Senior Design Project Proposal for Year 2023

Pothole Detector using Machine Learning

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1. Introduction

Potholes are a common problem on roads and highways, they can cause significant damage to vehicles, lead to accidents, and increase maintenance costs. Potholes are often difficult to detect, especially at high speeds or in poor lighting conditions. Drivers may not see potholes until it is too late, which can cause a safety hazard for drivers, passengers, and pedestrians. Potholes can also be inadvertently costly for cities and municipalities due to possible significant damage to roadways and infrastructure caused by traffic accidents if left untreated.

To address these issues, I am proposing a pothole detection system to help identify and locate potholes in real-time. This system uses the YOLOv4-Tiny machine learning repository combined with a Raspberry Pi 3 and Raspberry Pi Camera Module to detect and track potholes, alert drivers to their presence and record the coordinates of the detected pothole into a ThingSpeak cloud database. By detecting potholes early, this system can help reduce the risk of accidents and damage to vehicles, as well as reduce the overall cost of city maintenance.

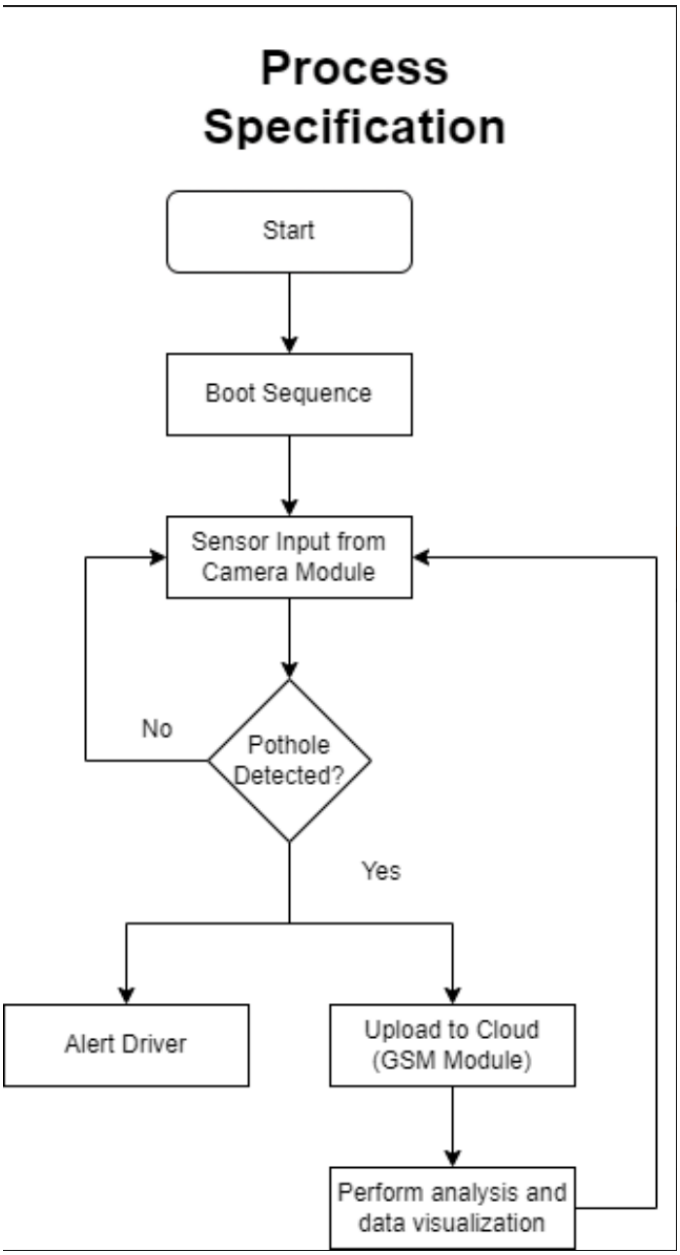
2. Proposed Design

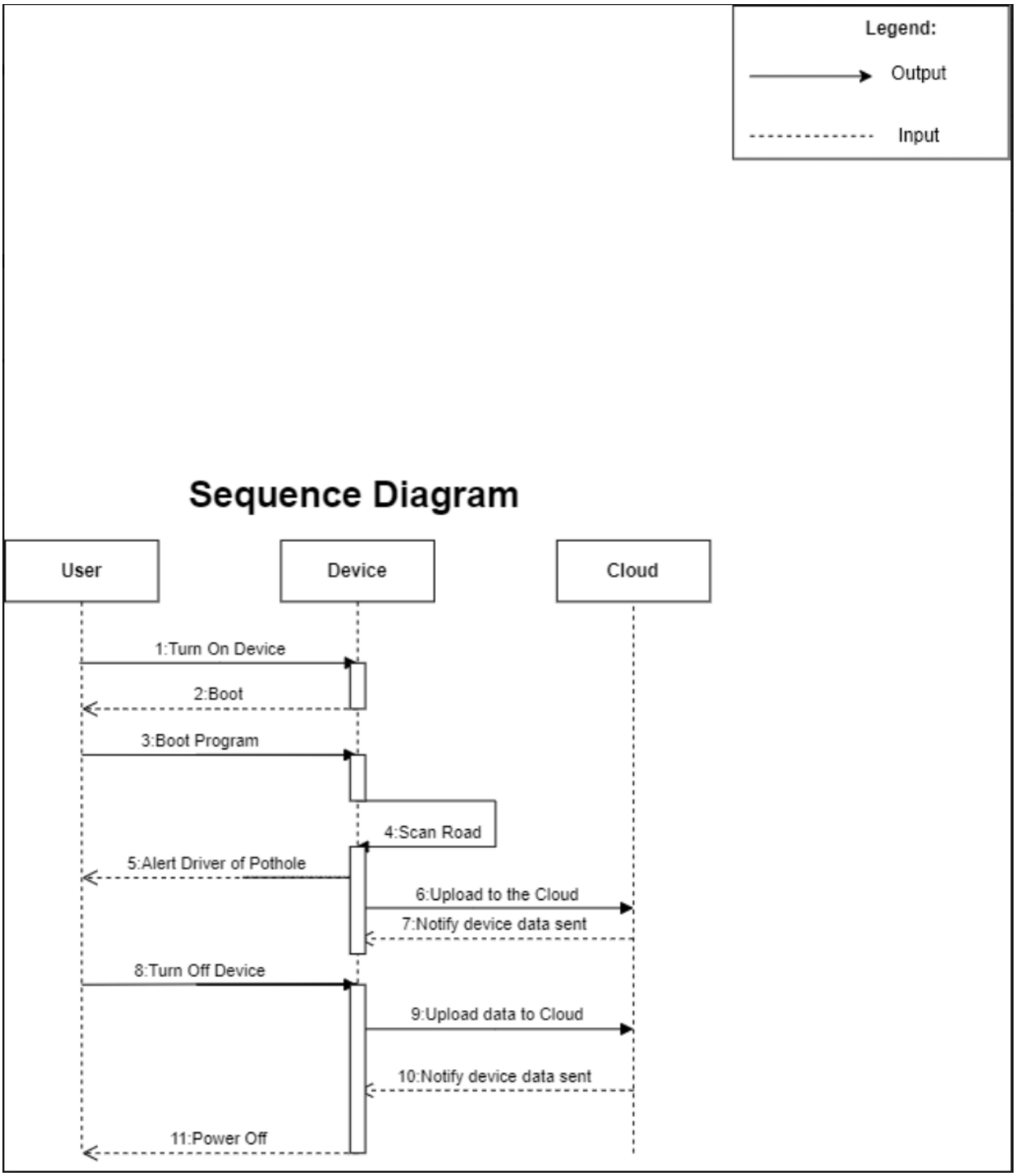
Function description and breakdown

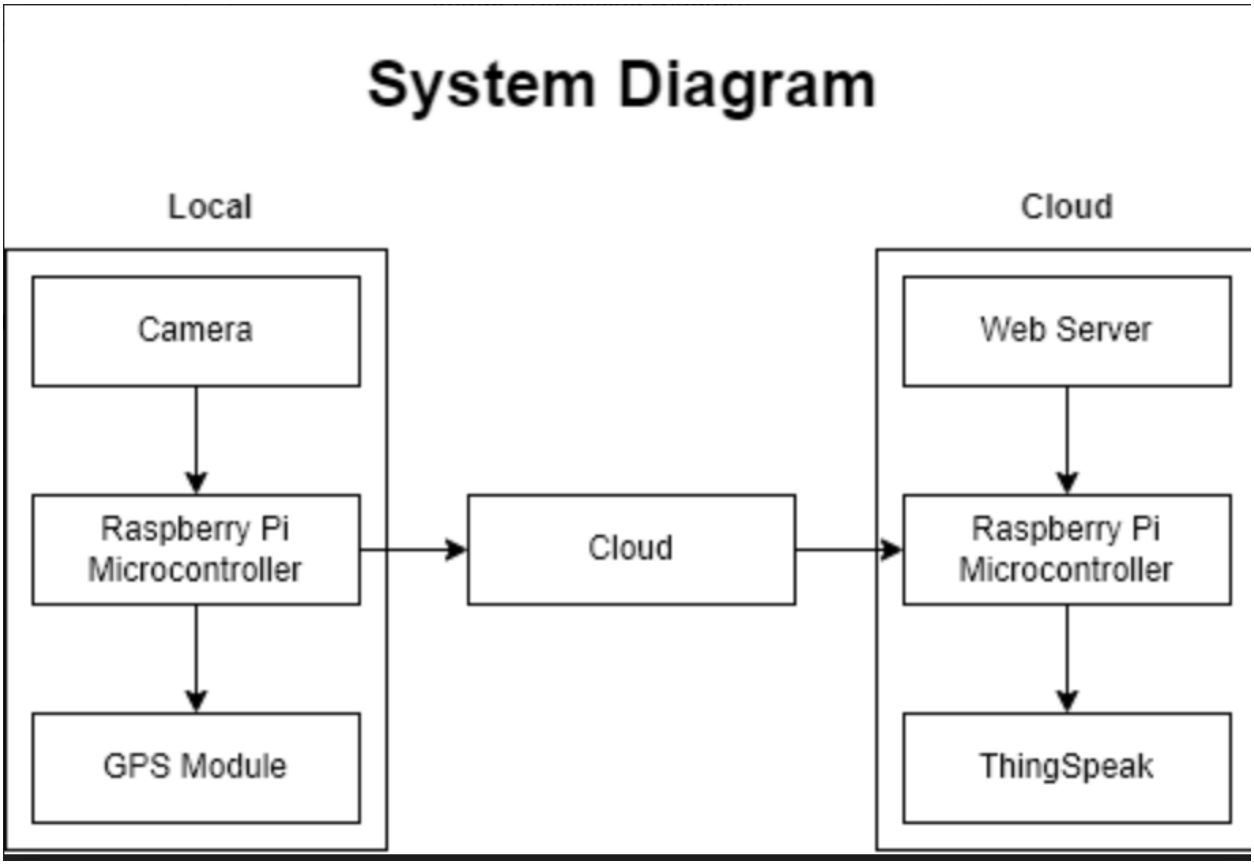
I propose to design the Pothole Detection System (PDS) utilizing a Raspberry Pi 3 Model B+, an Arducam 5MP camera. The YOLOv4-Tiny object detection library is chosen to operate on the Raspberry Pi 4 due to its high detection accuracy of 90% at a length of 10 meters and a high Frames Per Second (FPS) of 31.92 [1]. The camera is connected to the Raspberry Pi 3 o\Model B+ to record the video stream while the device remains on. If a pothole is detected by the camera within 10 meters the device alerts the driver and uploads the coordinates of the pothole to the cloud. Below are the base line and upgraded functions, as well as diagrams of the PDS.

PDS Functionalities

Baseline/ Fundamental Functions	• Detect potholes and alert driver. • Allow night-time detection capabilities. • Update travel route on pothole detection. • Upload pothole data to Cloud database
Upgraded Functions (optional)	• Detect other possible hazards (object collision detection, flash floods, fires, etc.)




Legend:
Output
Input
Sequence Diagram
User
Device
Cloud
1:Turn On Device
2:Boot
3:Boot Program
4:Scan Road
5:Alert Driver of Pothole
6:Upload to the Cloud
7:Notify device data sent
8:Turn Off Device
9:Upload data to Cloud
10:Notify device data sent
11:Power Off



For this project the required skills include electrical and computer engineering concepts such as machine learning for utilizing the pre-trained model for detecting potholes, circuit analysis, embedded systems and IoT design.

Specification and design constraints

Purpose: A pothole detection system that alerts the driver when an upcoming pothole has been detected using a night vision camera and Raspberry Pi 3 Model B+ and uploads GPS location data of the pothole to a cloud database for reference and data visualization.

Behavior: PDS should begin scanning for potholes once powered on. The system is pre-trained with images of various potholes to accurately detect and alert the driver. PDS estimates the size of detected potholes (roughly 1ft-5ft wide) in every frame it records.

System Management Requirement: The system should provide object detection, GPS, GSM, and cloud-based functionality.

Data Analysis Requirement: The system should perform cloud-based analysis of the pothole coordinate data using ThingSpeak.

System and Module Specifications

Pothole Detection Device (Local)	**Input:** User credentials, video camera recording, battery power supply w/switch (USB-C) **Output:** Data uploading to cloud, alarm notification **Power Requirements:** 5V, 2.5A DC **Data Transmission Protocol:** WebSocket Protocol, RS232 and TTL UART, 802.11 b/g/n/ac Wireless LAN **Pothole Detection Range:** Roughly 10 meters **Weight:** 9.814 ounces **Dimensions:** **Constraints:** There should be enough light to detect the pothole and the vehicle should be moving below 45mph for the system to get a good quality video of the road.
Pothole Detection Database (Cloud)	**Input:** Coordinates of identified potholes **Output:** Visual representation of pothole data **Power Requirements: N/A** **Data Transmission Protocol:** WebSocket Protocol **Measurement Range: N/A** **Constraints:** Data should be transmitted in intervals of 30 seconds to prevent data congestion.
Raspberry Pi 3 Model B+	**Processor:** Broadcom BCM2837B0, Cortex-A53 64-bit SoC @ 1.4GHz **Memory:** 1GB LPDDR2 SDRAM **Connectivity:** 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless, LAN, Bluetooth 4.2, BLE, Gigabit Ethernet over USB 2.0 (maximum throughput 300Mbps), 4 × USB 2.0 ports **Access:** Extended 40-pin GPIO header **Video & Sound:** 1 × full size HDMI, MIPI DSI display port, MIPI CSI camera port, 4 pole stereo output and composite video port **Multimedia:** H.264, MPEG-4 decode (1080p30); H.264 encode (1080p30); OpenGL ES 1.1, 2.0 graphics **SD Card Support:** Micro SD format for loading operating system and data storage **Input Power:** 5V/2.5A DC via micro USB connector, 5V DC via GPIO header, Power over Ethernet (PoE)–enabled (requires separate PoE HAT) **Dimensions:** 85 x 56 x 17 millimeters **Weight:** 7.1 ounces **Operating Temperature:** 0 to +50 °C
Arducam 5MP Camera Module	**Input Power:** 1.5V to 3.0V DC **Peak Current:** 300mA **Sensor:** OV5647

	Connection: 15 cm flat ribbon cable to 15-pin MIPI Camera Serial Interface (CSI) connector **Lens:** Fixed Focus Lens **Angle of View:** 54° Horizontal x 41° Vertical **Field of View:** 2.0 x 1.33m @ 2m **Resolution:** 5 Megapixels, 2592 x 1944 **Frame Rates:** 30fps@1080P, 60fps@720P, 90fps@480P **Fixed Focus:** 1m to Infinity **Dimensions:** 4.7 inches x 0.2 inches x 0.1 inches **Weight:** 0.32 ounces **Operating Temperature:** -30 to+70 °C
GSM Module	**Input:** 3.3V to 5.0V @ 45.0mA DC **Data Transmission Protocol:** GSM, TCP/IP, SMS, Bluetooth **Operating Temperature**: -40°C to 85°C **Dimensions:** 30.2mm x 65.0mm **Weight:** 4.6 ounces
System Power Supply Unit	**Output Voltage:** 5.0V DC **Dimensions:** 3.66 x 2.28 x 1.54 inches **Weight:** 2.394 ounces **Input:** 6 x 1.5V AA Batteries (9V)
6-AA 9V Battery Pack	**Input:** 6-AA Batteries **Output:** ~9.0V DC **Dimensions:** 3.625 inches x 2.25 inches x 0.625 inches **Weight:** 0.634 ounces
LM2596 DC/DC Buck Converter	**Input Voltage:** 3.0V to 40.0V DC (must be higher than 1.5V DC) **Output Voltage:** 1.5V to 35.0V w/ 3.0A DC **Dimensions:** 45.0 inches x 20.0 inches x 14.0 inches **Weight:** 1.76 ounces **Operating Temperature:** -40°C ~ 85°C

Table of employed standards:

Standard	Link or References
IEEE Standard for Sensor Performance	https://standards.ieee.org/ieee/2700/6770/

Parameter Definitions	
Standard for Harmonization of Internet of Things (IoT) Devices and Systems	https://standards.ieee.org/ieee/1451.99/10355/
IEEE Draft Standard for Automotive System Image Quality	https://standards.ieee.org/ieee/2020/6765/

Table of Open Source Codes/APIs:

Open-Source Code/API	Link or References
Raspberry Pi Tensorflow Package	https://github.com/tensorflow/build/tree/master/raspberry_pi_builds
Picamera Python Package	https://github.com/waveform80/picamera/tree/release-1.13
Darkflow Repository	https://github.com/thtrieu/darkflow/

3. Major Components/Parts

Part Description	**Function**	**Amount Needed / Unit Price**	**Subtotal**	**Purchase Link**	**Datasheet Link**
Raspberry Pi 3 Model B+	Central controller for reading sensor data, alerting the driver and passengers of an upcoming pothole, and uploads the	1/$35.00	$35.00	https://www.adafruit.com/product/3775?src=raspberrypi	https://datasheets.raspberrypi.com/rpi3/raspberry-pi-3-b-plus-product-brief.pdf

	data to a cloud database for future reference and data visualization.				
Arducam 5MP Camera Module OV5647	Camera module for scanning the road and detecting potholes in low-light conditions	1/$9.99	$9.99	https://www.amazon.com/Arducam-Megapixels-Sensor-OV5647-Raspberry/dp/B012V1HEP4?ref_=ast_sto_dp&th=1&psc=1	https://docs.arducam.com/Raspberry-Pi-Camera/Native-camera/source/OV5647DS.pdf
Coolwell Raspberry Pi GSM HAT GSM/GPRS /GNSS/Bluetooth Module	GSM module with GPS support used to send pothole coordinates to the ThingSpeak cloud when a pothole is detected. The module also receives a confirmation message when the data is received by the cloud.	1/$37.20	$37.20	https://www.amazon.com/Coolwell-Raspberry-Bluetooth-Module-Supports/dp/B0BS42WPGQ/ref=sr_1_8?keywords=raspberry+pi+gsm+module&qid=1677371035&sprefix=raspberry+pi+gsm+mo%2Caps%2C323&sr=8-8	https://www.waveshare.com/w/upload/4/4a/GSM_GPRS_GNSS_HAT_User_Manual_EN.pdf

Jumper Wires (4in and 8in pack)	Connecting the modules to their appropriate pins to perform pothole detection and data uploading.	1/$6.49	$6.49	https://www.amazon.com/dp/B01L5ULRUA?ref_=dp_atch_dss_base_image	N/A
Cylewet 10Pcs 5V Active Buzzer	Buzzer component for alerting the driver of upcoming pothole	1/$6.98	$0.14	https://www.amazon.com/gp/product/B01N7NHSY6/ref=ewc_pr_img_1?smid=A2O4FZXIRZDLHA&psc=1	N/A
6-AA 9V Battery Pack	Power supply of the system	1/$6.99	$6.99	https://www.amazon.com/Battery-Holder-Enclosure-Connector-Cable/dp/B01N2INSBR/ref=sr_1_8?crid=1LM4N7NY5TJD2&keywords=6+aa+battery+pack+holder&qid=1679283954&sprefix=aa+battery+pack+holder%2Caps%2C203&sr=8-8	N/A

LM2596 DC to DC Buck Converter	Supplies the system with 5V to meet Raspberry Pi 3 Model B+ power requirements.	5/$8.99	$0.56	https://www.amazon.com/LM2596-Converter-3-0-40V-1-5-35V-Supply/dp/B08NV3JCBC/ref=sxin_17_ac_d_rm?ac_md=1-1-YnVjayBjb252ZXJ0ZXI%3D-ac_d_rm_rm_rm&content-id=amzn1.sym.b09913c7-88ee-4b06-b977-3fd4ebd29a25%3Aamzn1.sym.b09913c7-88ee-4b06-b977-3fd4ebd29a25&cv_ct_cx=LM2596&keywords=LM2596&pd_rd_i=B08NV3JCBC&pd_rd_r=490c4f97-64fd-4551-90e5-	https://www.ti.com/lit/ds/symlink/lm2596.pdf?ts=1679251371627&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FLM2596

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4. Responsibilities of Team Members

My responsibilities for the PDS project will consist of purchasing the necessary components and equipment, writing progress reports, system design, debugging, training the system to detect potholes, and programming the hardware to alert the driver and send data to the ThingSpeak cloud.

5. Timeline and Milestones

Weeks (xx/xx - xx/xx)	Team member 1's tasks

Week 5-6 (02/12-02/25)	Submit Full Proposal.
Week 7-8 (02/26-03/11)	Receive feedback and purchase the following items: • Raspberry Pi 3 Model B+ • Raspberry Pi GSM • Raspberry Pi Night Vision Camera • Battery Pack/Power Supply Begin Progress Report I
Week 9-10 (03/12-03/25)	Download the YOLOv4-Tiny library and construct training dataset for detecting potholes (~300 images). Finish and submit Progress Report I.
Week 11-12 (03/26-04/08)	Begin end of semester report and presentation. Upload training data to Raspberry Pi 3, connect the night vision camera module and conduct detection accuracy tests.
Week 13-14 (04/09-04/22)	Connect GSM module and buzzer component and test for data transmission and alarm module. Finish End of Semester Report and Presentation.
Week 33-34 (08/27-09/09)	Finish prototype on breadboard. Begin Progress Report II
Week 35-36 (09/10-09/23)	Perform finalized breadboard tests and finish Progress Report II
Week 35-36 (09/10-09/23)	Design PCB and design 3D case for system. Begin Progress Report III
Week 37-38 (09/24-10/07)	Fabricate PCB, print and assemble PBC components and 3D printed case for system. Begin Poster and record demonstration videos.
Week 39-40 (10/08-10/21)	Perform system tests (Cloud database and data visualization, solder components, finalize mobile application). Finish Progress Report III
Week 41-42 (10/22-11/04)	Test pothole detection and with PCB components and 3D printed case design for portable usage. Test with cyclist point-of-view.
Week 43-44 (11/05-11/18)	Test system and finalize design
Week 45-46 (11/19-11/02)	Finish presentation slides and final report

6. References

[1] M. H. Asad, S. Khaliq, M. H. Yousaf, M. O. Ullah, and A. Ahmad, “Pothole Detection Using Deep Learning: A Real-Time and AI-on-the-Edge Perspective,” Advances in Civil Engineering, vol. 2022, p. e9221211, Apr. 2022, doi: https://doi.org/10.1155/2022/9221211