Department of Computer Science & Engineering
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Architectural Design Specification
CSE 4316: Senior Design I
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Erbie

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Revision History

Revision	Date	Author(s)	Description
0.1	11.09.2023	HA	document creation
0.2	11.09.2023	HA	complete Section 1-3
0.3	11.12.2023	CD	rough draft of section 5
0.4	11.27.2023	CD	final edits to section 5
0.5	11.29.2023	AH	completion of section 6
0.6	11.29.2023	PT	completion of section 7
0.7	11.29.2023	BG	completion of sections 4 and 6
1.0	11.29.2023	HA, CD, AH, PT, BG	Review and Submission

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1 Introduction

Erbie is a robot that serves Arabic coffee. This service includes providing cups, pouring coffee, and collecting empty cups. Serving protocol will also include responses to some hand gestures. The robot will also be able to navigate around without a significant amount of external input. An attendant will have to make the coffee for service. The attendant would have access to a front-end service that is running on the robot which would used to maintain it. This would include refilling the reservoir, collecting used cups, and adding freshly cleaned cups.

2 System Overview

The system consists of 4 layers each specifiying a specific role. The highest layer would be Command and Control which provides and intermediary for all the other layers.

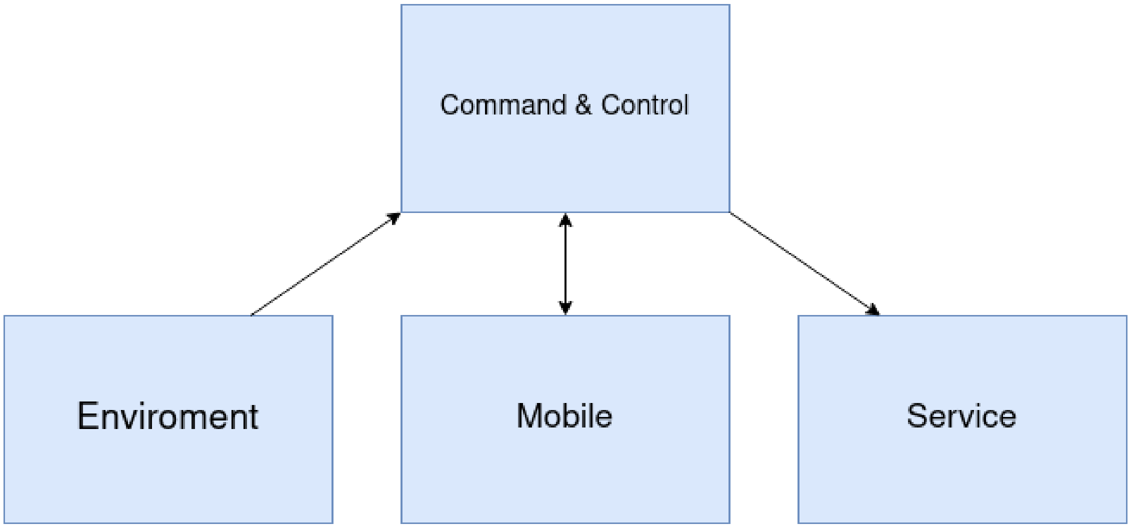

Figure 1: Erbie architectural overview

2.1 Layer Command and Control Description

This layer provides two main purposes. Being the host of the "brain" of the system that functionally commands all layers. And it hosts the external interface for the operator. This interface would display critical information to the operator about the current state of the robot.

2.2 Layer Mobile Description

This layer provides two functions. First managing the motors on the robot and translating command from command and control into lower level controls for the motors. It also contains the battery which will be used to provide power to the system.

2.3 Layer Service Description

This layer provides the essential fucntions of the robotic service. This includes controlling the system for cup dispensment, cup collection, and pumping coffee into the cups.

2.4 Layer Enviroment Description

This layer consists of a camera and an IR system. Both of these provide critical information to command and control to inform movment direction and recognize gestures.

3 Subsystem Definitions & Data Flow

Below is the detailed system diagram that includes all subsystems within each layer. It shows the directions of flow for data between these systems. The centrisity of this system is shown even more in detail and how these systems interact with each other to create one cohesive service. The flow of data between each layer to central command is different, where some systems take commands only others only send information. The mobile system is the only one that takes commands and sends data.

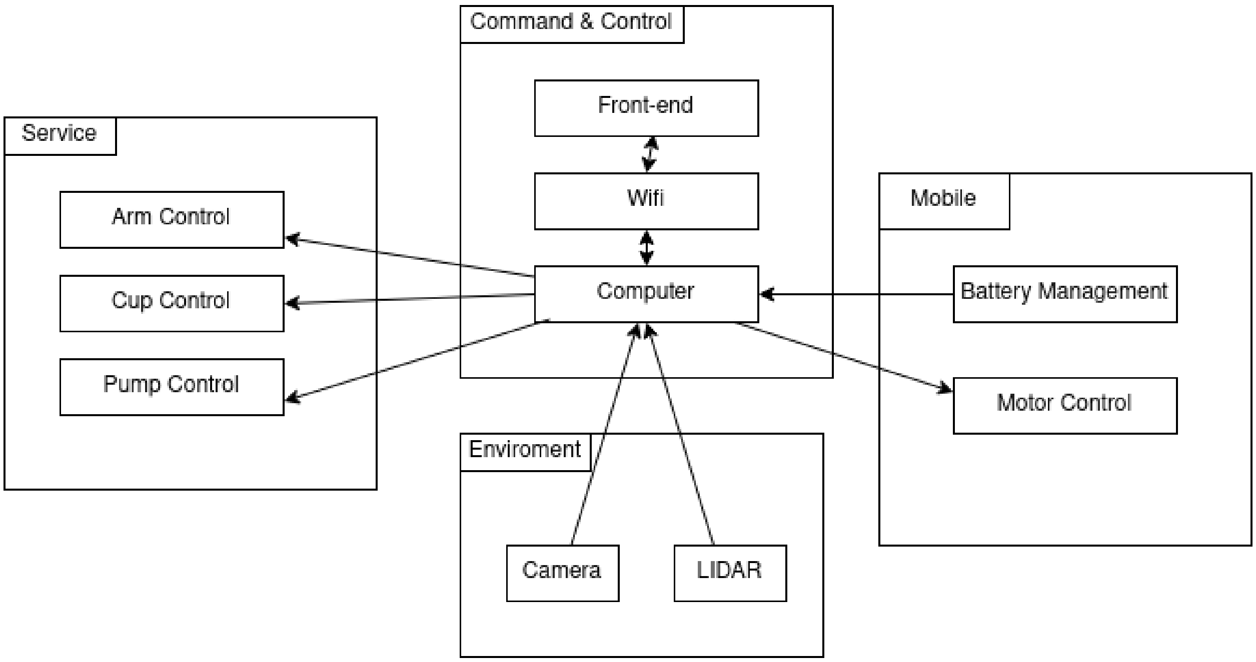

Figure 2: Detailed data flow diagram

4 Command and Control Layer Subsystems

The Command and Control Layer will function as the brain of the system. It will be responsible to controlling the secondary systems and ensure a coordinated functionality for Erbie. This layer will consist of an user interface where it'll provide user with controls of the robot while ensuring that the system is coordinated between the environment, mobile and service layers. It'll integrate different senses while carrying the system's actions and providing live data and stats generated from the programming logic and machine learning algorithms.

4.1 Subsystem 1

This section should be a general description of a particular subsystem for the given layer. For most subsystems, an extract of the architectural block diagram with data flows is useful. This should consist of the subsystem being described and those subsystems with which it communicates.

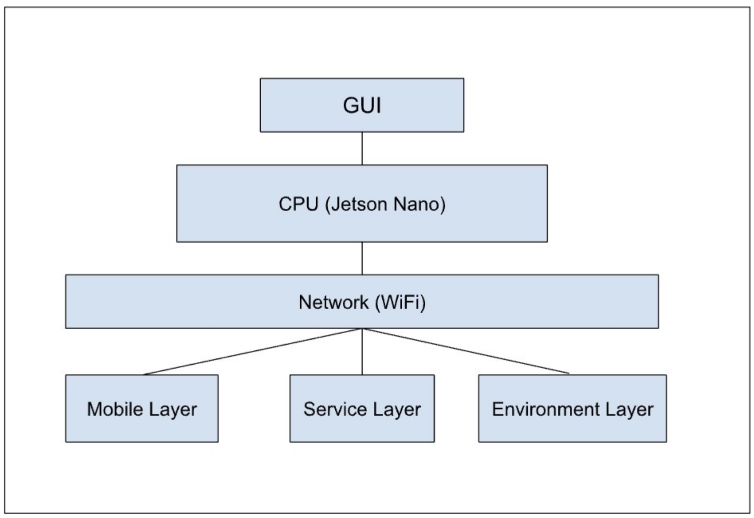

Figure 3: Figure 3: Diagram of Command and Control Layer

4.2 Computer

The computer utilized for Erbie would be a Nvidia Jetson Nano, which is excellent at carrying out real-time actions and posseses the computation power required to integrate with our other layers.

4.2.1 Assumptions

It is assumed that the Jetson Nano will provide a seamless integration with the webcam and Lidar sensors as well as the mechanical motors and controllers present within the robot.

4.2.2 Responsibilities

As the Central Processing Unit, it will be responsible for carrying out all the data processing tasks and running a multiprocessing application to process real time video, sensor data analysis and motor controls. It will coordinate with the other systems and ensure that real time actions are carried out efficiently without substantial delay.

4.2.3 SUBSYSTEM INTERFACES

Table 2: Subsystem interfaces

ID	Description	Inputs	Outputs
#1	GUI	User Controls	Robot Operations and data logging
#2	Sensor(s)	Environment data	Sensor influenced operations
#3	Mobile Layer	Power, motor, and battery	Movement Commands
#4	Service Layer	User Interactions (Gestures)	Task specific actions

4.3 FRONT-END

This Front-End or display interface will be responsible for receiving user input and providing the user an insight into the robot's actions. This will serve as the key resource to monitor the system and log essential data for the developers and the users to view.

4.3.1 ASSUMPTIONS

The Graphical User Interface (GUI) will be a neat dashboard with user friendly commands and intuitive information display. It will provide real time data and inform the controller of the systems ongoing status.

4.3.2 RESPONSIBILITIES

It will facilitate display of the robots health and fetch data from the secondary layers (mobile, service, and environmental). This will provide users with controls to monitor and control Erbie if needed.

4.3.3 SUBSYSTEM INTERFACES

Table 3: Subsystem interfaces

ID	Description	Inputs	Outputs
#1	Jetson Nano *CPU*	Computed Data	Information Dashboard

4.4 WIFI

- This will the the networking and intercommunication subsystem. It will be the gateway for data transmission within the mobile, service, and environmental layers alongside the external source to the front end.

4.4.1 ASSUMPTIONS

It is assumed that a proper and secure network connectivity is available in form of a local WiFi. It is also assumed that it can handle the data volume within the robot and maintain data integrity without losing essential information of the system.

4.4.2 Responsibilities

This will manage internal and external communications. It will be responsible for efficient data exchange between the CPU (Jetson Nano), motor, battery, camera, sensors and other controllers. It will monitor network performance and validate data that is processed in order to carry out the robots activities seamlessly.

4.4.3 Subsystem Interfaces

Table 4: Subsystem interfaces

ID	Description	Inputs	Outputs
#1	CPU	Data Request and Control Commands	Process Message
#2	GUI	User controls	System status

5 Mobile Layer Subsystems

The Mobile subsystem includes the battery and regulator, motors, motor controller, and wheel speed sensors. The motor controller is separate from the Command and Control layer because the latter will be multitasking. Delayed inputs to the motor signals (or delayed detection of wheel speed sensor output) would adversely affect control of the system. This separation also allows the motors to safely come to a stop should the Command and Control layer malfunction or become unresponsive. Many motors of various sizes and power ratings are capable of operating on the voltage chosen for the battery pack (12V), which means that the motors used may be easily changed during development should the original motors be unsatisfactory.

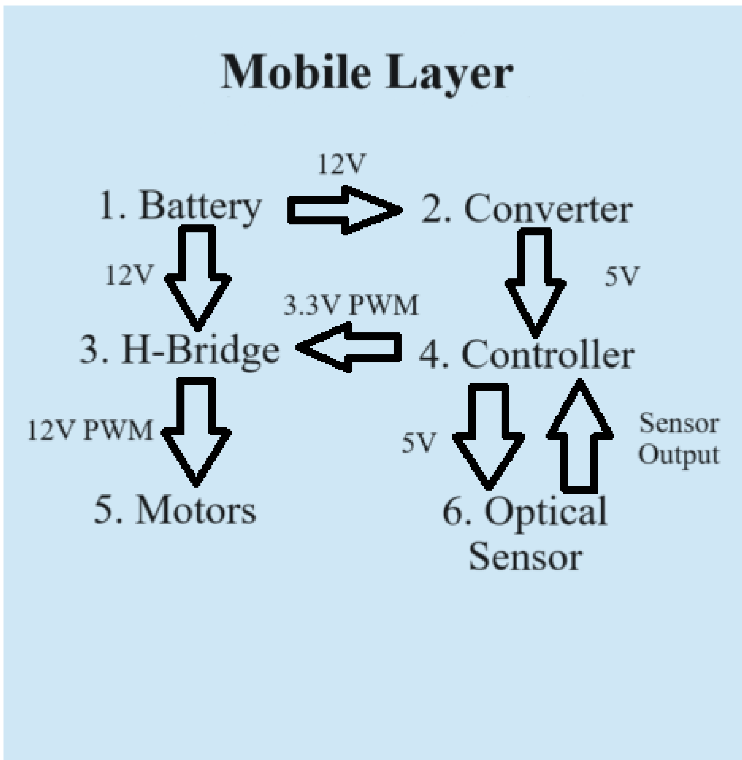

Figure 4: Diagram of Mobile Layer

5.1 Battery

A 12V nickel-metal hydride (NiMH) battery pack will provide power for the robot. As specified in the Project Charter, the battery pack will be easily replaceable and will not be chargeable while it is within the robot. A 12V-to-5V DC-DC regulator will step down the voltage to supply power for the motor controller and subsystems in other layers that require 5V supplies.

5.1.1 Assumptions

The definition of this subsystem assumes that no large and continuous current draws are needed that are beyond the capabilities of a 12V NiMH battery pack. It is assumed that a battery pack without an integrated charge level monitoring system may be monitored by an external system. It is assumed that the motors will draw more current than the other systems of the robot, which makes stepping 12V down to 5V more efficient than stepping 5V up to 12V.

5.1.2 Responsibilities

The Battery Subsystem must be capable of providing enough power to the robot to maintain operations for a minimum of 30 minutes as mandated by the System Requirements Specification. As a Jetson Nano will likely be used to run the Command and Control layer, the Nano's maximum current rating of 10A will be used as a benchmark to select an appropriate battery pack and DC-DC converter. The battery pack must be connected to the robot's 12V wiring by a quick-disconnect type of attachment to facilitate the quick-change requirement also specified by the SRS.

5.1.3 Subsystem Interfaces

Table 5: Subsystem interfaces

ID	Description	Inputs	Outputs
#1	Battery Pack	Electrical Charge	12 V to H-bridge/Converter
#2	DC-DC Converter	12V wiring	5V to Motor Controller/other layers

5.2 Motors/Motor Controller

The robot will be driven by two brushless DC motors, each connected to one drive wheel. The motors will operate off of 12V delivered from the battery through an h-bridge. The h-bridge will be controlled by a microcontroller ('Motor Controller') which operates off of a 5V supply from the DC-DC converter. The Motor Controller will communicate with the Command and Control layer over SPI or I^2C.

5.2.1 Assumptions

It is assumed that the motors chosen for the product will be capable of driving it, that the drive wheels can be printed with gear teeth strong enough to withstand applied loads, and that the Command and Control layer will be capable of sending and receiving information over SPI or I^2C.

5.2.2 Responsibilities

The motors must be capable of accelerating the robot at the same rate a human begins to walk. The motors must be controlled so that they do not induce an excessive amount of jerk, which could cause damage to other components of the robot either through mechanical stress or spilled coffee. The h-bridge must be capable of withstanding the currents drawn by the motors. The Motor Controller must be capable of monitoring battery levels, speed sensor inputs, and reporting information to the Command and Control layer.

5.2.3 Subsystem Interfaces

Table 6: Subsystem interfaces

ID	Description	Inputs	Outputs
#3	H-Bridge	12V Supply 3.3V PWM	12V PWM
#4	Motor Controller	5V Supply Cmd/Ctrl Signals Wheel Speed	3.3V PWM Info. to Cmd/Ctrl
#5	Motors	12V PWM	Motion

5.3 Sensors

The speed of each drive wheel will be monitored through an optical sensor. That sensor will either detect the passing of teeth protruding from the wheel or will detect reflected IR light from evenly-spaced material placed on each wheel.

5.3.1 Assumptions

Based on previous experience with other projects, it is assumed that noise will interfere with the speed measurements produced by optical sensors.

5.3.2 Responsibilities

The spacing of the teeth or reflective material must be as symmetrical as possible to provide accurate signals to the Motor Controller. The optical sensors must also be kept clean, which implies that they should be shielded from spilled coffee.

5.3.3 Subsystem Interfaces

Table 7: Subsystem interfaces

ID	Description	Inputs	Outputs
#6	Optical Sensor	5V Supply	Sensor Output

6 Service Layer Subsystems

The service layer encompasses the aspects of the robot that will deal with the preparation and delivery of the coffee through the use of an arm control layer, a pump layer and a cup control layer. Each of these layer will be working with each other to ease the process of serving coffee to the patron. Although, they will all be separate allowing the continued function of each process should one of the three process malfunction.

6.1 Arm Control

A robotic arm will be the general form of serving the coffee to the patron. It will consist of 3-4 servo motors that will be programmed by a micro-controller which will help aid in its basic functions. The gripper will be non-slip rubber which will aid in grabbing and holding the coffee cups.

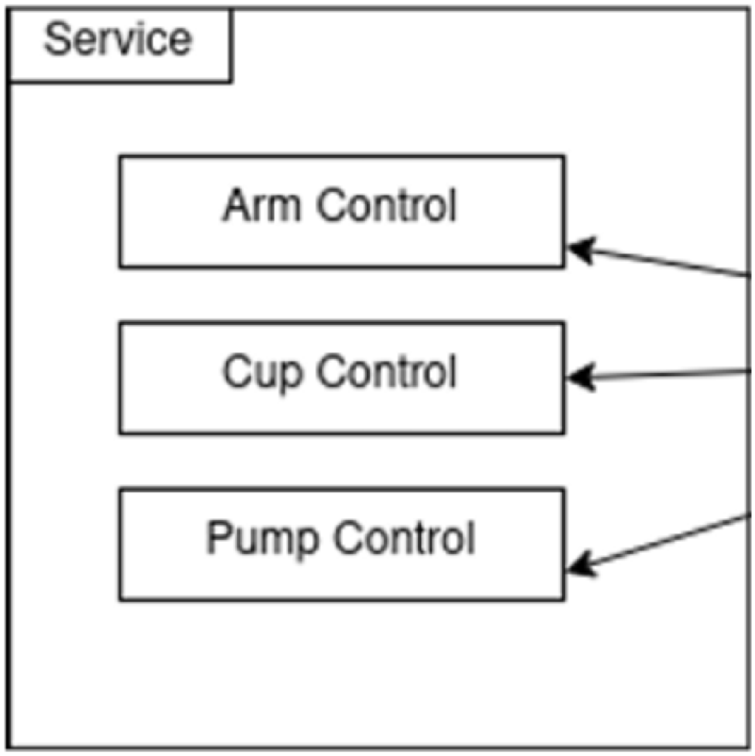

Figure 5: Diagram of Service Layer

6.1.1 Assumptions

It is assumed that it will be a seamless integration with all the other controls for this layer. It is assumed that the power will be derived from the micro-controller.

6.1.2 Responsibilities

The Arm control must be capable of in a upwards and downwards motion as well as swivel at least 180 degrees. It must be capable of holding an average weight of about 9 oz which include the cup and the coffee. The robot arm must be able to grip the cup and hold onto it and then serve it to the patron.

6.1.3 Subsystem Interfaces

Table 8: Subsystem interfaces

ID	Description	Inputs	Outputs
#1	Servo Motors	cmd/ctrl signals	movement

6.2 Cup Control

The cups will be stored in a tube that at the base that will have a mechanism that will rotate and lift the cups up through the use of a servo motor.

6.2.1 Assumptions

The mechanism will work in a corkscrew fashion that will dispense each cup after a new one has been selected.

6.2.2 Responsibilities

When the robot arm picks up a cup, the servo motor will turn the base where the cups are positioned turning the corkscrew mechanism and preparing another cup to be dispensed.

6.2.3 Subsystem Interfaces

Table 9: Subsystem interfaces

ID	Description	Inputs	Outputs
#1	Servo Motor	cmd/ctrl signals	movement

6.3 Pump Control

The coffee will be stored in a reservoir that will be fitted with a peristaltic pump that will help dispense the coffee.

6.3.1 Assumptions

It is assumed that the reservoir and the pump are food safe and can handle the high temperatures of the coffee. It is assumed that a servo motor will be used to help the pump function.

6.3.2 Responsibilities

The pump will attach to the reservoir where the coffee is stored and will dispense a specific amount of coffee which will be controlled by a servo motor that will be connected to a micro-controller. The cup will be put in position by the robot arm to facilitate the coffee dispenser.

6.3.3 Subsystem Interfaces

Table 10: Subsystem interfaces

ID	Description	Inputs	Outputs
#1	Servo Motor	cmd/ctrl signals	movement
#2	Pump	cmd/ctrl signals	Dispense

7 Environmental Layer Subsystems

The Environment subsystem includes the camera and IR sensor systems that the robot will be utilizing for both movement and gesture recognition. The camera would be used as a way to recognize any gestures performed by the customer and determine whether or not a cup needs to be refilled, taken back, or no action. The IR sensor system is used as for the robot to navigate through the bar and make sure that it's movements are smooth and accurate to prevent any coffee spillage or collisions. All outputs are directed towards the command center which will direct information to the computer for it to be processed.

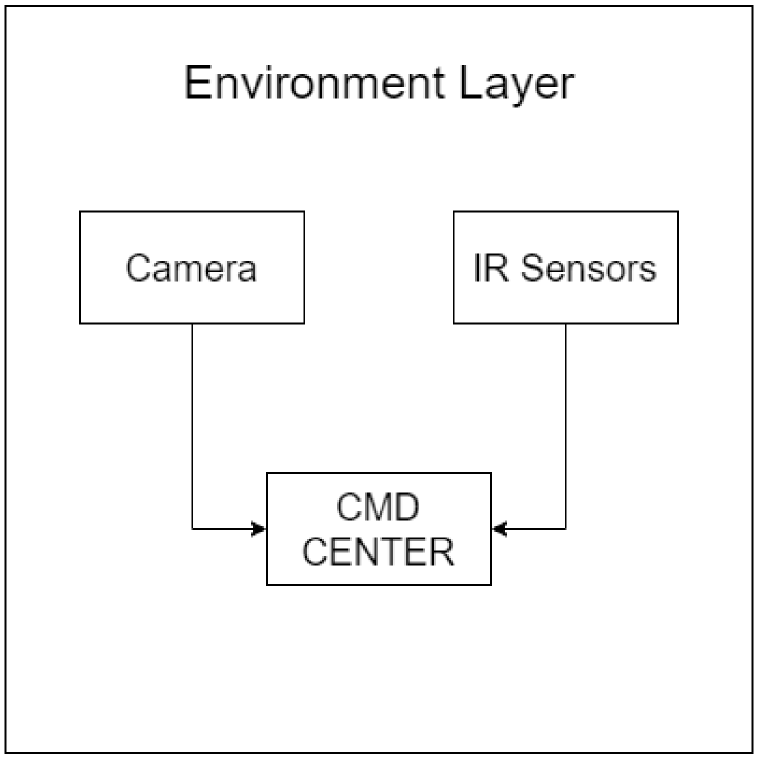

Figure 6: Diagram of Environmental Layer

7.1 Camera Subsystem

A web camera will provide the visuals needed for the robot to recognize gestures. When the camera is running and detecting gestures, it's important to have a clear enough visual of the gestures being performed for the software to be able to recognize. For this process, a general camera that is at least 1080p and captures at 30 fps would be sufficient enough for this.

7.1.1 Assumptions

It is assumed that the camera will be positioned on the robot in an area that is level with customers and any objects that they might be interacting with as well as the lighting conditions to be an indoor setting. The camera will be provided power and a connection to the computer to communicate any visual information from the camera.

7.1.2 Responsibilities

The camera must be able to focus and adjust to indoor lighting situations as customers enter the camera's field of view. It should be able to provide a clear view of the customers in order for the computer to recognize any customer gestures and be able to send that information back to the computer. When the customer comes into view of the camera, it should also be able to depict any objects clearly that the customer may be holding for the computer to perform any software.

7.1.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here. Create a table with an entry for each labelled interface that connects to this subsystem. For each entry, describe any incoming and outgoing data elements will pass through this interface.

Table 11: Subsystem interfaces

ID	Description	Inputs	Outputs
#1	USB Webcam	5V USB	Video Data

7.2 IR Sensors

An array of IR sensors will be positioned on the robot in an area that is able to provide the path needed to follow as well as detect any incoming obstacles within its proximity. For this process, multiple IR sensors will be required and positioned in different locations in order to receieve information.

7.2.1 Assumptions

It is assumed that the IR sensors will be positioned on the robot that allows for the sensors to detect a given path as well as detect if it is about to collide with an object. The sensors will be provided power and a connection to the computer to communicate information from the sensors. There will also be a path laid out on the floor where the robot will follow during it's operations.

7.2.2 Responsibilities

The IR sensors responsible for the path following must be able to detect and determine if the path is within the field of operation on the robot. As for the IR sensors responsible for the collision detection, they must be able to detect whether there is an object in the range of the sensors and if the robot is going to collide. Both sets of sensors must be able to communicate the information received back to the computer and do so consistently and accurately.

Table 12: Subsystem interfaces

ID	Description	Inputs	Outputs
#2	IR Sensors	5V Supply	Digital Signal

References