

Final Project Report

Team 3

Project Title:

Multipurpose Cart-robot Service

Course Name: Intelligent V2X Design[202301-ISE2234-001]

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**Executive Summary and Introduction.**

In this Final Project Report our team outlined the conceptual design for a Multipurpose cart-robot designed with an intention to be integrated with new apartment buildings. The motivation behind this project stems from the observation of individuals struggling to carry their shopping items from parking areas to their apartments within apartment buildings. Primarily, the project is objected to provide residents with convenient solution for transporting goods from their vehicles or local shops to their apartment doors, while also offering potential for local delivery services. The cart robot is designed to seamlessly integrate with the building infrastructure, taking into consideration factors such as mobility, safety, user experience, and the inclusion of a mobile app service. Our team is considering use of a range of advanced sensors, including front facing LiDAR for precise environment perception and obstacle detection. Linearly moving ultrasonic sensors on the sides enhance proximity sensing, enabling safe launch and navigation through corridors, and avoiding obstacles effectively. An additional ultrasonic sensor at the rear is meant to provide rearward detection, assisting in the safe maneuvering and backups. In addition to the sensor suite, our team planning to implement multiple cameras to the project. Two front-facing cameras, potentially depth-detecting ones, offer visual data for object recognition and depth perception, enhancing navigation and interaction with environment. A wide-angle camera position at the rear top is planned to provide situational awareness and aid in safe movement during reverse operations. Visual data from cameras also meant to serve as a black-box data as well. An LED monitor is designed to be fixed the rear sheet of the robot body providing interaction with users. We also want to equip our cart-robot with four tri-wheels designed carefully to ensure stability and maneuverability, even during stair navigation. This feature allows for easy transportation on roads that include stairs, and additional ability to move between floors of the building, complementing the integration with elevators as part of the overall user experience. In terms of our cart-robots design, we tried to incorporate it with features and dimensions similar to an average shopping cart, ensuring familiarity and ease of use.

To facilitate seamless integration with the local area and enhance user experience, our team is also considering a development of a mobile app. Services including convenient request of the cart-robot's assistance, specifying delivery details, and ability to track the progress of the deliveries in real-time are intended to be provided through our mobile application. Additionally, remote control, automated scheduling, and user feedback are the features we want to provide the residents through our app.

In terms of integration with the local area, the cart robot adheres to designated lines for bicycles and pedestrians. This ensures safe and efficient movement within the building premises, minimizing disruptions to pedestrian traffic and maximizing operational efficiency. We also want to implement SLAM technology, and inbuilt, yet constantly modified, local area and parking lot maps to our robot software allowing ease and safety of the navigation.

**Hardware Design**

**Mechanical Structure**

Our team wants to design our cart-robot with a sturdy and lightweight frame to ensure durability and ease of maneuverability. The is expected to be constructed using high-strength materials such as aluminum or steel to withstand heavy loads. We want to feature it with a spacious cargo area with adjustable dividers and securing mechanism to accommodate various sizes and types of goods. In the purpose of ease of movement and safety our robots base is lifted 20 cm above the ground, and the combination with tri-wheel configuration provides stability, flexibility, and efficient movement, allowing the robot to navigation through narrow spaces and traverse stairs.

**Power System**

The power source of our cart-robot is expected to be a system of 4 individual Brushless DC motors, one for each tri-wheel, and battery pack capable of power the whole system of the robot.

Our robot is expected to weigh about 50kg and be able to handle 50 kg payload and move at the of 2-3 m/s, which is a current normative for sidewalk delivery robots. This speed allows the robot to navigate safely among pedestrians and obstacles.

To get the sufficient moving force, we calculated that the rolling resistance of the cart robot in a fully loaded state is expected to be about 5kg assuming the rolling resistance coefficient is around 5%. Assuming that conservative acceleration value is 1 m/s2  acceleration force turns out to be 100N. Total force required is 100N+5N= 105N required is, and assuming the speed of our robot is 2m/s the total motor power needed is 210W, we also came into decision that 32V would be sufficient in our application.

Regarding the types of the motor, we chose brushless DC motor as they are typically more efficient and have longer lifespan compared to brushed motors. They offer higher power-to-weight ratios that make them suitable for applications with weight limitations. In our case we chose them for longer lifespan, better performance, higher efficiency, and requirement for less maintenance.

Choosing the battery, we assumed that our robot is expected to move about 2 kilometers, and assumed that the energy consumption per delivery is 400 watt-hours, including the power consumption of the motors, electronics, sensors, and other components during a typical delivery. We decided that our robot should be able to make 10 deliveries per charge, we get the total energy requirements per charge is 4000 watt-hours, adding a safety margin as 20% we get 4800 watt-hours. Converting it to the battery capacity we get 4800Wh/36V approximately 130 ampere-hours.

**Sensors**

The cart robot integrates various sensors to enable environment perception and obstacle detection. A front-facing LiDAR sensor provides precise distance measurements and generates a detailed map of the surrounding environment within 30 meters. Linearly moving ultrasonic sensors on the sides detect nearby obstacles and aid in safe navigation, it also mainly used to safe launch. An additional ultrasonic sensor at the rear assists in rearward detection and maneuvering. Ultrasonic sensors with a range of 2 meters were selected. We also want to equip our robot with GPS sensor, internal measurements units and wheel encoder sensors. These all sensors in combination with SLAM navigation technology provide autonomous control to our robot.

**Connectivity and Control**

The hardware design includes the integration of wireless communication modules, such as Wi-Fi and Bluetooth, to enable seamless connectivity with the mobile app service and Local Area Network. This allows us to collect data to local server or cloud, and send commands remotely to the robots. Residents can also interact with the robot, monitor its progress, and provide instructions through their smartphones. A Raspberry Pi 4 single-board computer was chosen as the central control unit to process sensor data, control motor operations, and facilitate communication between different components of the system.

**Integration**

During the project we mainly focused on Vehicle to Infrastructure integration. We also wanted to our project to get included during the designing process of the buildings and new local apartment areas, and area reconstructions processes as well. Our idea is using repeating patterns on road sides as key factor of localizing, such as the pedestrian-barriers, street lamps, street guiding fliers. These patterns can be used for distance, speed and even location measuring assistant tools. We also want to our robot to be able to access building elevator systems and be able to call it.

**Conclusion**

In summary, the designed cart robot offers a practical solution for goods transportation within apartment buildings and their local nearby area. By combining a well-designed mechanical structure, precise sensors, reliable SLAM navigation, and seamless integration with a mobile app service, the cart robot enhances efficiency, convenience, and safety in carrying goods from parking areas to residents' doors.