BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

EEE 318 (January 2023)

Control System I Laboratory

Final Project Report

Section: B2 Group: 05

Autonomous Shopping Cart

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Academic Honesty Statement:

IMPORTANT! Please carefully read and sign the Academic Honesty Statement, below. Type the student ID and name, and put your signature. You will not receive credit for this project experiment unless this statement is signed in the presence of your lab instructor.

"In signing this statement, We hereby certify that the work on this project is our own and that we have not copied the work of any other students (past or present), and cited all relevant sources while completing this project. We understand that if we fail to honor this agreement, We will each receive a score of ZERO for this project and be subject to failure of this course."

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1 Abstract

The "Autonomous Shopping Cart " project presents the design and implementation of an autonomous shopping cart system capable of tracking and following a specified person within a retail environment. This project aims to enhance the shopping experience by eliminating the need for customers to physically push their carts, providing a hands-free shopping experience.

The project utilizes a combination of computer vision, robotics, and navigation technologies to achieve its objectives. A key component of the system is a vision sensor (Pixy2 camera) mounted on the shopping cart, which is responsible for detecting and tracking the specified person. The sensor captures real-time images and processes them to identify and follow the person based on predefined visual cues, such as unique clothing colours or markers.

The autonomous shopping cart is equipped with a motorized drive system that allows it to move in a controlled and safe manner. The cart's movement is controlled by an onboard microcontroller (Arduino uno), which communicates with the vision sensor and implements the necessary algorithms for person following. The system ensures that the cart maintains a safe distance from the person it is tracking and can navigate through obstacles within the store environment.

Overall, this project serves as a testament to the fusion of robotics and computer vision technologies in a real-world application, showcasing how smart systems can enhance everyday activities and provide innovative solutions to common challenges in the retail industry.

2 Introduction

The goal of this project is to build an autonomous shopping cart that will follow the specified person through the shopping mall. In order to achieve that, there are complexities we need to overcome. Firstly, we need to build a system that is capable of identifying and tracking colors from images. Secondly, we need a microcontroller that will serve as the decision-making device. This microcontroller will decide when to move, when to halt etc. Lastly, we need a motor driver that will control the speed and direction of the motor's rotation based on the decision that microcontroller provided.

3 Design

3.1 Problem Formulation

3.1.1 Identification of Scope

We intend to complete this project considering these several targets:

- Identifying a signature.
- Identifying the movement of the signature.
- Processing this data and driving the motor accordingly

3.1.2 Literature Review

Implementation of a CameraSensor Pixy 2 CMUcam5 toA Two Wheeled Robot to Follow Colored Object [1]

Pixy: a static analysis tool for detecting Web application vulnerabilities [3]

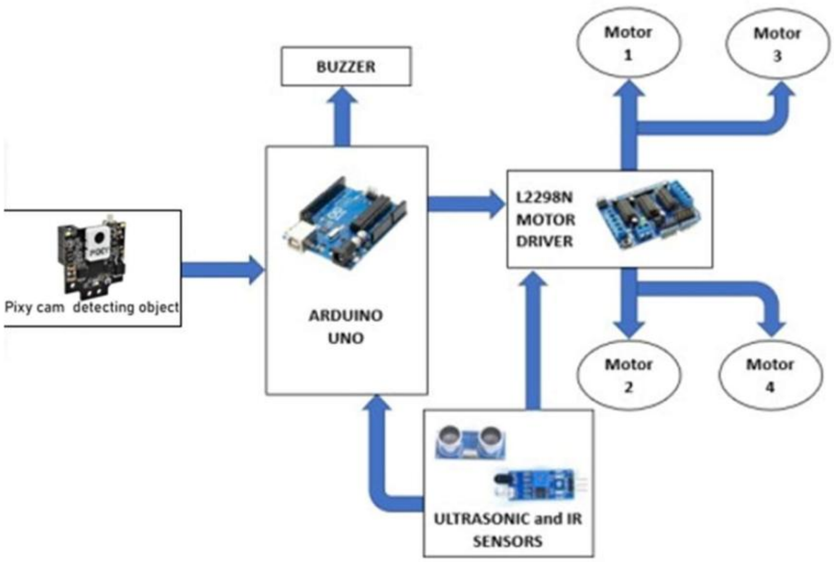
Colour tracking technique by using pixy CMUcam5 for wheelchair luggage follower [4]

3.1.3 Formulation of Problem

- Core Challenge: The project's central challenge is to create an autonomous shopping cart that can accurately identify and follow a designated person within a crowded retail environment.
- Navigation and Path Planning: The project's central challenge is to create an autonomous shopping cart that can accurately identify and follow a designated person within a crowded retail environment.
- Real Time Control: Implementing real-time control mechanisms to adjust the cart's movements based on the detected person's position and user settings is a technical challenge.

3.1.4 Analysis

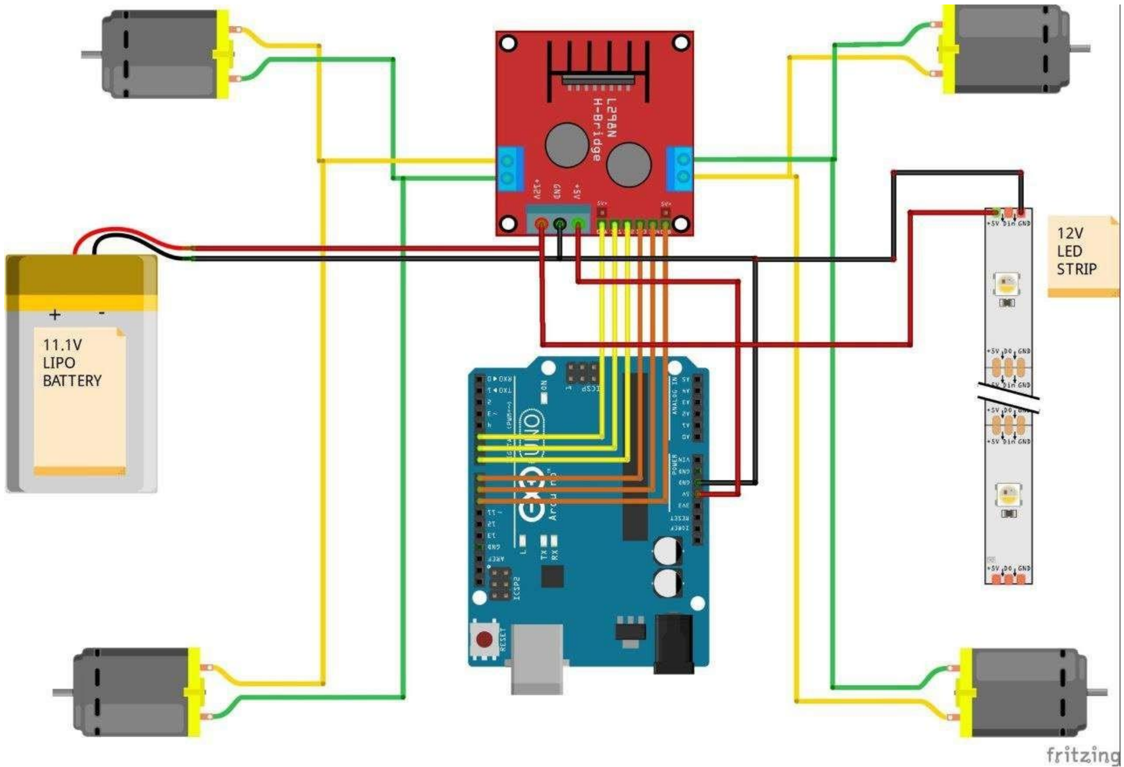
This block diagram explains the basic principle of our project:



3.2 Design Method

We employed the Pixy2 camera to recognize distinct color signatures, and this information was subsequently transmitted to an Arduino Uno Rev3 for processing, analysis, and decision-making. The Arduino Uno Rev3 then relayed instructions to an L298 dual motor controller, which was utilized to govern both the direction and speed of all four motors in our autonomous shopping cart system. Pixy cam takes color, height and weight of object.

3.3 Circuit Diagram



3.4 Full Source Code of Firmware

```
#include <SPI.h>
#include <Pixy2.h>
Pixy2 pixy;


//////////////////////////////////////////////////////////
// ENA IN1 IN2 IN3 IN4 ENB int myPins[6] =
{5, 6, 7, 8, 9, 10}; float deadZone = 0.15; //int
baseSpeed = 130;


//////////////////////////////////////////////////////////


int cont = 0;
int signature, x, y, width, height; float cx, cy, area;


void setup() {   Serial.begin(9600);
  Serial.print("Starting...n");   pixy.init();
  for (int i = 0; i < 6; i++) {     pinMode(myPins[i], OUTPUT);
  }
}
void loop() {
  float turn = pixyCheck();
  if ((-turn) > -deadZone && (-turn) < deadZone) {     turn = 0;
  }
  if ((-turn) < 0) {     moveRobot(-80, 170);
  }   else if ((-turn) > 0) {
moveRobot(170, -80);
  }   else {
    moveRobot(70, 70);
  }
  delay(1);
}
  float pixyCheck() {   static int
i = 0;   int j;   uint16_t blocks;
char buf[32];
pixy.ccc.getBlocks();
  int objectSignature, objectX, objectY, objectWidth, objectHeight;
  // Check if any objects are detected   if
(pixy.ccc.numBlocks) {
    // Iterate through all detected blocks
    for (int i = 0; i < pixy.ccc.numBlocks; i++) {
      // Get object information
       objectSignature = pixy.ccc.blocks[i].m_signature;        objectX =
pixy.ccc.blocks[i].m_x;        objectY = pixy.ccc.blocks[i].m_y;
objectWidth = pixy.ccc.blocks[i].m_width;        objectHeight =
pixy.ccc.blocks[i].m_height;
      // Process object information (e.g., control robot movement based on
detected object)       // ...
```

```
// Print object information to serial monitor
      Serial.print("Object Signature: ");
      Serial.print(objectSignature);
      Serial.print(", X: ");
      Serial.print(objectX);
      Serial.print(", Y: ");
      Serial.print(objectY);
      Serial.print(", Width: ");
      Serial.print(objectWidth);
      Serial.print(", Height: ");
      Serial.println(objectHeight);
    }
  delay(100); // Adjust the delay time as needed for your application
     x = objectX;     y = objectY;     width =
objectWidth;     height = objectHeight;     cx = (x +
(width / 2));     cy = (y + (height / 2));     cx =
mapfloat(cx, 0, 320, -1, 1);     cy = mapfloat(cy, 0,
200, 1, -1);     area = width * height;
   }   else {     cont += 1;     if
(cont == 100) {       cont = 0;
cx = 0;
    }   }
  return cx;
}
float mapfloat(long x, long in_min, long in_max, long out_min, long
out_max)
{
  return (float)(x - in_min) * (out_max - out_min) /
(float)(in_max - in_min) + out_min;
}



void moveRobot(int leftSpeed, int rightSpeed)
{
  if (leftSpeed >= 0) {
    digitalWrite(myPins[1], 1);//1     digitalWrite(myPins[2], 0);
  }   else {
    digitalWrite(myPins[1], 0);     digitalWrite(myPins[2], 1);
  }
  if (rightSpeed >= 0) {     digitalWrite(myPins[3], 1);
digitalWrite(myPins[4], 0);
  }   else {
    digitalWrite(myPins[3], 0);     digitalWrite(myPins[4], 1);
  }
  analogWrite(myPins[0], abs(leftSpeed));
analogWrite(myPins[5], abs(rightSpeed)); }
```


Table: Source Code for the main program

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4 Implementation

4.1 Description

Figure: Implementation of Design

4.2 Experiment and Data Collection

```
Object Signature: 1, X: 138, Y: 122, Width: 88, Height: 79
Object Signature: 1, X: 157, Y: 146, Width: 30, Height: 4
Object Signature: 1, X: 131, Y: 122, Width: 90, Height: 55
Object Signature: 1, X: 138, Y: 122, Width: 88, Height: 53
Object Signature: 1, X: 132, Y: 119, Width: 92, Height: 66
Object Signature: 1, X: 129, Y: 138, Width: 82, Height: 16
Object Signature: 1, X: 128, Y: 102, Width: 84, Height: 76
Object Signature: 1, X: 134, Y: 100, Width: 80, Height: 78
Object Signature: 1, X: 129, Y: 105, Width: 90, Height: 55
Object Signature: 1, X: 117, Y: 66, Width: 30, Height: 3
Object Signature: 1, X: 123, Y: 82, Width: 38, Height: 27
Object Signature: 1, X: 109, Y: 112, Width: 14, Height: 5
Object Signature: 1, X: 171, Y: 122, Width: 30, Height: 6
```

4.3 Data Analysis

Actual Distance(cm)	Pixy cam x axis	Pixy cam y axis	Width	Height	Normalized centre of x axis
31	212	136	80	130	0.575
44	202	134	50	90	0.57
56	180	120	48	60	0.275

86	166	104	34	49	0.0375
104	129	62	28	17	-0.19375

4.4 Results

Here as the x axis of the pixy cam changes, the normalized value of the x axis is changing accordingly. With this change in the normalized x axis our cart is detecting the left or right movement of the human leader and changing its direction accordingly.

5 Design Analysis and Evaluation

5.1 Novelty

The novelty of the "Autonomous Shopping Cart for Person-Following" project lies in its innovative approach to enhancing the retail shopping experience through the integration of advanced technology and robotics. Here are some key aspects of novelty in this project:

Enhancing the Shopping Experience: This project takes a fresh approach to revolutionize the retail shopping experience. Unlike traditional robotic systems, our autonomous shopping cart is designed to actively follow and assist individual shoppers as they navigate the store.

Customizable Shopping: What sets our project apart is the ability for shoppers to tailor their experience. Imagine being able to adjust the following distance, speed, and other settings of the cart, making it a personalized shopping companion.

Meeting Evolving Consumer Expectations: We recognize the changing expectations of today's consumers. Our project aligns perfectly with the desire for a more convenient, efficient, and engaging in-store shopping experience.

5.2 Design Considerations

5.2.1 Considerations to public health and safety

Safe following Distance:
We designed the system to maintain a safe following distance from the person it is tracking. This distance ensured that the shoppers have enough personal space and avoid any sense of discomfort or intrusion.
Accessibility:
We ensured that the autonomous cart is accessible to all customers including those with mobility challenges.

5.2.2 Considerations to environment

We optimized the cart's power consumption to extend battery life. We implemented standby mode to reduce energy consumption.

5.2.3 Considerations to cultural and societal needs

We designed the cart with features that can provide assistance to shoppers with special needs, such as those with disabilities, without drawing undue attention or causing discomfort.

5.3 Investigations

5.3.1 Literature Review

Implementation of a CameraSensor Pixy 2 CMUcam5 toA Two Wheeled Robot to Follow Colored Object [1]

Pixy: a static analysis tool for detecting Web application vulnerabilities [3]

Colour tracking technique by using pixy CMUcam5 for wheelchair luggage follower [4]

5.3.2 Experiment Design:

We designed the physical setup of the experiments, including the layout of the retail environment, the positioning of the autonomous shopping cart, and the placement of sensors and cameras.

5.3.3 Data Analysis and Interpretation

From the data we collected, we can reach conclusion that the cart follows the human leader fairly well. However, for sharp changes in direction it sometimes fails to follow.

5.4 Limitations of Tools

This autonomous shopping cart may fail to work correctly if it detects multiple objects with same signature. For example, let us consider the cart is following a person bearing a combination of green, red and blue color signature. If the camera detects another signature of the same color combination, it may not be able to follow the actual human leader anymore.
This designed shopping cart may not turn swiftly with the turn of human leader. A 360 wheel might solve this problem but we could not implement the idea within the time limit.

5.5 Impact Assessment

5.5.1 Assessment of Societal and Cultural Issues

This project has a lot of social impacts. Some of these are explained below-
Accessibility and Inclusivity: Autonomous shopping carts can enhance accessibility for individuals with mobility challenges, making it easier for them to navigate and shop independently in stores.

Convenience for Shoppers: These carts can provide added convenience to shoppers by reducing the physical effort required to push and maneuver a traditional shopping cart. This can be particularly beneficial for the elderly and individuals with physical disabilities.

Time Savings: Autonomous shopping carts can help shoppers save time by efficiently guiding them to the products they need, potentially reducing the time spent in stores.

Reduced Shopper Fatigue: Shoppers often experience fatigue when pushing heavy carts, especially during large grocery trips. Autonomous carts can alleviate this physical strain, making shopping less tiring.

5.5.2 Assessment of Health and Safety Issues

Offer clear instructions and support for shoppers who may be anxious about using autonomous carts. Ensure that the technology is user-friendly and intuitive to reduce stress.
Encourage shoppers to engage in physical activity outside of shopping, promote awareness of the importance of exercise, and design the shopping cart experience to encourage moderate movement.
Our designed project has an issue of colliding with other objects. Implementing robust sensor systems (e.g., lidar, ultrasonic sensors, cameras) and collision avoidance algorithms can detect and avoid collisions.

5.5.3 Assessment of Legal Issues

The entire project is fully compliant with all legal requirements and regulations. Our operations have no adverse impact on the environment, society, or any other factors that may raise concerns about the legality of our endeavor.

5.6 Sustainability and Environmental Impact Evaluation

Conducting a Sustainability and Environmental Impact Evaluation for the development and deployment of an Autonomous Shopping Cart for Person-Following is crucial. This evaluation includes a Life Cycle Assessment (LCA) covering all project stages, from raw materials to disposal, and assesses energy efficiency, sustainable material use, and carbon footprint. It considers energy sourcing, waste reduction, and transportation emissions while ensuring compliance with environmental regulations and implementing eco-friendly policies. Additionally, long-term environmental impact and community engagement are emphasized, with a focus on continuous improvement, aligning the project with sustainability and environmental responsibility principles.

5.7 Ethical Issues:

Safety Concerns:
Issue: Ensuring the safety of shoppers and store personnel is paramount. Malfunctions or accidents involving autonomous carts can have ethical implications.
Mitigation: Develop robust safety mechanisms, including emergency braking and collision avoidance, and conduct rigorous testing to minimize safety risks.
Inclusivity and Accessibility:
Issue: The system must be inclusive and accessible to all shoppers, including those with disabilities or special needs.
Mitigation: Design the cart with features that accommodate diverse needs and provide clear instructions for users.

6 Reflection on Individual and Team work

6.1 Individual Contribution of Each Member

Building the robot structure and assembling the robot from scratch.	1906124,1906121,1906117
Implementing code, testing and debugging	1906125,1906122,1906123

6.2 Mode of Teamwork

In this project, we have undertaken a collaborative approach to our work. The mode of operation is division of labor.

6.3 Diversity Statement of Team

We have placed significant emphasis on fostering an inclusive environment where each team member is not only valued and respected but also empowered to contribute their distinctive perspectives and insights.

6.4 Log Book of Project Implementation

Date	Milestone achieved
Week 3	Planning
Week 7	Buying hardware and Implementation
Week 10	Assembling and testing
Week 11	Programming and implementing
Week 13	Finalizing and completion

7 Communication

7.1 Executive Summary

In this project we designed and implemented an autonomous shopping cart system that will follow a specified person. We can divide the whole project in three sections. First there is a pixy2 camera that will identify the color and track it. Second, the decision-making device for which we used Arduino uno Rev3. And last there is a L298H dual motor driver controller that controls the speed and direction of rotations of the four DC motors.

7.2 User Manual

To operate the shopping cart first we need to set a specific color signature. This color can be the specific color combination that the person is bearing which will be unique for every person. Open pixymon 2 app in PC and set the color as signature and that’s all. The cart will now follow the person throughout the shopping mall.

8 Project Management and Cost Analysis:

8.1 Bill of Materials:

Component’s Name	Price
Arduino Uno Rev 3	1050
Cart Chassis with motor	1140
L298N dual motor driver	200
Pixy cam 2	12000
Cables and connection	500
Additional Components	110
Total	15000

9 Future Work:

Further development can be done for the more ease of use. We are planning to implement a feature that provides shoppers with real time information for different goods as they select items. We are also planning to add a feature for the blind or visually impaired shoppers. This could include a voice-guided interface that provides information about the store layout, product locations, and aisle identification. Once price information is integrated and the shopping cart can identify selected items, we will consider implementing an automated billing mechanism. This could involve linking the cart to shoppers' payment methods, enabling seamless checkout without the need to visit a traditional cashier or selfcheckout station. We also want to extend language support to cater to diverse customer demographics. Implement multilingual interfaces, voice commands, and product information displays. If we can successfully implement that then we can further development the automated billing mechanism.

10 References

[1] https://journal.umy.ac.id/index.php/jrc/article/view/10110/6000

[2] https://www.eneuro.org/content/4/1/ENEURO.0245-16.2017.full

[3] https://ieeexplore.ieee.org/abstract/document/1624016?fbclid=IwAR3YB33WalCtOeZH8H vLXX76UHb6WvLeX3fmgLv2kARV7CYRvneeixub1CI

[4] https://ieeexplore.ieee.org/abstract/document/8284402?fbclid=IwAR31DFpvfOd9PQGsYYsukpQVWOJWBKhfobG6eqQUwIeDbAofD4wrP3lqXF0