Faculty of Electronics & Computer Technology and Engineering

HARDWARE DEVELOPMENT OF REAL-TIME POTHOLE MANAGEMENT SYSTEM USING GPS TRACKER AND ULTRASONIC SENSOR

NUR SYAFIQAH BINTI MOHD SHAFFRY

Bachelor of Computer Engineering Technology (Computer Systems) with Honours

2024

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A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Computer Engineering Technology (Computer Systems) with Honours

Faculty of Electronics & Computer Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI DAN KEJURUTERAAN ELEKTRONIK DAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Hardware Development of Real-time Pothole Management System Using GPS Tracker and Ultrasonic Sensor

Sesi Pengajian : 2023/2024

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I declare that this project report entitled “Hardware Development Of Real-Time Pothole Management System Using Gps Tracker And Ultrasonic Sensor” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of **Bachelor of Computer Engineering Technology (Computer Systems) with Honours**

Signature :

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Date : 13/2/2024

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Date :

DEDICATION

To my beloved mother, Azizah Kasim,

and father, Mohd Shaffry,

and

To my mentor supervisor, DR. Suhaila Bt Mohd Najib and

My fellow friends

ABSTRACT

Potholes are significant safety hazards on roads and detecting them in real-time can help prevent accidents and reduce traffic congestion. The bulk of road accidents in many developing nations are caused by potholes, humps, and abrupt interference from barriers on the road. The roads in the region need to be kept in good shape at all times so that people can travel without risk. This research aims to identify the depth of the potholes using two sensors and two types of microcontroller such as GPS, Ultrasonic Sensor, Arduino Uno and Raspberry Pi. Sensor-based systems rely on sensors such as ultrasonic sensors to detect potholes, while machine learning-based systems use algorithms to analyze sensor data and identify patterns associated with potholes. The reviewed studies demonstrate high accuracy rates in detecting the depth of the potholes on different types of roads condition. This system was built by using python language and YOLOv5 object detection model which is one of the computer vision approaches. 2146 images were trained and tested using the model to achieve high accuracy of potholes detection.

ABSTRAK

Lubang jalan adalah salah satu jenis bahaya dalam keselamatan jalan raya yang dapat dikesan dalam masa nyata bagi mengelakkan kadar kemalangan serta mengurangkan kesesakan lalu lintas. Sebahagian besar kemalangan jalan raya di banyak negara membangun berpunca daripada jalan berlubang, bonggol dan gangguan daripada penghadang di jalan raya. Jalan raya di rantau ini perlu dikekalkan dalam keadaan baik pada setiap masa supaya orang ramai boleh melakukan perjalanan tanpa sebarang risiko. Kajian ini bertujuan untuk mengesan kedalaman lubang jalan mengunakan dua jenis sensor dan dua jenis mikropengawal seperti pengesan GPS, Sensor Ulrasonik, Arduino Uno dan Raspberry Pi. Sistem sensor bergantung pada sensor yang digunakan seperti sensor ultrasonik untuk mengesan lubang, manakala sistem berasaskan pembelajaran mesin menggunakan algoritma untuk menganalisis data sensor dan mengenal pasti corak yang dikaitkan dengan jalan berlubang. Kajian yang disemak menunjukkan kadar ketepatan yang tinggi dalam mengesan kedalaman jalan berlubang pada pelbagai jenis keadaan jalan raya. Sistem ini dibina dengan menggunakan bahasa python dan model pengesanan objek YOLOv5 yang merupakan salah satu pendekatan penglihatan komputer. 2146 imej telah dilatih dan diuji menggunakan model untuk mencapai ketepatan tinggi pengesanan jalan berlubang.

ACKNOWLEDGEMENTS

First, I would like to express my gratitude to my supervisor, Dr. Suhaila Binti Mohd Najib, for her great advice in this project. The encouragement given by Dr. Suhaila able for to get through some difficulties on the project. The most help given by her in manner of technical to fulfil and achieve the success of the project. My highest acknowledgment goes to my parents, younger sister and younger brother for their console and prayer during when making of my project. Besides, the stress and mental challenge I go through able to overcome with their full support. Finally, I would like to covey my thanks to my fellow friends and classmate for sharing their ideas on how to progress in my project. The thoughts to provision me to conduct the project well. I am very appreciating for having a kind and caring friend around me.

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LIST OF ABBREVIATIONS

YOLO - You Only Look Once

SSD - Single Shot Detector

CNN - Convolutional Neural Network

CHAPTER 1

INTRODUCTION

1.1 Background

Numerous safety features such as parking sensor, reverse sensor, and anti-lock brake system (ABS) are now common in modern vehicles to assist drivers with safer driving. However, it still can cause traffic accidents to the drivers where it causes from external or environmental factors. Accidents are often categorized as major, or minor based on their severity. Although each accident is unique, the severity can be determined by the type of collision, risk variables, and vehicle impact pattern.

According to MIROS' 2018 Value of Statistical Life (VSOL) (n.d), Malaysia's government has suffered losses of at least 3.12 million for each life. With an average of 18 people dying in traffic accidents every day in Malaysia, the country faces a significant public health concern. Additionally, it emphasizes the urgent requirement for a successful policy response. The current Malaysia Road Safety Plan 2014-2020 has as its goal to achieve the goals of the United Nations Decade of Action for Road Safety 2011-2020 with the goal of stabilizing and reducing the forecast level of road accident fatalities by 50% by 2020 from 10,716 fatalities in 2020 to 5,358 fatalities.

Table 1.1 shows the number of road accidents has increased during the last ten years. The number of fatalities has been gradually decreasing over the past ten years, peaking at 7,152 in 2016 and showing its lowest reading at 6,167 in 2019.

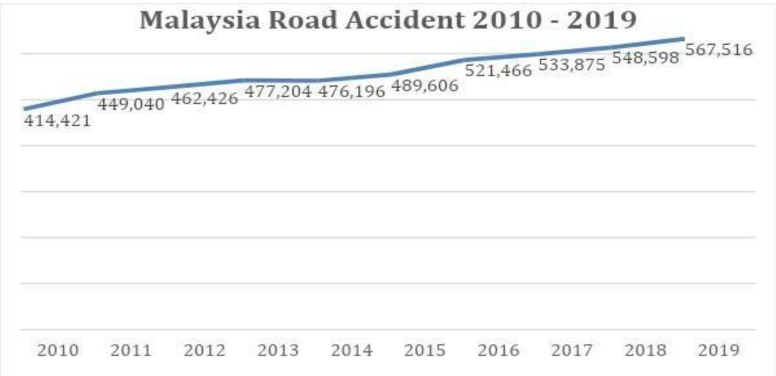


Figure 1.1 Malaysia Road Accident 2010-2019

Source: https://www.mot.gov.my/en/land/safety/road-accident-and-facilities

Figure 1.2 Malaysia Road Fatalities Index 2010-2019

Source: https://www.mot.gov.my/en/land/safety/road-accident-and-facilities

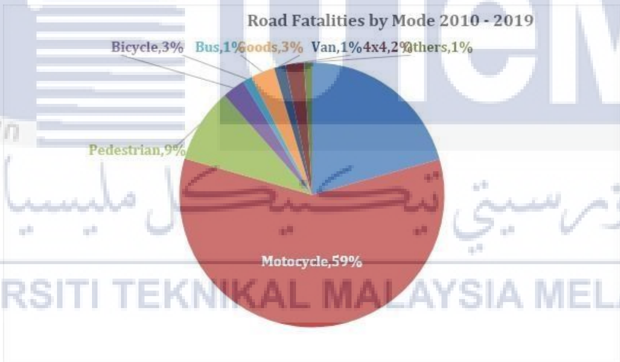


Figure 1.3 Distribution of road fatalities mode from 2010-2019

Source: https://www.mot.gov.my/en/land/safety/malaysia-road-fatalities-index

Besides, Malaysia has seen a continuous decrease in fatalities caused by road users and road types since 2010. Based on Figure 1.3, Motorcycles account for 59% of all road fatalities, while passenger cars account for 21% of all fatalities among all road users.

One of the major causes that can lead to traffic accidents is poor road conditions. Road hazards such as potholes, loose gravel, and others can make drivers lose control of their cars and cause collisions with other vehicles or objects. Potholes can be found frequently on both roads as well as highways. Despite advancements in pothole detecting systems, there are still some issues to be solved. Pothole detecting systems, for example, can be affected by factors such as road surface conditions, vehicle speed, and the presence of other cars. Furthermore, the high cost of installing these systems on a big scale can be an impediment to their widespread acceptance. In the future, there is a lot of room for research into pothole detection systems. Improving the accuracy of these systems, particularly in difficult traffic circumstances like as bad weather or uneven road surfaces, could be one area of study. Integrating pothole detecting systems with current road infrastructure could also assist to streamline maintenance processes and save repair costs.

In Malaysia, every road has a pothole, but the government won't take it seriously until a major crash occurs or a month before and after the Malaysian general election. According to the article from The Smart Local Malaysia, 2021, from Figure 1.4 and 1.5, a motorcyclist in the video, can be seen stopping abruptly in front of the massive pothole which he did not seem to notice from far away. However, keep in mind that every pothole is unique, no potholes are the same. Because of criteria like machine quality and workmanship, certain potholes may cost more to repair than others. Hence, this project is developed to help the local authorities to take a further action before it becomes worst.

Figure 1.4 Image of massive pothole in Sabah

Source: https://thesmartlocal.my/pothole-in-sabah/

Figure 1.5 A CCTV footage of delivery rider braking suddenly in front of a massive pothole

Source: https://thesmartlocal.my/pothole-in-sabah/

1.2 Awareness

These studies are focusing on the safety hazards since it can cause damage to vehicle which will affect vehicle stability and handling. Besides, it can contribute to an increased risk of accident that may lead to injuries. Other than that, it may have a legal consideration since the system involve the collection and storage of data, that including the GPS information and image capture by the sensors. Hence, these issues contribute to enhancing road safety and protecting data privacy.

1.3 Problem Statement

Recently, several accidents have been reported due to the increasing number of deaths after people losing control of their vehicles while navigating them. In Malaysia, potholes have turned out to be one of the major causes of road accidents. Potholes are often difficult to detect, and their presence can be dangerous for drivers, especially in situations where the driver is not familiar with the road or is driving at high speeds. All these considerations need the gathering and dissemination of information about dangerous road conditions. There is various type of pothole with different size and depth.

A system for detecting potholes captures, transmits, and records data within the vehicle must be developed to alert the driver of impending uneven road and potholes. All the information of the potholes will be sent to the database as a reference to the local authority. The goal of this review is to provide a comprehensive understanding of the current pothole detection technologies and the potential of future research in this area.

1.4 Objective

The objectives of this study are as follows:

a) To provide a real-time potholes database for local authority references based on different depths and locations.

b) To detect potholes in real-time using computer vision method and ultrasonic sensor.

1.5 Scope of Project

Here's a description of what the project is all about:

a) The dataset for this project is 2146 datasets and divided into three which 70% images is the training dataset, and 30% images is the validation dataset.
b) The deep learning framework and object detection models used for this project is Pytorch and YOLOv5.
c) This approach involves analyzing video frames captured by cameras to identify potholes.
d) The use of sensors such as ultrasonic sensors and GPS to detect depth and the location of the pothole respectively.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Recently, several accidents have been reported due to the increasing number of deaths after people losing control of their vehicles while navigating them. In Malaysia, potholes have turned out to be one of the major causes of road accidents. Potholes are often difficult to detect, and their presence can be dangerous for drivers, especially in situations where the driver is not familiar with the road or is driving at high speeds. Hence, the purpose of this system is to detect potholes in realtime using computer vision method and to provide potholes database for local authority based on different depth. However, while deploying this system has numerous benefits, it is critical to be aware of potential safety risks and legal difficulties that may occur.

There are two main types of pothole detection systems which is sensor-based and machine learning-based. In this project, I use sensor-based system which is ultrasonic sensors. The performance of pothole detection systems depends on various factors, including the type of sensor used, the location of the sensors on the vehicle, the speed of the vehicle, and the road surface conditions. Researchers have conducted experiments to evaluate the accuracy of pothole detection systems in different conditions, including different types of roads, different speeds, and different weather conditions. Pothole detect will be used to train the system to recognize and detect the potholes which have been captured by the camera located under vehicle. Besides, ultrasonic sensor and GPS tracker installed to measure the depth of the potholes and identify the location of the potholes, respectively.

Despite the progress made in pothole detection systems, there are still some challenges to be addressed. For example, the accuracy of pothole detection systems can be affected by factors such as road surface conditions, vehicle speed, and the presence of other vehicles. Furthermore, the cost of implementing these systems on a large scale can be a barrier to their adoption. Looking forward, there is significant potential for future research in pothole detection systems.One area of focus could be improving the accuracy of these systems, particularly in challenging road conditions such as poor weather or uneven road surfaces. Additionally, integrating pothole detection systems with existing road infrastructure could help streamline maintenance processes and reduce repair costs.

All the information of the potholes will be sent to the database as a reference to the local authority. The goal of this review is to provide a comprehensive understanding of the current pothole detection technologies and the potential of future research in this area. We hope that this review will contribute to the development of more accurate and efficient pothole detection systems, which will improve road safety, reduce vehicle damage, and repair costs, and enhance the overall quality of transportation infrastructure.

2.2 Advancement in Pothole Detection System

Potholes were an important concern when it comes to maintaining road infrastructure because they can be hazardous and inconvenient for users. Detecting the road imperfections in a timely manner is crucial for ensuring safe and efficient transportation. In order to solve this problem, different approaches have been developed. There are three prominent methods that will be discuss which it is sensor-based detection, vision-based detection and mobile phone-based detection.

2.2.1 Sensor -based Pothole Detection System

Even for humans, let alone machines, recognizing potholes may be challenging especially in bad weather. On rainy days, potholes could be concealed by or resemble puddles. Water on the car windshield can reduce visibility and make it difficult to spot the road damage. Fog's reduces sight and can easily cause vehicle damage from potholes. Hence, the automatic detection of objects based on deep computer vision models can, to some extent, suppress various adverse influences.

Based on research by Gayathri et.al (2019), they were using 2D LiDAR and Camera. LiDAR is used to obtain angle and distance information as illustrated in Figure 2.1. Other than that, they also use MATLAB has been used to train the system based on the existing number of pothole texture extraction and comparison. Rachitka et.al (2019) used Raspberry Pi, camera, ultrasonic sensor, and Wi-Fi module.

Ultrasonic sensor works on the principle of reflected sound waves to measure distance between vehicle and road surface. When a pothole is detected, the image will be captured and sent to the authorities' system.

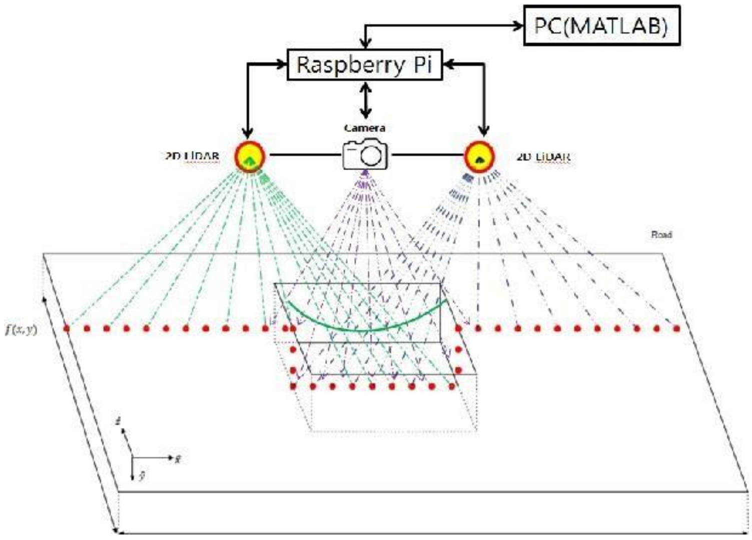


Figure 2.1 Pothole Detection model using 2D LiDAR

Source: https://www.semanticscholar.org/paper/Pothole-detection-system-using-2D-LiDAR-and-camera-Kang-Choi/f3626a7e06c2f73c0a5ea0dd5b815813c6299d3f

2.2.2 Vision-based Pothole Detection System

The image threshold needed to identify the pothole was calculated using an image histogram in this method. It will give the sharp contrast between the black of the road condition and the white of the pothole, it was determined that the pothole would be represented as a big peak close to the lighter pixel bins.

There are several research that use image processing to detect the pothole by considering the road condition. Based on the research conducted by Pranjal A. Chitale (2020) detected the pothole and estimated the dimension of the system which implemented image processing and Deep Learning technique which was Convolutional Neural Network (CNN).

Another research from Anas et.al (2021) stated three approaches which Vibrationtechnique, 3D reconstruction technique and Vision technique. This study deployed and tested different deep learning architectures to detect the presence of potholes. Other than that, to compare pothole detection performance, real-time deep learning algorithms with various configurations such as SSD TensorFlow, YOLOv3-Darknet53 and YOLOv4-CSPDarknet53 were used.

2.2.3 Pothole Detection System Using Mobile Phone

Smartphones sensors analyze variety of environmental factors such as ambient light, device orientation and movement. Every smartphone is equipped with a three-dimensional coordinate system. Sensors in your smartphone detect and record changes in real time using this technique. The type of sensor in the smartphone is accelerometer. An accelerometer sensor is a device that monitors the acceleration of any body or object at rest. Chou Wu et.al (2020) suggested an autonomous pothole detection system make used of the GPS receivers and built-in vibration sensors in smartphones. Using specialized vehicles, smartphone and a mobile application specifically created for this study to collect the data of a road condition.

2.3 Python Language and OpenCV

OpenCV is a Python package that enables image processing and computer vision tasks. This technique offers a wide range of image modification techniques to help researchers in their work. It was developed to speed up the incorporation of machine perception into consumer goods and to offer a standardized infrastructure for computer vision applications. It has many features, such as object detection, face recognition, and tracking. Furthermore, the OpenCV image-training programmed is necessary to train images from datasets divided into two categories which is training and testing. In addition, the utilized software for this purpose is PyCharm with Python being employed as its primary programming language. With an image processing approach being used, it is possible to determine the diameter of the pothole. With several images in its training process, this model is being utilized.

2.4 Computer Vision Perspective and Machine Learning Algorithm

Pothole detection systems use a variety of methods and algorithms to examine the visual data that is recorded by cameras from the standpoint of computer vision. To identify pothole related patterns and extract relevant characteristics from images or video, computer vision techniques are used. Machine learning approaches are also important in pothole detecting systems. These algorithms are trained using labelled datasets containing instances of potholes and non-potholes. In this application, common machine learning methods include decision trees, random forests, support vector machines (SVM), and deep learning models like convolutional neural networks (CNNs). Based on the retrieved features, these algorithms learn from the training data to identify future instances as potholes or non-potholes.

Machine learning algorithms learn from data patterns to produce accurate predictions, whereas computer vision techniques extract meaningful information from visual input. This combination of computer vision and machine learning enables pothole detection systems to locate potholes automatically and efficiently, contributing to enhanced road maintenance and safety.

2.5 Comparison Between the Sensors

There are several types of sensors that can be used for detecting the pothole such as Ultrasonics Sensor, LiDAR Sensor, Gyroscope Sensors, and Accelerometer Sensors. Without the need for physical contact, ultrasonic sensors provide a cost-effective way to find, count, and identify things. Figure 2.2 shows the working of ultrasonic sensor to detect the speed bump and pothole. However, because they don't disturb adjacent areas when scanning a room, they aren't effective for finding quickly moving things or objects that are out of reach. LiDAR sensors operate similarly to ultrasonic sensors in terms of their fundamental principle. LiDAR's employ a laser beam rather than sound waves to measure distance and analyze objects, with the sole difference being the frequency at which they operate. However, compared to ultrasonic and IR sensors, the expense of using LiDAR is more expensive. It is also harmful to the naked eye because high-end LiDAR devices may employ harsher pulses that could impact human eyes.

Other than that, an accelerometer is a device that measures the speed of a falling object. Accelerometers in mobile phones are used to determine the phone's orientation. The gyroscope extends the information provided by the accelerometer by tracking rotation or twist. Both sensors are a cost-effective component to use.

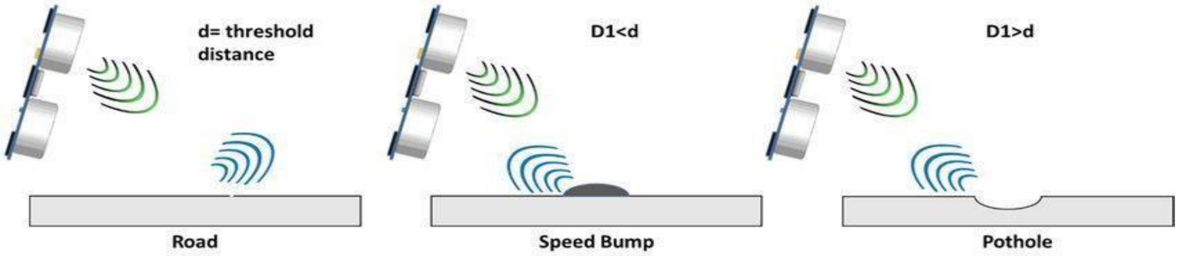


Figure 2.2 Example of Working Of Ultrasonic Sensor

Source: Hrishikesh Mehta 2021

2.6 Comparison of The Previous Works on Pothole Detection System

Table 2.1 The comparison of the road pothole detection system

NO	TITLE	AUTHOR	DETECTOR SENSOR	OBJECTIVE	ADVANTAGE	DISADVANTAGE
1.	A Real-time Pothole Detection Based on Deep Learning Approach	Yeoh Keng Yik, Nurul Ezaila Alias, Yusmeeraz Yusof, Suhaila Ishaak (2020)	• Accelerometer sensor	The article seeks to introduce an innovative system for real-time pothole detection that utilizes deep learning techniques and the YOLOv3 algorithm. The objective is to enable the system to swiftly detect potholes in real-time through the use of a webcam, and then to mark their precise location using the Google Maps API for visualization purposes. The proposed system represents a practical and efficient means of monitoring potholes that could have significant benefits for both the public and government agencies.	• The benefit of the YOLOv3 algorithm is that it offers a reliable and effective method for tracking potholes in real time. • Allows for easily developed and high accuracy detection, which can be installed into the embedded system of public vehicles with minimal effort. • The system can also log the location of potholes using	• Limitation of traditional methods for monitoring road conditions, such as relying on government vehicles or public efforts to report abnormalities. • Accelerometer detection can result in false detections and damage to the vehicle suspension system. • Machine learning-based detection requires extensive time and knowledge to develop feature extractors.

				Furthermore, the authors suggest that installing the system in public transport or taxis could help to minimize accidents caused by potholes on roads in Malaysia.	Google Maps API for visualization, making it easier for the public and government to monitor potholes.	
2.	IoT Based Real Time Potholes Detection System Using Image Processing Techniques	Kulwant Singh, Sristy Hazra, Chandra Mukherjee, Sushanth.G, Sanjith Gowda. (2020)	• Ultrasonic sensor	The system's primary objective is to notify drivers of potholes and record their geographical location in a database that municipalities and road maintenance organizations can access for maintenance purposes. The paper also presents several techniques for detecting potholes on the road, including image-based systems, smartphone sensors, and accelerometer-based systems. Additionally, the document explores the feasibility of automated pavement condition surveys and the difficulties associated with them. The ultimate aim of this	• It can improve road safety. • Efficient maintainace which the location of the potholes is saved in a database, which can be accessed by government authorities and road maintenance agencies for immediate maintenance or repairing of potholes. • It is cost effective.	• Limited coverage since the system relies on vehicles equipped with sensors which not cover all areas of road. • The accuracy of the system may be affected by factors such as the speed of the vehicle, the angle of the sensor, and the quality of the road surface. • Requires regular maintenance. • Privacy concerns if the data is not properly secured.

				proposed system is to minimize accidents due to potholes and enhance road infrastructure maintenance.		
3.	An Application Study on Road Surface Monitoring Using DTW Based Image Processing and Ultrasonic Sensors	Sunil Kumar Sharma, Haidang Phan and Jaesun Lee (2020)	• Ultrasonic Sensor	The intention of this research paper is to propose a new system for detecting potholes and speed humps in India. It use a combination of ultrasonic sensor and image processing techniques. It is a cost-effective and accurate proposed system to provide real-time alerts on road hazards. The proposed system was tested in Noida and the results revealed a high accuracy rate of 95.48%. It also highlights the limitation of the proposed system and suggests future research direction.	• Cost-effective proposed system which it used ultrasonic sensors and HUD modules • The proposed system can be used for various sorts of road conditions and in different whether.	• Requires regular maintenance. • The accuracy of the model depends on the quality and quantity of data used for training.
4.	Development and Analysis of Pothole detection and Alert based on NodeMCU	Etukala Jaswanth, Reddy, Padhuri Navaneeth Reddy, Govindula	• Ultrasonic sensor	The proposed system is designed to identify the location and depth of potholes without the need for intensive computation and processing.	• The system provides continuous monitoring of road conditions, allowing	• Limited coverage since the system relies on vehicles equipped with sensors which not cover all areas of

		Maithreyi, M. Bharath Chandra Balaji, Santanu Kumar Dash, K. Aruna Kumari (2020)		Subsequently, the detected pothole locations are transmitted to maintenance authorities via an IFTTT server. The document refers to various previous research on technology for pothole detection and road monitoring, emphasizing the necessity for economical methods to detect substandard road conditions.	maintenance authorities to take timely action to repair potholes. • The GPS module used in the system provides accurate location detection of potholes, enabling maintenance authorities to quickly locate and repair them. • The system is easy to install.	road. • The accuracy of the GPS module may be affected by weather conditions. • The ultrasonic sensor may detect other objects as potholes, leading to false positives and unnecessary alerts to maintenance authorities. • Requires regular maintenance.
5.	Efficient pothole detection using smartphone sensors	Kshitij Pawar, Siddhi Jagtap, Smita Bhoir (2020)	• Accelerometer sensor • Gyroscope sensor	The purpose of this paper is to tackle the issue of road safety in India due to potholes. The proposed solution employs data gathered from the accelerometer and gyroscope sensors of smartphones to train a neural network model that can distinguish between instances of potholes and	• It is affordable device since it is cost-effective as it uses the in-built sensors of a smartphone. • It is scalable and efficient as neural networks can handle large data sets. • It does not	• It requires a sufficient amount of data to train the neural network. • It requires periodic updates and maintenance to ensure its continued accuracy. • It relies on the availability of a smartphone with in-

				non-potholes. The document also provides a survey of existing techniques for pothole detection and highlights research gaps.	require any special configuration.	built sensors.
6.	An Automated Machine-Learning Approach for Road Pothole Detection Using Smartphone Sensor Data	Chao Wu, Zheng Wang, Simon Hu, Julien Lepine, Xiaoxiang Na, Daniel Ainalis, Marc Stettler. (2020)	• Triaxial accelerometer	This approach can save time and resources needed for pothole detection. The document explores the feasibility of this idea, demonstrating that machine-learning models can achieve high accuracy in pothole classification using features extracted from acceleration signals along three axes. The document also introduces a complete workflow for data processing for pothole detection using smartphones, including novel concepts for segmenting a continuous signal sequence using a sliding window and appropriate thresholds to remove irrelevant data.	• The use of machine-learning models with features extracted from acceleration signals along three axes achieved significant precision and recall for pothole classification. • It is universal and does not rely on specific data sets. • It is easy to deploy and use.	• It requires different models to be trained on a mixed data sets. • This method may not be suitable for detecting moderate potholes in urban roads, as the model trained on a mixed dataset tends to detect severe potholes in suburban roads. • It may increase the burden on the server for machine-learning classification.
7.	Real-time machine learning-	Oche Alexander Egaji, Gareth Evans, Mark	• Z-axis Accelerometers sensor	The objective of this research was to create an intelligent system for	• Can compare the performance of five different	• Used relatively small data set which limit the

	based approach for pothole detection	Graham griffits, Gregory Islas (2021)	• Gyroscopes sensor	detecting potholes using machine learning and data from mobile sensors. The study intended to evaluate and compare the performance of five binary classification machine learning models in detecting potholes, specifically for balanced data, and to determine the most effective model for the task. The research also aimed to enhance the performance of the chosen model using random search hyperparameter tuning. The end goal was to create a practical and precise approach to detect potholes in real-time using mobile devices.	machine leraning models. • The study optimized the performance using random search hyperparameter tunig.	generalizability. • It may not capture the severity or size of potholes since it focuses on binary classification. • It does not consider the impact of weather conditions or other external factors on pothole detection.
8.	Learning To Automatically Catch Potholes In Worldwide Road Scene Images	J. Javier Yebes, David Montero and Ignacio Arriola (2021)	• Ultrasonic sensor • Accelerometer sensor • Image based pothole	The article discusses the development of an automated method for detecting and identifying potholes in road scene images from around the world. The method uses deep learning techniques to analyze the images and provide actionable insights	• Automated pothole detection can save time and resources compared to manual inspections. • Consistent and objective	• The initial setup and training of the deep learning model can be time-consuming and expensive. • The accuracy of the model depends on the quality and quantity of data used for training.

				to improve road safety and maintenance. The approach has been tested on a large dataset of road scene images and shows promising results in terms of accuracy and efficiency.	identification of potholes regardless of human bias.	• The model may not be able to detect all types of potholes or accurately identify their severity.
9.	Automated Management Of Pothole Related Disasters Using Image Processing And Geotagging	Madhura Katageri, Manisha Mandal, Mansi Gandhi, Navin Koregaonkar, Prof. Sharmila Sengupta	• Not stated	The purpose of the article is to introduce a system that can automatically manage pothole-related disasters through image processing and geotagging. The system involves a smartphone app that captures images of potholes, which are analyzed using computer vision techniques to determine their severity. The system also uses geotagging to pinpoint the location of the pothole and send alerts to appropriate authorities for repair.	• It is a cost-effective since it just use smartphones. • It allows citizens to actively participate in identifying and reporting potholes, leading to quicker repairs. • It use Geotagging to tract the location of the pothole accurately.	• Loss of semantic information caused by light or bad weather, small vehicle objects and other challenges under complex road conditions.. • There may be privacy concerns regarding geotagging and sharing images of roads.
10.	Real-Time Pothole Detection Using Deep Learning	Anas Al Shaghouri, Rami Alkhatib, Samir Berjaoui	• Smartphone's built-in accelerometer. • Gyroscope sensor	To propose a real-time pothole detection system that utilizes deep learning algorithms to detect potholes on roads. In this article, it discuss about system's design, which	• It is a cost-effective since it use smartphones. • The proposed system was tested on	• The system's performance may be affected by adverse weather conditions • It requires periodic updates and maintenance to

				uses a convolutional neural network (CNN) to analyze images from a camera mounted on a vehicle to identify potholes. The proposed system was tested on a dataset of images of road surfaces with and without potholes. The results showed that the proposed system achieved high accuracy and precision in detecting potholes. The article aims to provide insights into the system's performance, accuracy, and efficiency and demonstrate its feasibility for real-world applications.	different types of roads and showed consistent performance, indicating its applicability to various road conditions.	ensure its continued accuracy.
11.	Pothole And Hump Recognition Using Lidar Sensor	V.N. Raj Sudharshan, S. Ramesh, S. Thamodharan, M. Uthavanatha Sarath Santhar, M. Kamalakannan (2019)	• LiDAR Sensor • GPS sensor	In this article, the system collects data from these sensors and uses Arduino UNO to identify potholes and estimate their depths and height of the hups. The light signals from the LiDAR sensor are initially sent rapidly. The sent signals scan the road surface and are reflected back to the sensor. The	• Allows for easily developed and high accuracy detection, which can be installed into the embedded system of public vehicles with minimal effort. • It may reduce	• It does not consider the impact of weather conditions or other external factors on pothole detection. • It requires periodic updates and maintenance to ensure its continued accuracy. • It is costly since the

				acquired data is processed by the microcontroller and compared to pre-programmed reference values using an appropriate algorithm. The result is generated using the processed data.It aims to accurately detect potholes and estimate their depths, as well as provide continuous monitoring of road conditions for timely repair.	maintenance costs by enabling authorities to repair potholes before they become severe.	LiDAR sensor a bit pricy.
12.	Automatic Pothol Detection And Notification System	Suchita Chavan, Mrunal Wagh, ArchanaUshir, Kalyani Aher, Shivani Sonawane	• Ultrasonic sensor • Pressure sensor	The objective of the article is to introduce a system that can detect and alert drivers of potholes and humps on roads automatically while also measuring the tire pressure of vehicles. The main aim of this system is to minimize road accidents caused by these factors.	• Notification of potholes and humps on roads to aid drivers. • Use of low cost sensors which is ultrasonic and pressure sensor. • Notification of road conditions delivered through the internet, bringing it to the notice of government officials for	• The system relies on the availability of internet connectivity to deliver notification to goverment.

					proper road maintenance	
13.	Pothole Detection using LiDAR	Vasha Prasad, Shivani Kumari, Suryatej I.P (2021)	• 2D LiDAR sensors • GPS sensor	This article focus on a conceptual framework for a system that can detect potholes on roads which are beyond the driver's visibility range in real-time by using LiDAR sensor. This sensor are provides 360˚ distance data by having the sensor on rotating platform. After the detection of a pothole, the GPS location of the pothole is obtained using a GPS sensor. The pothole data, including its location, is subsequently sent to a cloud database. A web application that uses the Maps JavaScript API to mark potholes on Google Maps incorporated in a custom webpage.	• Use better and more reliable method for pothole detection which can bring about a radical change in the existing road transportation system. • 2D LiDAR sensors deliver highly accurate spatial contour data regarding distance, angle, and remission, as well as reflector data, with rapid speed throughout a 360-degree scanning path.	• Requires significant maintenance to ensure its accuracy. • Challenge in implementing the system such as installing the laser sensor on vehicles. • Low visibility of pothole from long distance. • Narrow width of potholes making it hard to detect using standard resolution cameras
14.	Smart Pothole Detection Using Deep Learning Based on Dilated	Khaled R. Ahmed (2021)	• GPS sensor • 3D laser	This research built effective CNN models taking into account the requirements to detect potholes in roadways correctly and in real-time.	• It is a affordable system because it is not use too much hardware and much use a deep learning.	• The accuracy of detecting potholes may be affected by false positive and false negative readings caused by

	Convolution			The tests performed in this research made use of a dataset that included photos of potholes that were captured under various lighting situations, on various roads condition and with various shapes and sizes. Research is being conducted to automate the process of finding potholes in roadways using a variety of methods, including sensor-based techniques, 3D reconstruction techniques, stereo vision-based techniques, image processing techniques, and model-based techniques. The performance of the models in validation sets was significantly impacted by the pothole images that were shot in poor road conditions, extreme weather conditions including snow, and from unusual camera angles. This research uses ten different CNN to train the pothole datasets.		the vibration sensor misidentifying junctions in roadways as potholes or failing to detect potholes in the centre of a lane, respectively.

				Experiments show that faster R-CNN is better. ResNet50 has the highest precision (91.9%) than the others.		
15.	Detection of Pothole in Real-Time Using Android Based Application	Tajeshwari Chouhan, Khushboo Kumari, Priyanka Kumari. (2021)	• Accelerometer sensor	This article highlights the development of system detecting potholes using android application. The technology used in this article is SVM and CNN. The proposed system can detect road condition and send real-time location to registered numbers in case of emergency. The document also discusses the use of machine learning and sensors in detecting potholes and the prospects and challenges of implementing the internet of things GPS in detecting and reporting potholes on roads.	• It is a affordable system because it is not use too much hardware. • Android application is more reliable. • Use Support Vector Machine algorithm which it produce better performaces.	• It may be not accurate since it use phones which it will effect the angle of the picture of pothole. • It relies on the availability of a smartphone with in-built sensors and GPS. • It requires periodic updates and maintenance to ensure its continued accuracy.
16.	Computer Vision Based Pothole Detection under Challenging Conditions	Lu Xiong, Xin Xia, Jiaqi Ma, Zhaojian Li and Marco Leo. (2022)	• Accelerometer sensor	This article are focus on the systematic approach for pothole detection using computer vision under challenging weather. The study found that the Yolo v3-SPP model achieved the	• The study found that the Yolo v3-SPP model achieved the highest accuracy, but at the expense of	• Specific set of object detection models and did not explore other potential models. • It does not consider the impact of

				highest accuracy, but at the expense of reduced detection speed.	reduced detection speed.	weather conditions or other external factors on pothole detection.
17.	Pothole detection system design with proximity sensor to provide motorcycle with warning system and increase road safety driving	Hadistian Muhammad Hanif, Zener Sukra Lie, Winda Astuti, Sofyan Tan (2020)	• Time of Flight(ToF) sensor • Gyroscope sensor	This article highlights the proximity sensor system which employs a camera and digital image processing technique that was used as a model for the creation of the pothole detection sensor. Other than that, an infrared-based ToF (Time of Flight) sensor was used as the proximity sensor. This sensor is a small part of the LiDAR sensor, which also measures distances using light. The microcontroller will receive the sensor's distance data to process it, and the results will reflect the state of the roads. The system can be readily constructed or modified using the Arduino programming language because the entire data	• Use affordable components. • User friendly from the feasibility and the finantial aspects. • Lower cost of maintenance.	• Limitation and challenges of existing method.

				processing was done on an Arduino-based microcontroller. After the data has been processed, the system will release it to the existing interface so that motorcycle riders can use it as information. As a result of this research and study, it was determined that the pothole detection distance should be within a 4% range from the sensor.		
18.	Design and Development of a Pothole Tracking System (PotAlert) using Web Progressive Application (WPA)	Aerina Sofea Rosli, Maryam Roslan, Azlin Nordin (2022)	• GPS sensor • Accelerometer sensor	This article describes the design and development of PotAlert, a pothole tracking system based on a progressive web application (PWA). The programme was created to enable road users and authorities to communicate and exchange information about potholes on the route. The authorities are also given analytical data visualisation of the reports to help them make decisions. To ensure that road users offer accurate and relevant information, they are also given the	• Use a low cost sensor • The drivers and government able to get notification about the road condition.	• The effectiveness of the model may depend on accuracy of the sensor. • The system relies on the availability of internet connectivity to deliver notification to goverment.

				option to make a comment and assign a severity level to potholes. The main reason to develop this system is to provide convenience and ease of access for both road users and authorities in the reporting and supervision of potholes.		
19.	Pothole Detection using YOLOv4 and Darknet	Sovit Rath (2022)	• Camera	In this article, it use YOLOv4 and Darknet which develop an accurate and efficient deep learning-based system that can detect potholes in real-time using CCTV cameras.	• Potholes can be accurately detected by deep learning-based algorithms by lowering the possibility of false positives or false negatives.	• The system may not work effectively in areas where CCTV camera coverage is limited or non-existent.
20.	A Smart App for Pothole Detection Using YOLO Model	Radhika V. Kulkarni (2021)	• Camera	The objective of this article is use smart app to detect the pothole which is using YOLO model. The app aims to improve road safety by alerting drivers of potholes in real-time and providing information to the authorities for timely repairs. The article also aims to evaluate the performance of the YOLO	• It is cost-effective since it just use smartphones. • Provides high accuracy since it use YOLOv3 model. • The app can provide a real-time information on	• It does not consider the impact of weather conditions or other external factors on pothole detection. • It requires periodic updates and maintenance to ensure its continued accuracy. • The system relies on

				model for pothole detection and compare it with other popular object detection models.	pothole	the availability of internet connectivity • The app dependent on user participation.

2.7 Review of The Comparison of Pothole Detection Table

Table 2.1 summarized data from 20 previous works on pothole detection system based on various detection system. Ultrasonic sensor and LiDAR sensor achieved a good performance and the most accurate in detecting potholes. For the Ultrasonic sensor, this can be approved by Sunil et.al (2020) where the system show better efficiency with a 95.5% detection rate for various road surface irregularities. It was agreed by Javier et.al (2021) where the sensors provide 96% detecting the potholes. On the other hand, Gayathri et.al (2019) implemented 2D LiDAR and camera managed to achieve the most accurate value since the sensor can be rotated to 360 degrees. Sudharshan et.al (2019), researchers agrees that the LiDAR sensor can give accurate data since it able to sense-data that includes pothole depth, hump's height and distance of potholes from the vehicles.

2.8 Summary

In this system, it incorporates multiple sensors including a camera, accelerometer, ultrasonic sensor, pressure sensor, gyroscope, and LiDAR sensor. To properly identify and monitor potholes on roads, the proposed pothole detection system employs a variety of modern sensors. The device includes a camera sensor that gathers visual data from the road surface are detecting the potholes based on visual signals and patterns. The pothole detection system utilizes an accelerometer sensor to gauge the vehicle's vibrations and movements, enabling the identification of abrupt changes in motion that occur when encountering potholes. Additionally, the system integrates an ultrasonic sensor to measure the distance between the vehicle and the road surface. By detecting substantial alterations in these distance measurements, the presence depth of potholes can be accurately determined, signifying the existence of road depressions. For this project, ultrasonic sensor has been choosen as the detection sensor which gain high accuracy based on the research made by the previous researchers and it is cost-effective rather than choose the LiDAR sensor which it do have a higher accuracy but it is more expensive.

CHAPTER 3
METHODOLOGY

3.1 Introduction

This chapter describes the flow and process of the development of a real-time pothole management system using a GPS tracker and ultrasonic sensor. This chapter consists of the flowcharts, block diagram and proposed system used in this project.

3.2 Methodology

This chapter will provide examples of the setup, programs, and methods used to accomplish the goals of this study. There are some methods involved in this project which is a combination of computer vision techniques and machine learning algorithms for detecting the potholes.

3.2.1 Block Diagram

Figure 3.1 and 3.2 shows the the block diagram for detecting depth and location of pothole. The main component of the system is the Raspberry Pi itself. The Raspberry Pi is connected to a GPS tracker, which tracks the location of the device. The GPS tracker is also connected to a push button, which can be used to send a signal to the Raspberry Pi. The push button can be used to send a signal to the Raspberry Pi, and the database can store data collected by the system. The depth and the location data will be processed and pass to the database. When a pothole is detected, system stores the required information at the Google Sheets. For figure 3.2, a camera mounted on a vehicle captures images of the road surface. If a pothole is detected, the system could log its location data using the Neo-6m GPS tracker.

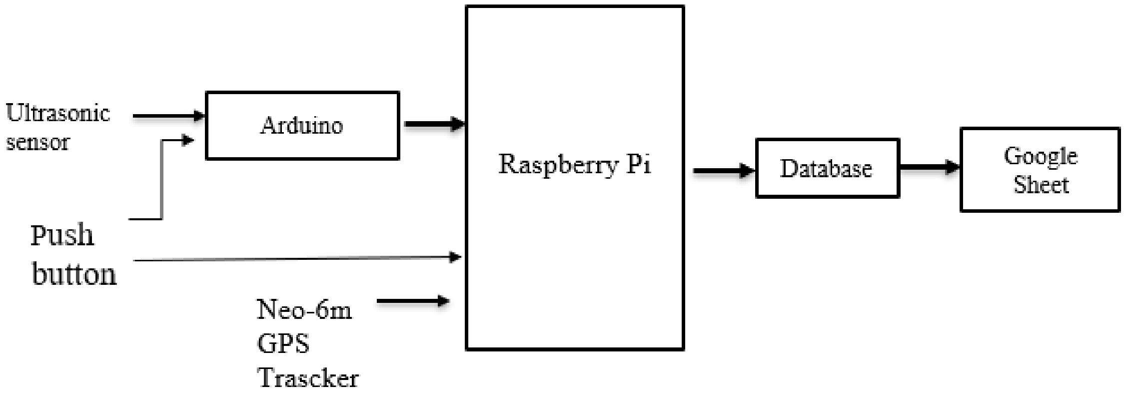


Figure 3.1 Block diagram for detecting depth and location of the pothole

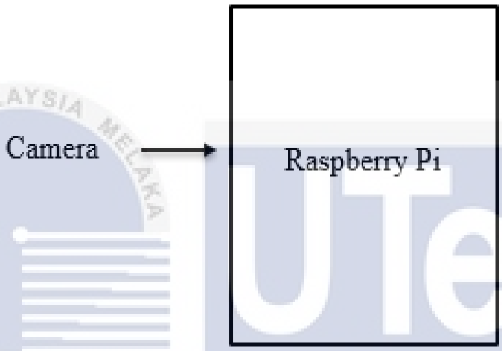


Figure 3.2 Block diagram for detecting depth and location of the pothole

3.2.2 Process Flow of Pothole Detection Using Image Processing Method

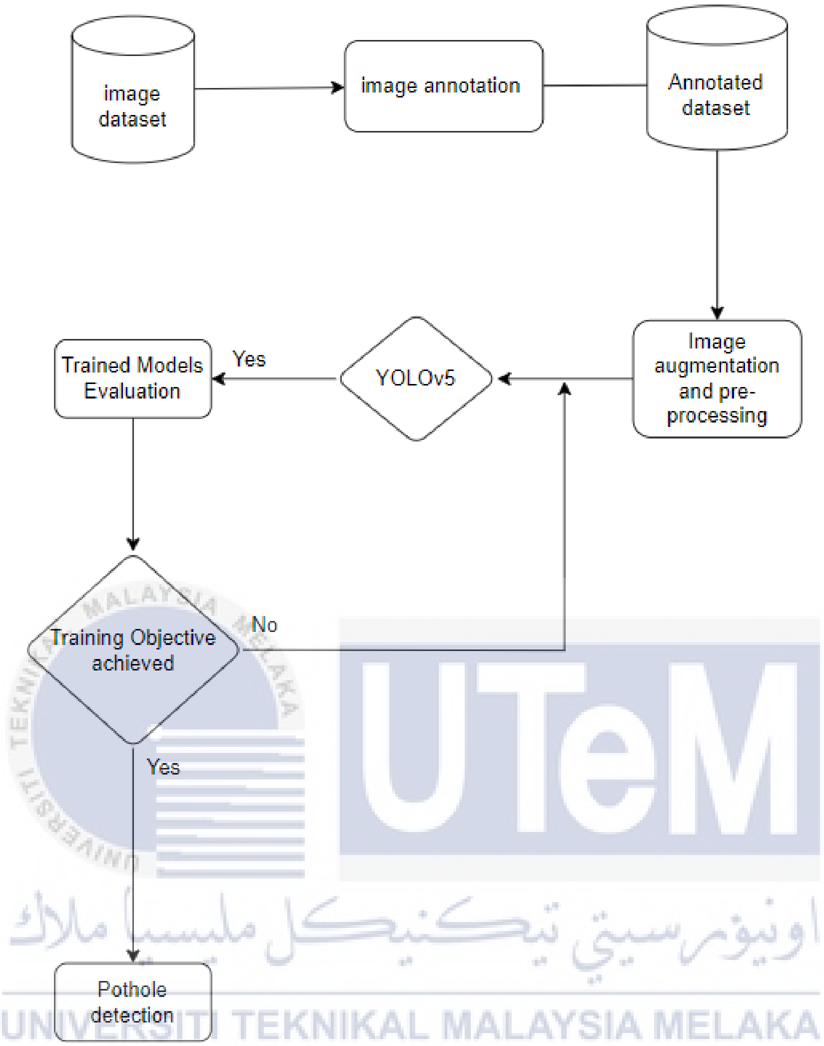


Figure 3.3 Operational Flow of Pothole Detection

a) **Image datasets:** For this system flowchart, the image dataset are acquired through online sources from a computer vision developer which is RoboFlow. The dataset consists of pothole images with 4960 image overall. It split into three categories which training dataset(4331 images), validation dataset (419 images) and testing dataset (210 images).

b) **Image Annotation:** It is a process of labelling features insides an image datasets. In the software used, labelling will be done manually by dragging the windows cursor. The labels are implemented to provide information of the coordinates of pothole which will be used in training and validation dataset.

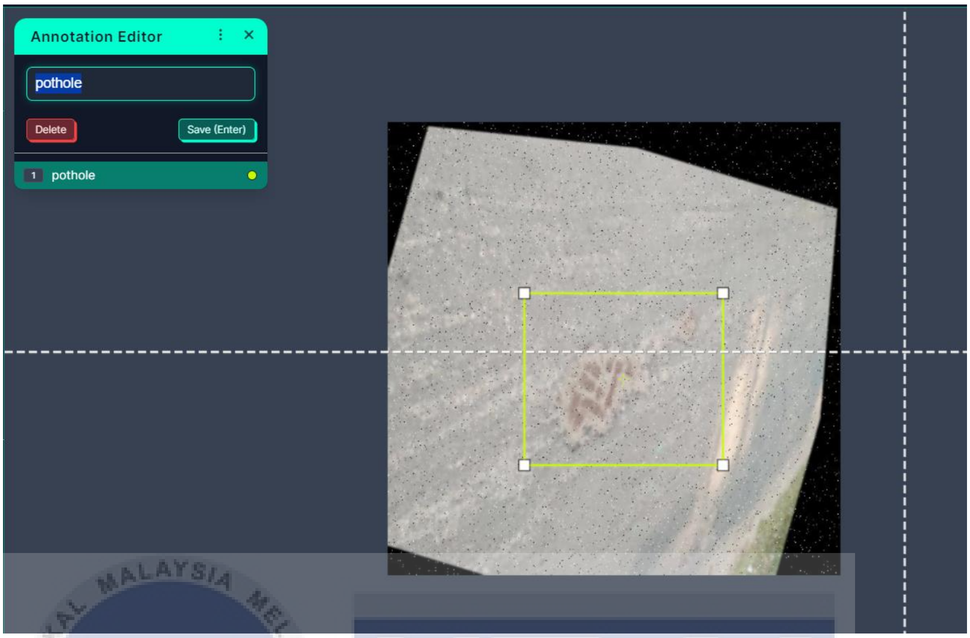


Figure 3.4 Annotation of one pothole

Source: Roboflow

c) **Image Augmentation and Pre-processing:** Data augmentation in machine learning increases process stability through the development of variants in the model. To train different types of pothole photos, multiple techniques are utilised to the training dataset. For instance, rotating, flipping, and cropping images. This process can classified the image using training dataset.

Table 3.1 Types of augmented image in training dataset

Various types of Data Augmentation

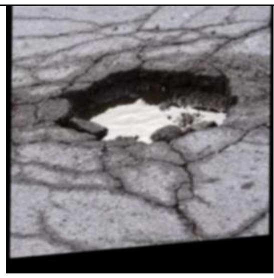
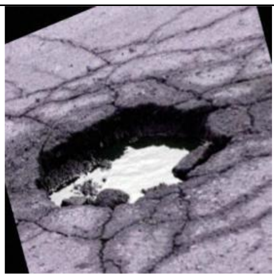
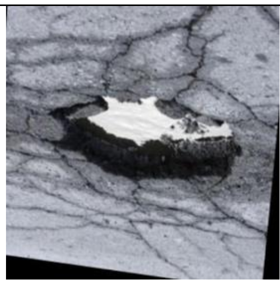
 Original	 Flipping	 Scalling
 Color jittering	 Blur + Cropping	 Rotation

Table 3.1 shows various techniques used in data augmentation. The operations consists of rotating, flipping, scaling, color jittering and scaling.

d) Model Evaluation: It is a process of determining the performance of the machine model on specific dataset. It is important to demonstrate the model's ability to generalise to new types of data and determine whether it is over- or underfitting the training set. It is important to demonstrate the model's ability to generalise to new types of data and determine whether it is overfitting or underfitting the training set. This may occur if the model has an insufficient parameter, or if it has not been trained for enough epochs. This can be seen by comparing model evaluations of each epochs, which consists of precision, recall, and mean average precision (mAP). The formula is shown in Equation 3.1, 3.2, 3.3 and 3.4.

$$P = \frac{TP}{TP + FP}$$

(3.1)

$$P = \frac{TP}{TP + FN}$$

(3.2)

where

P = Precision

R = Recall

TP = True Positive

FP = False Positive

FN = False Negative

Both P and R values are expressed as a percentage. P is the accuracy level of prediction, and R is the results of all positive potential that may be discovered. P and R are dependent on the values of TP, FP, and FN.

$$AP = \frac{1}{11} \sum_{r \in \{0.0,\dots,1.0\}} P_r$$

(3.3)

where

AP = Average Precision

R = Recall value

P = Precision at certain Recall values

The formula for calculating the Average Precision (AP) is presented in Equation 3.3. AP is the average precision at a set of eleven recall values ranging from 0 to 1. Next, the mean of the AP values is denoted by the symbol mAP, is calculated using the method provided in Equation 3.4 below.

$$mAP = \frac{1}{N}\sum_{i=1}^{N} AP_i$$

(3.4)

where

mAP = Mean Average Precision

AP = Average Precision

i = Number of Average Precision

N = Total number of class in model

e) Image Detection: The final step is to test the model on testing dataset. The images from testing dataset will be used as an input images to test the model. The bounding box and its accuracy value will appear on the output image.

3.2.3 YOLOv5 Object Detection

The YOLOv5 algorithm, an abbreviation for "You Only Look Once Version 5," employs a grid-based approach for object recognition. The task of identifying objects within a specific grid cell is assigned to the object detector. Recognized for its swiftness and precision in object detection, YOLOv5 is renowned in the realm of object detection techniques. The YOLOv5 open-source initiative comprises a collection of models and detection algorithms rooted in the YOLO model, pre-trained on the COCO dataset. This project is publicly accessible, and Ultralytics oversees its maintenance, symbolizing the company's commitment to open-source exploration of the future developments in computer vision.

3.2.4 Training, validation and testing the dataset.

For this particular project, the dataset is sourced from the Roboflow Universe website, containing 4960 images depicting road potholes. In the training and validation datasets, 4331 images are selected for training the YOLOv5 model, while 419 images are reserved for validation. The training process, illustrated in Figure 3.5, involves data augmentation, followed by training and validation of the YOLOv5 model to generate predicted bounding boxes for the images. Subsequently, these predicted bounding boxes are compared with the ground truth bounding boxes depicted in Figure 3.4. This comparison yields a comprehensive IoU loss, incorporating factors such as overlap area, distance, and aspect ratio. This entire process iterates until the specified epoch is reached.

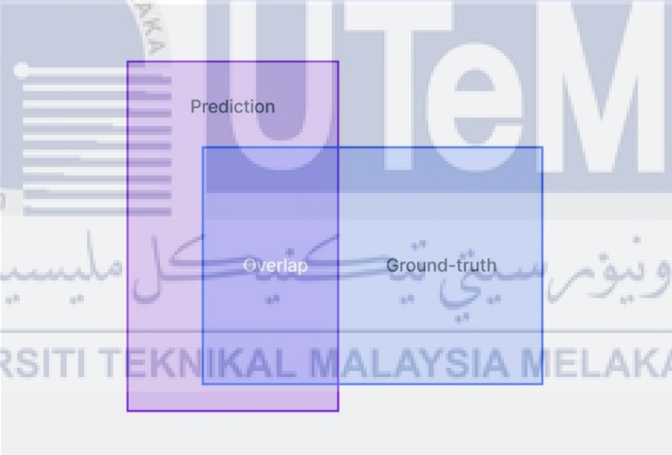


Figure 3.5 Intersection Over Union (IoU)

Source: Deval Shah 2023

$$IoU = \frac{Area\ of\ overlap}{Area\ of\ union}$$

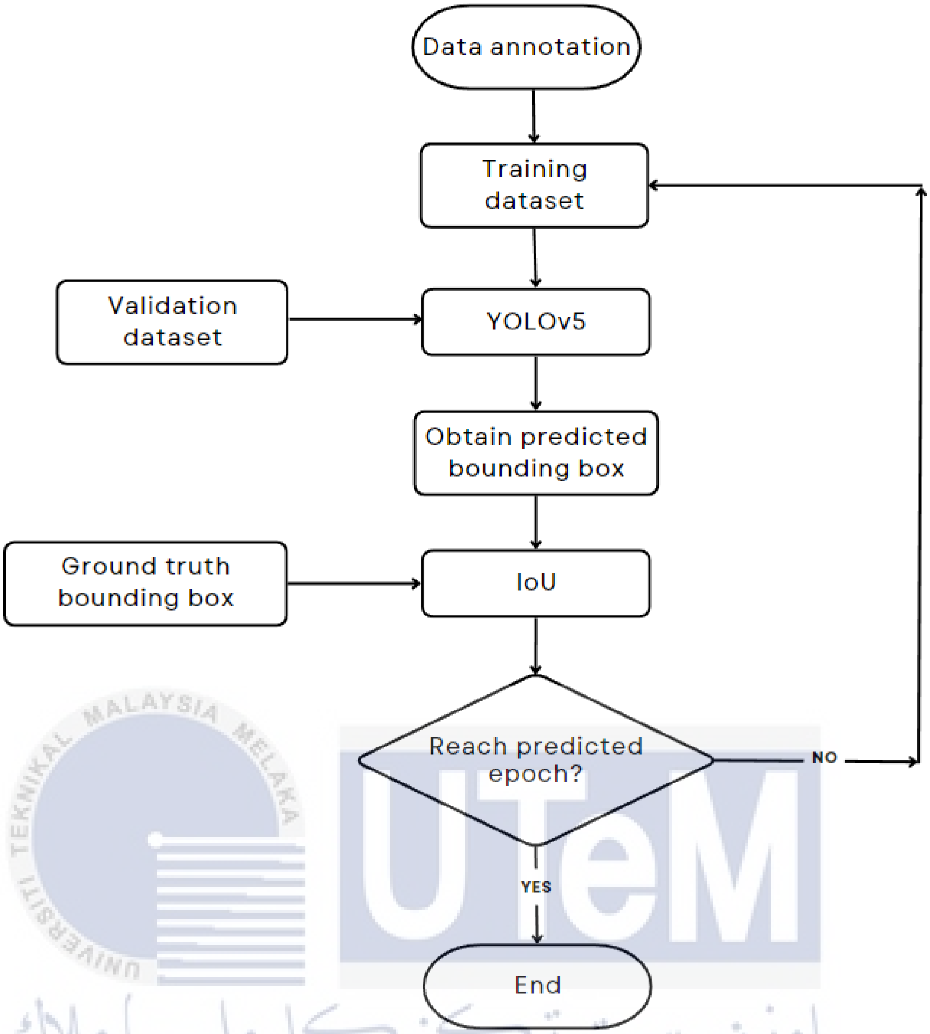


Figure 3.6 Training flowchart of YOLOv5

For the testing dataset, 413 images are chosen from a total of 2163 images to assess the trained YOLOv5 model. It's crucial that the images in the testing dataset are distinct from those in the training dataset, constituting what is referred to as unseen data or images the model has not encountered during its learning phase. The evaluation of the trained model's performance is gauged by examining the output values of the bounding boxes. The flowchart in Figure 3.6 outlines the testing process for the YOLOv5 model, where testing images serve as input, and the process concludes upon reaching the last image. The desired output comprises images displaying detected potholes, complete with bounding boxes and their respective confidence levels.

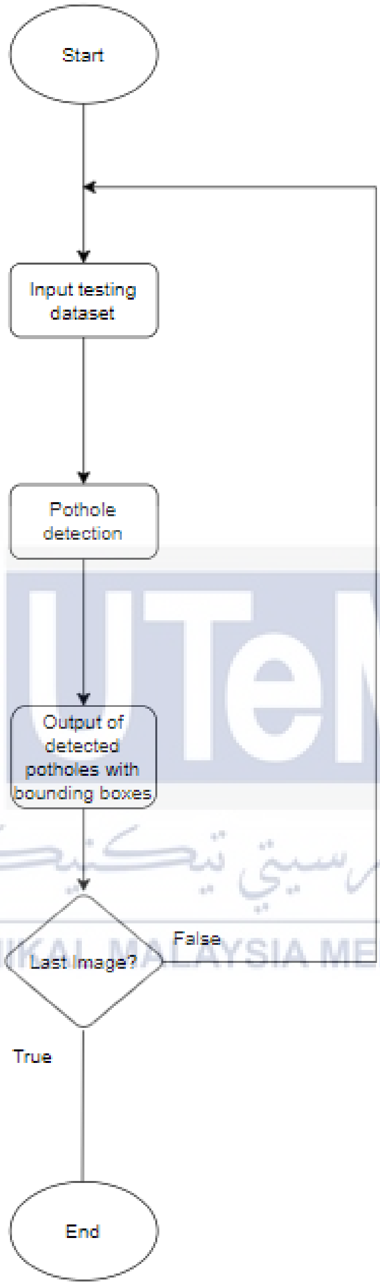


Figure 3.7 Testing flowchart using trained YOLOv5

3.2.5 Pothole detection flowchart

For figure 3.7, the flowchart for pothole detection. This process are starting from the system flowchart. Once the camera detect the potholes, it will calculate the depth of the pothole and detecting the location of it and save the data to the database. But, if it cannot detect the potholes, the process will be looping until it detect another potholes.

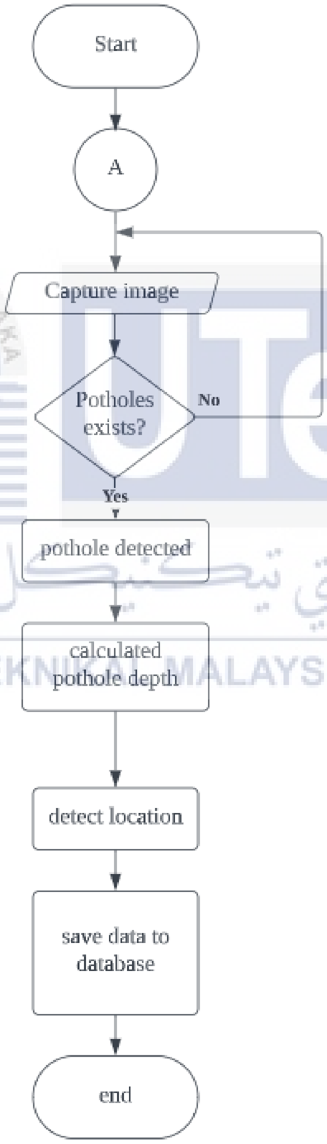


Figure 3.8 Image of pothole detection flowchart

3.2.6 Dataset Collection

The collection of data is an important step in the development of deep learning and machine learning models since the quantity and quality of data used to train a model have significant effects on its performance. In the literature, several methods for gathering data have been used for speech recognition, object detection, and image classification, among other things.

Manual annotation is a common technique for data collection that involves manually annotating the data with the necessary information, such as item bounding boxes in an image or transcriptions of voice sounds. Although it takes a long time, this data collection method is considered to be the most reliable and trustworthy.

Using pre-existing datasets such as ImageNet, COCO, and Open Images is another strategy for data acquisition. These datasets, which contain a substantial quantity of data that can be used to train models, have been assembled and annotated by researchers. These datasets, however, might not always be suitable to particular domains or activities, and the data might not be an accurate reflection of the situation in the real world.

In conclusion, data collecting is an essential stage in the creation of machine learning and deep learning models. Several approaches for data collection have been suggested in the literature. The selection of a data collection method relies on the particular application and the resources available, but it is crucial to take accuracy, cost, and flexibility into considerations.

3.3 Hardware Components

To develop a hardware system for this real-time pothole management some components are required to used as shown below:

1. Raspberry Pi 4 Model B (4 GB)
2. GY-NEO6MV2 flight control GPS module
3. HC-SR04 Waterproof ultrasonic sensor
4. Arduino Uno

1. Raspberry Pi 4 Model B (4 GB)

Raspberry Pi is a tiny simple credit card-sized computer with an ARM processor that can run Linux. It offers a range of connectivity options, including dual-band Wi-Fi, Bluetooth 5.0, Gigabit Ethernet, USB 3.0 ports, and micro HDMI ports for dual 4K display support. To operate this components, it requires an SD card with operating system on it. It runs at a clock speed of 1.5 GHz, providing a significant performance boost compared to previous models.

Figure 3.9 Image of Raspberry Pi

Source: https://my.cytron.io/p-raspberry-pi-4-model-b-4-gb-and-kits

2. GY-NEO6MV2 flight control GPS module

This GPS module is a cost effective component but yet it is very powerful. A cost-effective solution that doesn't sacrifice power: The GPS module with a built-in ceramic antenna specifically designed for optimal signal reception efficiency on board this module, including multiple satellite navigational systems in addition to GPS such as Galileo improves the precision in which we receive positional information.Communication between systems happens through an integrated circuit known as GYNEO6MV2 which connects via serial interface and at voltage levels of up to 3v.It provides accurate position data and supports various satellite system. In this project, we will use it to detect the pothole location with longitude and latitude. This also are very important to share the location of the pothole to the local authorities.

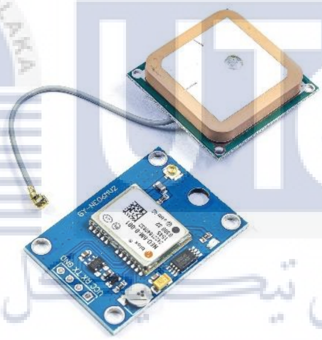


Figure 3.10 Image of GPS module

Source: https://my.cytron.io/p-gy-neo6mv2-flight-control-gps-module

3. HC-SR04 ultrasonic sensor

The HC-SR04 ultrasonic sensor is a versatile and durable sensor used for distance measurement and proximity sensing. It consists of a transmitter and receiver. The sensor measures distance of things without touching it and it uses sound waves to get the measurements right. The range of detection spans from 2 cm to 400 cm. The frequency of

4MHz enables it to provide accurate measurements. It provides accurate measurement information with a resolution of around 3 mm, meaning that there may be a small discrepancy between the estimated and real distances from the item.

Figure 3.11 HC-SR04 Ultrasonic sensor

Soirce: https://www.sparkfun.com/products/15569

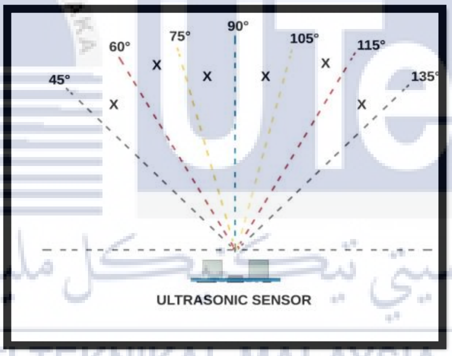


Figure 3.12 Image of angle marking on sensor angle range

Source: https://toposens.com/wp-content/uploads/2020/02/Physics_3D_Ultrasonic_Sensors_Toposens.pdf

4. Arduino Uno

The Arduino Uno microcontroller board is an incredibly versatile and user- friendly tool for developing interactive electronic projects. In this project, the Arduino Uno plays a crucial role in several aspects. Firstly, it can interface with an ultrasonic sensor to read data, providing more consistent results such as pothole depth. It acts as a bridge between the digital and physical components of the system. Secondly, the microcontroller on the Arduino Uno performs real-time data processing while receiving information from the ultrasonic sensor. It executes computations and prepares data for subsequent actions, ensuring timely and accurate responses.

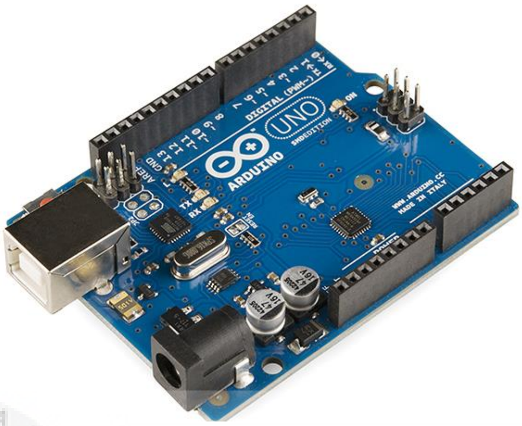


Figure 3.13 Image of Arduino Uno

Source: https://en.wikipedia.org/wiki/Arduino_Uno

3.4 Cloud-based Implementation

1. Google Collaboratory

Google Colab is a highly effective cloud-based platform that enables users to create and train deep learning and machine learning models. It gives user access to a Jupyter notebook environment where they can create and run code as well as strong GPUs and TPUs for training models. Access to powerful GPUs and TPUs for free is one of the key benefits of using this tool, which allows teams and users to accelerate their machine learning model training. This is particularly advantageous for developing a robust pothole detection system, as deep learning models can be quite computationally demanding. By leveraging these advanced resources, users can significantly enhance the accuracy and efficiency of their work. Additionally, Google Colab offers a built-in Google Drive integration that enables users to conveniently store and access their data and models. The simplicity of collaboration provided by Google Colab is another benefit. It enables several people to view and modify the same Jupyter notebook, which is helpful for research and group projects. A built-in link between Google Colab and Github makes it simple to share and collaborate on code.

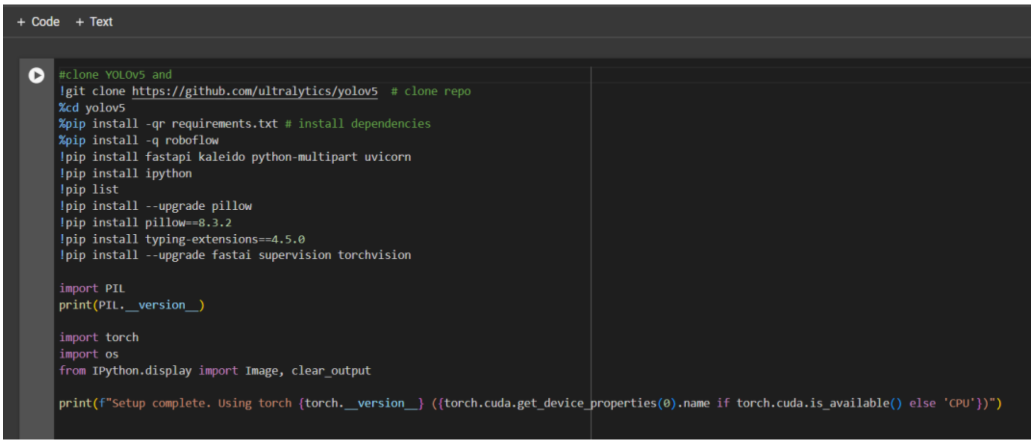


Figure 3.14 Google Colab
Source: https://colab.research.google.com/drive/1wBf75L3QqQsRIZnJtt-DGK8ucHJGmDO9

The first step is to install the requirements. This step is to set up the programming environment to be ready to run object detection training and inference commands.

Figure 3.15 Google Colab
Source: https://colab.research.google.com/drive/1wBf75L3QqQsRIZnJtt-DGK8ucHJGmDO9

This code is using the RoboFlow library to interact with the Roboflow API and download a dataset for training a YOLOv5 model.

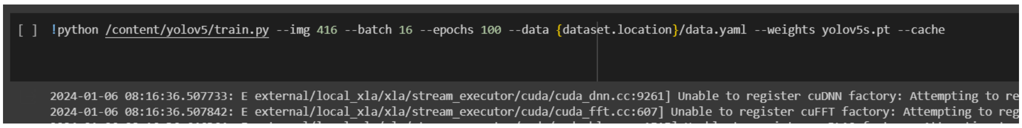


Figure 3.16 Google Colab
Source: https://colab.research.google.com/drive/1wBf75L3QqQsRIZnJtt-DGK8ucHJGmDO9

```
    Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
     0/99      1.52G    0.08062    0.02935          0         34        416: 100% 271/271 [00:52<00:00,  5.15it/s]
                Class     Images  Instances          P          R      mAP50   mAP50-95: 100% 14/14 [00:06<00:00,  2.11it/s]
                  all        419        721      0.473      0.414      0.406      0.144

    Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
     1/99      1.67G    0.05399    0.02675          0         40        416: 100% 271/271 [00:47<00:00,  5.76it/s]
                Class     Images  Instances          P          R      mAP50   mAP50-95: 100% 14/14 [00:03<00:00,  3.97it/s]
                  all        419        721      0.624      0.569      0.592      0.215

    Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
     2/99      1.67G    0.04945    0.02536          0         24        416: 100% 271/271 [00:46<00:00,  5.79it/s]
                Class     Images  Instances          P          R      mAP50   mAP50-95: 100% 14/14 [00:04<00:00,  3.19it/s]
                  all        419        721      0.689      0.634      0.678      0.286

    Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
     3/99      1.67G    0.04698    0.02564          0         47        416: 100% 271/271 [00:47<00:00,  5.69it/s]
                Class     Images  Instances          P          R      mAP50   mAP50-95: 100% 14/14 [00:03<00:00,  3.92it/s]
                  all        419        721      0.707      0.598      0.646      0.283

    Epoch    GPU_mem   box_loss   obj_loss   cls_loss  Instances       Size
     4/99      1.67G    0.04439    0.02487          0         29        416: 100% 271/271 [00:45<00:00,  5.93it/s]
                Class     Images  Instances          P          R      mAP50   mAP50-95: 100% 14/14 [00:04<00:00,  3.26it/s]
                  all        419        721      0.762       0.61      0.699      0.315
```

Figure 3.17 Google Colab
Source: https://colab.research.google.com/drive/1wBf75L3QqQsRIZnJtt-DGK8ucHJGmDO9

This command trains the YOLOv5 model on the dataset which sets the batch size for training to 16 and sets the number of training epochs to 100.

3.5 Open Source

1. Roboflow

Roboflow is a platform for computer vision engineers that attempts to make the process of model training and data annotation easier. The platform has tools for model training, data annotation, and data augmentation, which can help to increase the effectiveness and precision of computer vision models.

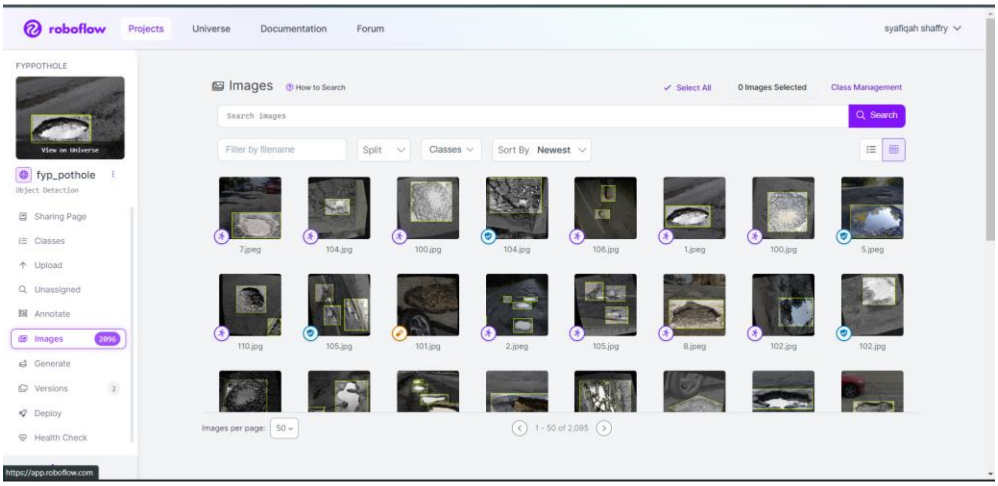


Figure 3.18 User-Interface of Roboflow
Source: https://app.roboflow.com/fyppothole/fyp_pothole-enpsd/browse?queryText=&pageSize=50&startingIndex=0&browseQuery=true

Users can import datasets, annotate pictures and videos, and create annotation files in the format needed by well-known object identification frameworks like YOLO and TensorFlow using the Roboflow software. In order to increase the robustness of the model, the platform also has a data augmentation function that enables users to apply various methods to the photos, including rotation, flipping, and color jittering.

A model training function on the platform enables users to develop and deploy computer vision models using well-known deep learning frameworks like TensorFlow and PyTorch. Users can also distribute their models to several platforms using Roboflow, including iOS, Android, and Raspberry Pi.

By offering a user-friendly platform with a variety of tools for data annotation, data augmentation, and model training, Roboflow seeks to make the process of data annotation and model training simpler. This can facilitate the development and deployment of computer vision applications by increasing the effectiveness and accuracy of computer vision models.

3.6 Development Environments

Software frameworks like TensorFlow can be used to program object detection. Google Colab will be use as the integrated development environment (IDE) and Python as the programming language to train the model. A user-friendly interface and tools for effective coding and debugging are provided by google colab. Several choices for evaluating the object detection model. Testing datasets can also be used to assess the model's performance. When it comes to deployment, a Raspberry Pi was used to run a Linux-based operating system to deploy the trained model. An affordable and portable platform for executing machine learning models in embedded devices is the Raspberry Pi.

3.7 Limitation of Proposed Methodology

There are some factors that may affect the project to succeed. This limitation can include:

1. The ultrasonic sensor is the focal stand of this project, thus the sensor have some boundary. The placement of the sensor in the system has to be strategical install in the vehicle which based on the angle and distance of the detection. An ultrasonic wave unable to penetrates through the water primarily due to its high acoustic impedance which limit the system to detect water-filled potholes and this might be difficult to differentiate potholes from the other road hazards.

2. The effective range of the HC-SR04 is normally between 2 and 400 cm. If the pothole's depth exceeds this range, the sensor will be unable to produce accurate measurements, particularly for small craters. The sensor normally offers straight-line distance readings. If the pothole is not immediately in front of the sensor, additional sensors or a mechanism that changes the sensor angle may be required for accurate results.

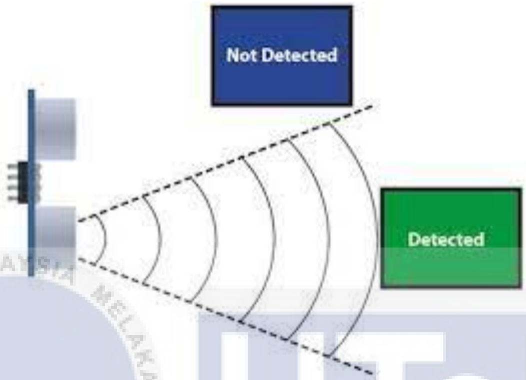


Figure 3.19 Image of Ultrasonic Sensor Range

Source: https://arcbotics.com/products/sparki/parts/ultrasonic-range-finder/

3. This sensor are practically placed under vehicle, since the HC-SR04 is not a waterproof, it can be damaged by water or humidity. Potholes frequently collect rainwater, and if the sensor comes into touch with it, it can cause failures or irreversible damage. Extreme temperatures may cause the HC-SR04 to work poorly, and exposure to harsh external conditions (such as freezing temperatures) may impair its accuracy and dependability.

4. In this system, GPS tracker is used to detect location, the limitation of GPS tracker in receiving poor GPS signal due to interference could affect the system's performance.

3.8 Gantt Chart

Table 3.1 Gantt Chart for PSM 1

Chapter 2						Chapter 3		Chapter 1		Chapter 4		Presentation	
W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
First meeting - Discuss suitable title for final project.	- Journal Research	-Research on computer vision techniques Install all the software used.	Start Chapter 2	Progress on literature review	Submission Chapter 2 to Supervisor via outlook	Find suitable methodology. - Design the system model. - Decide object detection used.	Submission Chapter 3	Start Chapter 1	Complete the report for Chapter 1	Resubmit and do correction for previous report.	Start to do preliminary result.	Prepare for presentation.	Presentation week

Table 3.2 Gantt Chart for PSM 2

Project Planning														
Project activity	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
BDP2 Implementation								Midterm Semester Break						
Discussion with SV														
Procedure planning														
Hardware purchase														
Hardware construction														
Project development														
Hardware functionality														
Chapter 3 draft														
Chapter 4 draft														
Chapter 5 draft														
Chapter 4 and 5 draft submission														
Report Finalization														
Report and poster preparation														

3.9 Summary

The aim of the project is to produce an intelligent pothole detecting system by combining computer vision techniques and machine learning algorithms. In this chapter, we are discussing more about the method that will be used when developing the project. It also discusses the components and the software that will be used and the specifications for each of it. Hence, the system is made to operate in real-time, continuously analyzing input data to precisely identify and identify potholes.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter is about the analysis, explanation and discussion of the experiment conducted on the project, which can explore the objective. Experimentation goes through a few phases; the project's groundwork starts with reviewing Chapter 2, which is understanding the previous work. The reference and modification of the previous research give a better analysis that will be needed for the current project.

The assembly of this system's components and software appeal need to be tested. The microcontroller could be crucial to the sensor. Although the sensor is input, the signal process between digital and analogue happens in the microcontroller. The software interference will be Arduino IDE and Raspbian; the verification, compiler and uploader occur here. The angle, range and visual will be critical because this classification prompts the result in output. The connection of pins and components used is significant by going through a schematic substantiation draw or sketch in the software available. Evaluation of the effectiveness of an object identification model requires testing the accuracy of the model's capabilities as well as its limitations. Various measurement criteria may be applied to analyze the model's performance and locate situations where it can be enhanced.

4.2 Training, Validation and Testing Results

Training YOLOv5 on Google Colab is a process that can be broken down into several steps. Figure 4.1 illustrates the training batch, employed for updating the model's weights. In this project, a batch size of 1 is utilized. The choice of train batch size can impact both the model's performance and the training speed. Increasing the train batch size may raise concerns about overfitting, but it could lead to a faster overall training process. Conversely, a smaller train batch size might expedite training. The system adjusts the model's weight based on the loss function calculated for each train batch.

Figures 4.2 and 4.3 depict the validation label and validation prediction (testing), essential for evaluating the model. The validation prediction encompasses the model's predictions for each dataset category, while the validation labels consist of the actual labels corresponding to each image in the validation dataset.

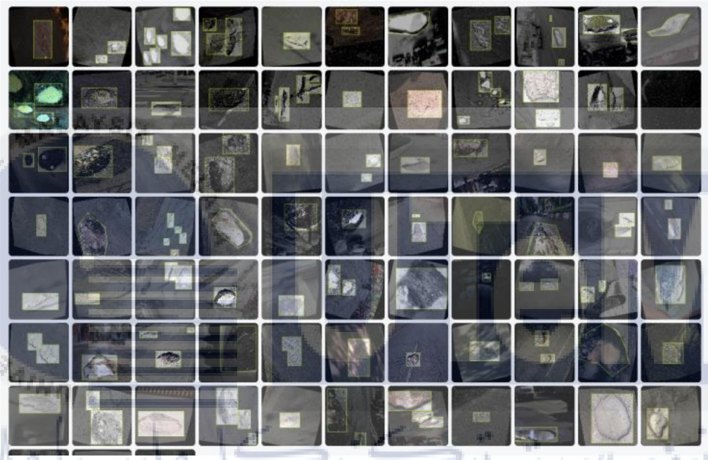


Figure 4.1 Output of training batch

Source: https://app.roboflow.com/fyppothole/fyp_pothole-enpsd/browse?queryText=&pageSize=50&startingIndex=0&browseQuery=true

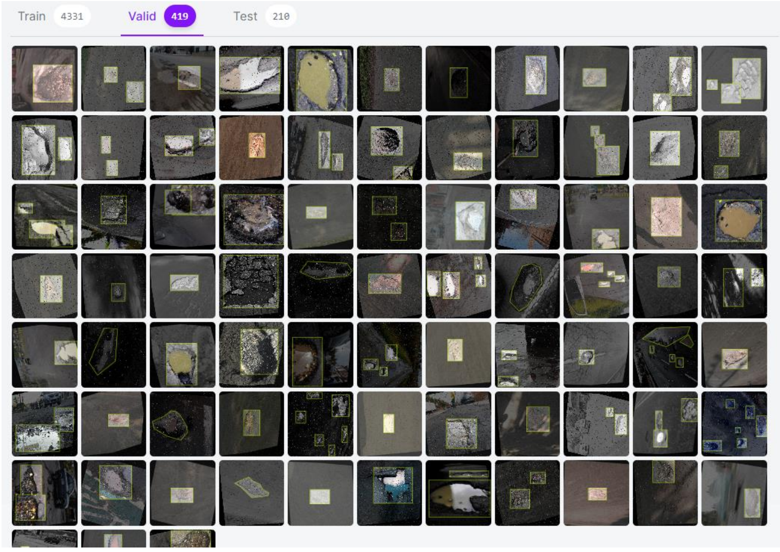


Figure 4.2 Output of validation

Source: https://app.roboflow.com/fyppothole/fyp_pothole-enpsd/browse?queryText=&pageSize=50&startingIndex=0&browseQuery=true

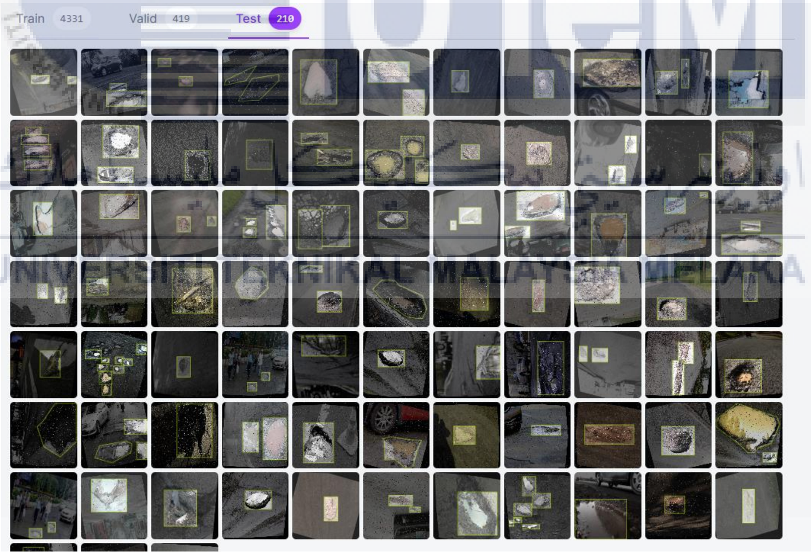


Figure 4.3 Output of validation prediction

Source: https://app.roboflow.com/fyppothole/fyp_pothole-enpsd/browse?queryText=&pageSize=50&startingIndex=0&browseQuery=true

4.3 Loss Functions of The Training and Validation Model

A loss function is a mathematical function that computes the difference between expected and actual values in a machine learning model. It acts as a metric for assessing the model's performance and is critical in guiding the optimization process by providing feedback on how well the model matches with the provided data (Shankar297, 2023). A loss function in YOLOv5 measures how much the model's outputs depart from the ground truth labels, and it then backpropagates the error rate throughout training. An image predicted with greater accuracy has a lesser loss. For training and validation, this project uses three defined loss functions: box loss, object loss, and class loss. The following are each loss function's roles:

1. Box Loss Function: A metric utilized to assess the extent of disparity between a model's predicted bounding box for an object and the actual ground truth bounding box.
2. Object Loss Function: Calculates the disparity between the model's predicted output and the genuine ground-truth labels linked to the identified object in the images. A lower loss value indicates greater precision.
3. Class Loss Function: The degree to which a model's predictions deviate from the actual ground-truth labelling of the object of interest in an image is measured using a metric called a class loss function. When the class loss function reaches a low value, the classification is more accurate.

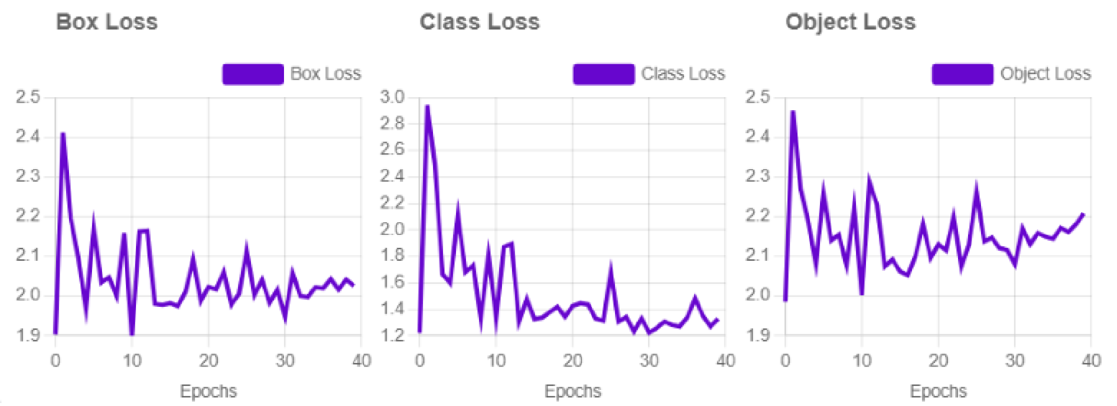


Figure 4.4 Loss function of training data

Source: https://app.roboflow.com/fyppothole/fyp_pothole-enpsd/2

4.4 Prototype of the project

The project needs to build in a secure circuit board without mislaying and wrong connection of wires. To obtain better results when demonstrate it, the circuit need to be mounted to something more solid or strong so it can hold the component and avoid it from slide which it will make the sensor cannot read or calculate the data correctly. Moreover, to avoid it from falling to the road surface.

The connection follows by the step used during the schematic sketch on the software to sort exact pins and wiring. Figure 4.5 display the circuit of Arduino Uno, Raspberry Pi 4B and the wire connection at the breadboard.

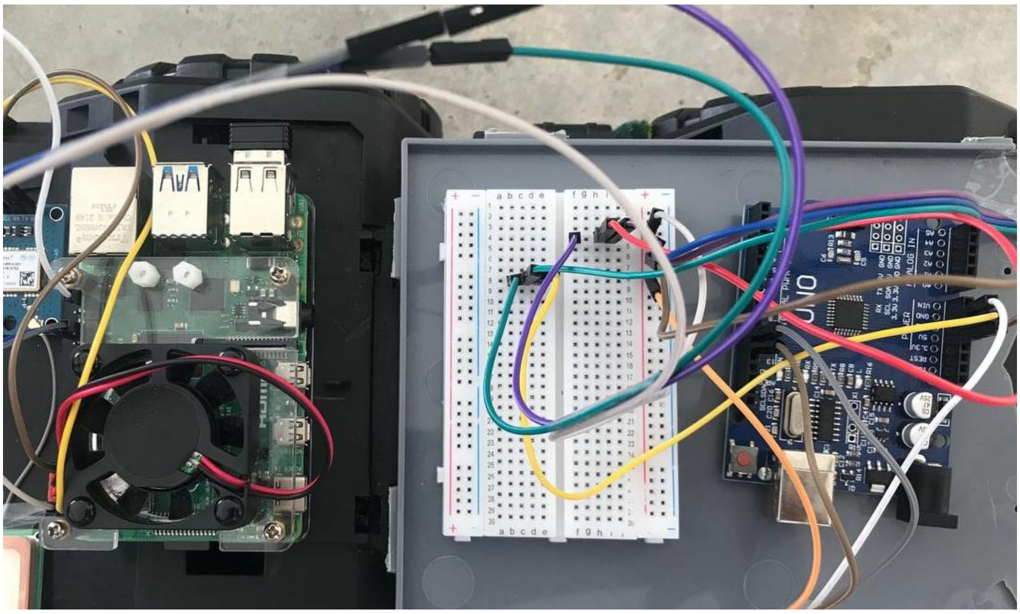


Figure 4.5 Connection between Raspberry Pi and Arduino Uno

The Ultrasonic sensor, Raspberry Pi camera and push button are being placed outside of the vehicle which at the bumper of vehicles during the demonstration. The Ultrasonic sensor being placed at the bottom of the box which it easier to detect the depth after the camera detect the pothole. The push button used to control the data send to the firebase. Figure 4.6 shows the Raspberry Pi camera and push button that are attach at the box which at the bumper of the car.

Figure 4.6 Project features

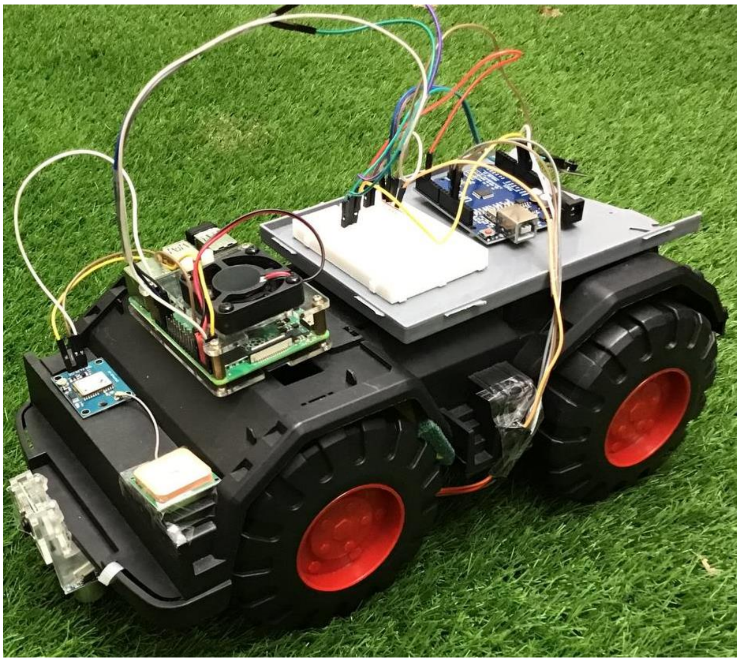


Figure 4.7 Comparison theoritical and Experimental Value graph

4.5 System Analysis

The analysis conducted on the components to check the capability, which could sustain the project success. Evaluation led on the three main components with role as input, Ultrasonic sensor, Neo-6m GPS tracker and Raspberry Pi camera. The test was conducted on bumper of Perodua Viva car for the analysis studies and research. There is some trial to make sure the sensor and camera will not face any weakness during the mechanism of project work. Possibility of analysis conducted based on calculation, precision, comparison and data collection on this system. This test is to validate the systems objective and scope.

4.6 Data Acquisition

According to Simplilearn (2023), data collection or data obtain is a process of gathering and analyzing accurate data from different sources. This involves utilizing sensors to capture actual events and turning them into digital signals using analog-to-digital converters. Signal conditioning can be used to improve data quality, and the resulting digital data is typically delivered in real time to a central processing unit or storage site via wired or wireless communication. Data is collected and saved in databases or files for further study. Based on Figure 4.8, the height between the sensor and road surface is been calculated while in Figure 4.9, the depth of the pothole are been calculated manually using ruler and it measured from sensors to the potholes.

Figure 4.8 The height between ultrasonic sensor and road surface

Figure 4.9 Measured height between sensor and pothole

Table 4.1 Data collection

Pothole Detection	Firebase	Google Sheet
	Depth: "32 cm" LAT: 2.238533 LNG: 102.27109716666666	Depth | 32 cm | 1/15/2024 LAT | 2.238533 | 1/15/2024 LNG | 102.2710972 | 1/15/2024
	Depth: "30 cm" LAT: 2.2681 LNG: 102.2806999	Depth | 30 cm | 1/13/2024 LAT | 2.2681 | 1/13/2024 LNG | 102.2807 | 1/13/2024
	Depth: "28 cm" LAT: 2.267813 LNG: 102.28068799	Depth | 28 cm | 1/13/2024 LAT | 2.267813 | 1/13/2024 LNG | 102.280688 | 1/13/2024

4.6.1 Calculation Between the Theoretical and Experimental Value

The height between ultrasonic sensor and road surface, actual = 26 cm

Table 4.2 Theoritical value and experimental value

Data	The Measurement of Depth Pothole	
	Theoretical Value (cm)	Experimental Value (cm)
1	32 – 26 = 6	30 – 26 = 4
2	30 – 26 = 4	28 – 26 = 2
3	28 – 26 = 2	29 – 26 = 3

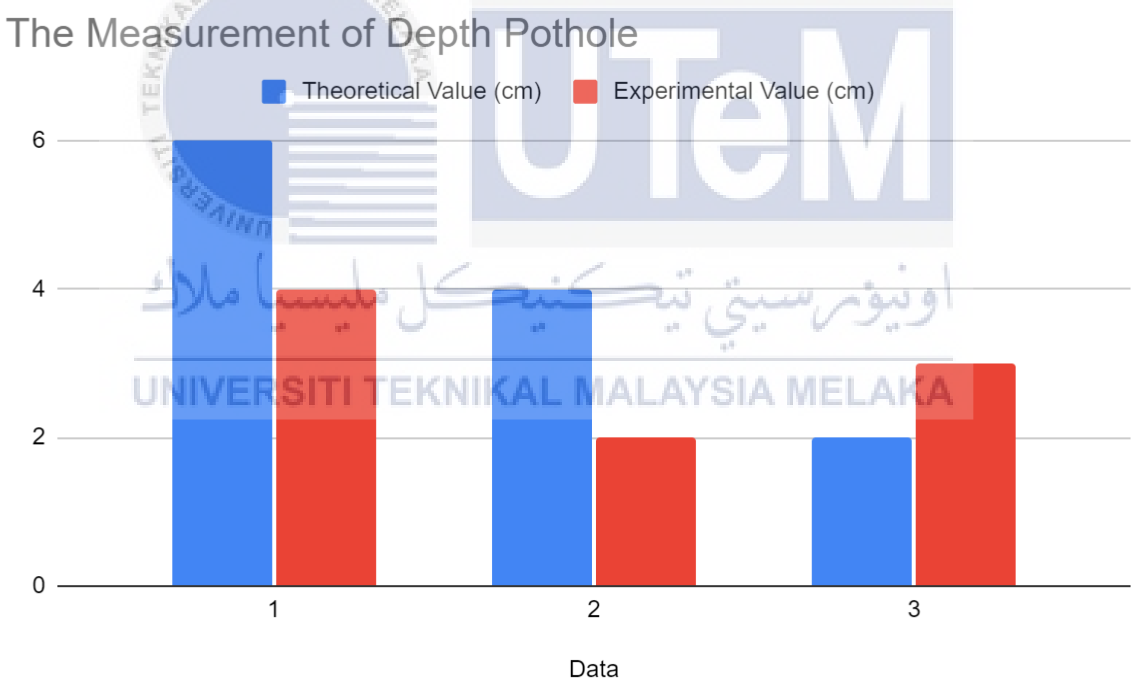


Figure 4.10 Comparison theoritical and Experimental Value graph

$$\% \text{ error} = \left| \frac{\# \text{experimental} - \# \text{actual}}{\# \text{actual}} \right| \times 100$$

Figure 4.11 Formula of percentage error

1. Percentage error of data 1

$$Percentage\ error = \left|\frac{4-26}{26}\right| * 100 = 84.62\ \%$$

2. Percentage error of data 2

$$Percentage\ error = \left|\frac{2-26}{26}\right| * 100 = 92.31\ \%$$

3. Percentage error of data 3

$$Percentage\ error = \left|\frac{3-26}{26}\right| * 100 = 88.46\ \%$$

The table 4.1 shows the depth readings that obtained using an ultrasonic sensor. The figure 4.7 shows comparison graph the theoretical and experimental values of the depth of a pothole. It shows the comparison between the theoritical depth and estimated value based on the sensor’s height from the road surface with the actual depth that obeserved by the sensor. Each measurement's percentage inaccuracy is also computed. Apart for data 3, the experimental values are lower than the theoritical values. There are a number of possible causes for this, including the sensor's angle and the rock fragments in the potholes.

4.7 Project Challenges During Collecting Data

Data collection for a project can be complex and demanding. A reliable infrastructure and systems are necessary to address the logistical challenges of managing massive volumes of data and assuring proper storage. Overcoming these obstacles requires meticulous planning and adaptability in the face of unexpected challenges.

4.7.1 Ultrasonic Sensor Challenges

There are two limitations or challenges that be faced during collecting data:

1. The object's reflective surface is angled at a shallow angle, so it will prevent the sensor wave from being reflected to the sensor. Hence, the value that get is differ from time to time.
2. The range of the sensor detect also will be one of the reason, the theoretical value and the experimental value are not same since the range of the ultrasonic sensor within a 30 degree cone.

4.7.2 GPS Challenges

During the experiment held, the limitation when tracking the location of the potholes is the GPS is continuously sending the data to the firebase. Hence, we cannot get the actual coordinate of the pothole location.

4.8 Summary

In summary, we have successfully measured the depth of the pothole, identified its location, and created a pothole database for the local authority based on different depths. However, encountered challenges while attempting to detect potholes using the Raspberry Pi, specifically related to difficulties in installing certain libraries in the Linux OS.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the development of real-time pothole management system by using object detection method has been a highly successful endeavor. The use of deep learning algorithms, specifically the YOLOv5 model, provided high accuracy in identifying the potholes in images and videos. The model's incorporation into a web-based platform has greatly increased the authorities' accessibility and usability. This strategic step ensures that the system is easily accessible from any place, allowing for a more rapid response to situations. The user interface was created with simplicity in mind, prioritizing ease of use for authority with diverse technical expertise. Furthermore, the seamless interaction with Google Sheets creates a centralized and collaborative data storage environment. This not only simplifies data management, but also allows for real-time updates and effective information exchange. Furthermore, the combination of a web-based platform with Google Sheets connection improves the system's overall effectiveness, making it a useful tool for decision-makers. This system can be further improved by incorporating real-time object detection and implementing the system on a larger data set for more accurate results. Overall, this system is focusing on helping the local authorities to detect the massive pothole that required further action to avoid any accident happening in future.

5.2 Potential for Commercialization

Considering the growing emphasis on smart city efforts and infrastructure optimization, this project is well positioned to meet market demands. The system's ability to deliver precise data on pothole locations and depths, enabling preemptive road maintenance, offers commercial possibilities. Partnerships with governmental organizations, local governments, and private companies that operate road infrastructure are possible commercialization routes. The system could be offered as a service, with subscription-based models for ongoing maintenance and data analytics.

5.3 Future Works

This study proposes a real-time pothole detection method based on computer vision and image processing techniques. Below is the future works that can be done in this project:

i. The camera should be connected together with other sensor to get an accurate data of the location of the potholes.

ii. Increasing the scope of the detecting item to train the models to distinguish between potholes, cracks in the road, speed bumps, and other road abnormalities to create a more complete system for managing road reconstruction.

iii. A various dataset that contains pictures and videos taken at various times of day that can help to increase the model's accuracy.

iv. Utilizing a waterproof sensor for pothole detection becomes particularly valuable in areas prone to challenging weather conditions. This addition can enhance the system's robustness and reliability, ensuring accurate detection even during adverse weather conditions.

v. Can use LiDAR sensor instead because it has a large measurement range and very good accuracy but a high cost.

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