ECE 445

SENIOR DESIGN LABORATORY

PROJECT PROPOSAL

Project Proposal for ECE 445
Autonomous Transport Car

ZHIXIN CHEN (zhixinc3)
ZHUOZHENG HE (zh37)
XINYUE LU (xinyue15)
SIZE FENG (sizef2)

Sponsor: Chushan Li

March 6, 2024

Contents

1 Introduction

1.1 Problem

In today's society, online shopping is a major choice for the vast majority of people to make purchases. The express delivery and retrieval work after shopping currently requires manual retrieval operations. Due to the current huge volume of express delivery, the sorting center and express station require a large amount of manpower for the storage and retrieval of express delivery.

For customers who are looking for their own express delivery at express stations, today's express station design requires them to search for their goods on the complex shelves based on the information they receive. During shopping festivals such as Double Eleven, express delivery stations can become overcrowded, resulting in very low efficiency in searching for packages. More importantly, there are a large number of cases of mistakenly picking up packages at express delivery stations. In the face of this situation, it is now necessary for express station staff to monitor and find lost packages.

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. We have designed a dedicated app to send information on picking up goods to 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 a position where the goods can be picked up, the mechanical arm carried on the car will use appropriate force to grab the goods. Then he picked up the goods and drove to the pickup area to put them down.

1.3 Visual Aid

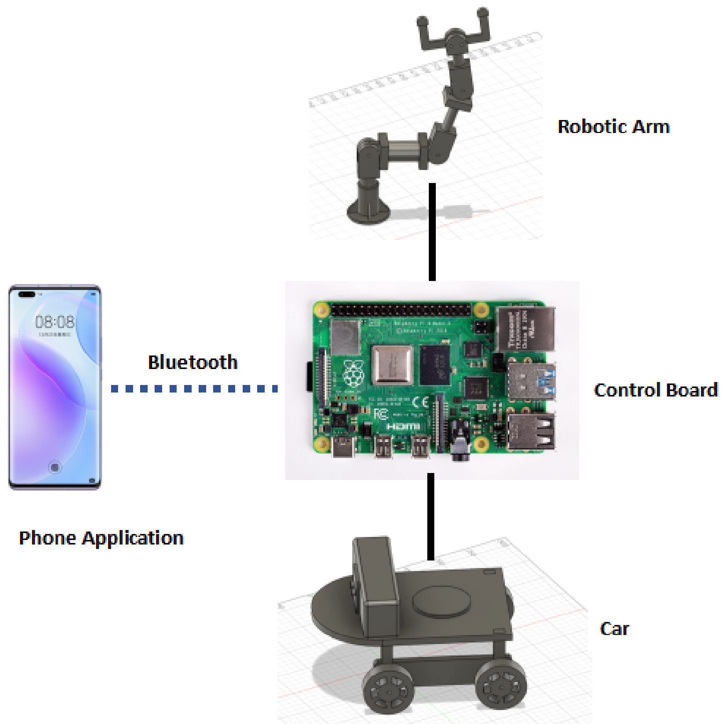

Figure 1: Enter Caption

1.4 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 Desigh

2.1 Block Diagram

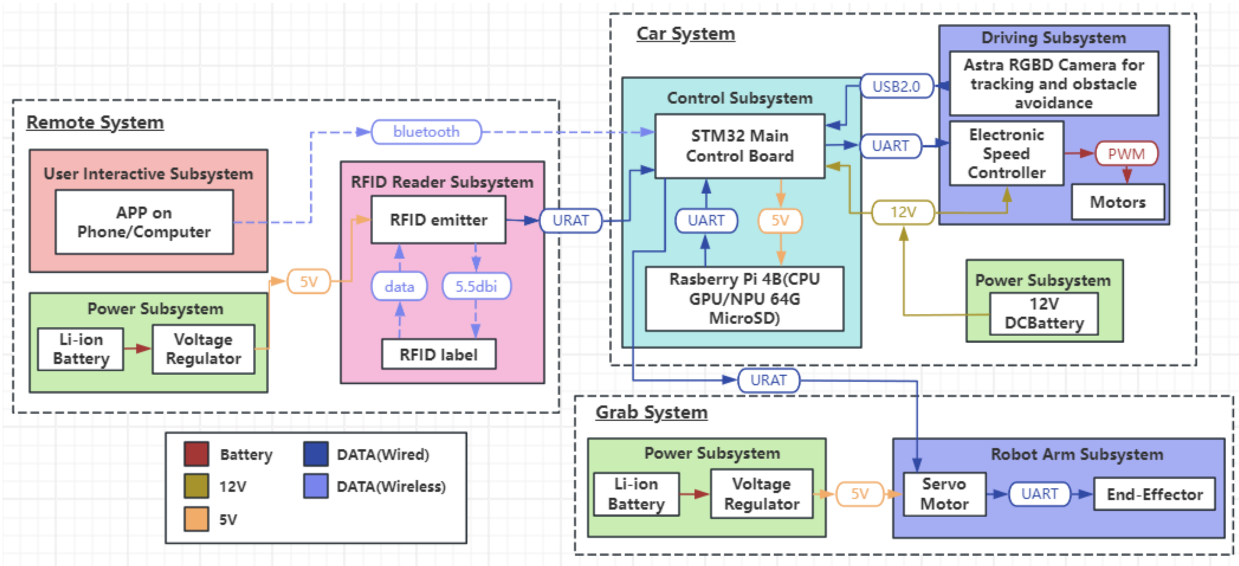

Figure 2: Block Diagram

2.2 Subsystem Overview

2.2.1 Remote System

The remote system consists of two subsystems: User Interface Subsystem and RFID reader Subsystem.

User Interface Subsystem: This is an app that provides users with the option to select the courier they need to pick up. After receiving the package selected by the user, the specific information will be transmitted to the RFID reader subsystem.

RFID reader subsystem: RFID reader is a device used to communicate with a tag on an item. RFID reader sends radio signals around and receives a response from the tag to determine the exact location of the good on the shelf. Then the control system receives the data from the RFID reader.

Operation Process:

The control subsystem mounted on the car communicates with a Bluetooth module and a mobile app.

For the operation of searching for items, the RFID module communicates with the control subsystem on the car through a serial port. After receiving the cargo information from the control subsystem. The RFID receiver starts working and will search for all tags. The label contains information about the goods and the location of the shelf. Therefore, the

RFID receiver can determine the location of the goods that need to be searched. Then pass it back to the control subsystem.

For the operation of storing items, after completing the placement of the goods, modify the RFID tag information carried by the goods.

2.2.2 Grab System

The Grab system mainly consists of two independent components: **end-effector**, **servo**.

The mechanical structure of a robotic arm consists of 4 joints, each of which is connected to an arm segment which is made of rigid material and forms in a chain-like structure.

For the first joint, it is used to control the whole robotic arm. This joint is driven by a servo located at the bottom of the robotic arm and used to rotate the whole arm. For the rest of the joints, they are used to control arm segments and driven by servos to rotate at the specific plane. To combined them together, the robotic arm will be able to reach to the exact location in three-dimensional space.

An end-effector is attached to the end of the robotic arm to perform the task of grabbing the good. To grab the good tightly, there are rubber bushings on the end-effector to increase the friction between the effector and the good.

For the servos, we use ZP series servos which can achieve precise angle control. The accuracy of the servo can reach 0.3 degree. The control method of servo is serial port and PWM.

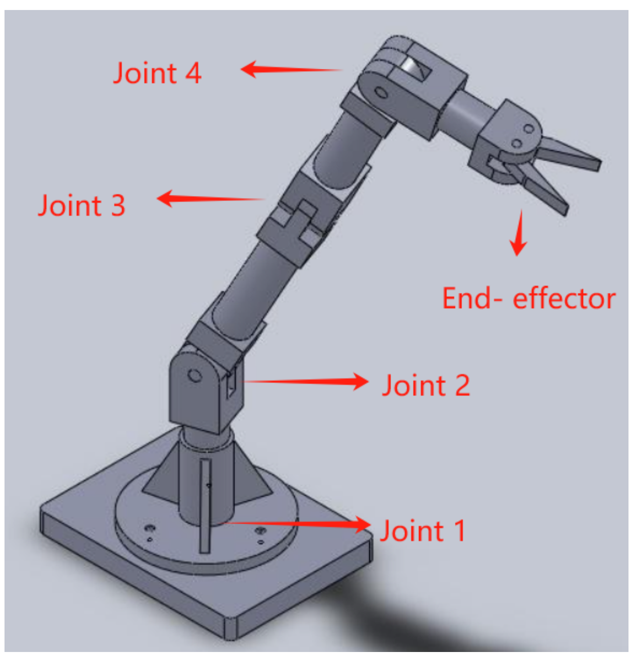

Figure 3: Robotic Arm

Operation Process:

When the cart reaches the shelf of the specified product according to the black line on the ground, the control system receives the data from the RFID reader, calculates the trajectory of the whole robot arm on the car and control the end-effector to grab the good we want. The whole process is supported by several servos located at every joint on the robot arm. Each joint on the robot arm can be rotated or moved in a straight line in 3D coordinate system.

2.2.3 Car System

The car system mainly consists of three independent subsystems: **control subsystem**, **tracking subsystem** and **obstacle avoidance subsystem**.

The control subsystem includes the STM32 control board and the Raspberry Pi control board, which are used for central scheduling of the work of various subsystems.

The pathfinding and obstacle avoidance functions are achieved by a depth camera, where the pathfinding function is achieved by the camera following the black line, and the obstacle avoidance function is achieved by the visual camera recognizing the object in front of it.

Operation Process:

After the car system receives destination instructions from the control system, the tracking subsystem will find the best route based on the stored map. The movement of the car will follow the black line. During walking, the visual obstacle avoidance system of the car will recognize whether there are obstacles or other cars ahead. After arriving at the designated location and waiting for the Grab system to complete the grabbing operation, the car will find the best route again and return to the pickup point.

Figure 4: Car

2.3 Subsystem Requirements

2.3.1 Remote System

- A phone with our APP
- 12V 0-3A 5600mAh Lithium Battery
- AMS1117 5V Regulator
- RFID Read and Write Module
- RFID Labels

2.3.2 Grab System

- 4 joint robotics arms
- 12V 0-3A 5600mAh Lithium Battery
- AMS1117 5V Regulator

2.3.3 Car System

- STM32F407VET6 Main Control Board
- Rasberry Pi 4B(CPU GPU/NPU 64G MicroSD)
- 12V 0-3A 5600mAh Lithium Battery
- 12V Regulator
- Astra RGBD Camera
- MG513 Motors

2.4 Tolerance Analysis

1. Considering the capacity of the battery, we need to calculate whether the lithium battery supports the car to complete the farthest gripping task. Furthermore, we need to calculate how many grabbing tasks the car can complete. To meet practical work needs. Here is our calculation.
    - Battery capacity: 5600mAh (but we assume 80% of it can be used)
    - Working power (both car and robot arm): 15W
    - Working voltage and current (both car and robot arm): 5V, 3A
    - Assumed one time fetching distance: 5m to the shelf and back, 10m in total
    - Moving velocity: 0.3m/s

- Ignore the RFID tolerance because RFID can last 30 days and won't be a bottleneck.
- Ignore the standby and fetching time by using 80% of the battery capacity.
- Ignore the effect of the weight of goods on the working power because they're small.

So, the calculated time the car can work without the standby time is:

$$\frac{(5.6 \times 3600A \cdot s) \times 80\% \cdot (5V)}{15W} = 5376\ s = 89.6\ min$$

And the number of times the cart can pick up the goods is:

$$\frac{5376\ s \times 0.3m/s}{10m} = 161\ times$$

Therefore, the selection of power supplies and components now meets our requirements.

2. It is necessary to consider whether the small car may overturn due to the weight of the goods during the process of grabbing and walking. After our modeling and testing, the robotic arm can stabilize its center of gravity in the plane of the car by adjusting its posture, so we believe that there will be no rollover.

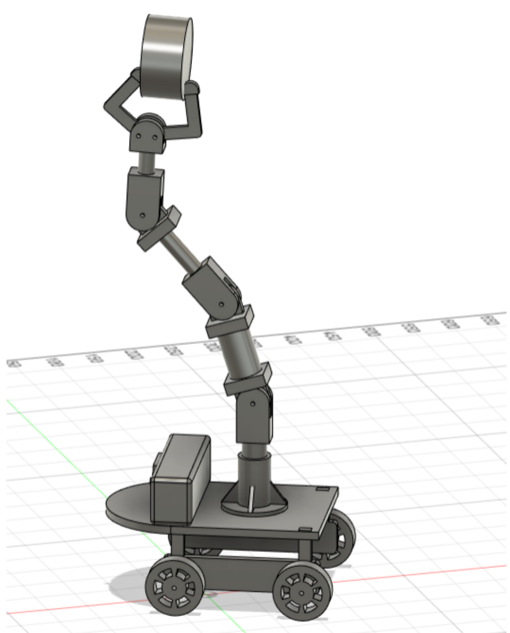

Figure 5: Car Model

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 humans and other living beings in their vicinity. This includes implementing safeguards 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 estimates 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).