Automated Parking Assistant

Team 8

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ECE 445

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1. Introduction

1.1 Problem & Solution Overview

It is difficult to argue against the idea that traffic congestion is one of the more annoying aspects of driving. Congestion causes more fuel burn, more delays, and can even cause health problems due to higher concentrations of air pollution, according to a survey by the University of Surrey. The US Department of Transportation's Federal Highway Administration notes 7 causes of congestion: traffic incidents, work zones, weather, fluctuations in normal traffic, special events, traffic control devices, and physical bottlenecks. Of these 7 causes, 3 (fluctuations in normal traffic, special events, and physical bottlenecks) have to do with traffic volume reaching road capacity. These capacity issues, while possible to correct on traditional roads, are extremely difficult to correct in parking lots. In order to remain economically viable, parking lots are required to maintain as many parking spaces as possible, reducing traffic capacity available for entrances, passages, and exits. The need to collect tickets at the entrance further reduces traffic volume capacity as each vehicle needs to stop for a few seconds in an already bottlenecked part of the parking lot. Even worse is that cars, once they collect their ticket, are forced to pay for time they spent roaming around the parking lot in search of a space. All these aspects of parking lots cause customer dissatisfaction.

This parking lot entrance bottleneck issue is what we are solving with this project. Further need for our solution can be found in a report released by the International Parking & Mobility Institute in 2018 underscoring the need for better parking lot entrance systems. Of the professionals in parking, transportation, and mobility surveyed, 46% said that there is demand for technology to improve access control systems. Our problem is that the parking lot customer experience is too poor due to congestion at the entrance and having to pay fees while looking for a parking space.

Our solution is to create a parking lot system that can remotely scan license plates and sense car movement to design a car payment system that is able to communicate with a central logger to handle payment systems without needless effort and materials. Our solution will combat the problem by automating all previously man-made bottlenecks at the entrance of the parking lot and delegating those responsibilities to individual modules located at each parking space. With our solution, we will eliminate the physical ticket, the need for cars to queue at the entrance, and needlessly wasted money spent by drivers roaming the parking lot in search of a spot.

1.2 Visual Aid

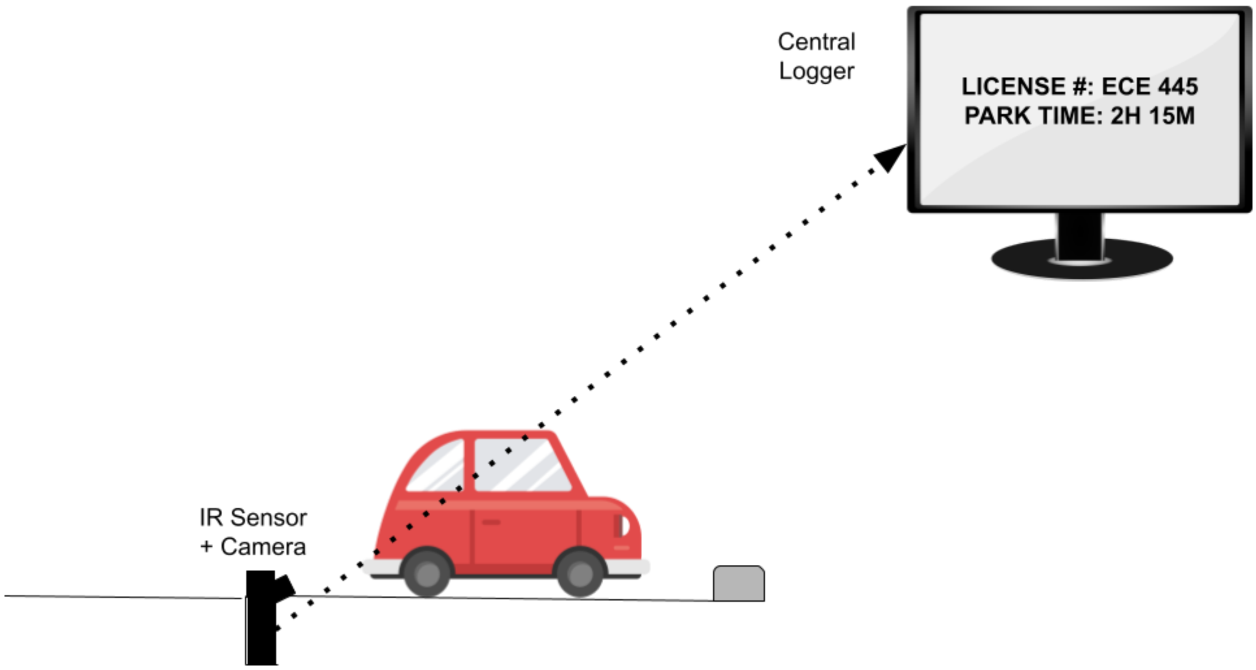

Figure 1. Visual Aid

1.3 High-level requirements list

- The automated parking assistant must be able to read a license plate to 85% (368/433 cars) accuracy when conditions are ‘reasonable’ (clear conditions, i.e - no obstruction in front of the camera)
- The automated parking assistant must be able to determine how long a car was parked and send the data via RF to the central logger system with a total latency not exceeding 5 minutes.
- The automated parking assistant must be able to withstand harsh weather conditions (-40°C to 40°C), waterproof (IPX4), and shock resistant (functional after a 10 ft. drop)

2. Design

2.1 Block Diagram

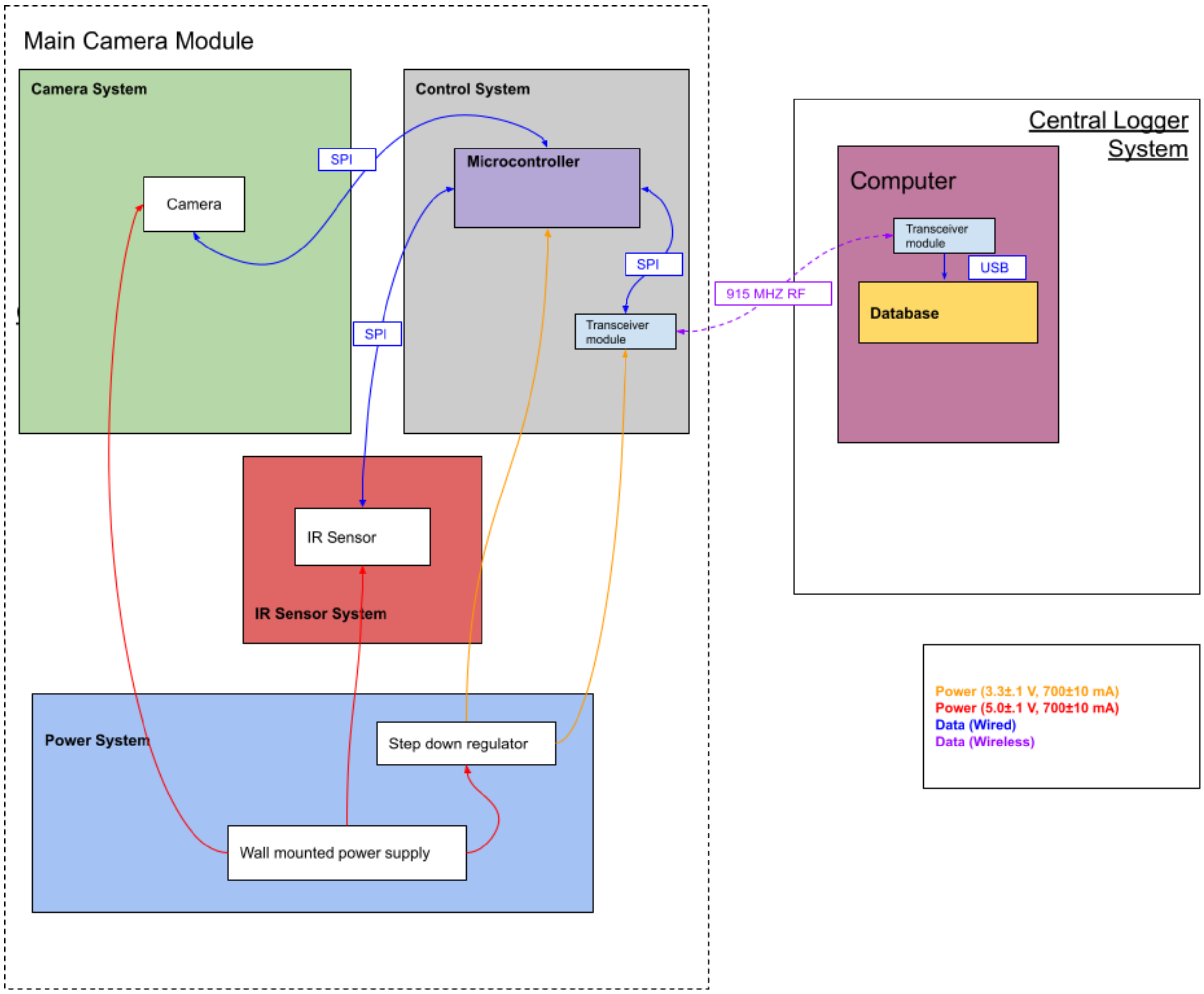

Fig. 2 Block Diagram

2.2 Physical Design

The Main Camera Module will be inserted in a plastic case from Polycase that will have a small window for the camera and a small opening for the USB-C connection for power. In order to satisfy the IPX4 rating, a rubber gasket will be inserted along the edge of the cap of the case. Foam will be inserted into the plastic case along the edges to minimize damage to the components inside when the case is hit with an impact. This will allow the Main Camera Module pass part of a high level requirement where it will be dropped from 10 ft in the air.

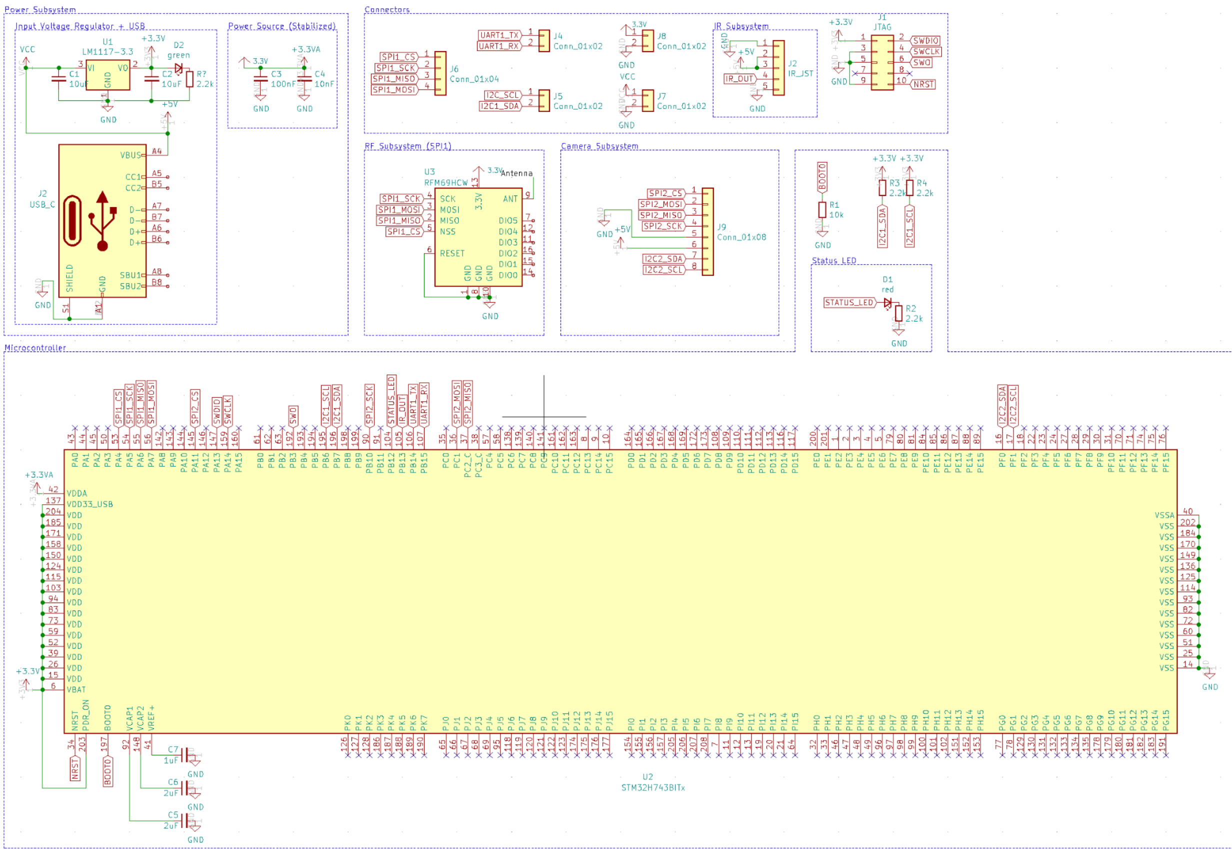

Fig. 3 Schematic

2.3 System Descriptions

2.3.1 Power System

The role of the Power System is to provide power to the rest of the Main Camera Module. Physical connections will be made to all modules in the Camera System. The Power System will get its power from a standard wall outlet, and it will be connected to a USB-C input to distribute power to all of the components. The goal of the Power System is to steadily provide 3.3 ± .1 V and up to 700 mA to the Main Camera Module so that it can be operational indefinitely as long as the wall outlet provides power to the power supply.

Requirements	Verification
1. Accept 5±.2 V from the wall mounted power supply as input and output 3.3±.2 V to the camera, IR sensor, microcontroller, and transceiver	1. A multimeter will be used to determine whether the voltage measured from the regulator is 3.3 ± .2 V once it is connected to the wall mounted power supply.

2. Accept 120-240VAC as input and output 5±.2 V and 700±25 mA.	2. When plugged into the wall, a multimeter will be used to determine whether the voltage measured is 5±.2 V and the current measured is at most 700 mA.

2.3.2 Control System

The role of the Control System is to link all of the systems together, send data, and to identify the license plate number from the picture taken by the Camera System. This will be achieved with a transceiver module and a microcontroller, which will be physically connected to each other and to the Power Subsystem. RF connections will be made with the other modules to send data.

2.3.2.1 Microcontroller

The microcontroller that is planned to be used is the STM32H743BIT6 because of the high computing power with the ARM Cortex-M7 processor. The microcontroller will collect the images from the Camera System once the IR sensor detects an object nearby and execute an image recognition program to identify the license plate number from the image. Then, it will send the license plate number to the transceiver where it will send the data to the Central Logger System to store the number in the database.

Requirements	**Verification**
1. The image recognition program on the microcontroller must have an accuracy of 85%. 2. The microcontroller must be able to correctly identify the license plate number from the pictures taken from the Camera System with an accuracy of 85%. 3. The microcontroller must be able to send the data collected from the image recognition program to the transceiver	1. The program will read 433 images of license plates in the Kaggle License Plate Dataset, and it must correctly identify at least 368 of the images [3]. 2. 20 pictures of license plates around UIUC campus will be taken using the Camera System, and it must correctly identify 17 of the license plates. 3. Set up a data stream that connects to a computer that correctly shows the correct value of the data sent from the microcontroller.

2.3.2.2 Transceiver

The transceiver must be able to send the data obtained from the microcontroller to the Central Logger System from a long distance reliably. The data will be sent at a rate of 19.2 ± 2 kbps. This data rate was chosen because the datasheet stated 19.2 kbps is a common data rate. The data rate is also quite reasonable since there is not a lot of data that needs to be transmitted over a short period of time.

Requirements	Verification
1. The transceiver must be able to successfully transmit the correct data from a distance of 150 ± 5 ft to ensure a successful communication over a long distance	1. Have a LoRa receiver successfully receive a packet from the transceiver that is 150 ± 5 ft away.

2.3.3 Camera System

The role of the Camera System is to take pictures of the license plate and send the data to the microcontroller. The Arducam camera was decided on because of the ability to take HD pictures so that it ensures good quality images for the microcontroller to conduct its image recognition program reliably. Also, it is compatible with Raspberry Pi so it will be relatively easy to implement with the microcontroller. Furthermore, the camera is very small, and it has capabilities to adjust to low light conditions.

Requirements	Verification
1. The Camera System must be functional between ambient temperatures of -40°C to 40°C. 2. The Camera System must be able to receive a signal from the microcontroller that allows it to take a picture and send the picture data out.	1. 2 operating condition tests to test temperature resilience: a. The camera will be placed in a freezer for 30 minutes, and it must still be able to satisfy the previous verification being taken out. b. The camera will be placed in an oven at 40°C for 30 minutes, and it must still be able to satisfy the previous verification after being taken out. 2. Send a signal through the SPI that should take a picture and verify whether or not the output data stream contains the picture that was taken.

2.3.4 IR Sensor System

The role of the IR System is to allow for a low-power method to see if a parked car is still there. This subsystem will be connected to the Power Subsystem and the Control System through the PCB. The reason the sensor was decided on was because of the long range capabilities of this IR sensor. It has a working range of 100 cm to 550 cm which allows the Main Camera Module to be placed in a spot that is not intrusive to the traffic in the parking lot.

Requirements	Verification
1. The sensor must be able to detect the car's distance correctly within 10 cm. 2. The sensor must be able to send a signal to the microcontroller if an object is identified to be within 120 ± 10 cm of the sensor.	1. The IR sensor will be given 10 scenarios where an object will be placed at randomly generated distances (within range of the sensor). The IR sensor must determine the distance within 10 cm of the actual distance in 9 of 10 scenarios. 2. A multimeter will be connected to the data stream output to the IR sensor so that if the IR sensor detects an object that is 120 ± 10 cm from the sensor, there should be a momentary increase in voltage from the multimeter.

2.3.5 Central Logger System

The Central Logger System will be an application on a computer. It must be lightweight and not intrusive to the computer. The application will be running at all times so that the Camera System can send in the gathered license plate numbers at all times. The computer must be able to receive the data that is being transmitted from the Camera System through the RF signals.

Requirements	Verification
1. The computer program must be able to read the incoming RF signals from the Main Camera Module using the USB transceiver. 2. The computer must have a database of 10 MB to store the parking lot occupancy data.	1. Send data packets through using 915 MHz and see if the computer receives the packets through the transceiver 2. Check the computer to see how much space it has allocated for the program and the database.

2.4 Tolerance Analysis

The system that will pose the greatest difficulty is the control system in the Main Camera Module. The image recognition process is the most important component of the whole system so it needs to be reliable. We have seen the output from users who have previously used the dataset and they have gotten a validation accuracy range of 74% to 86%. Therefore, we believe that we can achieve a validation accuracy of 85% since there have been programs that have gotten a better accuracy. The pictures in the dataset are quite clear which means we will need a decent camera to capture the license plates to match our data set better. American law states that license plates must be at least 2.5 inches in height and "proportionally wide", meaning that characters usually hover around 1 inch in width.

Our decision to use the OV5647 Arducam module comes from its field of view and resolution. We plan to deploy the Arducam under 5.5 meters from the car's license plate. Given the datasheet values, the Arducam is rated to capture an image of the objects within a rectangle of 5.5 meters in length and about 3.68 meters in height. By using a 1080p camera, this would give us a pixel density of about 71.48 pixels per square inch. Using the given dimensions of license plate characters, each character would take up about 2.5 square inches, meaning that about 179 pixels are dedicated to each character in a worst-case scenario. Given that license plate characters are about 0.2 to 0.4 inches in stroke width, there cannot be any characters that are obscured by lack of pixels. This is in line with European highway recommendations for automatic license plate recognition technology in use.

In the case of a situation where the parking assistant is unable to read the license plate, or it reads it incorrectly, the IR sensor will know when a car is in the parking spot so it can communicate with the camera system and the central logger system that a car is in the spot and it will need to input the license plate number manually into the central logger system so that the car's license plate number will still be in the central logger system.

3. Cost & Schedule

3.1 Cost Analysis

3.1.1 Labor

Based on UIUC's ECE website, the average starting salary of a computer engineering student is $96,992 and the average starting salary of an electrical engineering student is $76,079 [10]. Since our team contains two computer engineering students and one electrical engineering student, the average salary for the three of us would be $91,232. We estimate that we will be working around 10 hours per week on developing our prototype for the next eight weeks.

Furthermore, we will need help from the machine shop which is estimated to cost $70/hr [14]. The work that needs to be done on the case is relatively simple so we were thinking it would take around five hours to finish it.

Student labor:
Salary = $91,232 ≈ $45/hr
$45/hour x 10 hours/week x 8 weeks x 3 people x 2.5= $27,000

Machine shop labor:
$70/hour x 4 hours = $280

3.1.2 Parts

Item	Manufacturer	Part #	Quantity	Cost	Total Cost
Camera	Arducam	OV5647	1	$9.99	$9.99
IR Sensor	Sharp	R316-GP2Y0A710YK	1	$14.00	$14.00
Microcontroller	STMicroelectronics	STM32H743BIT6	1	$19.18	$19.18
Transceiver chip	Adafruit Industries LLC	3070	1	$9.95	$9.95
Power supply	iMBAPrice	iMBA-5V500MA-1PK	1	$6.99	$6.99
FPC Connector	TE Connectivity AMP Connectors	1-1734248-5	1	$0.98	$0.98
Case	Polycase		1	$10.00	$10.00
USB C Input	GCT	USB4110-GF-A	1	$1.41	$1.41
PCB			1	$5.00	$5.00
Camera Module					$77.50
USB Transceiver	Seeed Technology Co., Ltd	113990939	1	$19.95	$19.95
Total Cost					$97.45

The cost for building one full prototype will be $97.45. However, we have expectations to scale the camera module so that multiple camera modules can be connected to one central logger. Therefore, we have split the costs to list the price for the scalable module, $77.50, and the total cost for one prototype, $97.45. We are planning to build two camera modules that connect to one central logger so our total cost of our parts will be:
2 x ($97.45) + $19.95 = $214.85

3.1.3 Grand Total

$27,000 + $280 + $214.85 = $27,086.04

3.2 Schedule

Week	Progress	Responsibility
9/27	Finish Design Document	Daniel, Freddy and Mehul
10/4	Finish designing PCB for first round approval	Mehul
	Finish ordering parts to possibly create prototype	Daniel and Freddy
10/11	Check connections on PCBs? (not sure if the PCB will arrive at this time)	Daniel and Mehul
	Start developing software for image processing	Freddy (and possibly Mehul)
10/18	Start designing second round PCB	Daniel, Freddy and Mehul
	Connect the camera to the microcontroller and capture an image	Freddy
	Connect the IR sensor to the microcontroller and detect a large object within 5 metres	Mehul
10/25	Finish second round PCB and get it approved	Daniel
	Verify a signal between the two transceivers	Daniel, Freddy
11/1	Have microcontroller program be able to pass verification	Mehul, Freddy
	Start soldering components onto PCB	Daniel
11/8	Finish soldering parts together	Daniel
	Test components on PCB and pass all requirements	Daniel, Freddy and Mehul
	Prepare outline for presentation and have all files uploaded	Daniel, Freddy and Mehul
11/15	Have prototype set up to be presentable and complete a draft of the presentation	Daniel, Freddy and Mehul
11/22	Party during break	Not Freddy :(
11/29	Finish Presentation	Daniel, Freddy and Mehul
12/6	Turn in everything o:	Daniel, Freddy and Mehul
	Receive an A in the class	Daniel, Freddy and Mehul

4. Discussion of Ethics & Safety

There are a few safety concerns that we have looked into that span from risks that could occur while developing our prototype to potential safety hazards that could happen while our product is in deployment. The safety concerns we have are electric safety, environmental interference, RF radiation risks, and general lab safety.

Because we are working with wall mounted power that will be generating 120 V, we will need to be cautious about our wiring to prevent damage to ourselves and other equipment that we will be using. While we are not dealing with extremely high voltage that can be lethal, 120 V can still harm us. We will be developing our prototype in our lab with electrical safety in mind.

Since our product will be used outside, we needed to take into consideration the different environmental effects that could damage our product and potentially cause damage to the area. Some of these factors are water and disruptiveness. We have set our product to have an Ingress Protection rating of IPX4 to protect it against low pressure water. We deemed IPX4 to be sufficient water protection because there should not be any scenarios where the case gets hit with high pressure water. While driving is a very common activity in today's society, it is quite dangerous because of the potential damage it could do to the environment and the amount of concentration that is required by the driver. We have designed our Main Camera Module with this in mind by having it be inserted into a little cubby in the ground so it is concealed. This way, the driver will not get distracted by the Main Camera Module to reduce the chance of an accident from occurring.

With the use of our RF transceiver, there is a risk for RF radiation. However, we have decided that this issue is not applicable because the rate at which we send the signals is very low and the power of the signals is much lower than the SAR limit for a cell phone [9].

The development of our prototype will be done in an electronics lab which has some safety hazards. There will be soldering irons in use and the use of electrical equipment. In order to stay safe in the lab, we have been certified to work in these conditions by acquiring a Laboratory Safety Training certificate.

A potential ethical issue related to image data could arise if the images taken by our solution contain sensitive data which may violate a person's privacy and in turn violate the 1st Code of Ethic (IEEE Code of Ethics, 2021). Our solution thus aims to avoid any sort of image data being transmitted by performing on-board image segmentation and transmitting only the acquired license plate data (which is public knowledge) through RF. This avoids any privacy breaches by disallowing any sensitive information to be vulnerable during transmission. Another source of concern could be encountered while handling the payment information, specifically associating license plates with Credit Cards(or other forms of payment). A simple way to deal with this would be to make use of industry standard encryption protocols and make use of secure services to facilitate payments.

5. Citations

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