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**College of Information Technology and Computer Engineering**  
**Department of Computer Systems Engineering**

**Project Name:**

**Smart shopping cart for people with disabilities or limited mobility**

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## **Abstract**

Today, robots are used in a number of fields and places, including factories, homes, airports, offices, and shopping malls. In this project, we will develop a prototype of an automated shopping cart that can track customers and avoid obstacles at the same time.

The methodology we are going to use includes C++ as a programming language and Arduino microcontroller, in addition to ultrasonic sensors, a pixy camera, and motors to control the movement of the robot.

This robot is expected to identify a consumer, track his movement, and avoid obstacles during the shopping process. As a prototype, the cart was attached to four wheels with a motor driver, add to use the ultrasonic sensor and pixy camera to assist in tracking and avoiding obstacles.

This project aims to support people with special needs to integrate into society and enjoy shopping ,while providing convenience, service, and safety to the customer.

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## Chapter 1: Introduction

### 1.1 Overview of the project

As one of the activities people do frequently and spend time doing, shopping isn't the easiest process. It takes a lot of time and effort, so it may be a strenuous and uncomfortable experience, especially for people with disabilities and those who have limited mobility who are unable to complete the activities that ordinary citizens perform.

Due to this, shopping, and especially pushing the shopping cart containing heavy goods is a difficult task for them, as they don't have the strength or ability to accomplish the shopping process, carry their purchases, and roam the markets comfortably for long periods of time.

### 1.2 Motivation

Currently, the world is moving towards integrating robots into our daily lives and making them an independent entity that contributes to human societies in various fields.

Furthermore, we wish to use robots to help people with limited mobility perform shopping tasks by themselves, without relying on others, and give them the ability to enjoy shopping as a way of integrating them into society as normal customers.

### **1.3 Importance**

Since robots are used in many scientific, industrial, and entertainment fields, we will have a smart shopping cart that will help people with disabilities to make their day-to-day lives easier and reduce their burdens. Furthermore, we will be able to help other groups of society such as mothers and the elderly to shop with their children conveniently and easily.

## 1.4 Requirements

Our project aims to develop a smart shopping cart that can be operated automatically and provides various benefits to people with limited mobility, including:

1. Allows easy movement throughout the market by allowing the cart to follow the customer throughout the entire shopping process.
2. Providing a comfortable and safe shopping experience.
3. Integration of people with disabilities into society and making shopping process enjoyable and easy.

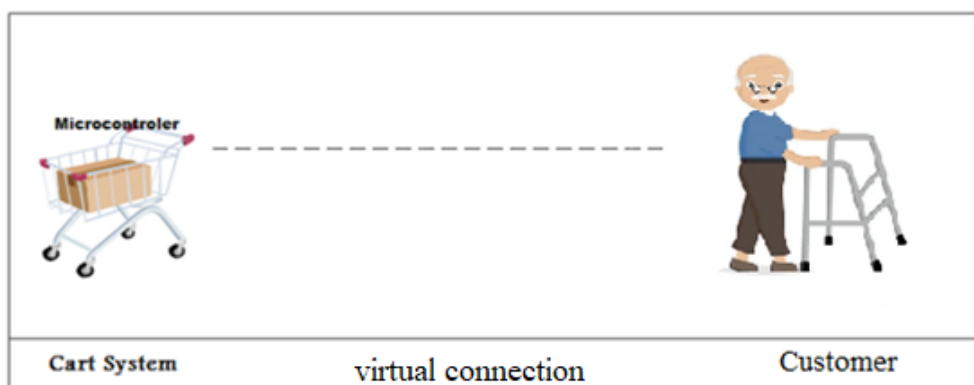
## 1.5 Problem Statement

There are many disabilities and limitations in mobility that contribute to difficulties faced by people with disabilities and those with limited mobility when going shopping.

Here, we are talking about people with disabilities who cannot do normal daily tasks like grocery shopping. When one goes shopping, he must push a shopping cart, which is a challenge for a certain class of customers, as they lack the ability or power to move it freely.

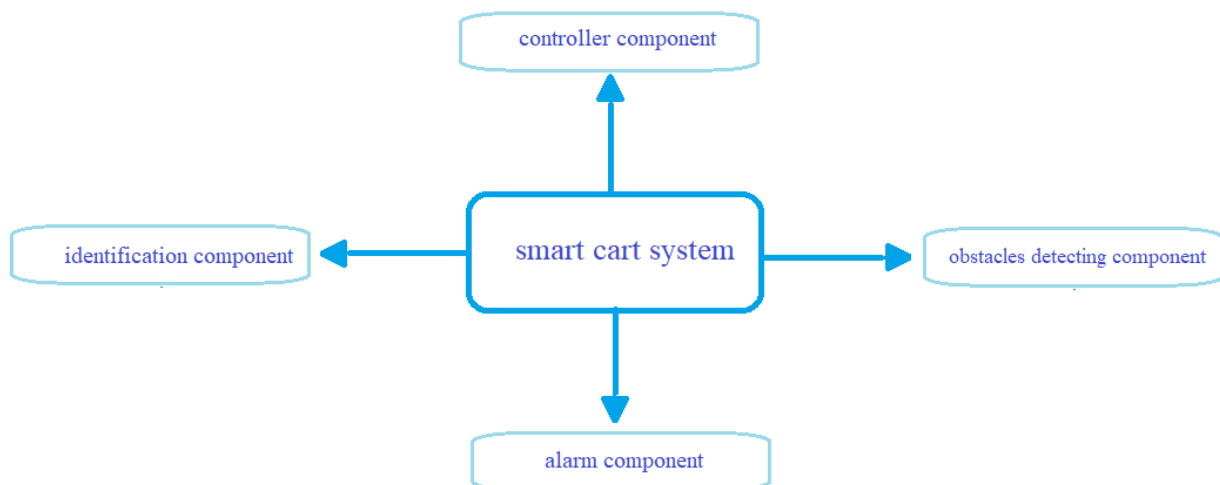
## 1.6 Short description of the system

As an overview of the two basic components of our cart system, Figure 1.1 shows the external environment of the smart shopping cart system. The first component is the smart shopping cart, which carries the goods of the customer, followed by the second component, the goal customer, which can communicate with each other.





The following Figure 1.2 shows the main components that make up the system. The controller part is a microcontroller like a Raspberry Pi or an Arduino that controls and directs the system for navigation, obstacles and exploring the roads. The detecting operation uses ultrasound, Bluetooth technology, RFID(Radio-frequency Identification), or an IR(Infrared radiation) sensor for guiding the robot. Identification involves checking the user's identity and following up his movements using Ultrasonic technology or a camera depending on the image processing technique for identifying the user. The alarm function gives a warning in the case of malfunction of the system, such as if the cart becomes stuck or cannot move.



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## 1.7 Objectives

The implementation of this project in a real system would require high-power driving controllers and motors to support heavyweights Furthermore, this requires enormous efforts to

develop these devices and that costs a lot, so we as students decide to come up with a prototype that achieves our project objectives and reduces the costs incurred.

As a result, we aim to design a smart system that includes:

1. The prototype cart has four wheels, so it can move easily.
2. An integrated control system monitors the power, synchronizes the wheels with the power and steers them with a simple microcontroller and motor driver.
3. The model needs a low power supply to move.
4. Detects and tracks users within a particular band with a pixy camera.
5. Detection of obstacles with an ultrasonic sensor.

## **Chapter 2: Background**

### **2.1 Overview**

This chapter introduces a theoretical background of the project, and description the hardware components and techniques we are going to use on building the system.

### **2.2 Theoretical Background**

This section will provide some information about some of the technologies used in the project. Specially:

#### **2.2.1 Sensors**

A sensor is " a device that detects and responds to some type of inputs from the physical surrounding environment. Input such light, heat, motion, obstacles, moisture, ...etc." ,the output is generally a signal that is converted to a human-readable form.<sup>[1]</sup>

#### **2.2.2 Arduino microcontroller**

The microcontroller is an integrated circuit (IC) or chip used to accept conditioned inputs from sensors, process the input, then process the required output.

An Arduino microcontroller is based on the open-source hardware/software programming platform named Arduino which is based on the Atmel microcontrollers. it's free to be used and modified by the people.

The Arduino microcontroller can be told what to do by connecting it to a PC with the help of a USB cable and then using the Arduino IDE to write the required code. This code can then be exported to the Arduino board and run.<sup>[2]</sup>

#### **2.2.3 Ultrasound frequency & Ultrasonic modules**

The ultrasonic sensor used in this project is HC-SR04, it uses sonar to determine the distance of an object, this sensor can detect an obtained object from 2 cm to 400 cm in 30c degrees, its sensitivity can be up to 3mm.<sup>[3]</sup>

The ultrasonic modules detect the distance to an object by sending out a short burst of ultrasonic sound and then listen for the echo of it, by measuring the time it takes for the sound to return to the sensor the module can determine how far away an object is.<sup>[4]</sup>

In each module, the left eye serves as a speaker and transmits the signal, while the right eye serves as a microphone and listens for the return signal. Each module has four pins. There is a ground pin, a voltage pin, a trigger input and an echo output pin, the module starts a measurement when the trigger pin receives a 5V pulse for at least 10  $\mu$ s.. The sensor then sends out a cycle of eight 40 kHz ultrasonic bursts and wait for any reflections to come back. When an ultrasonic burst is received back the echo pin is set to 5V and delays it for a period proportional to the distance the burst have travelled.

The distance to the object in front of the sensor can thus be calculated from the echo signal and the detect objects in a range utilizing the speed of sound .

## **2.2.4 Pixy (CMUcam) Camera**

It's a small camera designed for object recognition, line tracking, and simple barcode reading.<sup>[5]</sup>

### **2.2.4.1 Pixy's Vision as a Sensor**

Pixy Vision (image) sensors are useful because they are so flexible, the image sensor can sense or detect practically anything, so If you want your robot to perform a task such as picking up an object, chasing a ball, locating a charging station, etc. And you want a single sensor to help accomplish all of these tasks, then vision is your sensor.

Pixy processes images from the image sensor and only sends the useful information to your microcontroller. And it does this at frame rate (50 Hz). The information is available through one of several interfaces: UART serial, SPI, I2C, USB, or digital/analog output. So your Arduino or other microcontroller can talk easily with Pixy and still have plenty of CPU available for other tasks.<sup>[6]</sup>

### **2.2.4.2 Pixy's filtering algorithm**

An image sensor is a pixel array, or color filter mosaic, which is a mosaic of tiny color filters over the pixel sensors to pick up color information, the color filters filter the light by wavelength range, such that the separate filtered intensities include information about the color of light. For example, it gives information about the intensity of light in red, green, and blue (RGB) wavelength regions, then converted to a full-color image (with intensities of all three primary colors represented at each pixel) by a demosaicing algorithm which is tailored for each type of color filter.<sup>[7]</sup>

## **2.3 Literature Review**

Nowadays, in many applications robots track and follow a person; a person-tracking mobile robot is an innovative mobile robot, which is able to Perform person-following and obstacle avoidance tasks simultaneously, by using an innovative RF/ultrasonic sensor system, an intelligent person-tracking mobile robot is to be implemented that is able to follow the target person in unstructured, practical environments.

There are lots of studies and projects that handle and implement the tracking technology, in both level locality and internationality .Here we are going to talk about some of those robots :

### **2.3.1 Previous project in Palestine Polytechnic University**

The previous project was based on the idea of a vehicle that moves on what the person chooses from the screen installed on the cart. Which shows the purchase list and then the cart moves towards the purchases based on the existing map, in addition to the function of adding purchases to the list and making sure of parts, and issuing an invoice. Both the barcode and NETWORK OF ZIGBEES technology were used.

Our project has different aims and will use different technology, which will be a tracking cart dependent basically on ultrasonic technology and a pixy camera, as we will explain later.

### 2.3.2 PERSON-TRACKING MOBILE ROBOT <sup>[8]</sup>

Person-tracking mobile robot as shown in (Figure 2.1). It is designed to follow a specific person while simultaneously implementing obstacle avoidance. The robot follows only the target person and regards all other objects as obstacles. It is a Nomad 200 mobile robot with an additional RF/ultrasonic positioning system. It has been adopted to implement person tracking. The Ultrasonic signals transmitted from several transmitters located on a specially made vest, which the target person wears as in (Figure 2.2). Two receivers located on the top of the robot receive the signals.

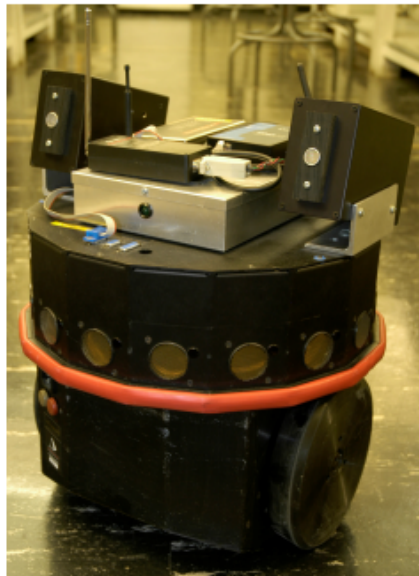


Figure 2. SEQ Figure\_2. \\* ARABIC 1:  
Person- Tracking Mobile Robot<sup>[8]</sup>



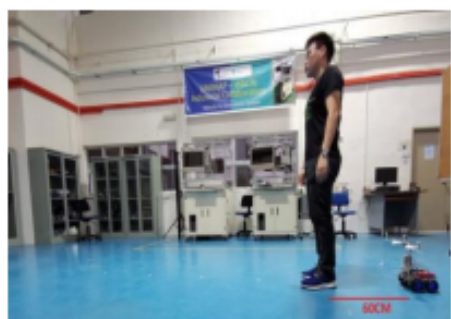
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Those signals processed to produce a part of the control inputs, which are in the form of distances and angles off the robot algorithm. A potential field algorithm used to implement person tracking, which uses the artificial potential field to regulate a robot around a certain space. Simplicity, consider a space divided into a grid of cells with obstacles and a goal node, to avoid obstacles and find the target.

### 2.3.3 Human following robot <sup>[9]</sup>

Human following robot system used the utilized ultrasonic sensor, which features with a wide detection area, less light dependency, the ability to detect glass and shining wall, smaller in size, lightweight, use a very low memory, cheaper than Laser Range Finder (LRF) or camera and lower power consumption.

The human following algorithm applied and integrated with four different conditions to follow the human's legs in a straight line. The robot has to check the human's legs in front of it, then first is for the forward action, second is for stop action, third is the standby mode and last is backward action, therefore it uses three pieces of ultrasonic sensors were used to perform tracking on the both human's legs as to show in Figure (2.3). The concept is that the sensors arranged horizontally with a specific distance, where this distance will be the average width of human legs when the human is walking normally.



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## 2.4 Design Options of Hardware Components

This section describes the main hardware components needed to construct our project, and it illustrates the function of each component.

### 2.4.1 Control system (Microcontroller)

We have two options to choose between for the board chip, Raspberry pi and Arduino. We compared them in Table 2.1, to decide the suitable one for our project.<sup>[10]</sup>

	Raspberry Pi 3	Arduino Mega 2560
System	Single Board Computer (SBC)	Micro-Controller based development board
based on	Broadcom SoC, an ARM Cortex A Series Microprocessor	Atmel Microcontrollers. Arduino UNO uses ATmega328P Microcontroller
operating system	based Linux Distribution called Raspberry Pi OS	there is no need for an operating system
cost	Expensive	Cheaper
Programming Languages	Python, Scratch, Ruby, C, C++	C or C++
Voltage	5V	7 - 12 V

Table2.1:Comparison between Raspberry and Arduino<sup>[10]</sup>



## Chosen Design Option: Arduino Mega 2560

As a result, we will use the Arduino Mega 2560 , since it is less expensive, and has an assortment of sensors and actuators such as motors. It is also easy to program with numerous tutorials, and can support a number of different programming languages.

### 2.4.2 Obstacle Detecting Component

Many distance measuring and obstacle detection sensors are available, but those two were known for their good performance, so we compared their performance in Table 2.2 , so we can choose between them.<sup>[11]</sup>

	HC-SR04 Ultrasonic Sensor	. IR Sensor
Working Method	Uses sound waves to measure the distance to the target by measuring the time between the emission and reception.	Uses Infrared light to determine whether or not an object is present.
Accuracy	Provide more reliable and accurate data	Less accurate
Range	2- 400 cm	10-80 cm
Interference	It is hard for it to be affected by sounds, It can only be affected by very high sounds	Can be easily affected by light intensity in the surrounding environment.
Cost	Expensive	Cheaper

Table2.2: Comparison between Ultrasonic sensors and IR sensors <sup>[11]</sup>

### Chosen Design Option: HC-SR04 Ultrasonic Sensors

According to the comparison shown, the ultrasonic sensor would be better to use for the tracking process, because it has a suitable range for this project and a decent field of view

angle. In addition, is more accurate and resistant to environment effects than the infra-red technologies which has a smaller field of view angles, and unsuitable for this application.

### 2.4.3 The identification Component

In the identification component, we compare two different camera types that can be used as shown in Table 2.3.<sup>[12][13]</sup>

	Pixy camera	Aluratek Portable USB Webcam
Microcontroller	Arduino Raspberry Pi, BeagleBone and similar controllers	Raspberry Pi
Image Capture Speed	50 frames per second.	30 frames per second.
Connectivity Technology	SPI, I2C, UART, USB or analog/digital output	USB
Programming language	supported C/C++ and Python	Python
Cost	Expensive	Cheaper

Table2.3: Comparison between Pixy camera and USB Webcam<sup>[12][13]</sup>

#### Chosen Design Option: Pixy camera

Using a Pixy camera as the electronic device to identify the objects ,since it has a fast vision sensor that can be quickly "taught" and can be connected directly to the Arduino, on top of that it is small and easy to use, which makes it perfect for the project.

#### **2.4.4 The alarm Component**

For the alarm system, we will use a buzzer, which is an audio signalling device, which can either be mechanical, electromechanical, or piezoelectric, which alerts the user when something goes wrong; it is an inexpensive and easy device to use.

#### **2.4.5 Motor control**

Four DC motors will be needed to drive the robot, and they will be controlled using the L298N DC Motor Driver. It is equally important to have enough power supply to make them move smoothly and turn accurately while maintaining their speed.

### **2.5 Software Component**

As a programming language, we will use the C++ language since it is simple, human-readable, and Arduino code is written using it, when you write a 'sketch' (the name given to Arduino code files), it is processed and compiled to machine code.

## Chapter 3: Design

### 3.1 Overview

This chapter illustrates the detailed design of the system; it also shows a block diagram of its components and the flow chart of the system.

### 3.2 Brief Description of the System

A smart shopping cart is designed to help people, specifically people with special needs, to have a smooth and easy shopping process. The robot is designed to walk on flat surfaces. If the height of the surface changes, the robot stops. Then it changes direction if there are no obstacles in its way. It does not need to handle large obstacles, but it should be able to follow small things. Figure 3.1 shows the features of the project.

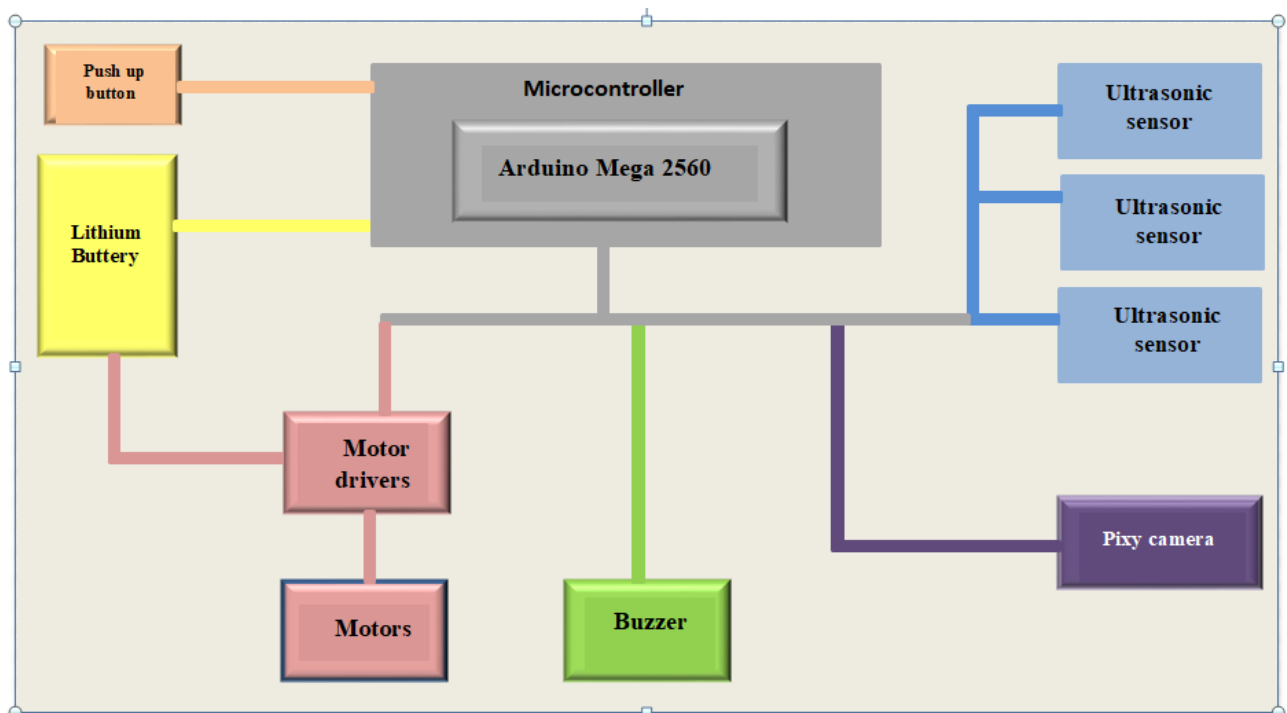


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Essentially, the system consists of ultrasonic sensors and embedded microcontrollers. which measures how far the cart is from the obstacle while the pixy camera recognizes the customer's identity and follows its movements throughout the shopping process. Finally, the motor driver is used to position the robot in the direction that the customer is in. In addition, the alarm device gives a warning when the robot cannot go nowhere, or when the customer is not visible.

### 3.3 System Diagram

The following section explains the general block diagram of the shopping cart system.

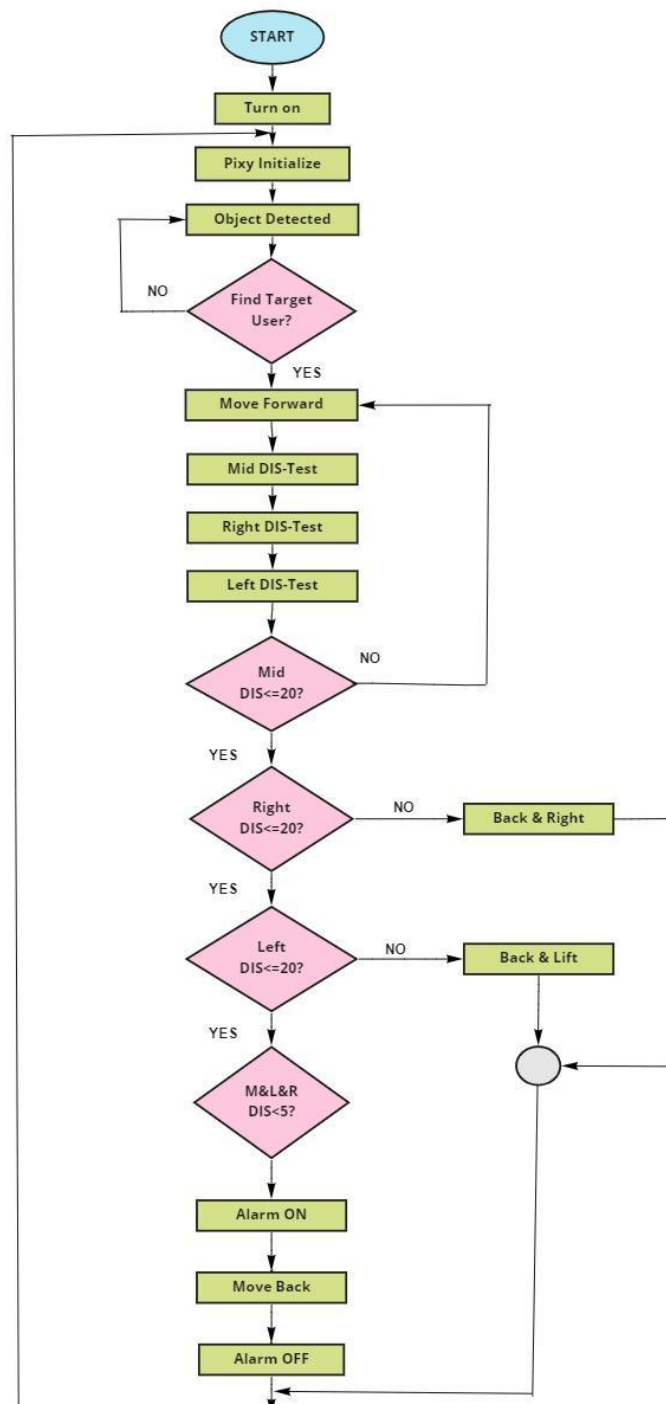


It is shown in figure 3.2 that the cart system operates with an Arduino mega 2560 as the microcontroller to control the whole system, connect the components, and organize everyone's work as one integrated system. The ultrasonic sensors are used to detect obstacles, while the

pixy camera determines the identification process. When there is an error, the buzzer plays a sound for a limited time ,the motor driver controls the motors and their movements ,the lithium battery supplies the power for the whole system .Finally, the push-button will control the whole system by turning on and off.

### 3.4 General Flowchart

The following section describes the steps the system will follow, as shown in Figure 3.3 below.



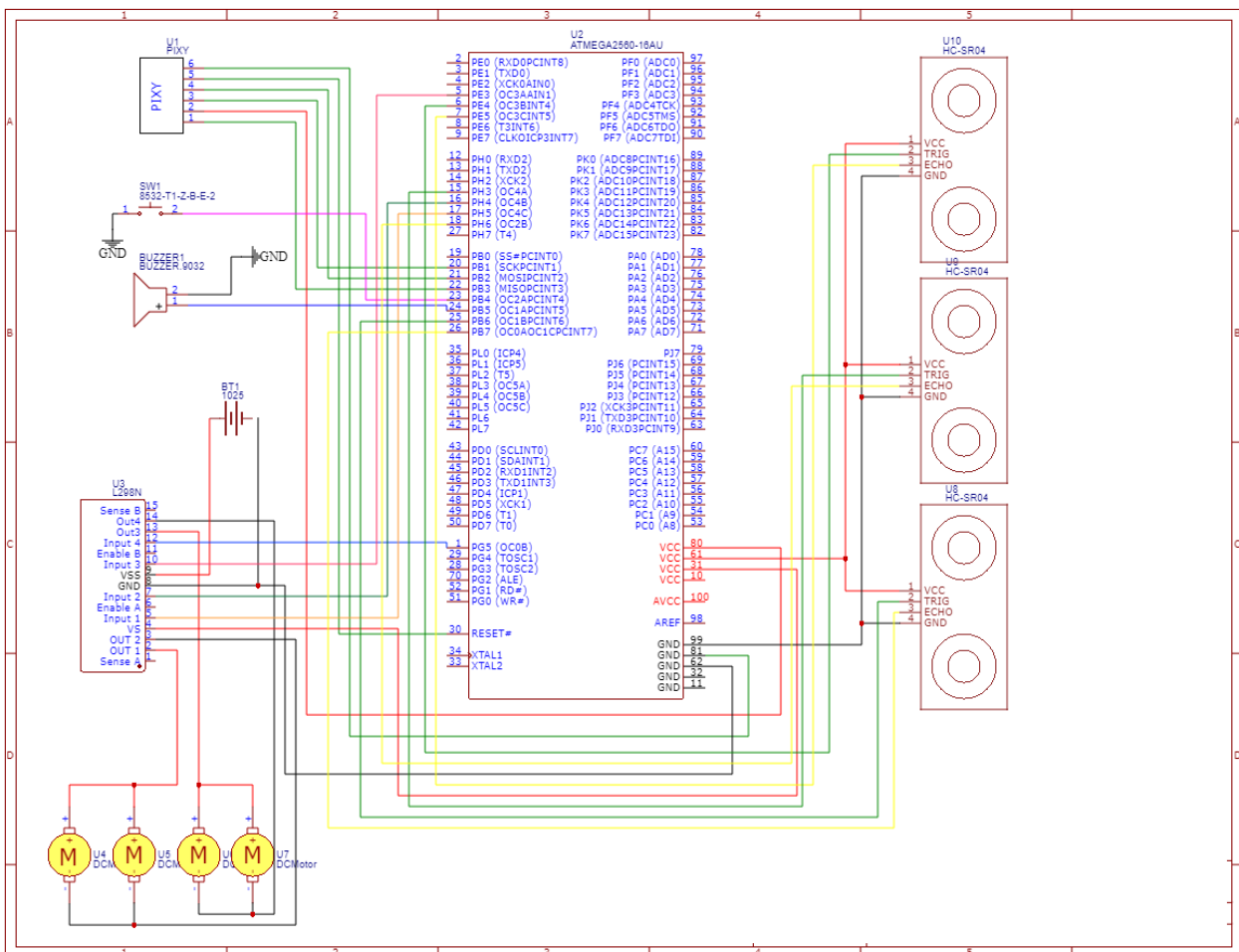
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In the beginning, user will press the button and the electric will start working. When the battery is on, the camera will define the target customer based on the sign already programmed in it and information that was previously stored in the microcontroller. Next, the pixy camera will send a signal to the Arduino that it is ready to follow the defined user. At this point, the microcontroller will control the direction of the motors and the cart will start moving.

During this time, the ultrasonic sensor will continually detect the paths in front of and beside the cart to avoid obstacles by sending a signal to the control system to steer the cart to its destination (left or right). If the cart is unable to avoid this obstacle, the alarm will sound, and then the ultrasonic sensors will attempt to avoid the obstacles, it will continue this process until the customer presses the off button.

### 3.5 System Schematics

Figure 3.4 shows the schematic diagram of the whole project, displaying the various hardware components of the system and their interconnections with each other.





Such we connect the three HC-SR04 Ultrasonic Sensor to pins [(2,3)(6,9)(12,13)], motor driver {EN1,1N1,1N2,1N3,1N4, EN2} to pins [4,5,8,9,14,15], and Buzzer to pin 11.

## **Chapter 4: Implementation**

### **4.1 Overview**

The focus of this chapter is to describe the implementation of our project including the software and hardware necessary to realize our project's goals, which are: Obstacle detection and identifications, and controlling cart movement.

### **4.2 Hardware implementation**

In this section, we show how the hardware components of our system are assembled. For our project, we implemented our shopping cart system using a car model rather than the real one, so the assembly process was simple and straightforward.

In our design, we used a car model with four wheels and two layers; one is for the DC-motors and their driver, for easy movement. While the other links the microcontroller to the wires of the entire system on the electric board. Also, we used a basket of suitable size to symbolize a real shopping cart's body.

Our first step is to connect all of the DC motors, wheels, the motor driver, and the battery, and we make sure that they all work properly. Next, we place one of the ultrasonic sensors on the second layer of the model to avoid the front obstacles, and the other two sensors are placed on the sides of the upper part of the model.

By taking into account that the range of the ultrasonic sensor ranges from 2-400cm within a 30° angle that could cover each one, this is a guarantee that can be detected and cover the wide

range possible, as shown in Figure 4.1, so, the sensors will be able to avoid people, vehicles, and obstacles that are at the same level as the cart.

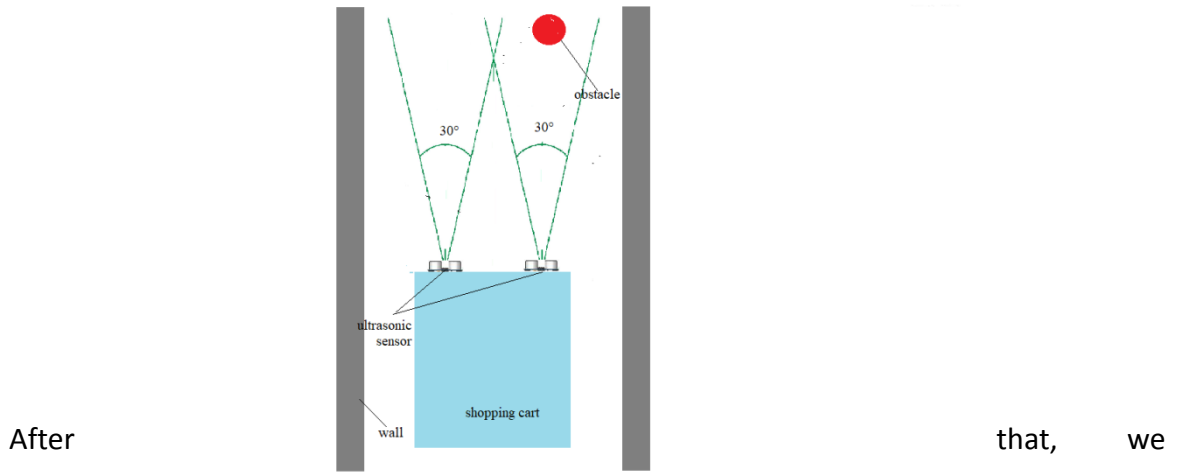
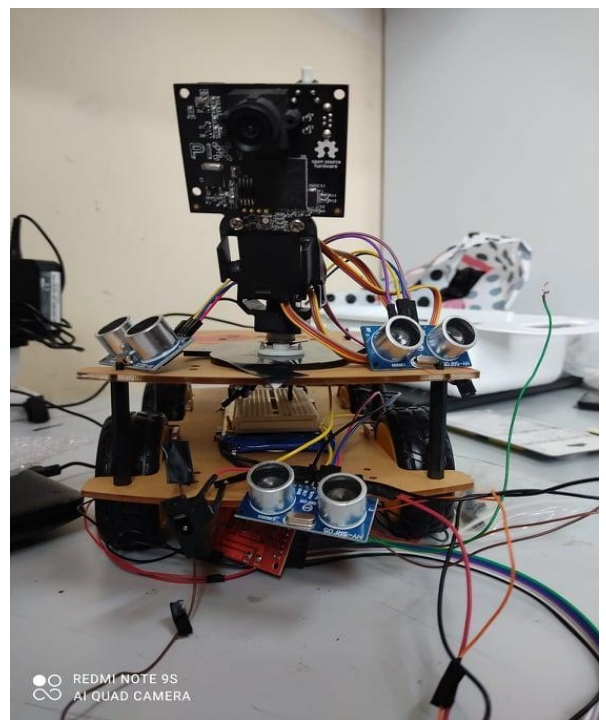
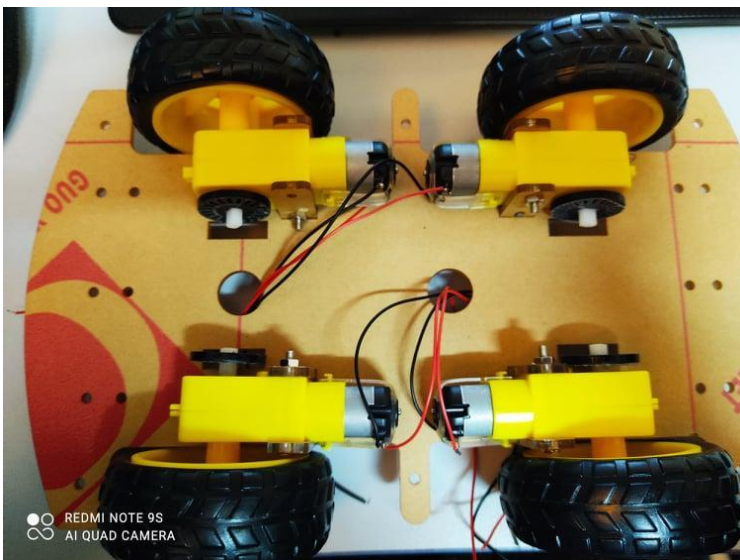


Figure 4. SEQ Figure\_4. \\* ARABIC 1: ultrasonic sensors range

place the pixy camera in the front of the cart and ensure that it has a fixed base so that it can clearly see the target user. Then, we use the push button to activate the control system and set it up to pass the signal to the buzzer, which representing the simple alarm system that runs when something goes wrong during the shopping process, such as when the cart stops working.

A copy of our original prototype is shown in Figures 4.2 and 4.3 which the first picture shows how the dc-motors are connected to its wheels while the second picture shows the pixy camera and ultrasonic sensors at the front.



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## **4.3 Software Implementation**

The following section provides details about how we implement the software components of the system to verify that they work adequately using the original codes of our components, then by using the Arduino IDE and the pixyMon app to implement the whole system to deliver our objective.

### **4.3.1 Arduino environment implementation**

This process is to prepare Arduino for working. It starts with downloading the latest version from the original page site<sup>[14]</sup>. When the download is finished, we get the unzip file. Then, we double-click on the folder to open it, and it gets ready to use and build our system in the Arduino software environment was ready to be used to build our system programming.

### **4.3.2 Download USB drivers**

We need USB drivers for the FTDI chip on the board to connect our Arduino board to the computer. In addition, we need to install the USB drivers before plugging in the Arduino for the first time. This demands downloading the latest version from this page site<sup>[15]</sup>. After that, we need to select port and select microcontroller type " Arduino Mega 2560".

### **4.3.3 Pixy camera implementation**

PixyMon app is the configuration utility for Pixy that runs on windows, we download "Windows version 2.0.9 (exe)" version from pixy site<sup>[16]</sup>, Then, we install the Arduino libraries to allow Arduino sketches/programs to talk to Pixy. The version we use "Arduino library version

0.1.7 (zip)". The next step is bringing up the Arduino IDE and import the Pixy library by selecting: Sketch → Include Library → Add ZIP Library.

## **Chapter 5: Validation and Software Results**

This chapter illustrates the testing process for all components in our system. We test all the parts to ensure that all of the functions work appropriately.

### **5.1 Hardware & software Testing**

This section discusses the testing process of each of our system components.

#### **5.1.1 Obstacle Detection Component**

A system of using ultrasonic sensors was developed for the purpose of detecting obstacles during a user's movement and avoiding them at the destination.

#### **5.1.2 HC-SR04 Ultrasonic Sensors Test**

As shown in Figure 5.1, each ultrasonic sensor is connected to an Arduino mega 2560 to carry out the testing process by applying the simple test code. The process is repeated for the remaining ultrasonic sensors.

When the Arduino is programmed by using its test code Next, we test it by moving an object in front of the sensor and measuring the distance. Again, we compare the measured distance with the actual one before confirming that it works correctly. All measurements in the serial port were correct as expected in Figure 5.2, indicating that it works correctly.

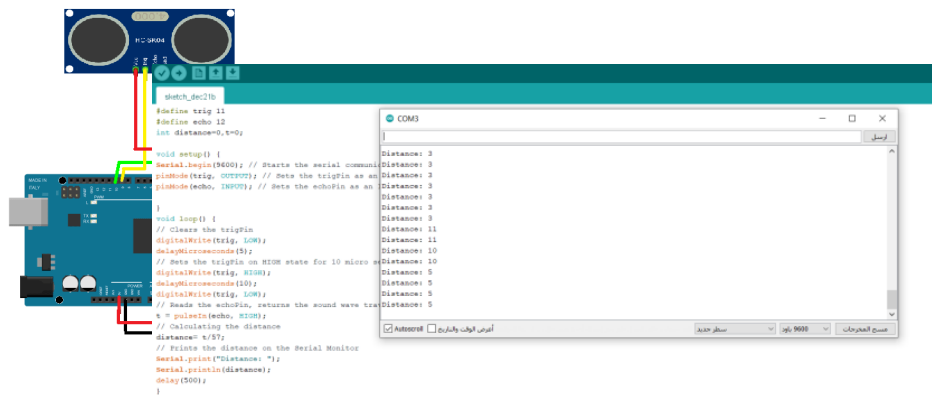


Figure 5. SEQ Figure\_5. \\* ARABIC 2: Connection of ultrasonic sensor with Arduino mega 2560

Figure 5. SEQ Figure\_5. \\* ARABIC 1: Distances measurements from HC-SR04 sensor

### 5.1.3 Motors control

Our project uses DC motors to move the wheels and control them with the L289 DC motor driver which controls that motor's speed and direction.

#### Body's driving DC Motors Test

The model consists of four wheels connected with four DC motors ,for control we connect two of the DC motors to a point in the motor driver L289N and the other two to a point in the driver ,the power and ground points are then connected and we observe that the wheel works as expected. As shown in figure 5.3.

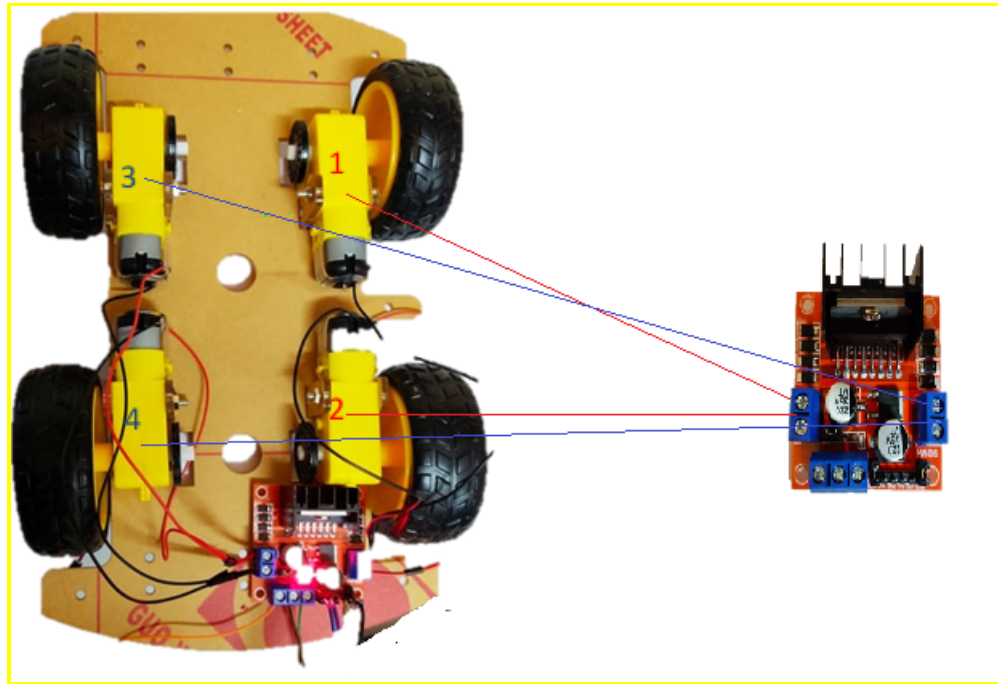


Figure 5. SEQ Figure\_5. \\* ARABIC 3: connected DC motor with driver

Our next step is to test it on a breadboard with an external power source. We then test all scenarios to make the wheel run forward and reverse After that, we test it again by connecting it with an Arduino mega 2560, and we run a simple test code including four scenarios:

1. turn on motors (1,2) alone
2. turn on motors (3,4) alone
3. turn all motors in forward direction
4. turn all motors in reverse direction

Figure 5.4 shows the motor driver testing codes.

```

motor $
void setup() {
  // Set all motor control pins to output
  pinMode(enA, OUTPUT);
  pinMode(enB, OUTPUT);
  pinMode(in1, OUTPUT);
  pinMode(in2, OUTPUT);
  pinMode(in3, OUTPUT);
  pinMode(in4, OUTPUT);
}
void demoone ()
//this function will run the motors in both direction at a fixed speed
{
  digitalWrite(in1,HIGH); // turn on motor A
  digitalWrite(in2,LOW);
  analogWrite(enA,200); // set speed to 200 in range (0-255)

  digitalWrite(in3,HIGH); // turn on motor B
  digitalWrite(in4,LOW);
  analogWrite(enB,200); //set speed to 200 in range (0-255)
  delay(2000);

  // change motor direction |
  digitalWrite(in1,LOW);
  digitalWrite(in2,HIGH);
  digitalWrite(in3,LOW);
  digitalWrite(in4,HIGH);
  delay(2000);

  digitalWrite(in1,LOW);
  digitalWrite(in2,LOW);
  digitalWrite(in3,LOW);
  digitalWrite(in4,LOW);
}

```

```

motor $
digitalWrite(in3,LOW);
digitalWrite(in4,HIGH);

for(int i=0;i<256;i++)
{
  analogWrite(enA, i);
  analogWrite(enB, i);
  delay(20);
}
for(int i=255;i>=0;--i)
{
  analogWrite(enA, i);
  analogWrite(enB, i);
  delay(20);
}

digitalWrite(in1,LOW);
digitalWrite(in2,LOW);
digitalWrite(in3,LOW);
digitalWrite(in4,LOW);
}

void loop() {
  // put your main code here, to run repeatedly:
  demoone ();
  delay(1000);
  demotwo ();
  delay(1000);
}

```

### 5.1.4 The identification Component

Pixy cameras are used for identification and tracking, where the target user is recognized and tracked throughout the shopping process.

#### Pixy camera test

The Pixy camera is tested in two ways. First, we connect it to a computer and set the signature (in this case, a green ball) as an object to represent the sign of the target user, as shown in Figure 5.5. Then, we test the camera's reaction in relation to another colour object, either said to be the detected object or not. Besides that, we set up the Pan-Tilt demo to see if the camera can follow the detected object (green ball) movement. It works, and it gives the expected result that it sees the ball and follows its movement.

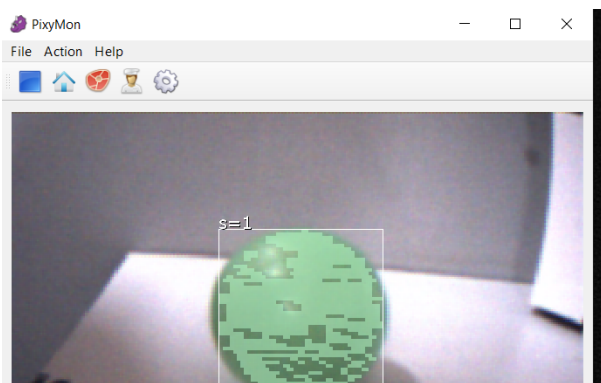
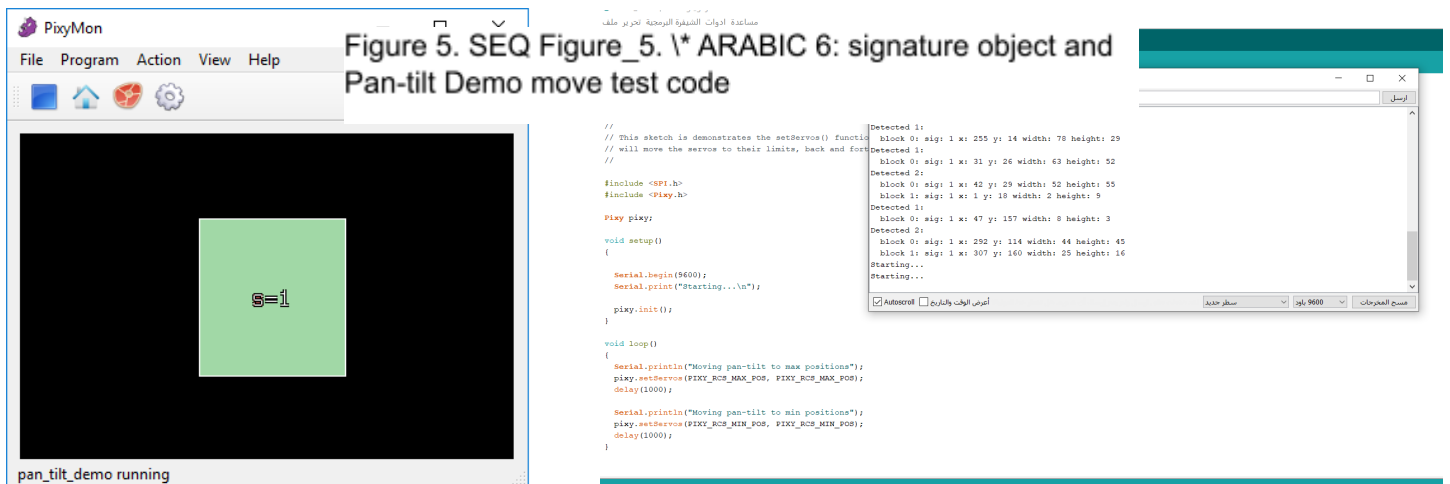


Figure 5. SEQ Figure\_5. \\* ARABIC 5: detected object

Next, we connect the Pixy camera to the Arduino mega2560 and set the signature object and the Pan-Tilt Demo move, that way, Pixy will track our chosen object and plot it in the video window PixyMon will switch to block-only mode, so the video window will turn black except for the areas Pixy is detecting (the rectangular blocks you see Figure 5.6).



It is important to mention that the model of the camera we are using is able to identify, track and identify the color and the shape of the objects you teach it. However, it is limited to a few colors and simple shapes, as we noted in the testing process that the camera can note the color green in its surroundings, but this doesn't affect the function of our project because it can note but not follow.

On the other hand, there is one case that may result in the pixy becoming confused, such as if it detects another green ball in its field of view, but it can be fixed if we replace our pixy with Pixy2, because it is faster, and it can recognize colors and shapes better .In our case, the



camera used for the system construction meets the project objectives, requirements, and clarifications that we have for the project.

Pixy2 is not available in our area, and it will take a few months for it to be purchased. Adding, it is expensive. The camera we used in our project is a version of Pixy that is available and owned by our university lab.

### **5.1.5 Overall System Test**

We tested the entire system in three stages: we tested the robot's movement during tracking and detecting processes, we checked sensors as they detected changes, and finally, we tested the overall stability and responsiveness of the system.

During the first phase we tested the robot's ability to move during tracking , by applying the pixy and motor codes to observe how the robot reacts to the target object (a green ball in our case),and whether it was able to follow it in a different direction ,at the same time, we examine the wheel to ensure that the robot moves smoothly and easily as it should .

Testing the detecting function was the second stage, so we applied the ultrasonic and motor codes, then watched the robot respond by putting different obstacles in front of it and beside it, in order to know what direction it will take and whether the response matched the code we programmed.

Thus the robot must check all directions before moving, when an obstacle is encountered on the front side less than 20 cm away, the robot will check to see if there are obstacles within 20 cm away in both directions, if the way is closed from the three direction the alarm was triggered, the robot will move backward, turn off the alarm, and then move left or right based on the empty direction.

Finally, we had to combine all the system components and modify all the code parts so that the system would function as one unit and achieve all features that the system was designed to.

### **5.1.6 shopping cart weight test**

Due to the fact that we used a prototype model, making the idea of calculating the weight that a cart can carry is not one of our priority, since our goal was to implement both tracking and avoidance as a basis for our project by applying different technological techniques.

Our model can carry a few grams of weight, which is proportional to the amount of energy the battery supplies to the engine as well as the ability of the wheels to turn.

Nevertheless, assuming that the project is implemented in real life, the weight of the cart will not be a problem , since the weight that the vehicle can carry is dependent on the battery power, the torque of the wheels, and the mechanics of the engine used.

## **Chapter 6: Conclusion and Future Work**

### **6.1 Conclusion**

In this project, the specific goal was to design and develop a smart shopping cart capable of tracking shoppers, and avoid obstacles, so to support and help people with disabilities to integrate into society and enjoy shopping.

Thus, we developed a prototype have the ability to detect the target user, follow him, and avoid obstacles at the same time, the shopping cart is represented by a car model with four wheels and basket, connected to motors controlled by a driver. Once the system has been turned on, the microcontroller will start taking various information from a pixy camera and the ultrasonic sensor to help it in the detecting process.

As a result, we built an intelligent shopping cart that moves automatically without being pushed and follows the user's movements.

## **6.2 Future Work**

Through this project, we aim to support and help people with special needs integrate into society and enjoy shopping, as well as to provide convenience, service, and safety to the customer.

Consequently, it may also be possible to add to the shopping cart other features/functions to make it smarter:

1. Utilize the latest version of the Pixy camera to improve the tracking process, so that it can identify more than one object.
2. Using the "items finder" function, which assists customers in finding the desired items in the shopping mall.
3. A queue management system can calculate the bill for shopping goods after the customer places the items in the shopping cart.
4. Design a smartphone application containing an automatic switch and a manual switch for turning the system on/off and moving the cart before/after the shopping process.

5. Adding a robotic arm that automatically brings the goods and puts them in the cart without the need for a person to do it.
6. Using image processing to recognize the target user from special tags .

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## **APPENDICES**

Here we have a simple virtual design for our project, if it is applied in a real ground, the three figures below show the real system views from three different perspectives

