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Interdisciplinary course of

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Project:

Movement and Localization Module

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Abstract

This project presents the design, development, and implementation of the movement module for a mobile social robot intended to manage access to microwaves in a university environment. The goal was to create a compact, autonomous platform capable of omnidirectional navigation, basic obstacle detection, and integration with future functional modules.
The mechanical structure consists of cut wooden platforms joined by vertical columns, housing all electronic and mechanical components. Movement is enabled by three DC motors with omnidirectional wheels, arranged in a triangular configuration, and controlled by motor drivers. A microcontroller governs the system, handling PWM motor control and ultrasonic sensor input, powered by a regulated LiPo battery setup.
The development process focused on early testing of individual components through a modular setup, followed by full system integration on the final chassis. The resulting prototype delivers a robust and adaptable movement platform, capable of supporting higher-level behaviors and other modules. It provides a solid foundation for building a functional and socially engaging service robot.

1 Phase 1: Discover

During the discovery phase, the team organized its structure, established roles for management, conducted research and developed initial proposals for the module.

1.1 Team Organization

Our team is composed of five students:

- **Ermelinda Giulivo**
- **Rafael Monllor Ballesteros**
- **Daniel Mauricio Ruiz Suarez**
- **Jurij Diego Scandola**
- **Abdul Moiz**

The team leader and **Backbone member** is Jurij Diego Scandola.
Our responsibilities and roles are:

- **Rapporteur**: Rafael Monllor Ballesteros
- **Schedule manager**: Jurij Diego Scandola

- **Art director**: Daniel Mauricio Ruiz Suarez
- **Tech manager**: Ermelinda Giulivo
- **Designer**: Abdul Moiz

1.2 Project Management

Our team plans to solve the tasks according to the following GANTT:

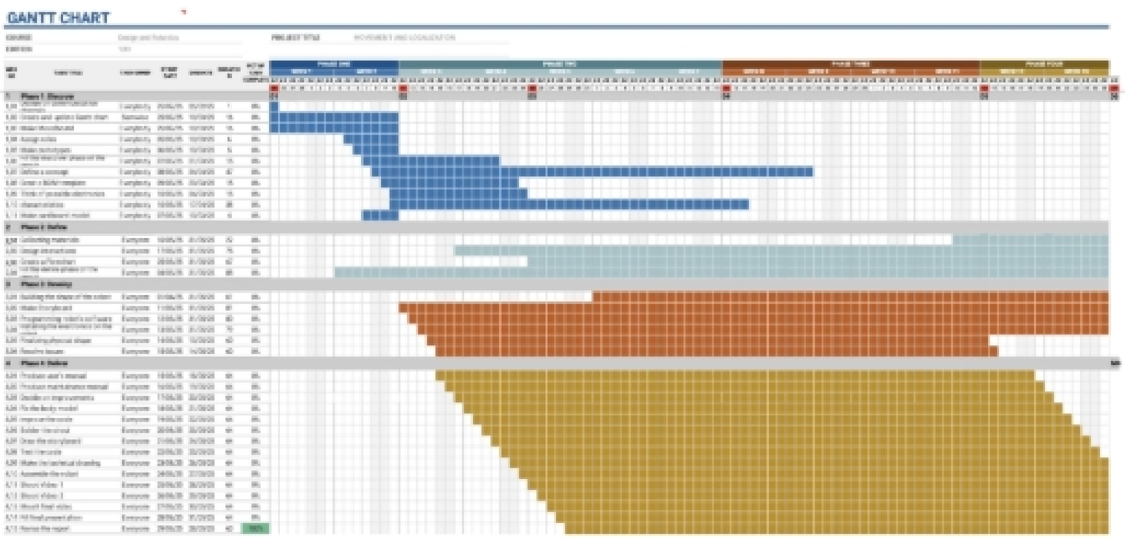

Figure 1: Project GANTT Chart

1.3 Research

The research phase is a critical foundation for the development of the movement and localization module of the indoor robot. At this stage, the primary objective is to explore and analyse existing technologies, methodologies and systems that enable precise navigation and positioning within indoor environments. Unlike outdoor settings, indoor environments present unique challenges such as signal attenuation, dynamic obstacles and limited access to GPS, making robust and reliable localization and movement a complex task.

1.4 Omnidirectional Movement Approach

For the movement and localization module of the indoor robot, an **omnidirectional movement** approach has been selected. This strategy enables the robot to move seamlessly in any direction without the need to rotate its chassis first. Typically implemented using omni-wheels or mecanum wheels, omnidirectional systems are particularly advantageous in constrained and dynamic indoor environments. However, this choice also comes with certain trade-offs.

- **Enhanced Manoeuvrability:** Omnidirectional movement allows for instant lateral, diagonal or rotational motion. This is highly beneficial in tight spaces or crowded indoor environments where flexibility is critical.
- **Simplified Path Planning:** Since the robot can move in any direction at any time, path planning algorithms can be more straightforward compared to traditional differential drive systems, reducing complexity in navigation.
- **Improved Positioning Accuracy:** Fine adjustments to the robot's position and orientation are easier, which is crucial for tasks that demand high precision, such as docking, object manipulation or alignment tasks.

- **Smooth Obstacle Avoidance:** The ability to sidestep obstacles without complex turning manoeuvres leads to smoother and often faster responses in dynamic environments.

Limitations:

- **Mechanical Complexity:** Omni-wheels and their assemblies are more mechanically intricate than standard wheels, potentially leading to higher manufacturing costs and increased maintenance needs.
- **Lower Traction and Load Capacity:** Due to the design of omni-wheels (which often rely on small rollers), they typically offer less traction and may struggle on uneven surfaces, affecting stability and limiting the robot's carrying capacity.
- **Energy Efficiency:** Omnidirectional systems can be less energy-efficient, especially during complex movement patterns, leading to increased power consumption.
- **Control Challenges:** Maintaining accurate and stable movement requires more sophisticated control algorithms. Wheel slip and small errors in motion can accumulate, potentially affecting localization accuracy if not properly managed.

1.5 Defining the Number of Wheels: Three-Wheel vs. Four-Wheel Omnidirectional Configurations

After selecting an omnidirectional movement strategy, the next major design challenge was to determine the optimal number of wheels for the robot. Specifically, we needed to choose between a **three-wheel** and a **four-wheel** omnidirectional configuration. This decision plays a critical role in the robot's stability, manoeuvrability, mechanical complexity and overall performance.

Three-Wheel Omnidirectional Configuration

- **Advantages:** Simplicity, compact design, sufficient mobility.
- **Disadvantages:** Reduced stability, weight distribution challenges, limited redundancy.

Four-Wheel Omnidirectional Configuration

- **Advantages:** Greater stability, improved traction, increased redundancy.
- **Disadvantages:** Higher mechanical complexity, larger footprint.

1.6 Defining the Robot's Shape: Square, Circular, Polygonal or Triangular Designs

Following the decisions on movement type and wheel configuration, another crucial design consideration was the **shape** of the robot's base. The geometry of the robot directly affects not only its aesthetic but also its **manoeuvrability**, **stability**, **sensor placement** and **ability to navigate tight indoor spaces**. The primary shapes considered were **square**, **circular**, **polygonal** and **triangular** forms, each offering distinct advantages and challenges.

- **Square:** Symmetry, ease of design, but corners can get caught and less smooth navigation.
- **Circular:** Excellent manoeuvrability, ideal for dynamic environments, but less space-efficient and more complex to construct.
- **Polygonal:** Balance between round and angular, unique structural advantages, but more complex to design and assemble.
- **Triangular:** Compact, simple three-wheel integration, but limited stability and challenging payload distribution.

1.7 Group Cardboard Prototype Proposals

When tasked with creating a cardboard prototype of the module, the group presented four different design proposals with detailed analysis of their advantages and disadvantages.

1.7.1 Omnidirectional robot with four wheels positioned at the vertices of a square

Proposed by: Ermelinda Giulivo

Figure 2: Square-based Omnidirectional Robot

Omnidirectional robot with four wheels positioned at the vertices of a square	
Pros	**Cons**
Excellent Stability: The square layout provides a wide and balanced support base, enhancing stability, especially when carrying payloads or navigating uneven indoor floors.	**Larger Turning Radius Compared to Circular Robots:** Although it can strafe and rotate, the square footprint is bulkier when fitting into very tight or irregularly shaped spaces.
Full Omnidirectional Mobility: With wheels positioned symmetrically, the robot can move smoothly in any direction — forward, backward, sideways or diagonally — without needing to rotate first.	**Wheel Synchronization Complexity:** Precise control of all four wheels is essential. Small discrepancies in motor performance can cause drift or errors in movement if not properly calibrated.
Simple Mechanical Symmetry: The square design makes mechanical construction easier and ensures even distribution of forces, reducing stress on the frame.	**Higher Energy Consumption:** Coordinated omnidirectional movement (especially diagonal motion) can be less energy-efficient compared to simpler drive systems.
Good for Sensor Placement: The square chassis offers clear and logical positions for sensors, allowing for easy 360-degree coverage with minimal blind spots.	**Cost and Mechanical Complexity:** Four omni-wheels and corresponding motors, encoders and controllers increase system cost and complexity compared to simpler two-wheel or three-wheel robots.
Predictable and Balanced Control: Because of the symmetry, the control algorithms (e.g., for velocity distribution across wheels) can be simpler and more consistent.	**Vulnerability to Wheel Slippage:** Omni-wheels rely on small rollers, which can slip on smooth or dusty indoor surfaces, potentially affecting localization accuracy.

1.7.2 Triangular-shaped, three-wheel omnidirectional robot

Proposed by: Rafael Monllor Ballesteros

Figure 3: Triangular-shaped Omnidirectional Robot

Triangular-shaped, three-wheel omnidirectional robot	
Pros	**Cons**
Compact Design: Three wheels in a triangular configuration create an optimally compact base while still maintaining stability.	**Lower Weight Distribution Stability:** Compared to four-wheel designs, triangular bases provide less stability for tall or top-heavy constructions.
Less Mechanical Complexity: One fewer motor and wheel compared to four-wheel designs means fewer components to maintain, calibrate, and potentially fail.	**More Complex Control Algorithms:** Achieving precise omnidirectional movement with three wheels can require more sophisticated software than four-wheel configurations.
Lower Power Consumption: Operating three motors instead of four reduces total energy usage, potentially extending battery life.	**Potential Payload Limitations:** The triangular base may support less weight or require more careful weight distribution than square configurations.
Efficient for Small Robots: Ideal for light-duty applications where high payload capacity is not necessary.	**Less Redundancy:** If one motor or wheel fails, the robot's ability to move properly is much more compromised than with four-wheel designs.

1.7.3 Polygonal-shaped omnidirectional robot with four wheels arranged in a cross configuration

Proposed by: Daniel Mauricio Ruiz Suarez

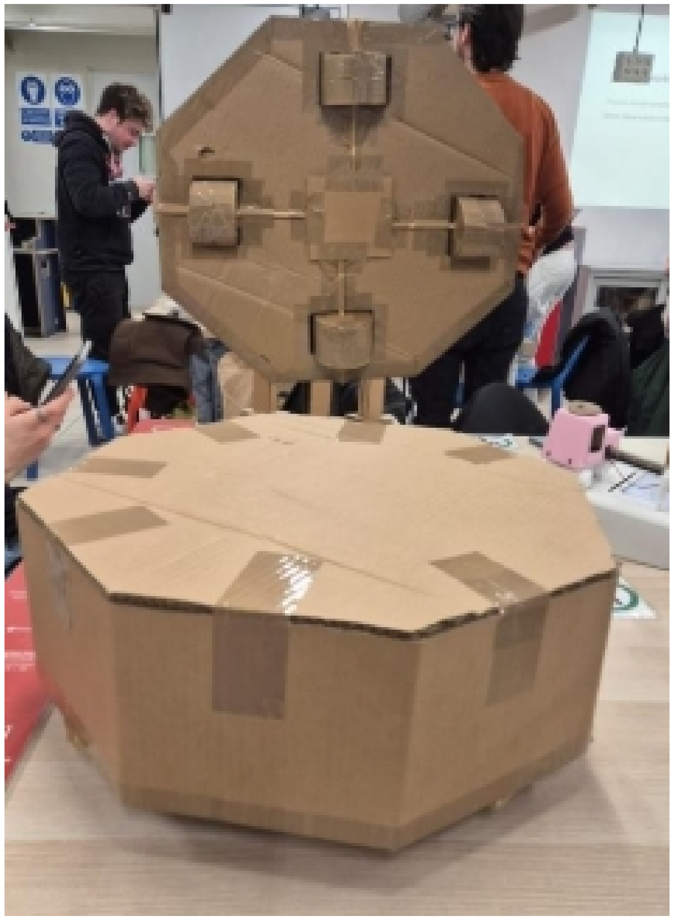

Figure 4: Polygonal-shaped Robot with Cross Wheel Configuration

Polygonal-shaped omnidirectional robot with four wheels arranged in a cross configuration	
Pros	**Cons**
Optimized Use of Space: The polygonal chassis (such as hexagonal or octagonal) better fits the cross pattern while allowing more efficient internal layout of components compared to a purely circular design.	**Design Complexity:** More complicated to design and assemble compared to pure circular or square robots.
Simplified Path Planning: Because the wheels are symmetrically arranged, control algorithms for movement and localization become more predictable and manageable.	**Potential for Increased Size:** Depending on the polygon shape and wheel placement, the overall footprint of the robot could become larger than necessary for tight indoor environments.
Better Obstacle Navigation: The extended wheel positions can help in negotiating tight spaces or approaching obstacles at different angles more smoothly.	**Higher Control Precision Needed:** Maintaining synchronized wheel movement across a cross configuration demands precise motor control to avoid unwanted drift or vibration, especially at higher speeds.
Load Distribution Sensitivity: Uneven weight distribution can negatively affect movement performance, as each wheel may bear different loads during turns or fast translations.	

1.7.4 Circular-shaped, three-wheel omnidirectional robot

Proposed by: Jurij Diego Scandola

Figure 5: Circular-shaped Omnidirectional Robot

Circular-shaped, three-wheel omnidirectional robot	
Pros	**Cons**
Excellent Manoeuvrability: The circular design eliminates corners, allowing smooth and uninterrupted movement and rotation in any direction — ideal for navigating tight, cluttered indoor environments.	**Reduced Structural Simplicity:** Building a strong, circular chassis (especially with flat materials like cardboard or sheet metal) can be mechanically more complex compared to square or polygonal shapes.
Compact and Symmetrical: The circular form naturally distributes mass and components around the centre, enhancing balance and improving dynamic stability during motion.	**Lower Load Capacity:** Three-wheel setups naturally provide less stability and support for heavy loads compared to four-wheel configurations and the circular frame can limit internal mounting options for large or heavy components.
Efficient for Omnidirectional Control: The 120° placement of the three wheels around the circle simplifies omnidirectional movement algorithms and ensures consistent movement performance.	**Challenging Internal Layout:** Fitting rectangular or square components (like batteries, boards, and sensors) inside a circular space can be inefficient and may lead to wasted internal volume.
Minimal Risk of Snagging: Without edges or corners, the robot can more easily avoid getting caught on obstacles, furniture, or tight doorways.	**Sensitivity to Weight Imbalance:** Proper balancing is critical; even slight asymmetry in weight distribution can significantly impact the robot's movement precision and stability.
Aesthetically Appealing: The circular shape often results in a cleaner, more modern appearance, which can be a factor in user-facing or commercial applications.	**Less Redundancy:** With only three wheels, if one wheel or motor fails, the robot's mobility is seriously compromised compared to a four-wheel design.

1.8 Selected Approach

After evaluating all prototype designs, the group decided on a modified polygonal approach that incorporated a **dodecagonal (12-sided) base** with **three omnidirectional wheels** arranged in a triangular configuration. This combined the stability advantages of a wide base with the mechanical simplicity of a three-wheel system.

Figure 6: Final Cardboard Prototype

This approach offered several advantages:

- The polygonal shape approximated a circle for smooth navigation while being easier to fabricate from flat materials
- Using three wheels reduced complexity and power consumption compared to four-wheel designs
- The wide base provided good stability without excessive weight
- The design allowed for sensor placement around the perimeter with minimal blind spots
- The balanced triangular wheel arrangement facilitated simple yet effective omnidirectional control

These early tests helped us set a clearer direction for both technical and conceptual development, bridging the gap between idea and implementation.

1.9 Selecting the Sensing Technology: LiDAR, Ultrasonic, Camera and Other Options

An essential step in developing the movement and localization module is selecting the **appropriate sensing technology**. The choice of sensors directly impacts the robot's ability to perceive its environment, perform accurate localization, avoid obstacles and navigate efficiently indoors. Different types of sensors offer different strengths and weaknesses depending on the operating environment, required precision, cost and computational complexity.

- **LiDAR:** High precision mapping, good range, strong performance in low light, but high cost and computational load.

- **Ultrasonic Sensors:** Low cost, simplicity, lightweight, but limited precision and susceptible to noise.
- **Cameras (RGB or Depth):** Rich environmental information, cost-effective, versatile, but lighting dependence and complex processing.
- **Other Options:**
  - **IMU:** Provides orientation and movement data, but sensitive to drift.
  - **Infrared Sensors:** Good for simple proximity detection, but limited in range and precision.
  - **Magnetic Sensors:** Useful for specific localization systems using magnetic markers, but not practical for general indoor navigation.

2 Phase 2: Define

After conducting broad research on existing social robots, user needs, and contextual use within shared spaces like university buildings, we moved on to define more specific goals for our own robot. Our challenge was to design a friendly, autonomous assistant capable of organizing turns for a shared microwave, while maintaining a mobile and socially engaging presence.
In this phase, we started shaping our concept through rough prototypes to test:

- Basic **movement mechanisms** using omnidirectional wheels.
- **Aesthetic identity**, considering a space between two separated bases for hiding the electronics.
- Key **functionalities**, for getting a proper movement of the robot.

The cardboard prototype that best adjusted to these ideas can be seen in the following picture.

Figure 7: Cardboard prototype

These early tests helped us set a clearer direction for both technical and conceptual development, bridging the gap between idea and implementation.

2.1 Strategy

Our strategy during this phase focused on transforming abstract ideas into concrete design and implementation plans for the movement module of the robot. We followed a structured approach to ensure consistency across form, function, and technology.

1. **Defining functionalities**

   We began by clearly outlining the movement module's responsibilities: patrolling the space, pausing at predefined locations to allow human interaction, and navigating autonomously to the charging station when battery levels are low. These core behaviors served as a foundation for every subsequent design decision.

2. **Considering the physical form**

   We aimed to create a friendly and humorous appearance aligned with the social nature of the robot. The form of a cooking pot was chosen for its simplicity, roundness, and instantly recognizable shape, which also fits thematically with the microwave queue scenario.

3. **Designing the 3D model of the movement module**

   Using 3D modeling tools, we created a rough prototype of the movement module's structure. This model focused on the chassis and physical arrangement of elements such as omnidirectional wheels, base support, and electronic housing. It helped us evaluate size constraints, stability, and potential mounting points for components.

4. **Selecting electronic components**

   We identified the necessary electronic components, including three omnidirectional wheels, motor drivers, a microcontroller (ESP32), sensors for obstacle detection and battery monitoring, and components for the ticket dispensing system. We also defined the logical wiring and signal flow between them.

5. **Beginning software development**

   In parallel, we started building the logic behind the movement module in code. This included route planning, obstacle avoidance, pausing logic, and low battery detection routines.

2.2 Functionalities

The movement module was designed to enable the robot to perform three key behaviors: patrol autonomously through a mapped environment, stop periodically to allow interaction with users, and navigate to a charging station when the battery level is low. These main functionalities can be seen in the following flow chart:

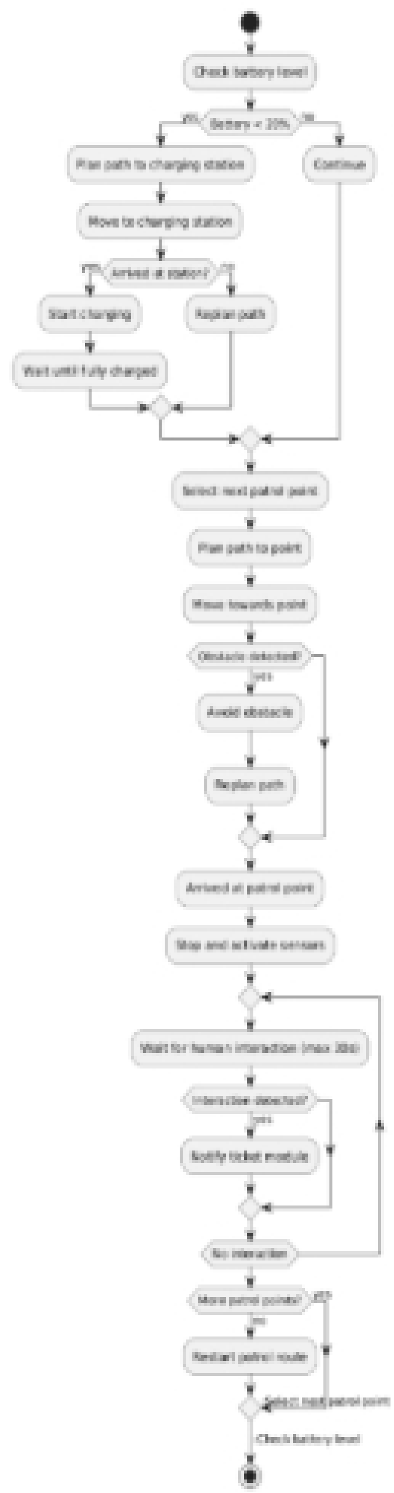

Figure 8: Movement Module Flowchart

2.3 Electronics

The design of the electronics during the development phase was guided by the functional needs of the movement module. At this stage, we focused on defining a system that would enable **precise motor control**, allow for **basic**

sensing capabilities, and remain **modular and scalable** for future upgrades.
Given that the robot needed to move holonomically using **three omnidirectional wheels**, it was essential to control **three independent DC motors** with precision. This required a microcontroller with multiple PWM-capable digital outputs and a structure that allowed us to drive each motor bidirectionally. We selected the **ATmega328P** microcontroller, due to its compatibility with the Arduino platform, which offered a familiar programming environment, low-level control, and access to a wide library of tested code.
To drive the motors, we needed reliable motor drivers that could handle the current demand and support direction and speed control. We opted for **DRV8871 single-channel H-bridge drivers**, one for each motor. These components provided sufficient current capacity, protection features, and a straightforward interface with the **ATmega328P**, using two digital pins per driver.
In addition to movement, the robot needed a basic level of **obstacle detection** to eventually navigate or stop when required. For this, we planned the integration of **ultrasonic sensors (HC-SR04)** around the perimeter. These sensors are simple, affordable, and widely used in robotics, but they require careful timing to avoid interference between readings. The ATmega328P offered enough GPIOs to connect up to six sensors, with logic implemented to trigger them sequentially.
All components would be powered by a **LiPo battery**, but since the system needed a stable 5V supply for both logic-level components and sensor operation, we included a **step-down voltage regulator (LM2596)** in the plan. This ensured consistent voltage despite the battery's natural variation underload.
From a wiring and assembly perspective, we anticipated the need to route motor cables and sensor wires efficiently between the top and bottom of the chassis. This led us to consider a vertical layout, with the **motor drivers placed near the motors** (on the bottom of the base), and the **microcontroller and logic-level components mounted on top**, minimizing wire length and simplifying troubleshooting.
In short, the electronics defined in this phase were selected not just for their individual performance, but for their ability to **integrate seamlessly** within a compact, layered robot structure, and support **clear, testable behaviors** during the next implementation stages.

2.4 Coding

The code developed so far focuses on the core functionalities of the movement module: patrolling the environment, stopping periodically for interaction, and returning to a charging station when battery levels are low. The code is being developed in C++, using the Arduino framework, since it offers:

- High compatibility with our chosen microcontroller (ATmega328P).
- Access to well-documented libraries for motor control, timers, and sensors.
- A simple structure that facilitates rapid prototyping and debugging.

The microcontroller is programmed directly via the Arduino IDE, allowing us to flash and test code iterations easily. The robot can switch between various behaviors such as:

- Patrolling predefined points.
- Stopping and waiting for user interaction.
- Navigating to the charging station when the battery is low.

In this phase, we focused on:

- Defining key states and transitions.
- Mapping out which pins control each motor and sensor.
- Testing the motors and sensors.

The code used for the testing of the HC-SR04 ultrasonic sensors, and the motors can be seen in the Appendix.

2.5 Structure

The physical structure of the movement module was designed to be simple, stable, and compatible with the circular ”cooking pot” appearance of the final robot. Its geometry allows for efficient assembly and proper distribution of electronic components, motors, and wheels. The chassis consists of two main dodecagonal plates:

- A **lower base plate** that holds the motors, wheels, the battery, and electronics.
- An **upper plate** connected by four vertical rods, providing structural support and space for mounting future upper modules (such as the ticket dispenser).

Between the two plates, there’s ample vertical space to safely house the internal wiring and maintain separation between moving and static parts. The structural elements were dimensioned using CAD software and detailed in the following technical drawings.

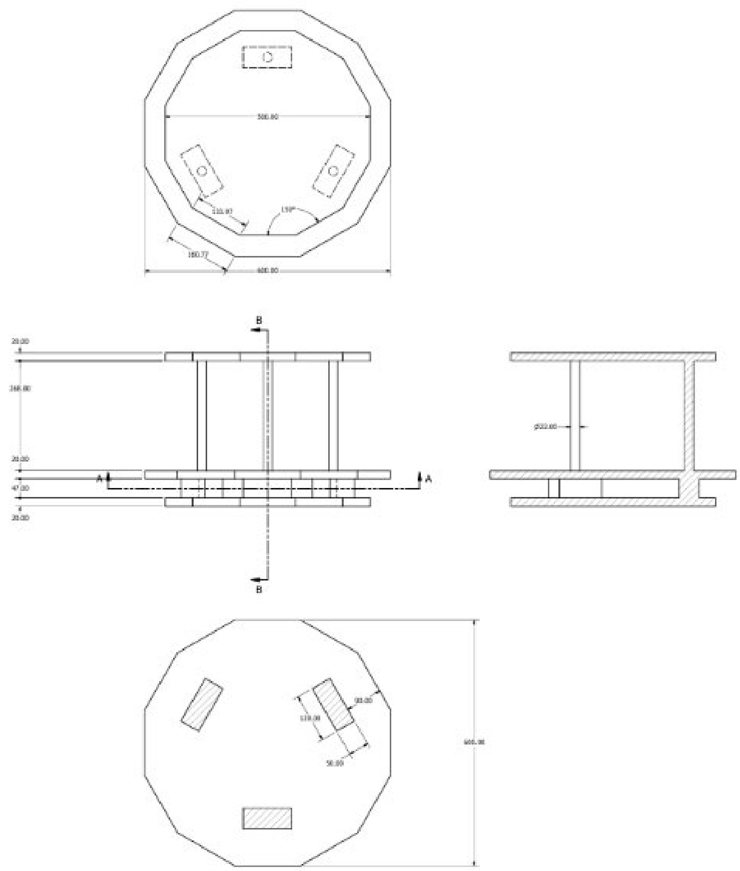

Figure 9: Structure Technical Drawings

The structure is primarily symmetrical, promoting balance and helping the robot move stably in any direction. This design prioritizes modularity, allowing individual parts to be adjusted, replaced, or expanded without affecting the rest of the system.

2.6 Shape

The shape of the robot was designed to convey friendliness, uniqueness, and a sense of purpose within its social environment. Taking inspiration from kitchen elements, the robot adopts a stylized form reminiscent of a cooking pot, reinforcing its role as a ticket dispenser for a microwave queue.

The overall geometry is conical, with a wide dodecagonal base that houses the movement module and narrows as it rises, creating a silhouette that is both functional and expressive. The lower section (in red) is where the wheels

and internal electronics are stored. The transparency of the conical section allows for visual access to internal components and lighting, adding both a technological and playful aesthetic.
At the top of the robot, the head is formed by a metallic-looking circular cap with a symmetrical design, integrating visual sensors, lights, or interface points. A pair of stylized "ears" or "handles" give it a characterful appearance, reinforcing its role as a social entity that invites interaction. The shape also leaves space at the front for a clearly visible ticket dispensing area.

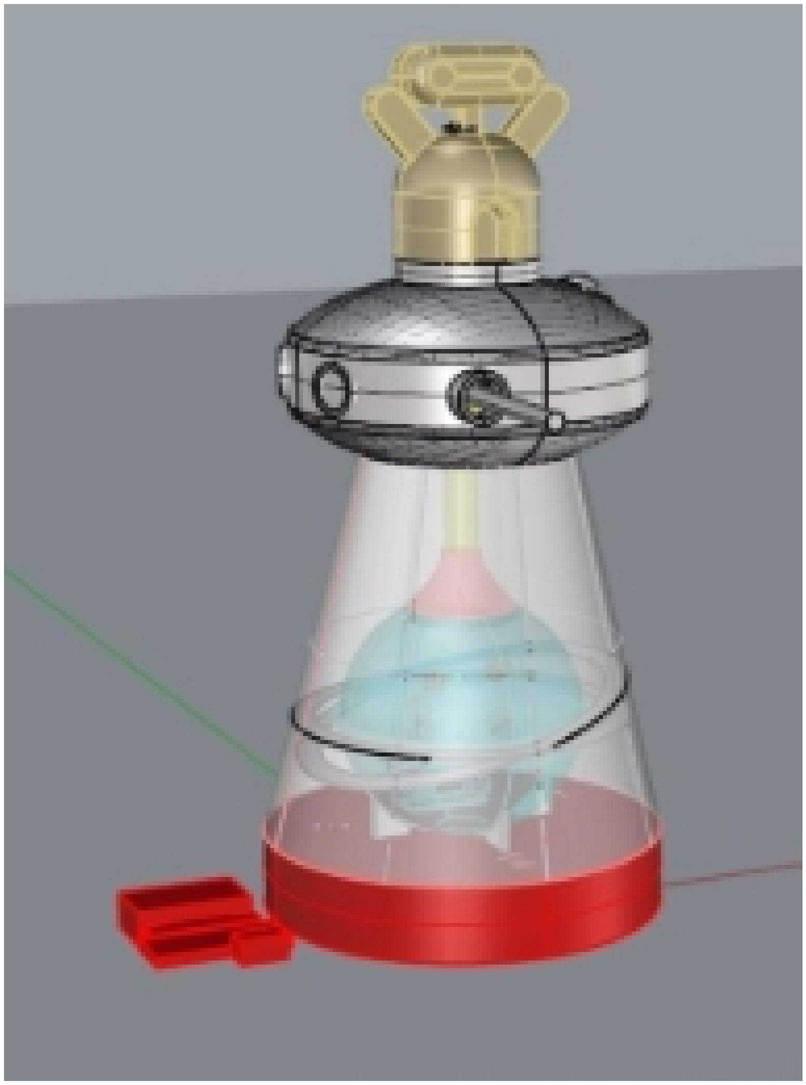

Figure 10: Robot Shape Design

2.7 Concept

The concept behind our robot is to create a social and functional assistant that organizes the use of a shared microwave in a university environment.
By dispensing turn tickets and patrolling the space autonomously, the robot aims to bring order to an otherwise chaotic or informal process, while adding an element of humor and engagement through its unique design.
Inspired by everyday kitchen objects, its cooking pot-like appearance makes the robot immediately relatable and non-intimidating, encouraging students to approach it easily. Its ability to move, pause, and react transforms a mundane waiting experience into a playful and organized interaction, promoting better coexistence in shared spaces.
The combination of functionality and personality defines the essence of this project:
a robot that not only helps manage tasks but also becomes a memorable part of its environment.

3 Phase 3: Develop

In this phase we describe the development process, departing from the first prototype to the final improvements regarding strategy, electronics, coding, structure, and shape.

3.1 Strategy

Our development strategy followed a bottom-up approach, starting with the physical structure and gradually integrating electronics and software. This allowed us to test each stage independently and ensure that all subsystems could function reliably before full integration.
The first step was to assemble the **structure** of the movement module in the Bovisa's *Prototipi* lab. Using wood as the base material, we cut and mounted the two dodecagonal plates, positioning the vertical supports and verifying spacing and alignment based on our technical drawings. This gave us a solid physical base to work with and validated the dimensions from our CAD model.
Once the chassis was complete, we proceeded to **mount the electronic components** onto the structure. The three motors were installed and connected to their respective motor drivers, which were in turn wired to the microcontroller and power supply. The placement of components was adapted slightly during this stage to fit the real-world constraints of the wooden base, which differed slightly from the original digital model.
Finally, with the hardware in place, we began **programming the microcontroller**. We uploaded and tested the first version of the code, focusing on motor control and basic behavioral states for future expansion. This phase allowed us to validate our approach and confirm that the robot could move and behave according to the logic defined.

3.2 Electronics

Before assembling the electronics on the wooden structure, we first created a **fully functional bench test setup** to validate our components and connections. This early prototype allowed us to test the behavior of the **DC motors with omnidirectional wheels** and the **ultrasonic sensors** in a controlled environment.
We mounted the three motors on metal brackets and connected them to their respective **DRV8871 motor drivers**. These, in turn, were wired to a breadboard where we centralized all the connections, including the **ATmega328P microcontroller**, **six HC-SR04 ultrasonic sensors**, and **power regulation circuits**. We used a laboratory power supply to ensure voltage stability during the tests.

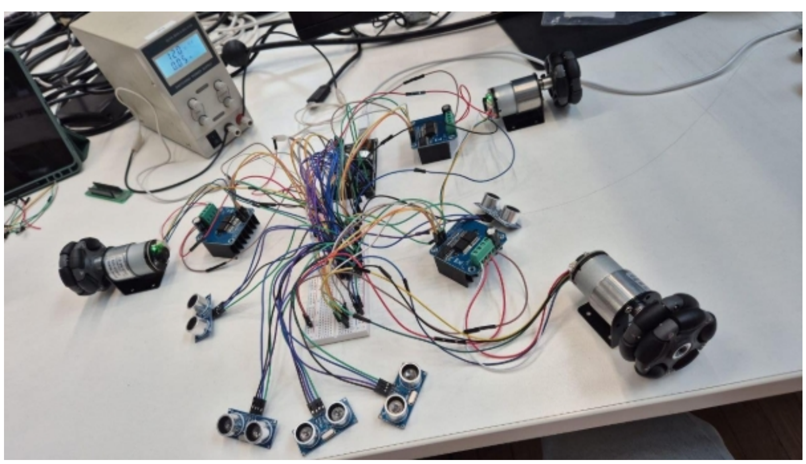

Figure 11: Electronics Bench Test Setup

Once the behavior of the components was confirmed, we moved on to physically **assembling the electronics onto the wooden chassis**. The three motors were mounted onto the underside of the lower wooden base. Their positioning followed the triangular configuration defined in our design, ensuring balanced and effective omnidirectional movement.

Once the motors were secured, we constructed **custom wooden supports** on the upper side of the base to hold the **motor drivers** (DRV8871). These supports allowed us to fix the drivers in place, providing both accessibility and protection for the connections. With the mechanical and structural elements ready, we proceeded to **wire the motors to the drivers**, carefully routing the motor cables through openings in the base. This ensured that the wiring remained organized and out of the way of moving parts.

Figure 12: Motor and Driver Setup

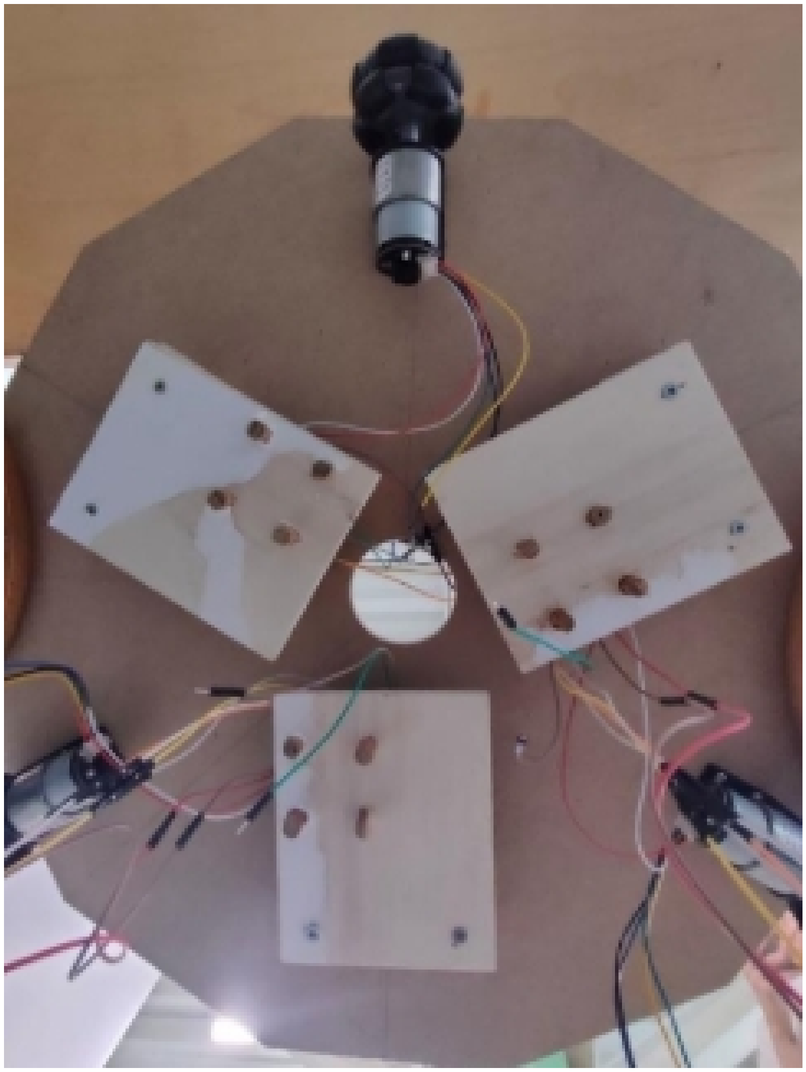

Figure 13: Motor Driver Installation

The cables were then guided to the top layer of the chassis, where we placed the **microcontroller, power distribution components**, and **sensor modules**. The next step was to connect the **motor drivers to the microcontroller**, completing the control path between the motors and the logic unit. To organize this section of the circuit, we mounted the microcontroller onto a **vertical blue plastic panel** attached to the structure using zip ties. This panel allowed us to keep the wiring centralized, accessible, and separated from the moving parts below. Once the core control system was in place, we installed the **ultrasonic sensors** around the robot perimeter. These were mounted on **alternating faces of the dodecagonal wooden base**, using custom white brackets to maintain stable orientation and optimal detection angles. The sensors were positioned to provide wide environmental coverage and were each connected to the microcontroller via dedicated digital pins.

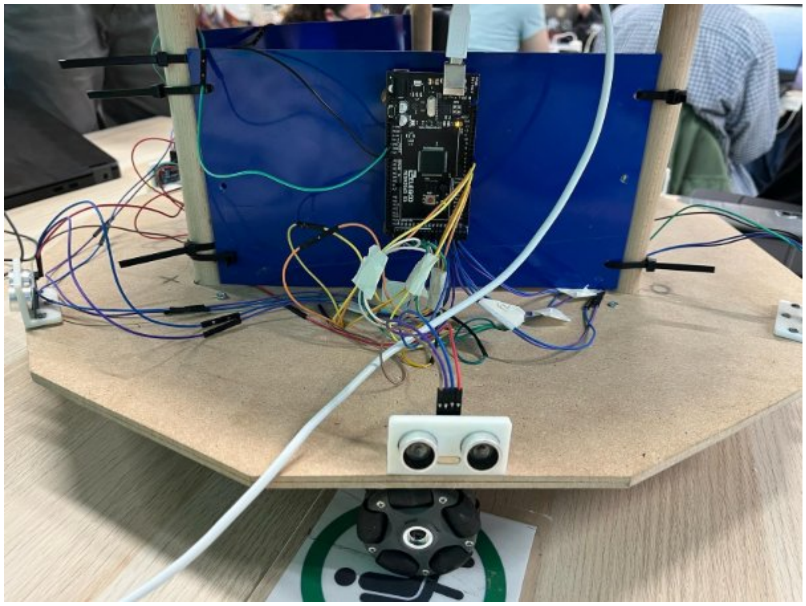

Figure 14: Ultrasonic Sensor Installation

To manage power and grounding efficiently, we used **two small green protoboards** mounted on another blue panel. The **right-hand board** was used to **distribute power (VCC)** to all critical components, including the ultrasonic sensors, motor drivers, and microcontroller. The **left-hand board** was dedicated to **ground (GND) connections**, ensuring a common reference for the entire circuit. This setup allowed us to organize the wiring more cleanly, reduce loose connections, and centralize the power layout in a way that is both stable and maintainable.

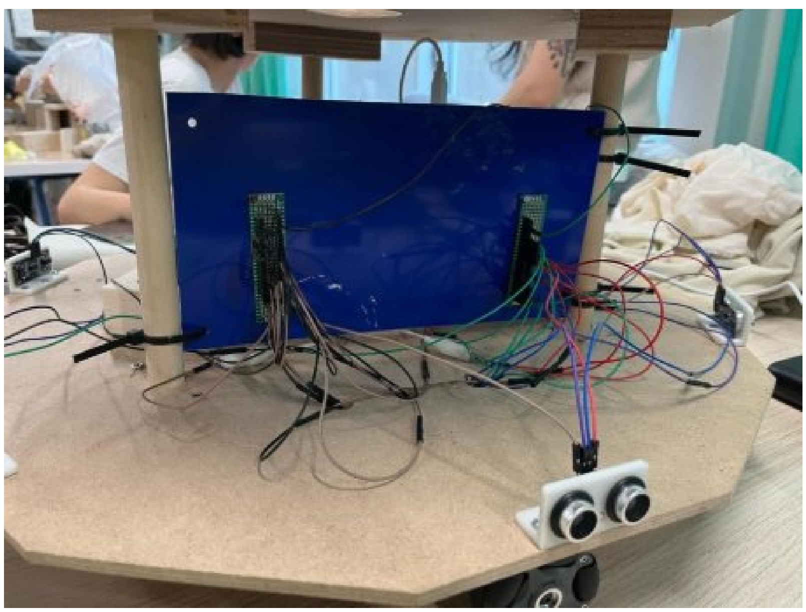

Figure 15: Power Distribution Boards

To verify that the electronics were functioning correctly after assembly, we first powered the system using a **laboratory power supply**. This allowed us to set a precise voltage and current limit, ensuring a safe environment for initial testing and protecting the components from potential surges or wiring errors.
Once the wiring was confirmed and all components—motors, drivers, sensors, and microcontroller—responded as expected, we replaced the power supply with the robot's actual **LiFePO4 battery**. With the battery installed

and secured to the base, we repeated the tests to confirm that the entire system could run autonomously on its intended power source. This step-by-step approach helped us detect and correct small connection issues early and ensured a smooth transition to portable, untethered operation.

Figure 16: Battery Installation

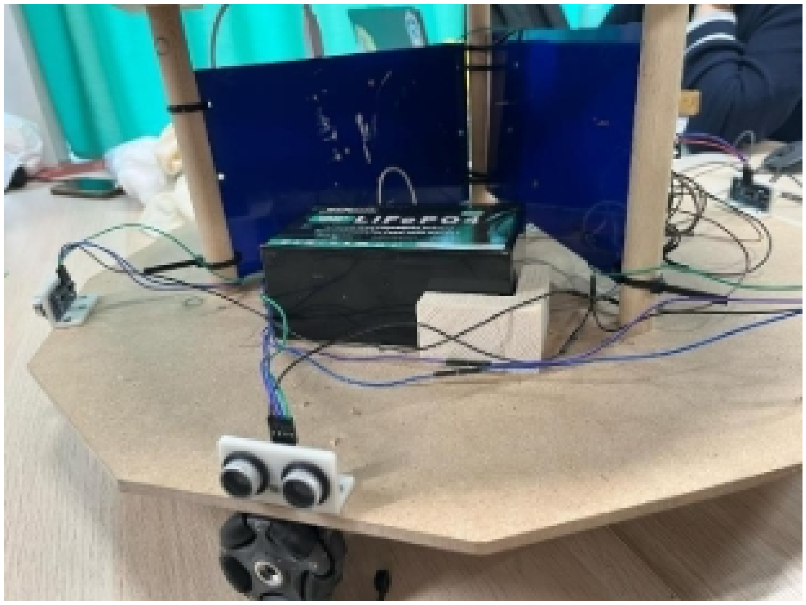

Figure 17: Complete Electronics Assembly

Additionally, during the development process, we decided to incorporate a **camera module** into the system in order to enable docking with the charging station using **QR code detection**. This addition allowed the robot to recognize visual markers and orient itself toward the charging point when needed. Since this feature was not planned from the beginning, it was not included in the initial design phase. The decision to implement it emerged organically as the project evolved and we identified the need for more reliable and autonomous behavior during low-battery scenarios.

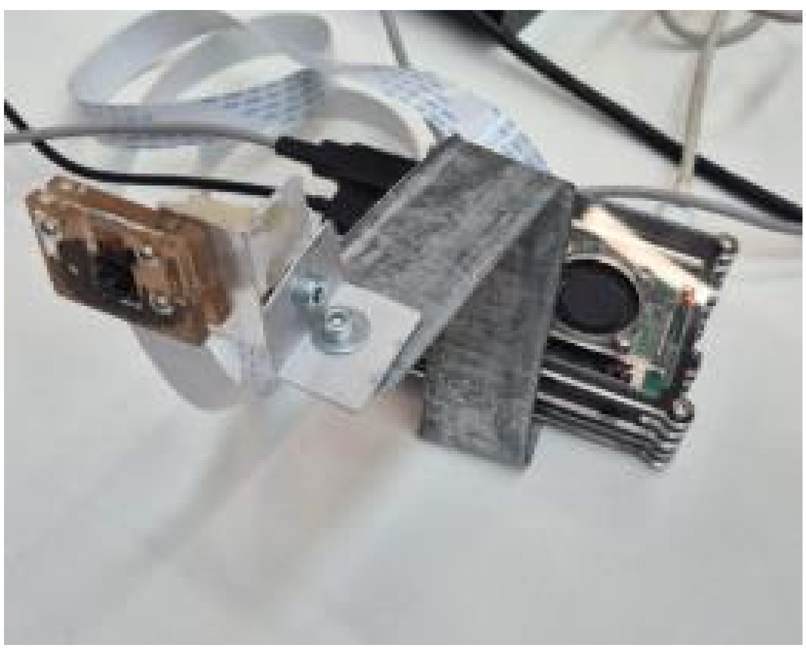

Figure 18: Camera Module Integration

3.3 Coding

During the development phase, we focused on implementing and validating the full control system for the robot. The process began with an **alpha testing program** (available in the annex), designed to test each subsystem independently—motors, sensors, encoders, and AprilTag detection—before integrating them into a unified control architecture.

In this first version, we structured the tests as **modular routines**, enabling selective testing of each component. This helped verify that the motors responded to PWM signals correctly, the ultrasonic sensors provided consistent readings, and the encoder data could be read and interpreted reliably. These tests were crucial to ensure that hardware and wiring were functioning as expected.

Once individual components were validated, we moved on to the **final implementation** of the control system. The core of the system is organized as a **state-driven architecture**, with multiple operation modes:

- **Manual mode**, which receives velocity commands over serial communication for direct control.
- **Autonomous mode**, in which the robot patrols predefined paths while avoiding obstacles.
- **Tag following mode**, where it adjusts its motion based on the position of a detected AprilTag.
- **Charging mode**, which guides the robot toward a docking station when low battery is detected.

Each mode encapsulates its own logic and can be triggered via commands, making the system modular and easy to expand. Additionally, a **20Hz control loop** manages sensor updates, decision-making, and movement commands, maintaining responsive and consistent behavior.

This structure has proven reliable in testing, with smooth transitions between modes and stable behavior in autonomous operation. Full implementation details and source code are available in the **annex** of this report.

3.4 Structure

During this development phase, we focused on building each physical component of the robot's structure based on the technical drawings and models defined in the previous stage. The entire chassis was built of wood using standard tools available in Bovisa's *Prototipi* lab. This choice of material allowed for fast prototyping, easy modifications, and rigid support for the movement module.

3.4.1 Base panel

This large dodecagonal panel serves as the foundation for the robot. It supports the motors, the battery, and the lower part of the vertical columns. We cut it from an MDF panel (220 x 152 cm, 3mm) with precision to match the dimensions in the technical drawing, ensuring symmetry and enough surface area for wheel spacing and internal wiring. It serves to mount the electronics and vertical panels and helps complete the structural frame.

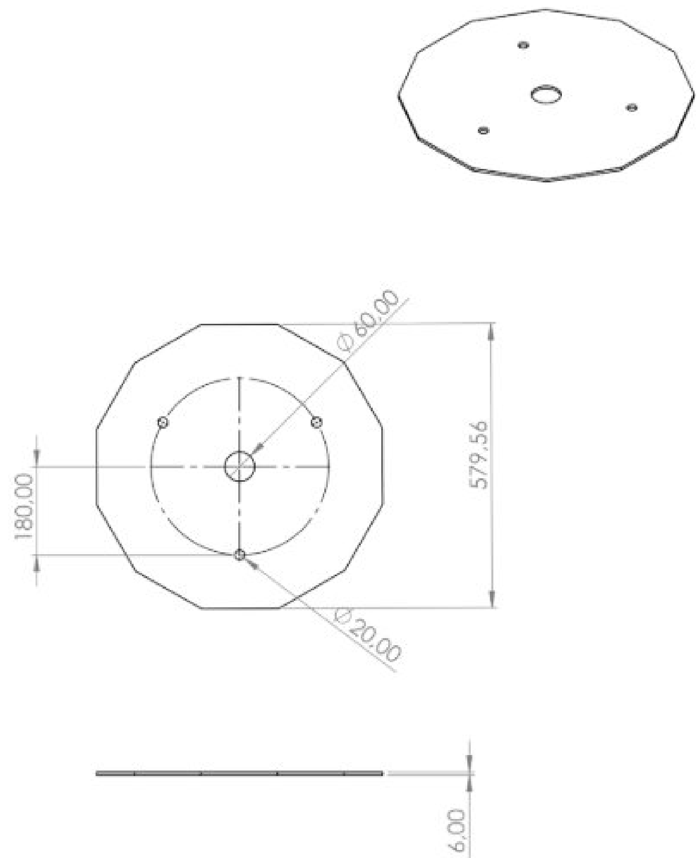

Figure 19: Base Panel

3.4.2 Upper platform

This smaller dodecagonal plate forms the top of the movement module. We constructed it to match the base's outer shape but at a smaller scale. It serves to mount the other modules and helps complete the structural frame.

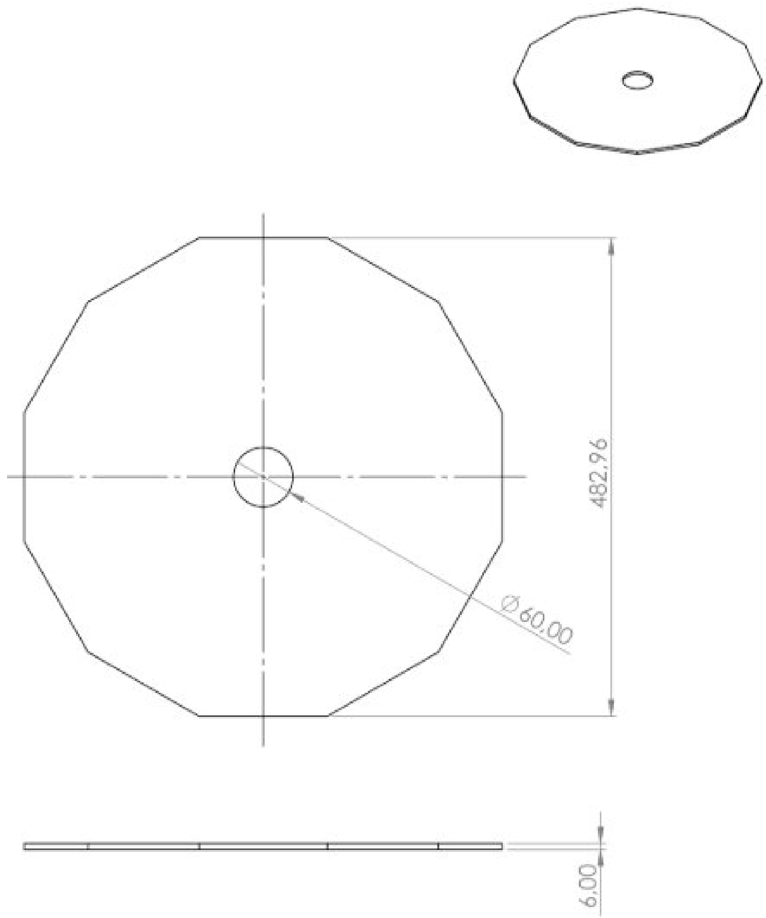

Figure 20: Upper Platform

3.4.3 Lower platform

This element was originally designed as a lower platform, located below the main base. Its purpose was to hold some of the electronic components, freeing up space on the main base. However, during the assembly and testing phase, we encountered a practical issue: this platform reduced the vertical clearance between the wheels and the ground, interfering with proper contact and compromising movement. In sight of this we decided to remove this platform and relocate its electronic components in the bottom face of the base panel.

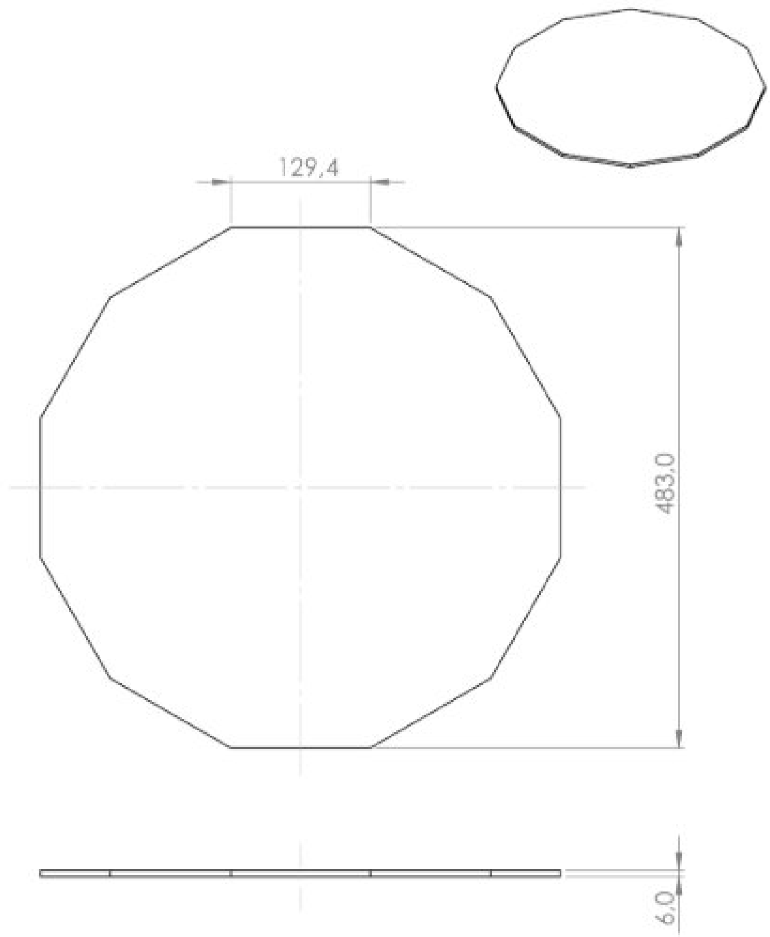

Figure 21: Lower Platform (Later Removed)

3.4.4 Columns

Three vertical wooden rods were cut and sanded to precise height to connect the base and the top plate. They ensure the structure is rigid and that both plates remain parallel.

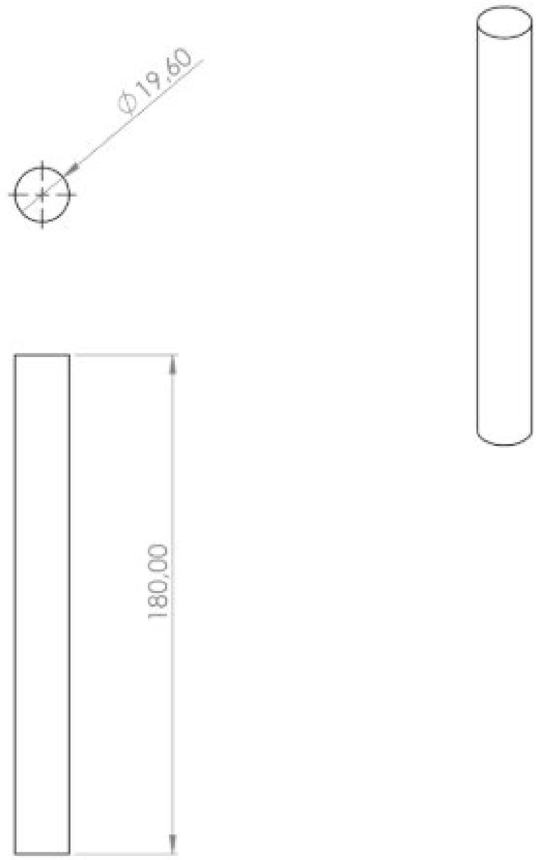

Figure 22: Vertical Column

3.4.5 Columns supports

These wooden components serve as the **connection points between structural levels**. Three of them are placed between **the lower platform and the base panel**, acting as a solid foundation and providing vertical spacing. The other three are positioned **between the top ends of the columns and the upper platform**, ensuring a stable connection. There are in total six units of these types of pieces, which help to distribute weight and keep the vertical supports firmly aligned, contributing significantly to the overall rigidity and symmetry of the structure.

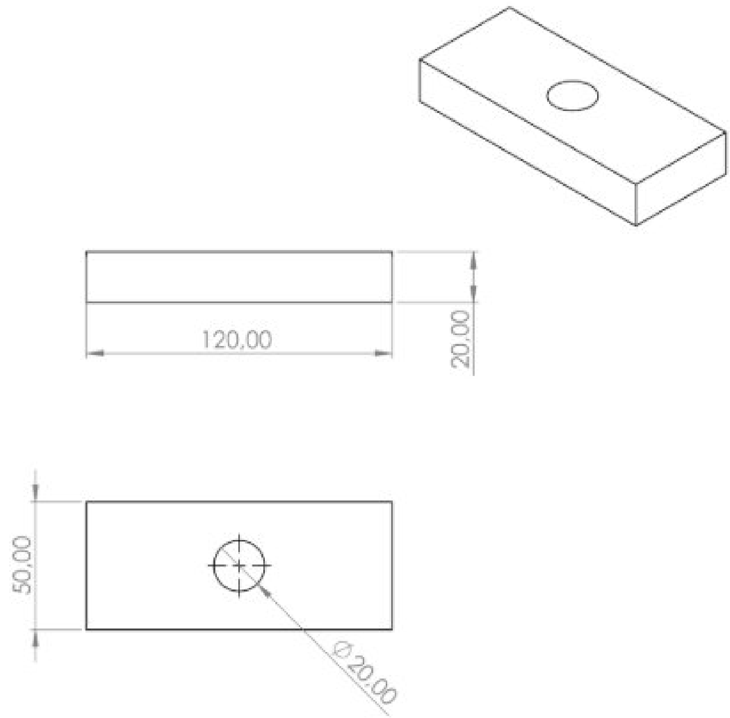

Figure 23: Column Supports

Each part was cut, assembled, and adjusted manually, allowing us to iteratively test fit and stability during the process. The built structure was robust enough to support the entire electronic system and the external aesthetic modules, while remaining accessible for maintenance and future upgrades.

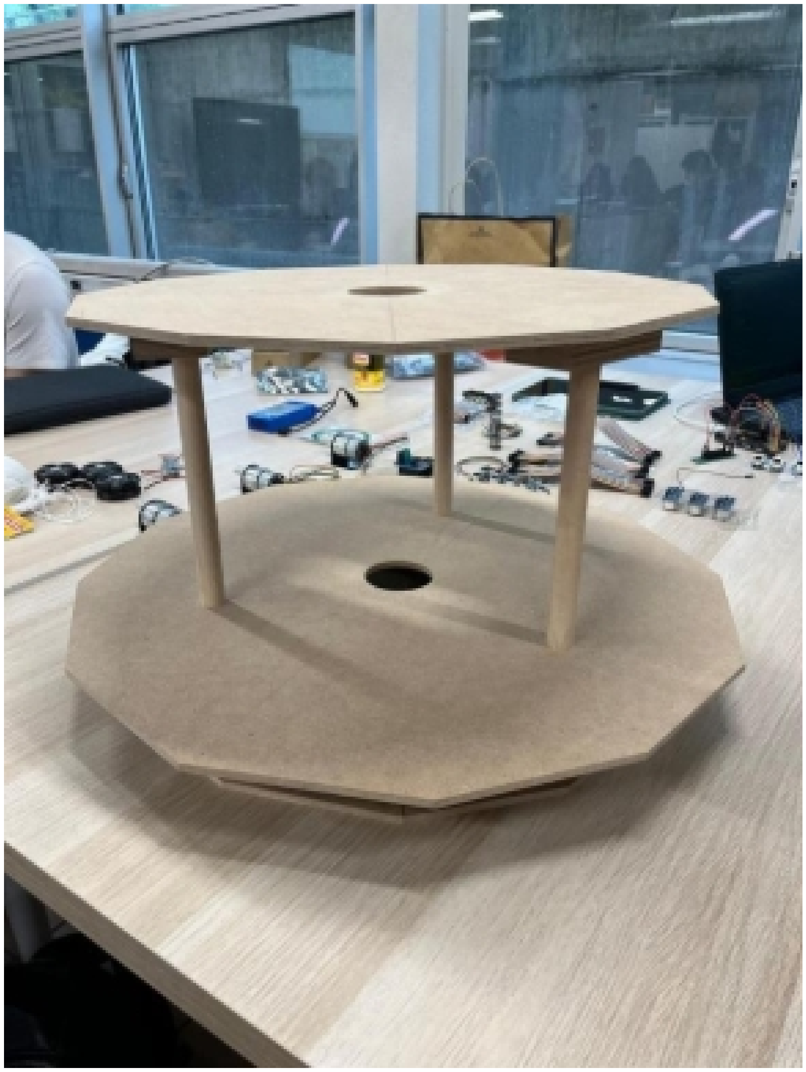

Figure 24: Assembled Structure

However, during testing, we found that this additional level **reduced the clearance between the omnidirectional wheels and the ground**, which significantly affected the robot's ability to move.
To resolve this, we decided to **remove the lower platform entirely**. As an alternative, we reorganized the layout of the components. The **electronic modules that were originally intended to be mounted on the removed platform were relocated** to the **base panel**. In the bottom face of the base panels three additional pieces like the ones that can be seen in the image were assembled to have more space for relocating the electronic modules. This change improved ground contact for the wheels and simplified the structural layout, while still maintaining proper distribution of the components across the chassis.

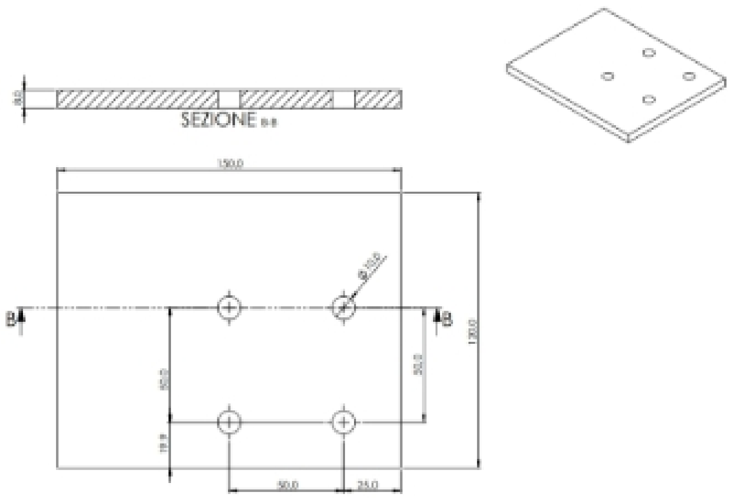

Figure 25: Modified Structure

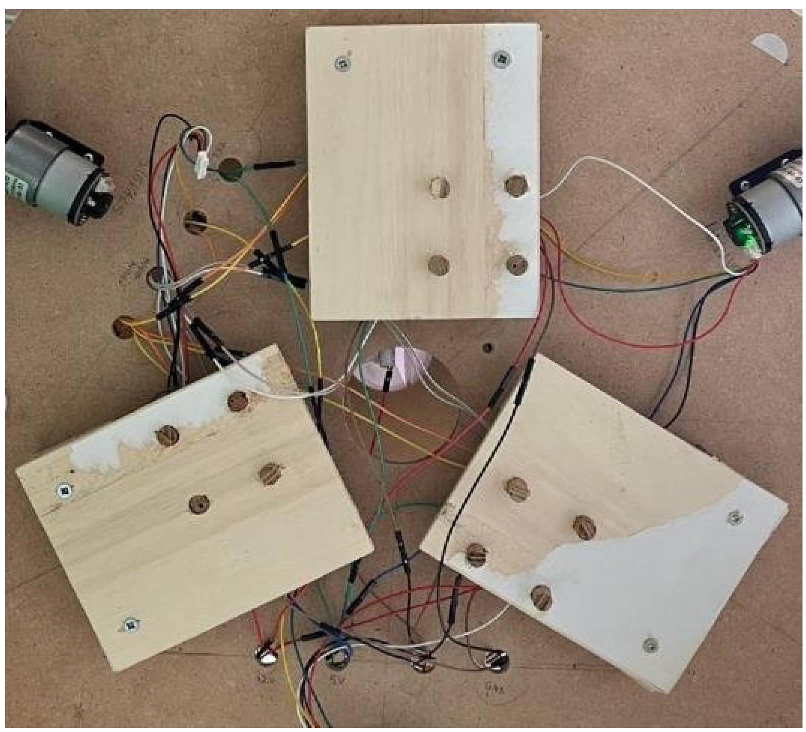

Figure 26: Final Structure Configuration

3.5 Shape

During the development phase, we began translating the conceptual design of the robot into a tangible and expressive physical form. The original inspiration was a cooking pot—round, friendly, and slightly whimsical—symbolizing the robot's function related to managing microwave access. However, as construction progressed, we adapted this concept to fit the realities of available tools, materials, and structural constraints in the lab.
As previously mentioned, the robot's physical skeleton was built using **two dodecagonal wooden platforms**—a base and a top—offering a structure that approximates a circular form while being much easier to manufacture using

flat wood sheets. This polygonal configuration provided excellent stability, allowed consistent mounting points, and gave us an ideal layout for placing the ultrasonic sensors around the perimeter, on alternating sides.
Once the structural base was completed and tested, we began the **aesthetic transformation** of the robot. In the first stage the robot was covered with a **white fabric draped over the wooden base**, giving it a soft and continuous outer surface. At this point, we also added the **first vertical supports** that would later hold the turn-dispenser module, made of transparent tubing and filled with balls to simulate a ticket lottery system.

Figure 27: Initial Fabric Cover

In the second stage, we moved beyond the clean fabric and began attaching **cotton padding** all around the robot. This gave the robot a fluffy, cloud-like appearance, softening its visual presence and introducing a playful, imaginative look that would appeal to users. This cotton layer also served to subtly obscure the structural hardware beneath, enhancing the illusion of a light, floating device.

Figure 28: Cloud-like Cotton Layer

Finally we embedded **LED lights inside the cotton structure**, creating a visual effect reminiscent of a **storm cloud**. When lit from within, the cotton shimmered and pulsed, adding depth and dynamic texture to the robot's presence. This stage brought the design much closer to an animated, expressive character rather than just a mobile object.

Figure 29: LED-Enhanced Cloud Appearance

Throughout this process, we continuously adjusted the shape based on technical needs and visual testing. The final form successfully merges functionality and storytelling, transforming the movement module from a structural base into a **key part of a characterful robot**.

4 Phase 4: Deliver

In this phase we describe the final robot in its completed form, highlighting the key features, functionalities, and design choices that define the finished product.

4.1 Final Robot Description

Our final robot represents the culmination of our design, development, and integration efforts throughout this project. The movement module serves as the foundation for a social robot designed to manage access to microwaves in a university environment. The completed robot successfully integrates technical functionality with an engaging aesthetic that invites human interaction.
The robot combines multiple modules working in harmony:

- A robust **movement platform** with omnidirectional capability
- An **obstacle detection system** using ultrasonic sensors
- A visually distinctive **cloud-like base** with embedded LED lighting
- A **transparent ticket dispensing system** as its core interactive element
- A character-driven **design language** that creates a friendly and approachable presence

The final robot achieves its primary design goals of being functional, modular, and socially engaging while maintaining a compact and maneuverable form factor suitable for navigating university spaces.

4.2 Strategy

The main objective of this final phase was to **prepare the robot for presentation and demonstration**, ensuring that the system was functional, understandable, and representative of the work carried out throughout the project. We began by **defining a clear list of deliverables**, which included:

- A working prototype of the movement module with integrated electronics and basic behaviors
- A clean and secure physical assembly, including internal wiring, battery placement, and sensor positioning
- A stable version of the control code capable of switching between manual and autonomous modes
- Visual and written documentation to support the explanation of the design and development process

To organize the work, we split tasks across the team, focusing on:

- Final code polishing and debugging
- Mechanical adjustments and reinforcement of the structure
- Aesthetic finishing touches to the robot's appearance
- Preparation of media and presentation material (images, diagrams, video, report)

This strategic approach allowed us to arrive at a functional and communicative prototype, aligned with the original goals and suitable for public demonstration and evaluation.

4.3 Shape

In the final delivery stage, the robot evolved from a technical prototype into a **fully integrated, character-driven system**. The movement module (previously shaped into a cloud-like base) was transformed into the foundation for a visually expressive and narratively rich design.

Figure 30: Final Robot Design

The bottom of the robot remained covered in **soft white cotton**, representing a storm cloud. This not only gave the robot a magical and playful appearance, but also **concealed the mechanical components** such as wheels, motors, and sensors. Embedded **LEDs inside the cotton layer** enhanced the illusion by simulating internal lightning effects, adding a sense of animation and depth.
Rising from this cloud base, a **transparent vertical column filled with white balls** was installed to symbolize the microwave ticketing mechanism. This interactive visual metaphor helped communicate the robot's core function in a light-hearted way. The structure was topped with a **dome shaped like a UFO**, reinforcing the fictional theme of an alien-operated machine that has landed in a university setting to distribute turn tickets.
At the peak, a **green alien figure** served as the face of the robot, further amplifying its friendly and approachable character. This figure helped attract attention and invited interaction, especially in the social environment of a shared student space.
The integration between the modules was carefully planned, both structurally and visually. The cloud base, the transparent ticket chamber, and the dome were aligned with the underlying mechanical layout, while also building a **consistent narrative language**. Every part contributed to the overall identity of the robot—not just as a machine, but as a **social object** with personality and purpose.

For full reference, **all technical drawings and 3D models used in the construction are available via the project repository**. These materials illustrate how the shape was designed, tested, and assembled, and serve as a foundation for future iterations or replication.

4.4 Mechanics

The final mechanical structure of the robot is composed of **two dodecagonal wooden platforms**: a **base platform** and an **upper platform**, connected by four vertical wooden columns. This simplified configuration was adopted after removing the initially planned intermediate layer, which had interfered with wheel clearance.
The **base platform** is the core of the system and holds **all the critical mechanical and electronic components**:

- On the **underside**, we mounted the **three DC motors**, each connected to a **58 mm omnidirectional wheel** in a triangular layout to enable holonomic movement. The **motor drivers** are also fixed on this side, close to the motors, to reduce wiring length and improve accessibility.
- On the **upper side** of the same platform, we installed the **microcontroller**, **sensor wiring**, **power distribution boards**, and the **battery**. A vertical plastic panel helps organize the electronics, and the ultrasonic sensors are positioned around the base perimeter on alternating sides.

The **upper platform** is structurally intended to support **other modules**, such as the ticket dispenser or user interface components. It is fixed to the columns and aligned with the base to maintain symmetry and provide vertical expansion space.

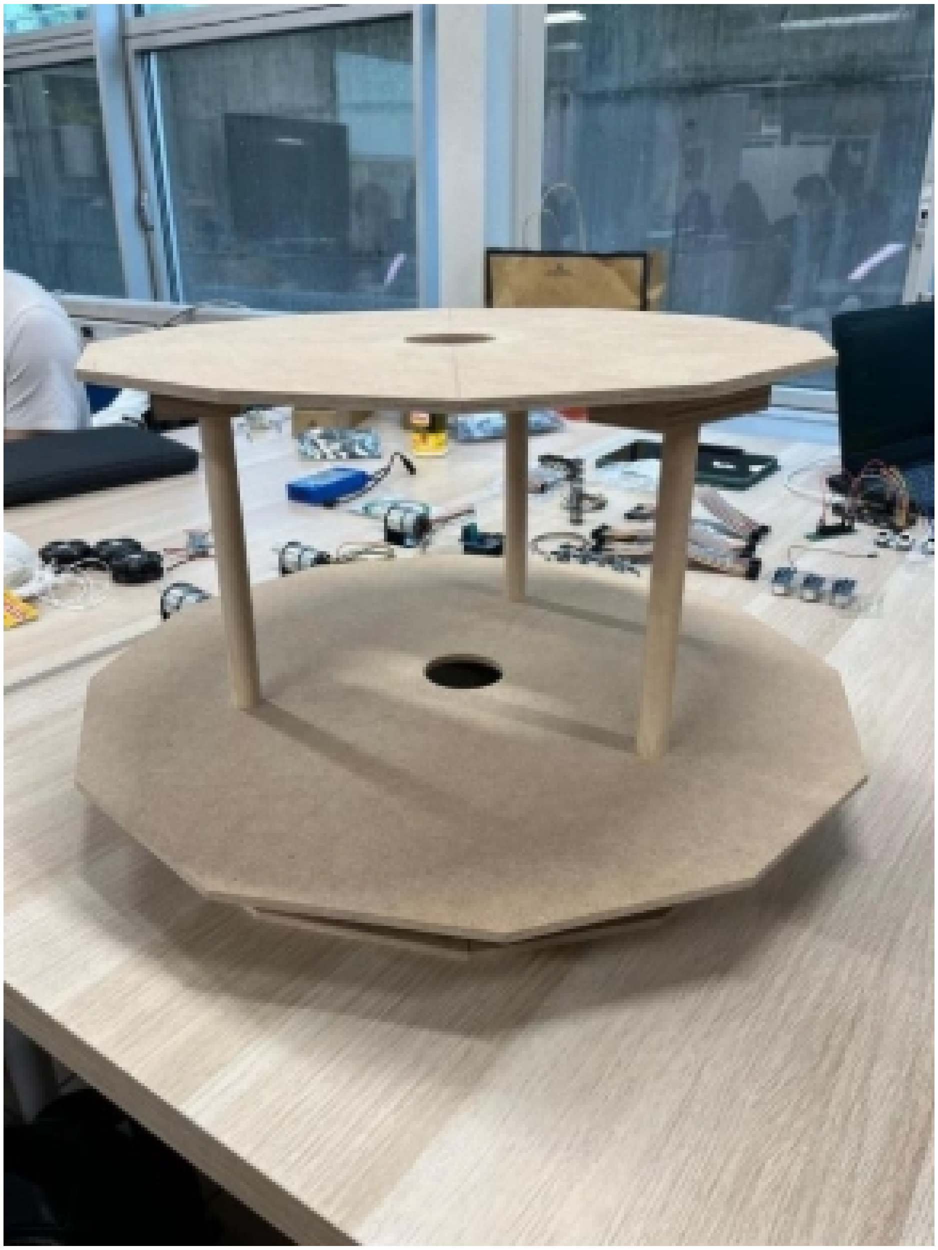

Figure 31: Final Mechanical Structure

All mechanical parts were fabricated using MDF panels and wooden supports, based on our technical drawings and 3D model. The final structure provides a **stable, modular, and compact skeleton** for the movement module, optimized for both functionality and future adaptability.

4.4.1 Movement System

The triangular configuration of the three omnidirectional wheels provides several key advantages:

- **Holonomic movement**: The robot can move in any direction and rotate in place without needing to change orientation first
- **Simplified control**: With three wheels at 120° intervals, the inverse kinematics calculations become more straightforward

- **Mechanical stability**: The weight distribution across three points provides good balance while minimizing the number of components
- **Improved maneuverability**: The design allows for efficient navigation in tight spaces, crucial for the robot's intended environment

4.4.2 Structural Adaptations

During assembly and testing, we made several mechanical adaptations to optimize performance:

- **Removal of lower platform**: To increase wheel clearance and improve movement reliability
- **Addition of cotton padding**: For both aesthetic effect and to protect internal components
- **Reinforcement of column connections**: To ensure rigidity during rapid movements and direction changes
- **Redistribution of component weights**: For better balance and stability during rotation

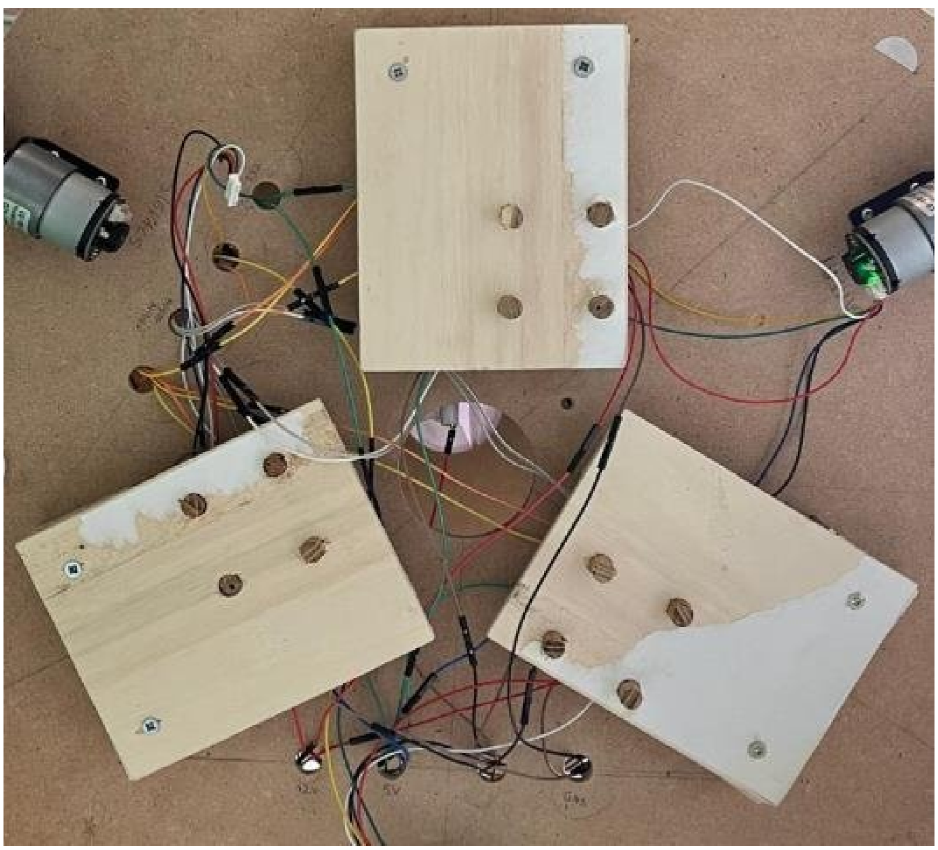

Figure 32: Final Structural Configuration

These mechanical features come together to create a reliable platform that successfully fulfills the movement requirements of our social robot design.

4.5 Electronics

The electronics of the movement module were designed to support omnidirectional movement and basic obstacle detection. Our approach was to keep the system modular, efficient, and easy to assemble, using well-documented components compatible with Arduino-based development.

4.5.1 Main Components and Setup

- **Microcontroller – ATmega328P**: Acts as the core of the movement module. It handles all the logic related to motor control, sensor reading, and decision-making. We used digital pins to interface with motor drivers and ultrasonic sensors.
- **DC Motors – JGB37-520 with encoders**: Three brushed DC motors are responsible for omnidirectional movement. Encoders are included for possible future use with closed-loop speed or distance control.
- **Motor Drivers – DRV8871**: Each motor is controlled through a dedicated DRV8871 H-bridge motor driver. These drivers are compact, reliable, and support the current required by the motors. Each driver is connected to the microcontroller via two control pins for speed and direction.
- **Omnidirectional Wheels – 58mm Nylon**: The wheels are attached to the motor shafts using 6mm aluminum hubs. These allow smooth and accurate multi-directional motion, essential for a patrol robot that must reposition itself easily.
- **Power Supply – LiPo battery with LM2596 regulator**: The circuit is powered by a LiPo battery. To provide consistent voltage to logic-level components and motor drivers, an LM2596 step-down regulator is used. It ensures the ATmega328P and sensors receive stable 5V output.
- **Obstacle Detection – HC-SR04 ultrasonic sensors**: Five ultrasonic sensors are distributed around the body of the robot to allow for basic obstacle detection. Each sensor is connected to a pair of digital pins on the ATmega328P, and they are intended to be triggered one at a time to avoid signal interference.
- **Wiring – Dupont cables and prototyping layout**: For prototyping, we used male-to-male and female-to-male Dupont jumper cables, enabling flexible reconfiguration and easy debugging during testing.
- **Camera module**: A compact camera module was added during the development phase to enable visual detection of the charging station via a QR code. This component provides the robot with basic computer vision capabilities, expanding its autonomy beyond obstacle-based navigation.

4.5.2 System Relationship Overview

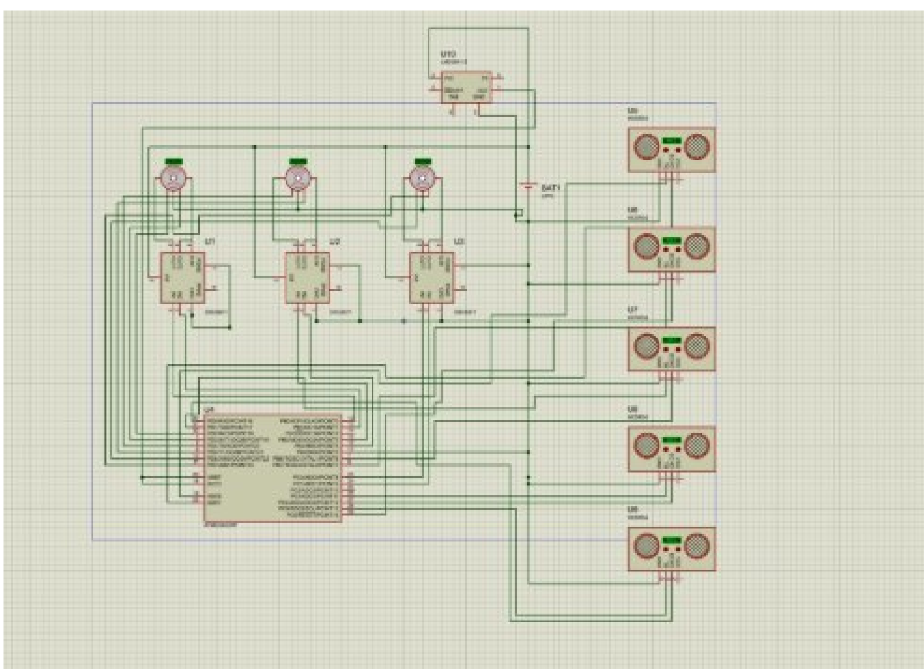

Figure 33: Electronics System Diagram

- The **ATmega328P** receives power from the regulated 5V supply.
- It sends PWM and direction signals to the **DRV8871 motor drivers**, which in turn control each of the **three motors**.
- The same microcontroller reads **ultrasonic distance values** from the HC-SR04 sensors.
- Based on sensor input and predefined logic, the microcontroller controls movement and reacts to obstacles through the actuation over the motors.

This configuration ensures the robot is capable of autonomous and reactive movement, with a clean base that allows for future integration of more advanced sensing and interaction features.

4.6 Informatics

The software architecture of the robot is designed around a modular, state-driven approach that enables clear separation of concerns while maintaining flexibility for future expansion. The core of the system is organized as a comprehensive control class that manages different operating modes and behaviors.

4.6.1 Architecture

Our final implementation follows an object-oriented design with a main `RobotController` class that encapsulates:

- **Operation modes**: Manual control, autonomous navigation, tag following, and charging modes that can be dynamically switched via commands
- **Sensor management**: Centralizing the reading and processing of ultrasonic sensors, encoders, and camera input
- **Motion control**: Implementing the omnidirectional movement algorithms, with functions for moving in any direction and orientation
- **State machine**: Handling transitions between different behaviors based on environmental conditions and user commands

The controller runs at a fixed update frequency of 20Hz, ensuring consistent response times while balancing processing requirements.

4.6.2 Key Software Features

- **Obstacle avoidance**: The robot dynamically adjusts its path when sensors detect obstacles, selecting the best direction to navigate around them
- **AprilTag detection**: Using camera input, the robot can identify and track special visual markers for navigation and charging station docking
- **Serial interface**: A simple text-based protocol allows external control and monitoring through standard serial communication
- **Sensor fusion**: Basic algorithms combine encoder and sensor data to maintain a more accurate position estimate during movement
- **Emergency stop**: Safety features that can immediately halt all operations if unexpected conditions are detected

The code is structured to maintain readability and maintainability, with clear function naming and organization. This approach facilitates both understanding of the current implementation and future extensions as new features are added to the robot.

5 Conclusion

Throughout this project, we gained valuable hands-on experience in building a functional robotic system from the ground up. One of the most important lessons was the need to balance ambition with time management. Although we had a clear concept early on, the time constraints forced us to make adjustments and prioritize essential features. This highlighted the importance of starting integration early and making incremental progress rather than deferring complex tasks until the final stages.
We also learned the value of clear and constant communication within the team. Coordinating tasks, sharing updates, and adapting plans based on each member's progress made the difference between individual work and collaborative engineering. Dividing the workload logically (mechanics, electronics, code) helped us move forward efficiently, but it was equally important to stay synchronized.
Movement control also presented technical challenges. While omnidirectional movement offered great flexibility, it also introduced some complexities, particularly during initial testing and mechanical adjustments. We had to iterate several times to achieve reliable, smooth motion.

5.1 Achievements

The movement module successfully met our primary requirements:

- **Omnidirectional mobility**: The three-wheel configuration with omnidirectional wheels allows the robot to move in any direction from any position, facilitating dynamic navigation in crowded spaces.
- **Basic obstacle detection**: The array of ultrasonic sensors provides adequate environmental awareness for autonomously avoiding collisions.
- **Modular design**: The final structure can easily integrate with other modules, thanks to its open architecture and clear electrical and mechanical interfaces.
- **Social presence**: The physical appearance successfully transforms a mechanical device into an engaging character that invites interaction.

5.2 Future Work

Several areas could be enhanced in future iterations:

- **Improved localization**: Adding more sophisticated sensors or algorithms for more accurate position tracking would enhance navigation precision.
- **Advanced obstacle avoidance**: Implementing predictive algorithms to anticipate obstacles and plan smoother paths around them.
- **Battery performance optimization**: Refining power management to extend operational time between charges.
- **Enhanced human-robot interaction**: Expanding the communication capabilities beyond physical movement to include audio or visual feedback.

Overall, the project successfully delivered a functional movement module that serves as both a technical platform and an engaging social robot, demonstrating the effective integration of engineering and design principles.

6 Appendix

6.1 Code Listings

6.1.1 Alpha Testing Script

Listing 1: Alpha Testing Script

```
class AlphaTest {
public:
    // Test modes
    enum TestMode {
        MOTOR_TEST,
        SENSOR_TEST,
        ENCODER_TEST,
        IMU_TEST,
        TAG_TEST
    };

    void runTest(TestMode mode) {
        switch(mode) {
            case MOTOR_TEST:
                testMotorSequence();
                break;
            case SENSOR_TEST:
                testSensors();
                break;
            case ENCODER_TEST:
                testEncoders();
                break;
            case IMU_TEST:
                testIMU();
                break;
            case TAG_TEST:
                testAprilTag();
                break;
        }
    }

private:
    void testMotorSequence() {
        // Test each motor individually
        Serial.println("Testing Front Motor");
        testSingleMotor(RPWM_RIGHT, LPWM_RIGHT);
        Serial.println("Testing Left Motor");
        testSingleMotor(RPWM_LEFT, LPWM_LEFT);
        Serial.println("Testing Back Motor");
        testSingleMotor(RPWM_BACK, LPWM_BACK);
        // Test combined movements
        // ... additional code ...
    }

    // ... additional test methods ...
};
```

6.1.2 Final Implementation Excerpt

Listing 2: Robot Controller Class

```
class RobotController {
public:
```

```
    enum OperationMode {
        MANUAL,
        AUTONOMOUS,
        TAG_FOLLOWING,
        CHARGING
    };

    RobotController() : currentMode(MANUAL) {
        setupHardware();
        calibrateSensors();
    }

    void run() {
        while(true) {
            updateSensors();
            processCommands();
            updateState();
            controlLoop();
            reportStatus();
            delay(50); // 20Hz update rate
        }
    }

private:
    OperationMode currentMode;
    bool emergencyStopped = false;
    unsigned long lastUpdate = 0;

    void setupHardware() {
        // Initialize all pins
        setupMotors();
        setupSensors();
        setupCommunication();
        Serial.println("Hardware initialization complete");
    }

    // ... additional methods ...
};

// Main program
RobotController robot;

void setup() {
    Serial.begin(115200);
    Wire.begin();
    robot = RobotController();
}

void loop() {
    robot.run();
}
```

6.2 Technical Drawings

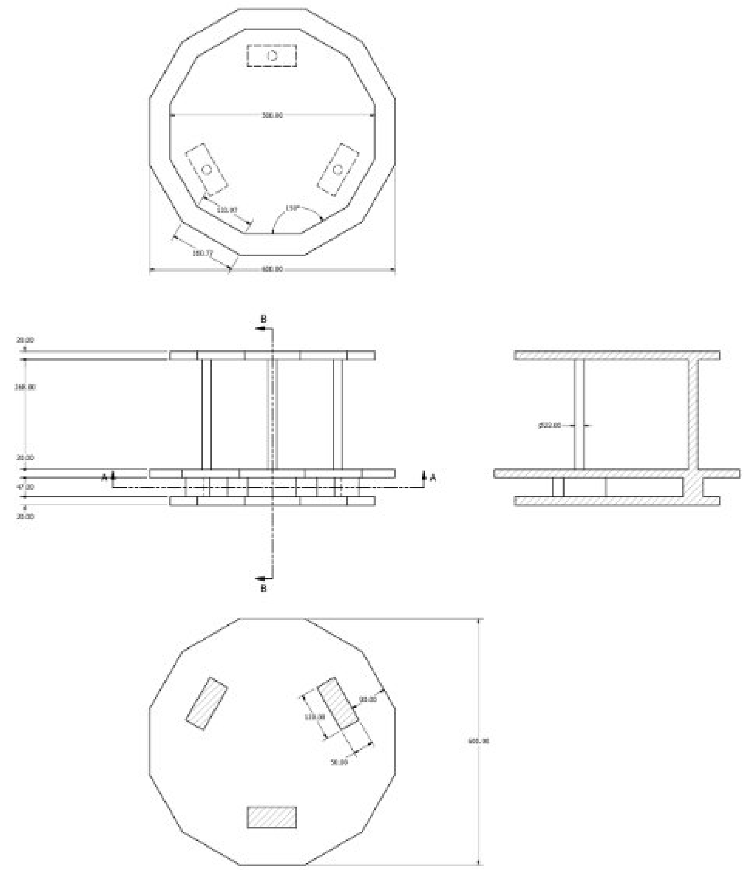

Figure 34: Structure Technical Drawings

6.3 Component List

- 3 × JGB37-520 12V DC Motors with encoders
- 3 × 58mm Omnidirectional wheels
- 3 × DRV8871 Motor drivers
- 1 × ATmega328P Microcontroller board
- 6 × HC-SR04 Ultrasonic distance sensors
- 1 × 11.1V 2200mAh LiPo battery
- 1 × LM2596 DC-DC Step-down power regulator
- 1 × Camera module
- Various wooden panels, supports, and fasteners
- LED strips for illumination
- Cotton padding and white fabric for aesthetic covering
- Transparent tube for ticket dispensing mechanism
- Decorative elements for the robot character

6.4 Testing Procedures

During development, we performed a series of standardized tests to validate the movement module's functionality:

1. **Motor calibration**: Testing each motor individually with varying PWM values to ensure consistent response and power consumption.
2. **Sensor validation**: Measuring detection ranges and accuracy of ultrasonic sensors at different distances and angles.
3. **Movement patterns**: Verifying basic movements (forward, backward, lateral, and rotational) followed by combined motions.
4. **Obstacle detection**: Running the robot in controlled environments with strategically placed obstacles to test avoidance behaviors.
5. **Battery endurance**: Measuring operational time under various movement patterns to estimate effective patrol duration.
6. **AprilTag detection**: Testing the reliability and range of visual marker recognition in different lighting conditions.

These tests were performed iteratively throughout development, with results informing subsequent design refinements and optimizations.

7 Minutes of the Meetings

7.1 Meeting: Project Kickoff

Date: March 10, 2025
Venue: Politecnico di Milano, Bovisa Campus, Building B12, Room 5.1
Attendees: Ermelinda Giulivo, Rafael Monllor Ballesteros, Daniel Mauricio Ruiz Suarez, Jurij Diego Scandola, Abdul Moiz
Topics Discussed:

- Introduction to project requirements and goals
- Team role assignments and responsibility distribution
- Initial brainstorming on robot concept and functionality
- Discussion of project timeline and key milestones

Decisions:

- Selected Jurij Diego Scandola as team leader and backbone member
- Assigned specific roles to each team member
- Agreed to focus on an omnidirectional movement system
- Established weekly meeting schedule for progress updates

7.2 Meeting: Design Phase Review

Date: March 17, 2025
Venue: Virtual Meeting (Video Conference)
Attendees: Ermelinda Giulivo, Rafael Monllor Ballesteros, Daniel Mauricio Ruiz Suarez, Jurij Diego Scandola, Abdul Moiz
Topics Discussed:

- Review of initial research findings
- Presentation and evaluation of different wheel configuration options
- Comparison of sensor technologies for obstacle detection
- Discussion of aesthetic concepts and physical form

Decisions:

- Selected three-wheel omnidirectional configuration
- Chose ultrasonic sensors as primary obstacle detection method
- Approved "cooking pot" aesthetic concept with cloud-like base
- Assigned team members to begin component procurement

7.3 Meeting: Development Phase Coordination

Date: April 7, 2025
Venue: Politecnico di Milano, Bovisa Campus, Prototyping Lab
Attendees: Ermelinda Giulivo, Rafael Monllor Ballesteros, Daniel Mauricio Ruiz Suarez, Jurij Diego Scandola, Abdul Moiz
Topics Discussed:

- Progress update on physical structure construction
- Review of electronics configuration and wiring plan
- Discussion of software architecture and control algorithms
- Timeline adjustment for remaining development tasks

Decisions:

- Modified structural design to remove intermediate platform
- Approved motor driver selection and power distribution approach
- Established coding standards and module interfaces
- Adjusted timeline to allow more time for integration testing

7.4 Meeting: Final Integration and Testing

Date: May 12, 2025
Venue: Politecnico di Milano, Bovisa Campus, Robotics Lab
Attendees: Ermelinda Giulivo, Rafael Monllor Ballesteros, Daniel Mauricio Ruiz Suarez, Jurij Diego Scandola, Abdul Moiz
Topics Discussed:

- Integration status of all subsystems

- Test results and performance metrics
- Remaining issues and troubleshooting
- Final presentation preparation

Decisions:

- Implemented additional stabilization code for smoother movement
- Added LED lighting effects to enhance visual appeal
- Assigned final documentation responsibilities
- Scheduled rehearsal for final presentation

7.5 Meeting: Project Wrap-up

Date: May 29, 2025
Venue: Virtual Meeting (Video Conference)
Attendees: Ermelinda Giulivo, Rafael Monllor Ballesteros, Daniel Mauricio Ruiz Suarez, Jurij Diego Scandola, Abdul Moiz
Topics Discussed:

- Final project status and demonstration readiness
- Report completion and review
- Lessons learned and project retrospective
- Future improvement possibilities

Decisions:

- Finalized demonstration script and responsibility assignments
- Approved final report for submission
- Agreed on project archiving process for documentation and code
- Discussed potential extensions for future project iterations

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