ECE 445

SENIOR DESIGN LABORATORY

PROJECT PROPOSAL

Project Proposal for ECE 445 Autonomous Transport Car

XUBIN SHEN (xubins3)
YIQI TAO (yiqitao2)
JINGYUAN MA (jm53)
HAOTIAN ZHANG (hz75)

Sponsor: Chushan Li

March 16, 2025

Contents

1 Introduction **1**

1.1 Problem ... 1

1.2 Solution ... 1

1.3 High-level Requirements List ... 2

2 Desigh **3**

2.1 Block Diagram ... 3

2.2 Subsystem Overview ... 3

2.2.1 Remote System ... 3

2.2.2 Grab System ... 4

2.2.3 Vehicle System ... 5

2.3 Subsystem Requirements ... 6

2.3.1 Remote System ... 6

2.3.2 Grab System ... 6

2.3.3 Car System ... 6

2.4 Risk Analysis ... 6

3 Ethics and Safety 7

3.1 Problems during the development of our project ... 7

3.2 Problems from the accidental or intentional misuse of my project ... 8

References **9**

1 Introduction

1.1 Problem

Nowadays, people have been getting used to shopping online. The express delivery and retrieval work for the goods purchased requires retrieval operations. The volume of express is always huge, wasting a large amount of manpower for the storage and retrieval of express delivery.

For customers who are finding their own express delivery at express stations, they need to search for their goods among the complex shelves with codes they receive. With this way of searching, express delivery stations are likely to be overcrowded, especially during some special days with more express in the stations. More importantly, mistakenly picking up packages may occur. In this case, staffs need to pay more efforts to deal with the mistakes.

1.2 Solution

For express delivery storage and retrieval work, we plan to use a robotic arm with a gripping function and a mobile car as the main body for transporting express delivery. A dedicated app is designed to send and receive information between small cars. After receiving the information to pick up the designated express delivery, the car will use RFID recognition to find the location of the goods that need to be picked up. After reaching this position, the mechanical arm carried on the car will use appropriate force to grab the goods, pick them up and drive back to the pickup area to put them down. Finally the car will send information back to the app.

1.3 High-level Requirements List

1. RFID chips and receivers can accurately identify the location of goods on specific shelves.
2. The car can strictly follow the route to the designated position and perform obstacle avoidance operations during the journey.
3. The robotic arm can grip the cargo with appropriate force, ensuring that it does not fall and does not damage the cargo

2 Design

2.1 Block Diagram

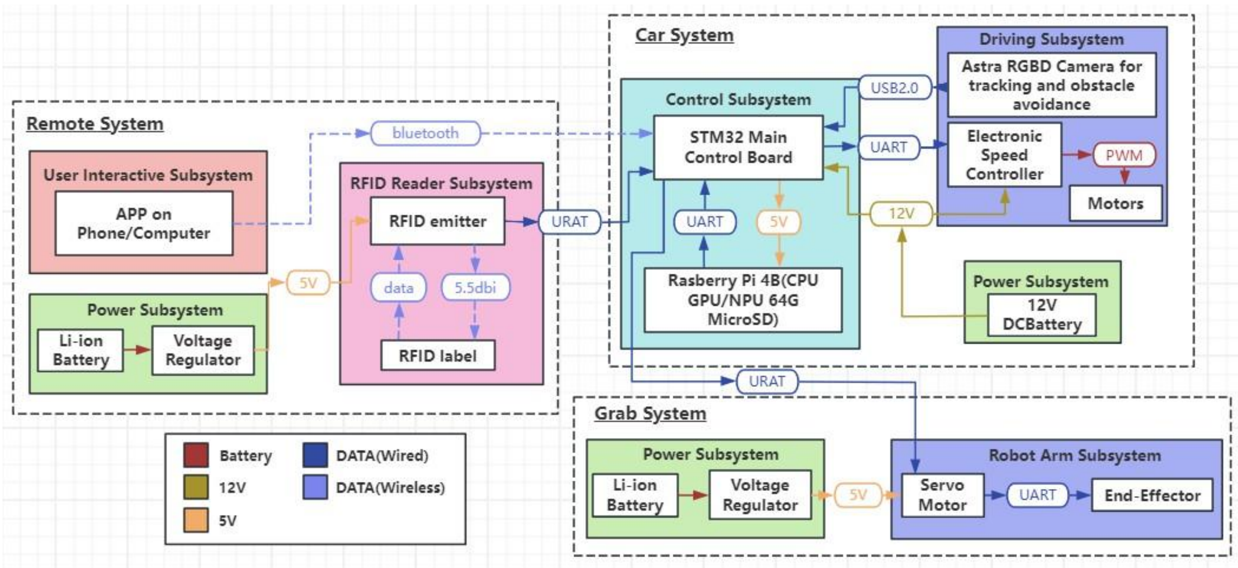

Figure 2: Block Diagram

2.2 Subsystem Overview

2.2.1 Remote System

The remote system consists of two subsystems: the user interface subsystem and the RFID reading and computer vision integration subsystem. The user interface subsystem (application) allows users to select the package they need to retrieve. After the user selects the package, the relevant information is transmitted to the RFID reading and computer vision integration subsystem. The RFID reader is a device which communicates with the tags on items. It sends radio wave signals and receives responses from the tags to determine the precise location of items on the shelves. The control subsystem then receives data from the RFID reader. The computer vision subsystem captures real-time images through a high-resolution camera. Subsequently, the control subsystem receives data from the RFID reader.

Operation Process:

1. The control subsystem on the vehicle communicates with the mobile application via a Bluetooth module.
2. When searching for items, the RFID module communicates with the control subsystem on the vehicle through a serial port. After the control subsystem sends the goods information to the RFID receiver, the RFID receiver starts working, searching for all tags. The tags contain goods information and shelf location information, which allows the RFID receiver to determine the location of the goods to be searched. After the computer vision subsystem analyzes and verifies the RFID data through the processing unit, it sends the information back to the control subsystem.
3. When storing items, update the RFID tag information on the goods after they are placed.

2.2.2 Handling System

The handling system mainly consists of two independent components: the end effector and the servo motor. The robotic arm is composed of four joints, each connecting a rigid arm segment to form a chain structure. The first joint controls the entire robotic arm and is driven by a servo motor installed at the base of the robotic arm, which can rotate the entire arm. The remaining joints control the arm segments and are driven by servo motors to rotate within a specific plane. Through the coordinated movement of these joints, the robotic arm can reach a designated position in three-dimensional space. The corresponding servo motor uses the ZP series, which can achieve precise angle control. The servo motor is controlled through a serial port and PWM.

Operation Process:

1. When the vehicle arrives at the designated shelf following the black line on the ground, the control subsystem receives data from the RFID reader.

2. It calculates the trajectory of the robotic arm and controls the end effector to grasp the required goods.

3. Throughout the process, the servo motors on each joint of the robotic arm support the movement, allowing each joint to rotate or move linearly in a three-dimensional coordinate system.

2.2.3 Vehicle System

The vehicle system consists of two independent subsystems: the control subsystem and the tracking subsystem. The control subsystem includes the STM32 control board and the Raspberry Pi control board, which coordinate the operations of various subsystems. The tracking subsystem covers path planning and obstacle avoidance functions, which are implemented through a depth camera. The path planning function navigates along the black line, while the obstacle avoidance function identifies objects in front through a visual camera.

Operation Process:

1. After receiving the destination command from the control subsystem, the tracking subsystem finds the optimal route based on the stored map.

2. The vehicle travels along the black line, and the visual obstacle avoidance system continuously detects whether there are any obstacles or other vehicles in front.

3. Upon reaching the designated location, the vehicle waits for the handling system to complete the grasping operation and then finds the optimal route again to return to the pick-up point.

2.3 Subsystem Requirements

2.3.1 Remote System

1.Must include a phone with our APP for user interaction.

2.Must be powered by a 12V 0-3A 5600mAh Lithium Battery.

3.Must use an AMS1117 5V Regulator.

4.Must include an RFID Read and Write Module for package identification.

5.Must use RFID Labels to store package information.

2.3.2 Grab System

1.Must include a 4-joint robotic arm for item manipulation.

2.Must be powered by a 12V 0-3A 5600mAh Lithium Battery.

3.Must use an AMS1117 5V Regulator.

4.Must be able to grab items of 200g.

5.Must be able to grab items at height of 0.5m.

2.3.3 Car System

1.Must include an STM32F407VET6 Main Control Board for coordination.

2.Must include a Raspberry Pi 4B (CPU GPU) for processing tasks.

3.Must be powered by a 12V 0-3A 5600mAh Lithium Battery.

4.Must use a 12V Regulator.

5.Must include an Astra RGBD Camera for pathfinding and obstacle detection.

6.Must use MG513 Motors for movement.

2.4 Risk Analysis

We think the RFID Reader Subsystem should be the most challenging part with the greatest difficulty in implementation. Because the RFID reader must accurately detect and differentiate between multiple RFID tags in a dense environment. But signal interference, read range limitations, and incorrect tag readings could disrupt the entire retrieval process. Good performance may be hard to achieve.

Acceptable Tolerances:

Read accuracy: ≥ 95% for successful tag identification.

Read range: 10-50 cm, to work in normal environment.

Response time: ≤ 500ms per tag to ensure efficient processing.

Relation to High-Level Requirements:

1.Must use seamless communication between the RFID reader and control system for item location.

2.Improve the efficiency and accuracy of the package retrieval process.

3.Ensure the reliability of the autonomous car system.

3 Ethics and Safety

3.1 Problems during the development of our project

1. There may be overpowering and burning out parts due to the inappropriate choice of car motor, so we should consider the suitable working power and speed of our car motor and then make the purchase.

2. There may be short circuit when connecting the driving circuit or the recognizing circuit, so we should design short-circuit protection circuits and regularly check and document progress.

3. Robotic arms should be designed and programmed to prioritize the safety of hu- mans and other living beings in their vicinity. This includes implementing safe- guards to prevent accidents, such as collision detection sensors, emergency stop buttons, and fail-safe

mechanisms.

4. If the ideal results of the experiments are hard to get, we should make sure that there's no plagiarism or fake and made up figures of the results, according to the IEEE code of ethics, "to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest and realistic in stating claims or esti- mates based on available data, and to credit properly the contributions of others."[1]

3.2 Problems from the accidental or intentional misuse of my project

1. If the car is upgrade to a bigger size and doesn't build a safe environment when using it in the factory to fetch large cargo, the car may run into people and cause injury. So safety fence can be erected around the shelf and the machine's path for movement.
2. When the machine malfunctions, people who are using it should give feedback in a timely manner and seek repairs.
3. People who operates the machine should be trained according to the IEEE code of ethics, "to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations."[1]

References

[1] IEEE. “”IEEE Code of Ethics”.” (2016), [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html (visited on 02/08/2020).