learnable options so that I can focus more on providing personalized service to customers without needing to learn about the robot explicitly.
- As a technician, I need the robot to have modular parts so that any repairs can be conducted swiftly and with minimal downtime.
- As a safety inspector, I need the robot to comply with all health and safety regulations so that it can operate safely in a restaurant environment.
- As a logistics manager, I need the robot to navigate the restaurant efficiently so that it does not cause delays or obstructions in service.
- As a user interface designer, I need the robot to have an intuitive control panel so that all users can operate it easily.
- As a quality assurance tester, I need the robot to undergo rigorous testing so that it performs consistently under various conditions.
- As a project manager, I need the robot to be delivered on time and within budget so that the project meets its deadlines and financial constraints.

High Priority Needs: Efficiency in food delivery, integration with existing system, cost-effectiveness, and enhancing customer experience.

Medium Priority Needs: Accuracy in order delivery, compliance with health and safety regulations, ease of use, and reliability of navigation systems.

Low Priority Needs: Modularity of parts, open API, and comprehensive testing.

5 Stimulate Ideas

Idea Generation Activities

To generate innovative and effective concepts for the restaurant robot, we employed several ideation techniques and collaborative sessions, ensuring a wide range of ideas that matches with our goals and user needs.

- **Brainstorming Sessions:** we organized multiple brainstorming sessions with the project team. These sessions aimed to see the ideas from different perspectives to generate a broad spectrum of ideas.
- **Mind Mapping**: To visually organize information, explore various aspects of the problem, and identify connections between different ideas.
  - We started with the central idea of a "restaurant robot" and branched out into subcategories such as "order taking", "food delivery", "customer interaction", and "navigation".
  - Each subcategory was further broken down into specific tasks and features. For example, under "navigation," we explored mapping, localization, path planning and navigation algorithms.
  - We identified potential connections between different features and how they could work together to enhance the robot's functionality.
- **Role Playing:** Also we done role playing to visualize the perspectives from the view of restaurant staff.

Generated Ideas

- Multi-functional Robot: A robot that not only delivers food but also takes orders, processes payments, and cleans tables.
- Multi-Color Line Detection: Develop a system where the robot can follow lines of different colors, each representing a different task or destination.
- Real-time Environment Mapping: Equip the robot with the capability to create real-time 3D maps of its surroundings, allowing for more efficient and accurate navigation.
- Automated Kitchen Assistance: A robot that helps in the kitchen by fetching ingredients, assisting with cooking, or plating dishes.
- Customer Entertainment: A robot that can entertain guests with light displays, music, or games while they wait for their food.

6 Develop Concepts (3 alternative conceptual designs)

In our exploration and brainstorming, and after evaluation of the ideas we've came up with three captivating conceptual designs(named considering navigation methodology): celestial navigation with markers on the ceiling, depth perception enabled by the Kinect2 sensor, and the simplicity of line following techniques marked upon the restaurant floor. Finally we used a proper marking criteria to come up with most versatile solution.

6.1 Marker Ceiling Path Navigation

Conceptual Design 1 involves the robot following paths marked with special markers. Think of it asthe robot "reading" these markers like road signs to find its way around the restaurant. This designis efficient and flexible, allowing the robot to navigate complex layouts easily

Figure 1: OMRON's patented Acuity generates navigation markers in ceiling

Background research

OMRON's patented Acuity technology is a significant innovation in the field of autonomous navigation. It generates navigation markers from ceiling lights and objects, which are more likely to remain fixed12. This allows robots to identify their position, regardless of changes in the environment on the floor12. This technology is particularly useful in environments where floor-based landmarks may be obstructed or change frequently. Other Marker Ceiling Path Navigation robots also utilize similar concepts. For instance, some systems recognize air-conditioning devices as landmarks located on the ceiling3, while others use ceiling light landmarks for path planning4. These systems provide a robust solution for autonomous navigation in dynamic environments.

Block diagram

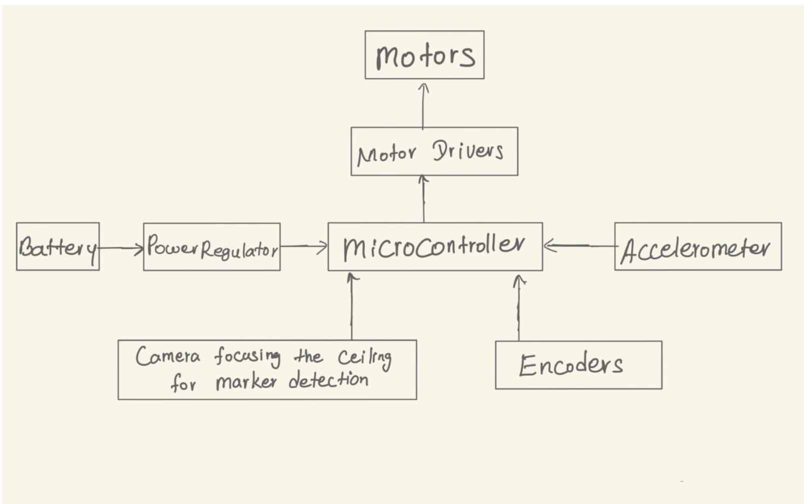
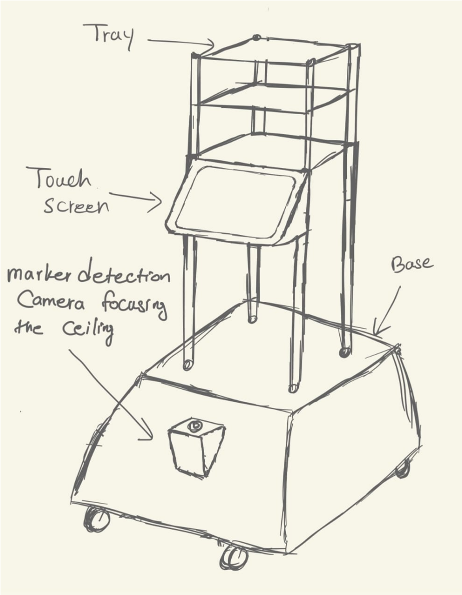


Figure 2: Block diagram of conceptual design 1

We use camera sensor to detect the markers on the roof. PID algorithm is used to follow the markers. Kp, Ki, Kd parmeters will be tuned during testing. Encoders are used to reach the final destination with high accuracy. Microcontroller gets inputs from camera sensor,encoders, accelerometer and gives the calculated control voltages to motor controller

Chassis Design



6.2 Vision-based Path Navigation

Figure 3: ABB upgrading AMRs with Sevensense navigation stack [8]

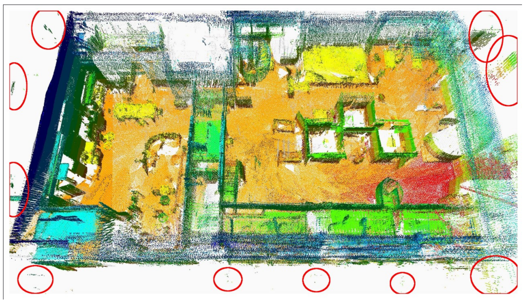


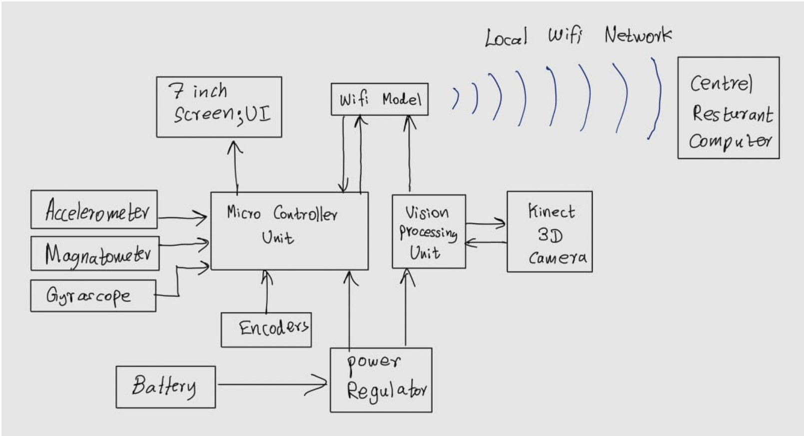
Figure 4: Research on Autonomous Navigation using a Real-Time 3D Point Cloud [6]

In Conceptual Design 2, the robot utilizes a Kinect2 sensor for vision processing. This means it can"see" its surroundings using advanced technology similar to what's used in gaming consoles. With this setup, the robot can detect objects and people, helping it navigate around the restaurant safely and efficiently.

Background research

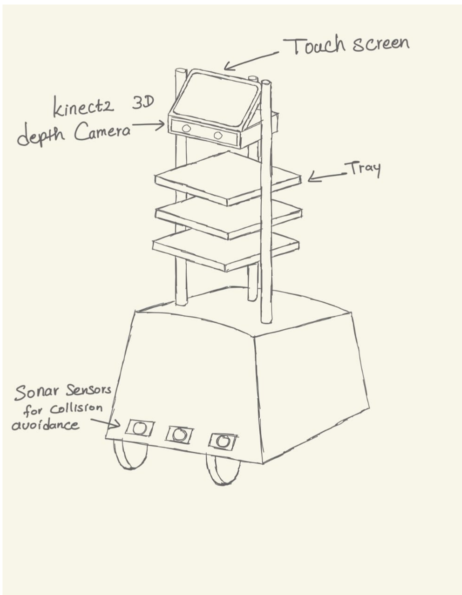
In Conceptual Design 2, ABB upgrades Autonomous Mobile Robots (AMRs) with the Sevensense navigation stack, as shown in Figure 3. This upgrade enables AMRs to navigate autonomously using a real-time 3D point cloud, as depicted in Figure 4. The robot employs a Kinect2 sensor for vision processing, similar to the technology used in gaming consoles. This advanced setup allows the robot to "see" its surroundings, detect objects and people, and navigate safely and efficiently around the restaurant.

Block diagram



Here we use a Kinect 3D depth camera at the top of the robot below the screen which works separately from our Microcontroller Unit PCB. It can generate 3D colored point clouds with 6 dimensions (x,y,z, R, G, B). All the sensors and motor controls are controlled by the MCU. The UI designing group's UI circuit connects the MCU and gets specific data they need. 12V-35Ah-Lead Acid battery and Power Regulator circuits properly power all the circuits. The Central Server connects receives and transmits specific location commands from a ROS node through the local WIFI network.

Chassis Design



6.3 Line Detection and Floor Grid Navigation

Cafe in Ningbo in China uses line following techniques in their restaurant

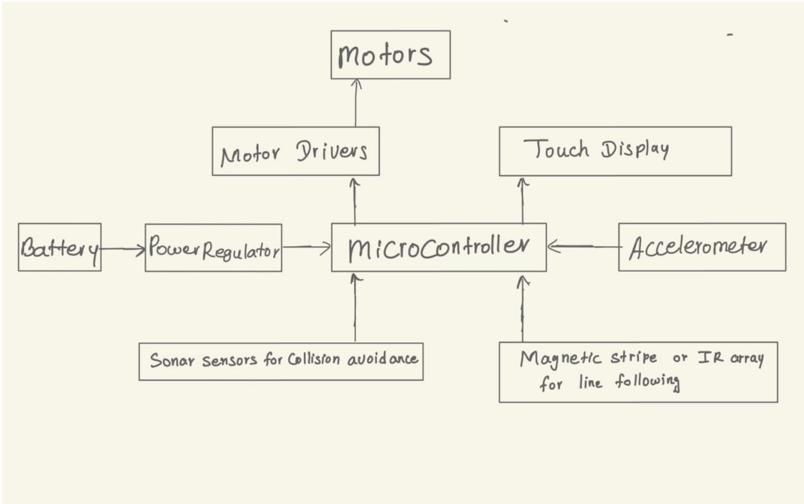
Conceptual Design 3 focuses on line detection and following. This can be obtained by navigating via a magnetic stripe or light sensitivity tracks. Imagine the robot following lines on the floor like tracks to reach its destination. This design is great for guiding the robot along specific paths in the restaurant, ensuring it reaches tables or service areas accurately and efficiently.

Background research

In 2014, a café in Ningbo, a seaport city in northeastern China's Zhejiang province, pioneered the use of line-following robot waitresses1. These robots, navigating via a magnetic stripe, efficiently served patrons, marking a significant evolution in service automation.

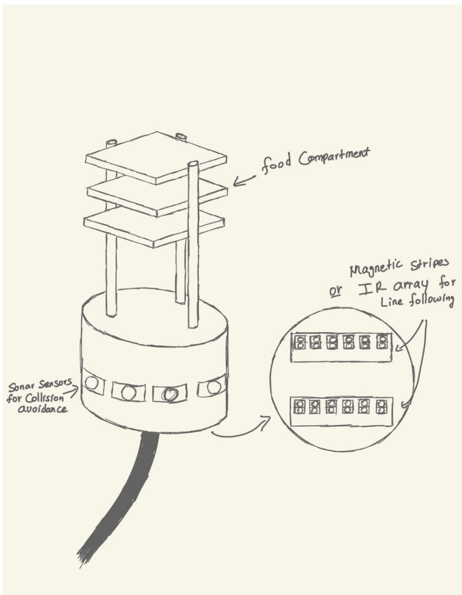
Similarly, a Singapore-based restaurant-bar chain adopted this technology, enhancing operational efficiency. The line-following navigation system in these robots not only streamlined service but also added an element of novelty, attracting customers and setting a trend in the hospitality industry.

Block diagram



Here is the Line detection and Line following Robot. We use a 12V 35Ah Lead acid battery as power supply. We use a buck convert and voltage regulator circuits to regulate the supply voltage to preferred voltages such as 3.3V and 5V. We give commands to the server, and the system transfers them to the microcontroller through WIFI technology. The microcontroller runs a code with PID controllers to drive the robot precisely using the motor drivers. When the robot starts and stops, it takes the accelerometer data, accelerates, and decelerates according to Newton's Law calculations. Also, the robot follows a predefined line. We use an IR array to detect the line, and we use a PID controller to drive the robot smoothly.

Chassis Design



7 Evaluation of Conceptual Design

Table 1: Complete Comparison of Conceptual Designs for Restaurant Robot

Criteria	**Conceptual Design 1**	**Conceptual Design 2**	**Conceptual Design 3**
Newly Added Features	Marker detection	3D depth image capturing	Line detection with PID
	Path planing with markers	Vision based path planning	Navigating via magnetic strip
Removed Features	3D depth camera	Line Detection	3D depth camera
Enclosure Design Criteria			
Stability	8	9	5
Durability	8	9	7
Accuracy	7	9	3
Performance	8	8	6
Aesthetics	8	9	7
Efficiency	7	8	6
Power Consumption	8	8	6
Simplicity	7	9	7
Safety	8	8	6
Cost	8	7	8
Total	77	88	56

In our evaluation of conceptual designs for the Restaurant Waiter Robot LUNA, we compared three potential designs based on various criteria including stability, durability, accuracy, performance, aesthetics, efficiency, power consumption, simplicity, safety, and cost. Conceptual Design 1 focused on marker detection and path planning with markers, Conceptual Design 2 incorporated 3D depth image capturing and vision-based path planning, while Conceptual Design 3 utilized line detection with PID and navigation via magnetic strip. Upon assessing these designs, Conceptual Design 2 emerged as the best option, scoring 88 points. It excels in several key areas such as stability, durability, accuracy, aesthetics, efficiency, and simplicity, making it the most robust and efficient choice. Consequently, we selected Conceptual Design 2, featuring a 3D depth camera for vision-based path planning, as the optimal design for LUNA.

8 Selected design

8.1 Introduction

We selected Conceptual Design 2 for the Restaurant Waiter Robot LUNA due to its effective integration of practical features and overall performance. This design includes 3D depth image capturing and vision-based path planning, allowing LUNA to navigate accurately and efficiently within a complex restaurant environment. The 3D depth camera provides detailed spatial information, enabling precise movement and obstacle avoidance. Conceptual Design 2 scored highest in stability, durability, accuracy, aesthetics, efficiency, simplicity, and power consumption, ensuring a well-rounded and robust solution.
Robot LUNA is designed with a focus on stability and precision. It is equipped with a dual camera setup, including an HD wide-angle camera and a Kinect-2 depth camera, enabling vision-based navigation in a 3D restaurant environment grid. The robot's enhanced stability ensures the safe delivery of food and drinks without spillage, even during braking, thanks to a dedicated stabilization tray circuit. Internally, LUNA has three Raspberry Pis for separate parallel processing tasks and is connected to a custom PCB based on Atmega2560 to get stable and accurate sensor and encoder readings, and to control motor drivers accurately. Externally, it communicates with a restaurant's local server computer using ROS 2 iron through the local wifi network, ensuring precise navigation paths and food order locations based on the restaurant tables. This combination of reliable technology and thoughtful design makes LUNA a practical and efficient addition to any restaurant staff.

8.2 Robotic Platform

The robotic platform serves as the foundation for the restaurant robot, providing stability and support. It includes:

- **Control circuit:** The robot chassis is encompassed with a PCB circuit at the base for the control of stability of the robot, obstacle avoidance and communication purposes.
- **Chassis:** A stable chassis designed to support considerable amount of weight and smooth navigation across various surfaces within the restaurant.
- **Food compartments :** The food compartments are made utilizing a stacked set of trays on top of the robot chassis.
- **Suspension System:** A suspension system to minimize vibrations and ensure the stability of liquid-filled containers during transportation, especially on uneven surfaces.

8.3 Communication Methods

ROS Serial Communication with the PCB:

- For serial communication with the PCB, we have decided to use the UART protocol.
- To enable serial communication with the SBC, we need to use several libraries, namely `rosserial` and set up the microcontroller programming IDE to program the microcontroller using the `ros.h` library.
- To enable serial communication with the UART protocol in the SBC, we need to configure the pins of the SBC to communicate with the microcontroller.

Local Network Communication:

- The robot communicates with other devices on the same WiFi network.
- It receives commands from a central control point using internet programming concepts such as HTTP requests.
- This approach helps the robot follow instructions quickly and reliably without requiring a powerful processing unit inside the robot.

Swarm Technology Compatibility:

- Our design is prepared for the future of swarm technology, allowing control of multiple robots simultaneously.
- The robots work together using the local network to coordinate their actions.
- This teamwork enhances the robots' efficiency and enables them to collaborate effectively in a group, improving overall operations.

Microcontroller-to-Microcontroller Communication (UART):

- Within the robot, there are two microcontrollers that need to communicate with each other.
- We use the UART communication protocol to enable the exchange of important information between them.
- This communication helps the robot follow commands received from the local network and perform tasks smoothly and quickly.

8.4 Computer System Requirements

1] The restaurant's main computer uses an NVIDIA GeForce RTX 2060 for vision processing and running the master ROS. Other recommended GPUs include the RTX 40, 30, 20 series, and GTX 16 series.

2] A low-power Single Board Computer (SBC) like the Raspberry Pi 4b or Jetson Nano is used to transmit 3D depth vision data via Wi-Fi and receive navigation commands from the main PC. SBCs with over 2GB RAM are required. Jetson Nano is the standard for industrial use.

8.5 Methodology

Navigation System

The navigation system of Luna is a critical component that ensures the robot can move autonomously and accurately within the restaurant environment. Luna's navigation system runs on Ubuntu 22.04 with ROS2 Iron Irwani. The key sensors used in the system include a Kinect v2 front projectile sensor for capturing depth data and a camera module for vision intake.

The depth data obtained from the Kinect sensor is converted into fake LiDAR data, which is then processed using the SLAM-toolbox package to generate a comprehensive map of the environment. This map is essential for the robot to understand and navigate its surroundings. The robot's physical and simulated models are created in Gazebo using URDF files, allowing the SLAM toolbox to map both simulated and real-world environments.

Mapping data is stored on the SBC device, and the `map_server` is used to host the map locally. For localization, the Adaptive Monte Carlo Localization (AMCL) algorithm is employed, which is tuned to improve the robot's localization accuracy relative to the generated map.

The ROS2 `navigation2` (nav2) package is utilized for path planning and navigation. A Python implementation enables the publication of goal posts, guiding the robot to move to specific target locations within the restaurant.

Stabilizing Tray

One of Luna's unique features is its stabilizing tray, which ensures that beverages remain stable and do not spill while the robot is in motion. This tray is controlled by stepper motors that adjust the angle of the tray to counteract the robot's accelerations. The tray is equipped with Inertial Measurement Unit (IMU) sensors that capture the robot's movements.

To maintain balance, the system employs Kalman and PID algorithms, which process the IMU data to make precise adjustments to the tray's orientation. This allows Luna to carry liquid beverages smoothly, enhancing its utility in a restaurant setting.

Vision-Based Actions

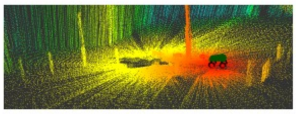
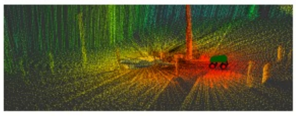
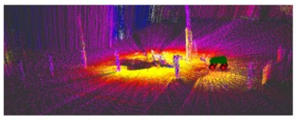
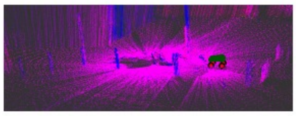
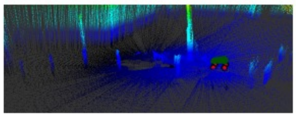
Luna is equipped with a camera module that provides visual input for various tasks. The vision system enables Luna to:

- Avoid obstacles detected in its path, ensuring safe navigation through the restaurant.
- Interact with customers, using facial recognition and gesture detection to enhance the dining experience.

The camera module analyzes frames in real-time, allowing Luna to take immediate actions based on the visual data. This capability is crucial for dynamic environments where the robot must respond to changing conditions and interact with people effectively.

In summary, Luna combines advanced navigation, stabilization, and vision systems to function autonomously in a restaurant environment. Its ability to navigate, stabilize beverages, and interact with customers positions it as a valuable asset for modernizing restaurant operations and improving customer service.

8.6 Vision based path planing with 3D Depth camera

Colour scheme	Advantages	Disadvantages	Example
White	Fast to render, no colour calculations	Difficult to perceive depth from a static viewpoint	
Radial distance to robot at time of scan	Excellent for detecting proximate obstacles	Doesn't highlight vertical changes	
Radial distance to robot at time of scan with fading over time	Excellent for detecting proximate obstacles and avoids highlighting dynamic obstacles	Need to recalculate colour of every point at required frame rate	
Remission value from laser	Useful for segmenting different objects which are close together, eg. glass from a window frame	Environments with uniform remission values are not very distinct	
Weighted linear combination of distance and remission	Good for detecting false readings off highly reflective surfaces	Problem of choosing suitable weights	
Altitude	Looks nice from long distance	Proximity to obstacles not evident enough for teleoperation	

Research on Autonomous Navigation using a Real-Time 3D Point Cloud [7]

Vision-based path planning with a 3D depth camera involves the use of advanced techniques for environment modeling and localization. The system generates a 3D point cloud from disparity images, which is then transformed into a 2D stochastic navigation map. This approach significantly improves the robot's understanding of a dynamic environment and its ability to avoid collisions.

8.7 Conclusion

In conclusion, the chosen design for our restaurant robot uses cutting-edge vision technology, with the utilization of a Kinect2 sensor for navigation. This innovative approach paves the way for the robot to perceive its surroundings enabling it to navigate safely and efficiently within the restaurant environment. By integrating advanced vision processing capabilities, the robot can detect objects and people, ensuring seamless and intuitive navigation throughout the restaurant premises. Moreover, the selected design aligns with future scalability, incorporating communication methods compatible with swarm technology, enhancing operational efficiency and adaptability. With a robust robotic platform, efficient communication methods, and advanced computer system requirements, our selected design promises to revolutionize the dining experience, offering patrons a seamless blend of automation and hospitality.

9 Allignment with EDR Learning Outcomes

We collaborated with the **user interface for restaurnt robot** team to identify how collaborating as a larger group can help us to achieve the goals of EDR course.

Identify a Suitable Design Model for a Given Problem

In our project, we explored various navigation solutions for restaurant robots, ultimately leading to three conceptual designs:

- **Marker-Based Navigation:** Utilizing ceiling markers for precise navigation.
- **Vision-Based Navigation:** Employing advanced vision processing with a Kinectv2 sensor.
- **Line Following:** Implementing simple, cost-effective line detection techniques.

By collaborating, we ensured a analysis of different navigation methods. It enables us to see the feasibility and efficinency of our solutions from different perspectives: Through this collaborative effort, we identified the more versatile and effective solutions, integrating the strengths of each approach to enhance the robot's performance. Also it helps to easily select the **Cambridge Design Model** as the suitable design model for our project.

Design Testable PCBs Complying with Industry Standards

Both groups included members skilled in PCB design, which was essential for developing the circuitry for each navigation method. Collaboration allowed us to:

- **Share Expertise:** Exchange knowledge on PCB layout, routing, and component selection to meet the specific needs of each navigation system.
- **Identify Key Challenges** It enables to discuss about how to address important aspects of PCB design, maintaining stability, durability, and efficiency.

Explain Testing Methodologies Used in Electronic Manufacturing

Collaboration enabled us to adopt and use testing methodologies suitable for our project. Also collaboration with them helps us to planning to implement ways to test our product with that group and their product with ours. Sharing knowledge with them about testing methodologies also enables us to design a testable final product.

Design Product Enclosures Complying with Industry Standards

By working together, we can achieve significant progress in designing enclosures for our restaurant robots. As it is easier to see faults for viewers than designers collaboration helps to detect design faults with them and to make enclosures that facilitate future planned extensions of our product(such as user interface needed to be integrated in to our robot):

- **Experience Sharing:** Diverse past experiences from our members allows us to design error-free and aesthetically pleasing enclosures by combining different ideas.
- **Standard Compliance:** Easy to detect faults so that can design enclosures meeting industry standards for safety, durability, and usability.

This collaborative approach resulted in high-quality enclosures that protect our electronic components and enhance the overall user experience.

Prepare Proper Documentation for Electronic Design

Our collaboration extended to thorough documentation of our design process:

- **Comprehensive Coverage:** Combined diverse skills and perspectives to create detailed and accurate documentation.
- **Clear Communication:** Collaboration ensures that all the aspects of the design, from initial concepts to final implementation, were well-documented from the beginning as it is a must for collaboration.

Proper documentation was essential for maintaining transparency and ensuring that all team members were aligned throughout the project.

Apply the Knowledge Gained to a Commercial Design Project Resulting in a Working Prototype

Working as a group allowed us to:

- **Leverage Strengths:** Utilize the unique strengths and skills of each member to enhance our design process and create a more efficient workflow.
- **Learn and Improve:** Collabortion helps to share feedback and suggestions to refine our designs, sharing new tools and techniques for continuous improvement.

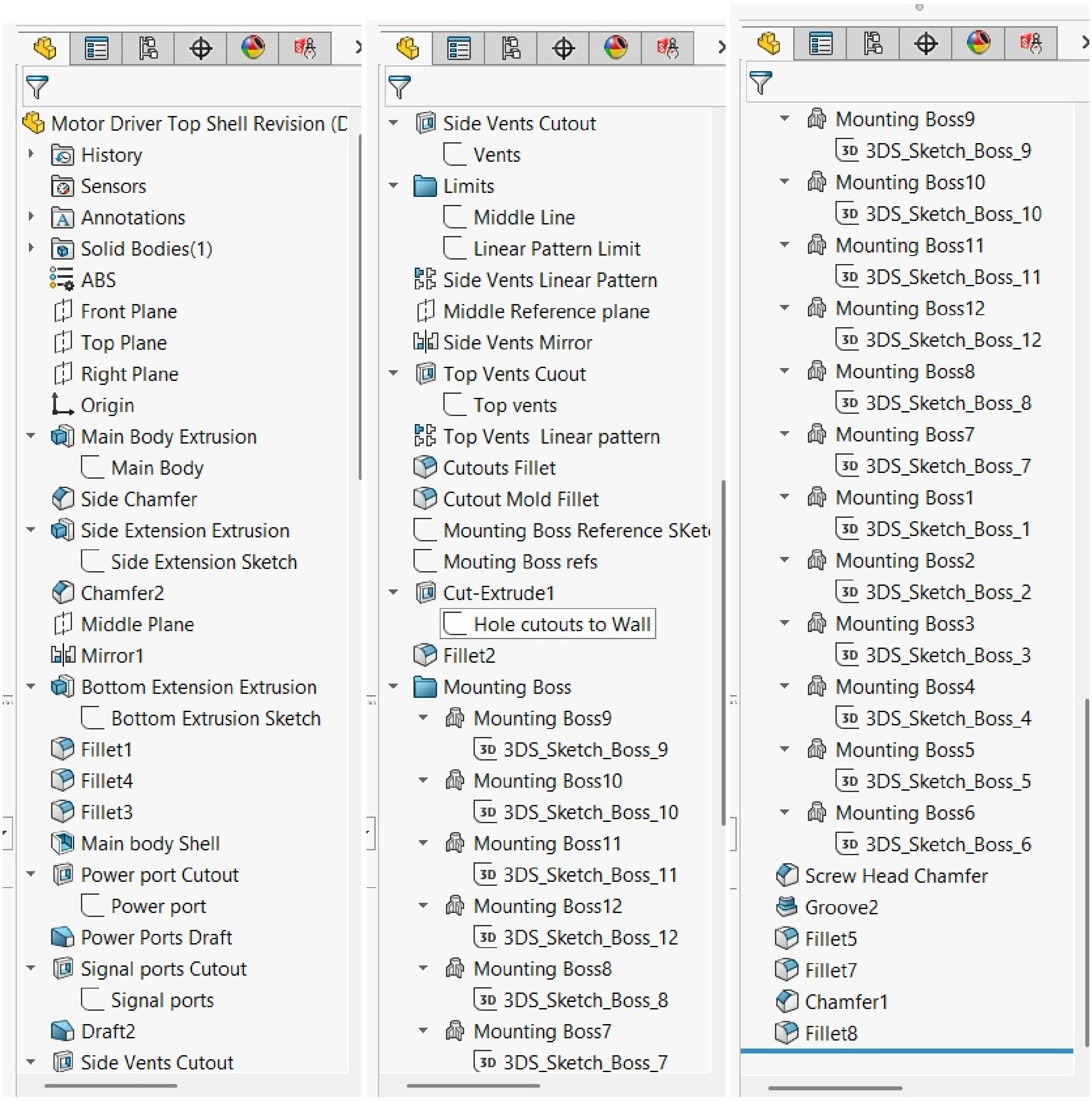
Our combined efforts will lead to the development of a working prototype that meets commercial standards and demonstrates the practical application of our learning. **Conclusion**
In conclusion, we can clearly state that by collaboration would enable us to more effectively achieve the goals of the EDR course integrating our knowledge, skills, and experiences.

10 Schematic Design

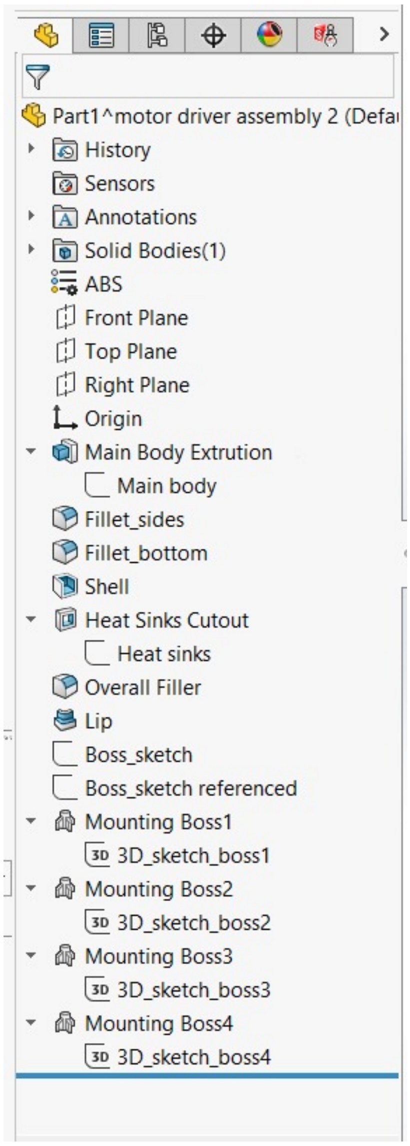
11 PCB Design

PCB and Schematic designs are attached bellow

12 Solid Work Design



Design Tree of the top part of the Motor Driver



Design Tree of the Lid part of the Motor Driver

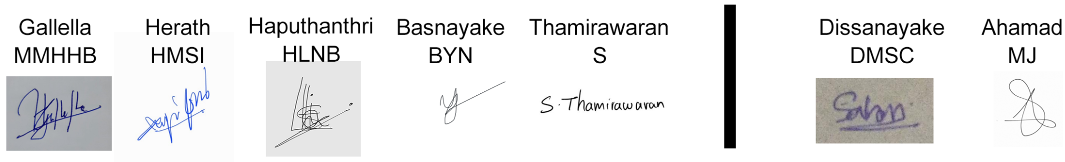


Figure 5: signatures of groups

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