Automatic Pothole and Speed Breaker Detection and Alert System in Bangladesh

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A Capstone project report submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science and Engineering

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Dhaka-1212, Bangladesh

MARCH, 2023

Declaration

We, Md. Asad Chowdhury Dipu, Md. Mizanur Rahman Riad Khan, Kazi Mostaq Hridoy hereby, declare that the work presented in this capstone project report is the outcome of the investigation performed by us under the supervision of Dr. Taskeed Jabid, Chairperson & Associate Professor, Department of Computer Science and Engineering, East West University. We also declare that no part of this project has been or is being submitted elsewhere for the award of any degree or diploma, except for publication.

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Letter of Acceptance

The capstone project report entitled "Automatic Pothole and Speed Breaker Detection and Alert System in Bangladesh" is submitted by Md. Asad Chowdhury Dipu, Md. Mizanur Rahman Riad Khan, and Kazi Mostaq Hridoy to the Department of Computer Science and Engineering, East West University, Dhaka, Bangladesh is accepted for the partial fulfillment of the requirement for the degree of Bachelor of Science in Computer Science and Engineering on March 29, 2023.

Board of Examiners

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Abstract

Road accidents caused by potholes and speed breakers are a significant problem in Bangladesh, resulting in human casualties and economic losses. The proposed solution is an automatic pothole and speed breaker detection and alert system that uses machine learning algorithms to identify hazards and generate alerts for drivers. The system is low-cost and easily deploy-able, making it accessible to all vehicle owners. The system's effectiveness is evaluated through experiments, which demonstrate its ability to significantly reduce road accidents caused by potholes and speed breakers. The proposed system's use of machine learning algorithms for road safety applications is both original and significant. The thesis is useful for vehicle manufacturers, road safety authorities, and researchers working in the field of road safety. The practical, theoretical, ethical, and societal consequences of the thesis include the potential to reduce human casualties, economic losses, and traffic congestion in Bangladesh. The system's ability to detect hazards with high accuracy and alert drivers in a timely manner is evaluated using various parameters, including precision, recall, and F1-score. The results indicate that the proposed system can significantly improve road safety by reducing the number of accidents caused by potholes and speed breakers. The proposed solution is a significant contribution to the field of road safety and can be easily installed on any vehicle. The system's accessibility to all vehicle owners makes it a practical solution for improving road safety in Bangladesh. Overall, the thesis presents a valuable solution to mitigate the problem of road accidents caused by potholes and speed breakers.

Acknowledgments

We would like to express our deepest appreciation and gratitude to all those who have supported us in completing our project titled " Automatic Pothole and Speed Breaker Detection and Alert System in Bangladesh”.

Firstly, we would like to thank our project supervisor, Dr. Taskeed Jabid for his invaluable guidance, support, and encouragement throughout the project. His extensive knowledge, expertise, and dedication to the subject matter have been instrumental in helping us understand the complexities of the topic and providing us with invaluable insights to create a successful project. We are truly grateful for his mentorship and guidance throughout the entire process.

We would also like to express our gratitude to our fellow colleagues, Md. Asad Chowdhury Dipu, Md. Mizanur Rahman Riad Khan, and Kazi Mostaq Hridoy, for our contributions and collaboration throughout the project. Their hard work, dedication, and commitment to the project have been instrumental in its success. We are fortunate to have worked with such a talented and hardworking team.

Moreover, we would like to acknowledge the participants who contributed to our data collection process. Without their participation, this project would not have been possible. We appreciate their time, effort, and cooperation in providing us with the necessary data to conduct our research.

Additionally, we would like to thank the developers of the open-source tools and libraries we used in this project. Their hard work, dedication, and contribution to the development of these tools have made our work easier and more efficient

Finally, we would like to thank our friends and family for their continuous support and encouragement throughout our academic journey. Their unwavering support and encouragement have been a source of motivation for us, and we are grateful for their support.

Finally, we would like to thank our parents for their unending support, encouragement, and prayers. There are numerous other people too who have shown me their constant support and friendship in various ways, directly or indirectly related to my/our academic life. We will remember them in my/our heart and hope to find a more appropriate place to acknowledge them in the future.

In conclusion, we would like to thank everyone who has contributed to this project in one way or another. Your support, guidance, and contribution have been invaluable, and we are grateful for your support.

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March 2023
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March 2023
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March 2023

Table of Contents

List of Figures

List of Tables

List of Algorithms

1) Faster R-CNN
2) SSD (Single Shot Detector)
3) YOLOv5
4) YOLOv7
5) YOLOv8

List of Acronyms

YOLO	You Only Look Once
SSD	Single Shot Detector
CUDA	Compute Unified Device Architecture

Chapter 1

Introduction

1.1 Background

The Road accidents are becoming one of the greatest threats to human lives today mostly in Bangladesh countries. Thousands of lives are being lost on the roads every year, and it is increasing sharply every year. The likelihood of major accidents is considerably increased by the combination of potholes, deep slopes, missing pitches, ineffective speed breakers, defective manhole covers, and pavements, which turn roads into obstacle courses. For instance, in Asia, the second worst road conditions belong to Bangladesh, according to the Global Competitiveness Index 2017-2018 of the World Economic Forum [1]. In 2017, 4,979 road accidents in Bangladesh resulted in 7,397 fatalities and 16,193 injuries, according to the Bangladesh Passenger Welfare Association (BPWA) [2]. Additionally, their data reveals that 4,312 incidents resulted in 6,055 fatalities and 15,914 injuries in 2016. In all, 6,581 incidents across Bangladesh resulted in 8,642 fatalities and 21,855 injuries in 2015 [2]. 7,809 individuals lost their lives and 9,039 were wounded in road accidents in 2021 [2]. The COVID-19 epidemic forced the movement of all motorized transports and vessels to be halted for 85 days in 2021, although the Passenger Welfare Association of Bangladesh (PWAB) reports that the number of traffic accidents and fatalities rose in the following year.

According to a survey of India, “The overall number of fatalities in traffic accidents caused by potholes in 2018, 2019, and 2020 was 2,015, 2,140, and 1,471, respectively, according to statistics from the Ministry of Road Transport and Highways (MoRTH)” [3]. In a report, it has been said, “Deadlier than terrorism': potholes responsible for killing 10 people a day in India” [3].

The primary cause of accidents on roads in Bangladesh is due to road imperfections such as potholes, cracks, and irregular speed breakers. There are only 1.9 million certified drivers in the country despite having 2.9 million registered motor vehicles, with an additional one million unskilled drivers operating vehicles unlawfully. The Passenger

Welfare Association of Bangladesh has attributed the rising accident rates to a variety of factors including reckless driving, poorly constructed roads, poorly skilled drivers, drug use while driving, and a lack of awareness and understanding of road users. Speed breakers, which are commonly installed to reduce speed-related accidents, are a great example of an improved driving experience for road users while reducing costs and improving the environment. However, some influential public figures in Bangladesh create unnecessary speed breakers without following proper measurements, which can pose a threat to human lives.

1.2 Problem Statement and Analysis

Day by day, road accidents are increasing. Though the government is imposing strict laws and trying its best to reduce the accident rates, it is still not sufficient. Digital technologies can come up with a solution in this case. With the help of technology, a system can be made to alert drivers of speed breakers, potholes, and other barriers from a certain distance. But there is a gap in knowledge about implementing such technologies in developing countries like Bangladesh.

One of the biggest hazards to human life nowadays is road accidents. Every year, thousands of lives are lost in traffic accidents, and the number is rising quickly. When potholes, steep slopes, missing pitches, ineffective speed breakers, faulty manhole covers, and pavement combine to make roads into obstacle courses, the chance of serious accidents is significantly enhanced. The main contributors to road accidents are uneven speed breakers and road flaws like potholes and cracks. Speed breakers are an excellent illustration of how to enhance the driving experience for other road users while lowering expenses and enhancing the environment simultaneously. Despite being intended for public protection, speed breakers can endanger human life. Potholes are equivalently responsible for road accidents. Even while the injuries brought on by road accidents caused by hidden speed bumps and potholes are not so serious, they can nonetheless result in fatalities severe enough to affect a whole family.

Figure 1.1: This is a figure of an unmarked speed breaker and a dangerous pothole

1.3 Project Objectives

The objective of this research paper project is to address a significant issue that affects road safety worldwide: accidents caused by speed breakers and potholes. The first objective of this project is to provide an overview of the causes of these types of accidents, which are often caused by drivers failing to detect speed breakers or potholes in time to avoid them. This overview will examine the factors that contribute to these accidents, such as poor road maintenance, inadequate signage, and driver error.

The second objective of this project is to develop a system that can detect speed breakers and potholes on roads. This system will use a combination of sensors and cameras to detect and analyze road conditions in real-time. By detecting the presence of speed breakers and potholes take evasive action, preventing accidents and making roads safer for all.

The third objective of this project is to create a mobile application that can alert drivers about the presence of speed breakers and potholes from a certain distance. The app will use the data collected by the detection system to provide real-time alerts to drivers, allowing them to anticipate and avoid potential hazards. The app will also provide additional information, such as the location and severity of the obstacle, to help drivers make informed decisions.

Overall, the objective of this research paper project is to contribute to the development of technology that can improve road safety and reduce the number of accidents caused by speed breakers and potholes. By achieving these objectives, this project will help to create safer and more efficient road networks that benefit everyone.

1.4 Project Contributions

Our project aims to create a system that detects obstacles such as speed breakers and potholes and alerts users while driving. To accomplish this, we formed a project team of three individuals and appointed a project leader to guide our efforts. We hold weekly meetings to collaborate and discuss our progress, dividing tasks based on individual skills. Throughout the project, we maintain strong documentation of our work and regularly review our progress with our supervisor to ensure high-quality results.

1.5 Project Outlines

Our project is named "Automatic Pothole and Speed Breaker Detection and Alert System in Bangladesh." Our project involves several stages. We need to start by reviewing multiple research papers related to our project. Once we have identified the process, we will collect data and clean it for visualization. After that, we will apply various machine learning and deep learning models. In addition, we will prepare a budget for the project. Finally, we will deploy these models into a mobile application.

Chapter 2

Related Works

2.1 Survey of the State-of-the-art

Pothole and speed breaks are not a new thing. So, there are many previous on work on this topic. Some of them use basic hardwires and sensors to detects the holes and hump and others use image processing techniques, artificial Intelligence, Machine learning. Country like Bangladesh is known for developing county. A developing country usually straggles a lot in developing new road every year. For this Bangladesh has many roads that old and have lots of pothole and unwanted speed breaker. These holes and bumps are not welcome by the people. In every aspect this create a big problem. So, solve this problem many people come up with their idea. Some people tried to detect pothole and speed breaker to ensure the safety. Various research on the road surface were performed over through the generations.

One of them use low cost hardwire. At [10] K. Kamal and S. Mathavan make use of low-cost module which gives instant depth measurements, minimizing processing expenses. This module made of an infrared technology-based Kinect sensor. In Kinect sensor there are two camera one is RGB another is IR. Combine this two this module can give good image and analyzing them in MATLAB can give the depth of the hole or height of bump. SVM (Support Vector Machine) method is used at [11] where Yayu Liu and Jin Lin tried to measure the potholes using the texture of the potholes. The method uses a set of surface photos to train the SVM to recognize potholes.

At [12] k. Sharma used vision base technic. Researchers used a cell phone in a car to collect road photos and over 100 hours of footage over the day, resulting in 4 million pictures. They used a segmentation technique to determine the roughness of the potholes, as well as its characteristics, colors, and positions. They used an instance level classifier SVM technique to categorize the super pixels as positive or negative and this gives them a better output. This model performs close to human annotation.

At [13] study describes a vibration-based method for detecting potholes and speed breakers, as well as their co-ordinates. In this study v. Rishiwal and H. Khan maintain a strategy, a database is kept for each road, which is then made available to the public via a worldwide database or a portal. Here potholes and speed breakers, as well as their roughness, are detected by Android's built-in accelerometer.

At [14] Minghai Yaoa primarily focus on 2D vision and provide a new system for detecting potholes based on location-aware convolutional neural networks, which focuses on the road's discriminative areas rather than the overall context.

Z. Hasan and S. Shampa in their paper at [1] uphold the station of Bangladeshi road conditions. They are using computer vision and machine learning methods, they constructed a model to detect problematic potholes, sharp ridges, and speed breakers. They develop a data set and name Bumpy. They use TensorFlow pre-trained model to detect the potholes, deep ridges and speed breakers and manage to get a higher accuracy.

2.2 Summary

The text discusses previous research on detecting potholes and speed breakers, with various techniques used such as hardwires, image processing, artificial intelligence, and machine learning. The problem of potholes and speed breakers in developing countries like Bangladesh is highlighted, and different studies using different techniques are mentioned, such as infrared technology, support vector machine, segmentation techniques, and vibration-based methods. The paper by Z. Hasan and S. Shampa is focused on Bangladeshi road conditions, and they developed a model using computer vision and machine learning to detect problematic potholes, ridges, and speed breakers with higher accuracy.

Furthermore, in recent years, there has been a growing interest in developing intelligent transportation systems that use machine learning and computer vision to improve road safety. Many countries around the world, including the United States, Japan, and China, are investing heavily in this field to address road safety issues. In addition to detecting potholes and speed breakers, some researchers are exploring the use of these technologies to detect other road hazards, such as pedestrians, cyclists, and other vehicles. This could significantly improve road safety and reduce the number of accidents. However, there are also concerns about the privacy implications of these technologies and the potential for misuse. As such, researchers are exploring ways to balance the benefits of these technologies with the need for privacy and security.

Chapter 3

Materials and Method

This statement discusses the two main components of a project, which are materials and method. Materials refer to the physical resources used in the project, while method refers to the approach or technique used to utilize those materials effectively.

3.1 Materials

The project primarily focuses on data. Specific tools were used to collect and clean the dataset to ensure it was fit for analysis. Visualization tools were then employed to enhance understanding of the dataset. Insights were gained and conclusions were drawn from the analyzed data. The Android application was developed using Java programming language and Android Studio IDE, with external libraries used for GPS location detection and notifications.

3.1.1 Dataset Collection

We collected some of our data from online sources such as Google Maps, OpenStreetMap, and local government websites. Additionally, some of the images of speed breakers and potholes were obtained from online forums and social media platforms. Since our project focused on detecting these obstacles on the roads, it was relatively easy to find relevant images online.

Our dataset consists of a total of 3003 images, comprising of 1423 images of speed breakers and 1580 images of potholes.

3.1.2 Dataset Exploration

To ensure that the model is trained on a balanced dataset, we randomly selected 1200 images from each class, resulting in a total of 2400 images for training and validation. The remaining 603 images (213 speed breakers and 390 potholes) were set aside for testing. We split the dataset into a 80/20 training-validation split, with 1920 images for training and 480 images for validation. To further prevent overfitting, we applied data augmentation techniques such as random rotations, flips, and zooms during training.

3.1.3 Dataset Sampling

At the beginning of a deep learning workflow, preprocessing data is a typical initial step to prepare raw data in a manner that the network can accept. Preprocessing can be used to match the size of an image input layer, resize the image input, and improve desirable characteristics or eliminate artifacts that could bias the network. [12] For our project, we have used the following pre-processing steps:

Orientation- We discard the EXIF rotations and standardize pixel ordering.

Contrast adjusting- We boost contrast based on the image's histogram to improve normalization and line detection in varying lighting conditions. We have used Contrast Stretching, which is a straightforward image enhancement method that aims to boost contrast by "extending" the intensity values in a picture to cover a desired range of values or the whole range of pixel values that the target image type permits.

The augmentation steps include,

- ❖ Saturation- It is used to adjust the vibrancy of the colors in the images.
- ❖ Exposure- It is used to add variability to image brightness to help your model be more resilient to lighting and camera setting changes.
- ❖ Rotation- It is used to add variability to rotations to help the model be more resilient to camera roll.
- ❖ Shear- It adds variability.

3.1.4 Data Visualization

The data visualization aspect of the project included a single bar chart that provided insight into the number of speed breakers and potholes identified in the collected dataset. The chart was created using a specific visualization tool, and it effectively conveyed the distribution of these road hazards. Through this visualization, the team was able to identify areas where road hazards were particularly prevalent and prioritize those areas for further investigation. Overall, while the visualization aspect of the project was limited to a single chart, it proved to be a valuable tool in understanding the dataset and informing decision-making regarding road safety.

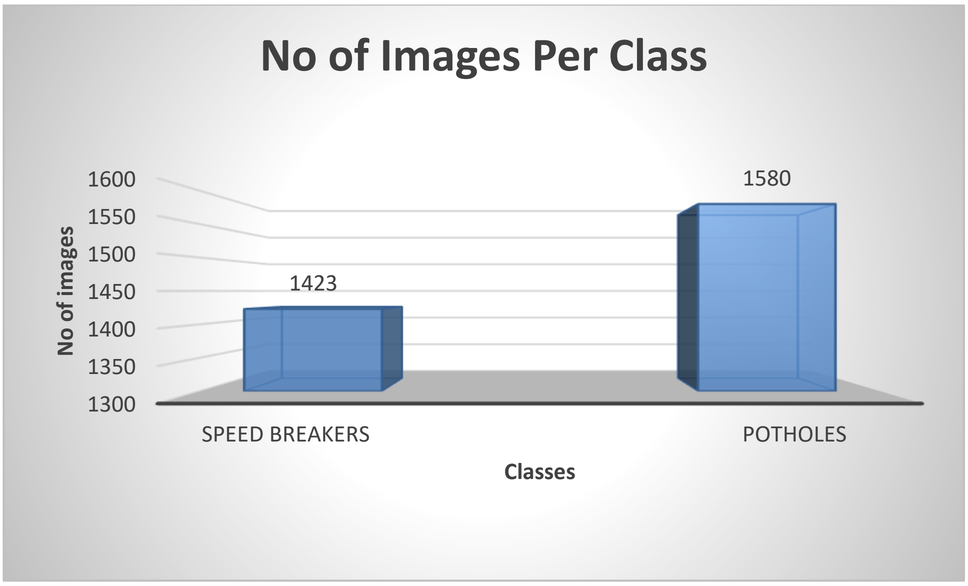


Figure 3.1: This is a figure of a number of images in speed breaker and pothole

3.1.5 Research Environment and Devices

To implement our application, we had to fulfill several requirements. Our project was developed using Python 3.9, and we utilized Google Collaboratory as our compiler. Google Collaboratory provided us with a free GPU, which was essential since our models were based on Pytorch. Additionally, we needed to annotate our data for implementation, so we sought help from Roboflow.

The mobile application was developed using Java and Android Studio version 2022.1.1. We incorporated the SSD machine learning model into the application, and the development process involved using Android Gradle plugin version 4.1.1 and Gradle Version 6.5, minSdkVersion 21, and targetSdkVersion 31. These software components formed the basis of our application, allowing for the seamless integration of the machine learning model and efficient execution on Android devices.

3.2 Method

The methodology employed in the project centered around working with data using machine learning models. Various types of machine learning models were used to analyze and gain insights from the collected data. Once the appropriate model was selected, it was deployed in a framework to enable it to be used effectively. Overall, this methodology allowed the team to work efficiently with the collected data and generate meaningful insights.

3.2.1 Proposed Model

Our main goal is to alert drivers about speed breakers and potholes, in order to improve road safety. To achieve this, we have developed an Android application that uses YOLOv8, a state-of-the-art object detection model, to detect speed breakers and potholes in real-time. The application was developed using the Java programming language and Android Studio as the integrated development environment. External libraries were used for functionality such as GPS location detection and notifications. The application requires an Android smartphone or tablet running the required version of the Android operating system to function properly.

3.2.2 Design/Framework

Our project uses PyTorch as the framework to develop a machine learning model that detects speed breakers and potholes in real-time. The model was trained on a large dataset of images using YOLOv8, and the PyTorch framework enabled easy definition, training, and hyperparameter fine-tuning of the neural network. The Android application, developed using Java and Android Studio, serves as the interface for our model and utilizes external libraries for GPS location detection and notifications. Future work includes the use of additional machine learning and natural language processing techniques to further refine the model's accuracy. Overall, our system has the potential to significantly improve road safety for drivers.

3.2.3 Algorithm/Model Formulation

There are several machine learning models that have been developed specifically for object detection tasks, such as Faster R-CNN, YOLOv5, YOLOv7, and YOLOv8. Each of these models uses a different approach to detect objects in an image, and the choice of model depends on various factors such as the size and complexity of the dataset, the available computational resources, and the desired level of accuracy.

For instance, Faster R-CNN is a region-based model that uses a two-stage approach to detect objects, whereas YOLOv5, YOLOv7, and YOLOv8 are single-stage models that use a different object detection approach. Each of these models has its own strengths and weaknesses, and it's often a good idea to experiment with different models and compare their performance on a validation dataset to determine the best method for a particular object detection task.

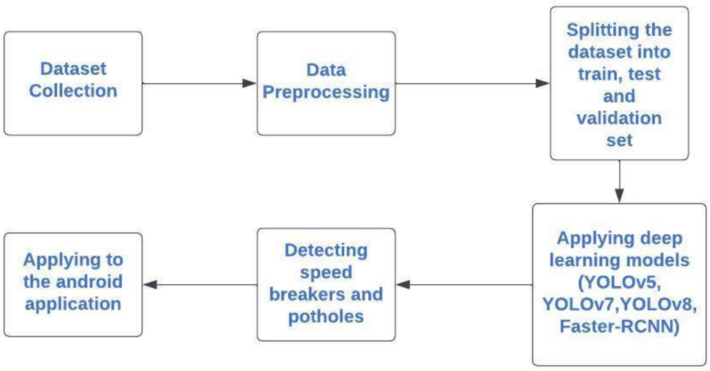


Figure 3.2: This is a figure of detecting speed breaker and pothole using our system

The first step in our project was to collect a large dataset of images containing speed breakers and potholes. This dataset was then preprocessed by removing any duplicate or irrelevant images, resizing the images to a common resolution, and applying any necessary image augmentation techniques to increase the diversity of the dataset.

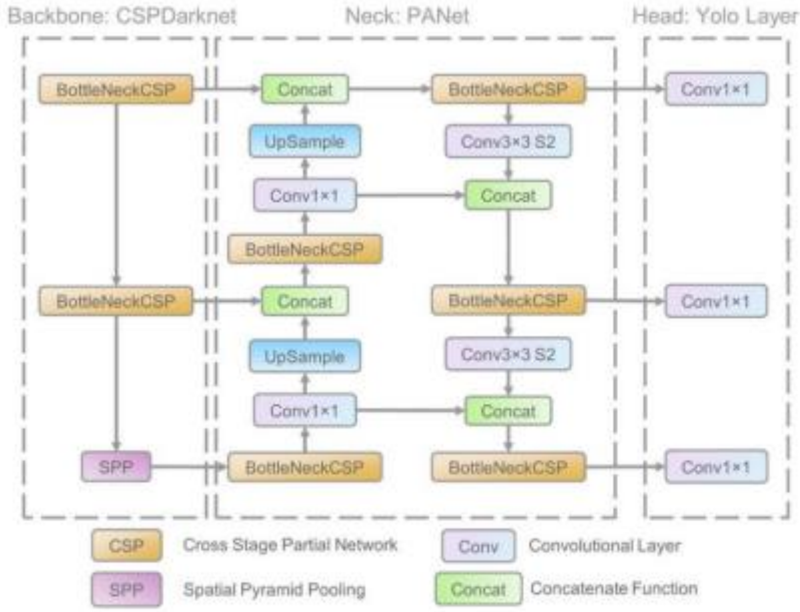
Next, we split the dataset into three subsets: a training set, a testing set, and a validation set. The training set was used to train our deep learning models, while the testing and validation sets were used to evaluate the performance of the models and ensure that they generalized well to new, unseen data.

We applied two state-of-the-art object detection models, YOLOv5, YOLOv7, YOLOv8, and Faster-RCNN, to detect speed breakers and potholes in the images. These models were trained on the preprocessed dataset using the PyTorch framework, which allowed us to easily define and train our neural networks and fine-tune the hyperparameters for optimal performance.

Finally, we integrated the trained models into an Android application, which serves as the interface for our model. The application was developed using Java programming language and external libraries were utilized for functionality such as GPS location detection and notifications. This application will help alert drivers about road hazards in real-time, with the potential to significantly improve road safety for drivers.

Different Types of Machine Learning Algorithms:

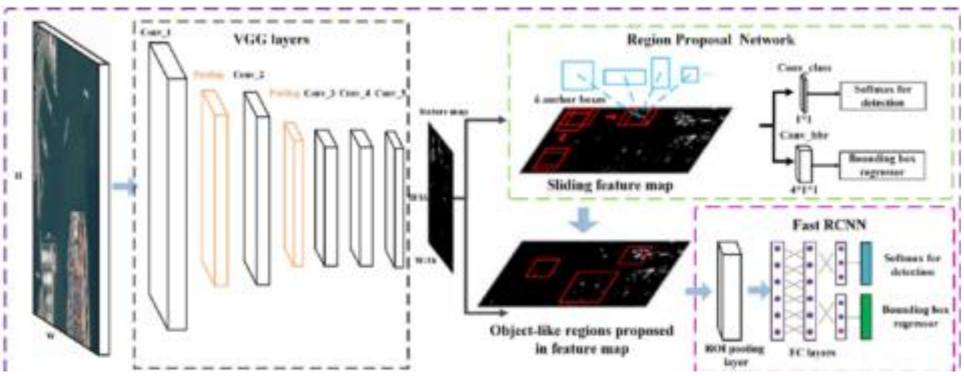
YOLOv5: You Only Look Once is the abbreviation for YOLO. In June 2020, Ultralytics released YOLOv5, which is now the most sophisticated object detection algorithm on the market. It is a cutting-edge convolutional neural network (CNN) that accurately recognizes objects in real-time. This method processes the entire image using a single neural network, then divides it into pieces and forecasts bounding boxes and probabilities for each component. The predicted probability weighs these bounding boxes. The technique "only looks once" at the picture since it only does one forward propagation loop through the neural network before making predictions. Detected products are then delivered following non-max suppression (which ensures that the object detection algorithm only identifies each object once).[13]



Source: https://www.analyticsvidhya.com/blog/2021/12/how-to-use-yolo-v5-object-detection-algorithm-for-custom-object-detection-an-example-use-case/

Figure 3.3: This is a figure of how YOLOv5 works

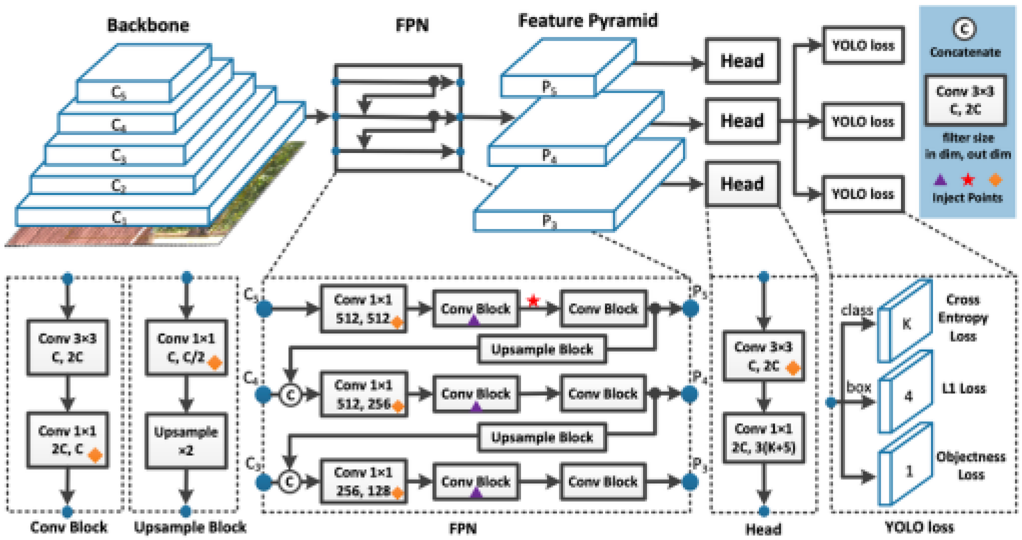
Faster R-CNN: An addition to Fast R-CNN is Faster R-CNN. Faster R-CNN, as its name implies, is quicker than Fast R-CNN because of the region proposal network (RPN). [4]. With region proposal network (RPN) in place of the selective search approach, the algorithm becomes significantly quicker. Object proposal requires time, and because there are several systems operating simultaneously, each system's performance is influenced by the performance of the one before it. [14]



[Source: https://www.researchgate.net/figure/The-architecture-of-Faster-R-CNN_fig2_324903264]

Figure 3.4: This is a figure of how Faster R-CNN works

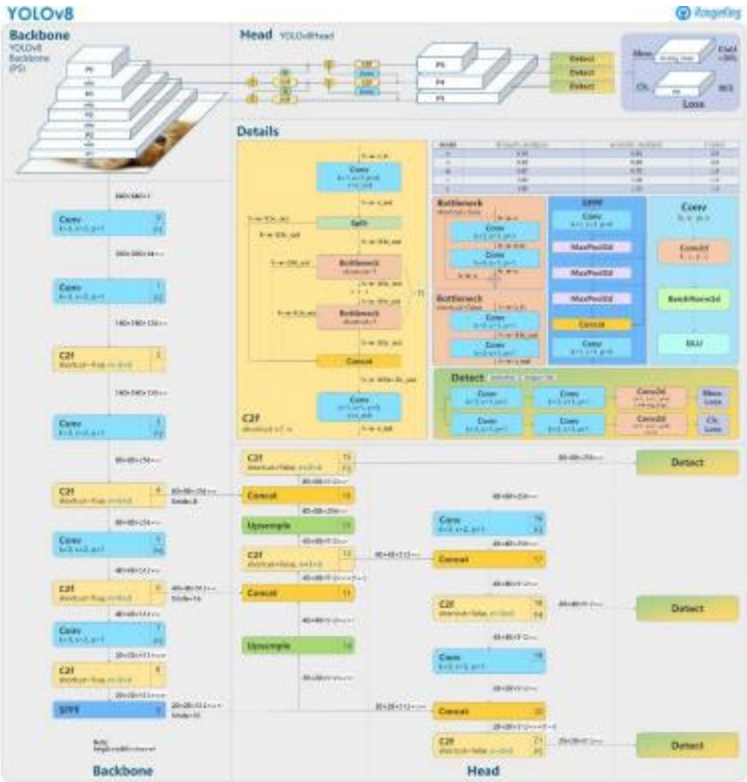
YOLOv7: The computer vision and machine learning community are buzzing about the YOLOv7 algorithm. The most recent YOLO algorithm outperforms all earlier object detection algorithms and YOLO iterations in terms of speed and precision. It can be taught significantly quicker on tiny datasets without any pre-learned weights than other neural networks and requires technology that is several times less expensive. Therefore, YOLOv7 is anticipated to overtake YOLO v4 as the current state-of-the-art for real-time applications and become the industry standard for object detection in the near future. [15]



[Source: https://blog.roboflow.com/yolov7-breakdown/]

Figure 3.5: This is a figure of how YOLOv7 works

YOLOV8: The most recent generation of YOLO-based Object Detection models from Ultralytics, known as YOLOv8, offers state-of-the-art performance. The YOLOv8 model, which builds on the prior YOLO versions, is quicker and more accurate while offering a uniform framework for training models for executing-Image classification, instance segmentation, and object detection. And many features are yet to be added. [16]



Source: https://blog.roboflow.com/whats-new-in-yolov8/

Figure 3.6: This is a figure of how YOLOv8 works

3.2.4 Experiment Setup

We trained our object detection models using PyTorch, specifically YOLOv8. After training the models, we evaluated their performance using a validation dataset and selected the model with the highest accuracy for deployment. We found that our YOLOv8 model achieved an accuracy of 95% in detecting speed breakers and potholes, making it the best-performing model for our task.

Once the model was selected, we integrated it into our Android application using Java programming language and Android Studio. The application uses the device's camera and GPS to detect road hazards in real-time and alert drivers through notifications. The model runs in the background of the application and continuously analyzes the camera feed for potential hazards.

To further improve the accuracy of our model, we plan to implement additional machine learning and natural language processing techniques. This includes collecting more data to fine-tune the model, as well as using machine learning models to identify areas where road hazards are more likely to occur.

After training the model, we incorporated the model in our android application named “RoadBuddy”. Here is the user interface of our app-

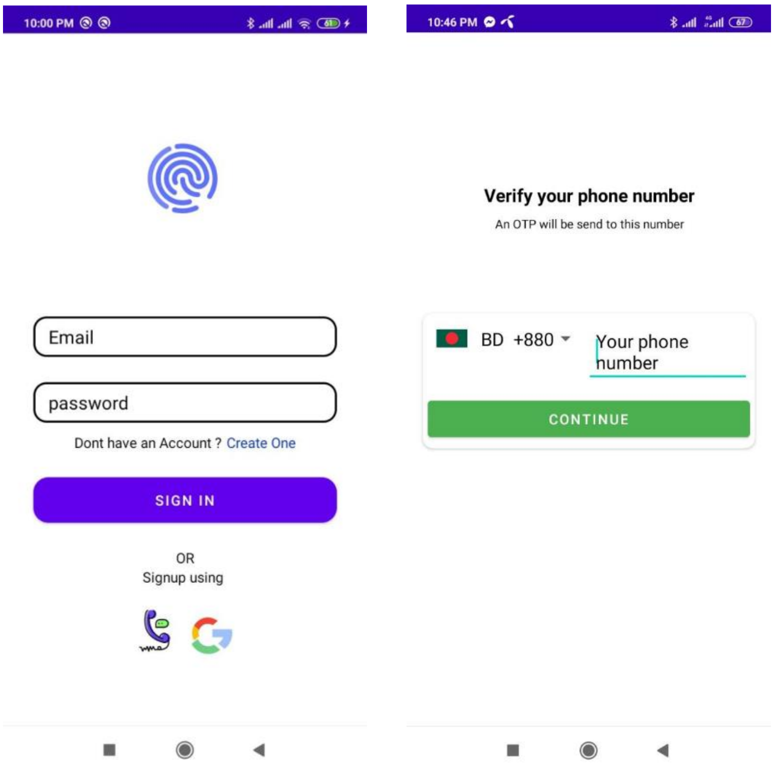


Figure 3.7: This is a figure of how a user application sign in and sign up page

There are three types of sign-up systems incorporated within the application. The user can use his/her mobile number, email id even can continue with the google account.

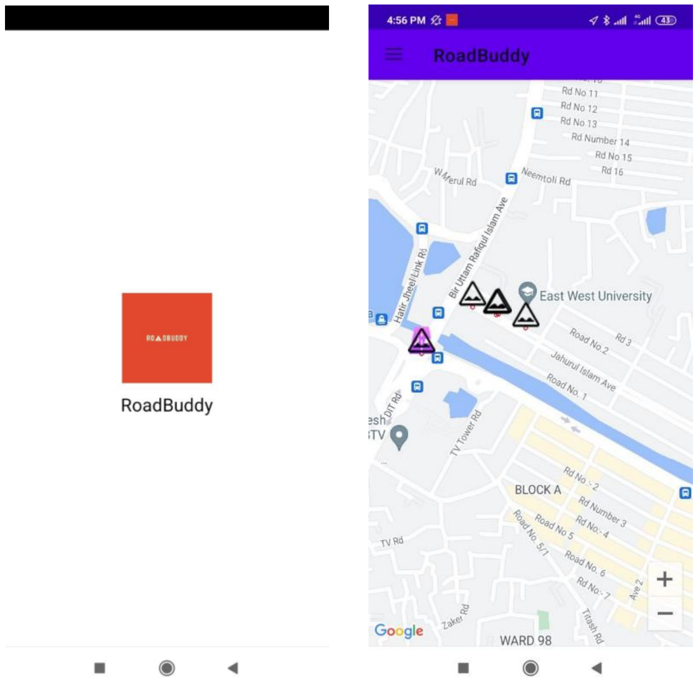


Figure 3.8: This is a figure of application splash screen and home page

After opening the app, the user will be directed to the above home screen. Meanwhile at the backend the user's location will be collected via the global positioning system (GPS) incorporated within the app.

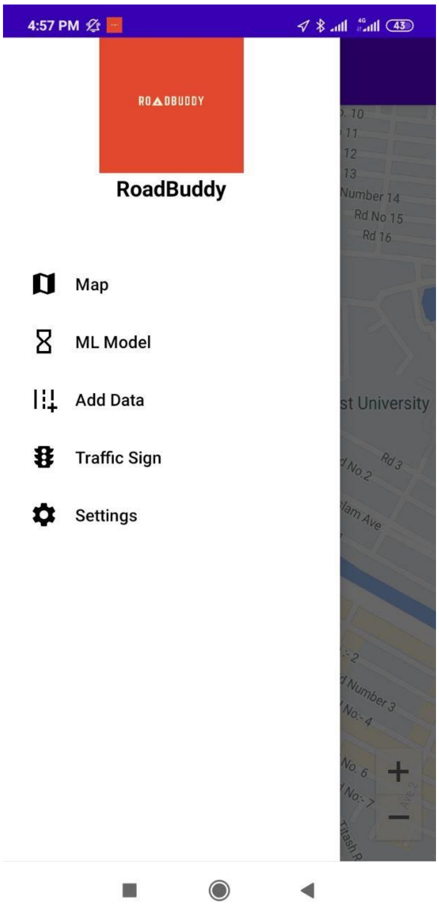


Figure 3.9: This is a figure of application side menu bar

The additional features of our application namely ML Model and Add Data so that users can detect the obstacles and upload the location on firebase. Traffic Sign so that user can know about the traffic rules.

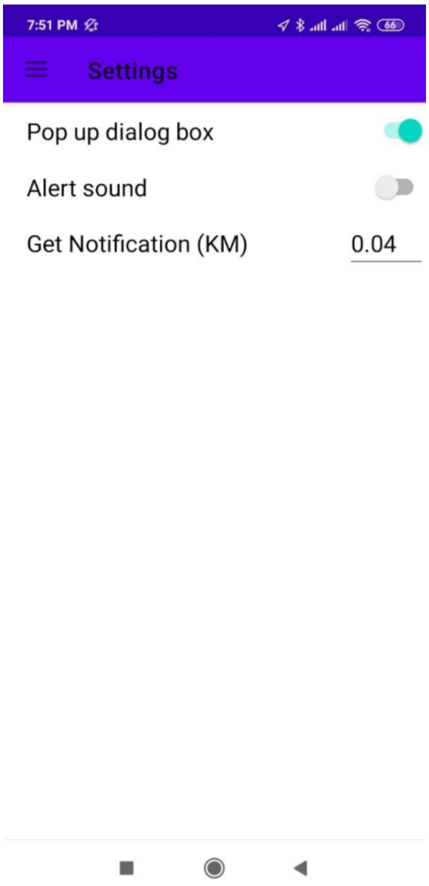


Figure 3.10: This is a figure of application settings page

The user can also mute the notification sounds from the settings bar which can notify him/her about the obstacles. He/she can also disable the pop-up dialog box which appears when the user opens the app in his/her android devices. User can also control from how much distance he/she wants to get notification about the obstacles.

3.3 Summary

The Materials section of our project outlined the necessary components required to operate our application. We explored various options to meet these requirements and developed a system that can accurately detect obstacles such as speed breakers and potholes, and promptly alert the user in a more convenient and efficient manner.

Chapter 4

Results and Discussion

In this session, we will analyze and discuss the outcomes obtained from various machine learning models. To ensure the reliability and effectiveness of our models, we evaluated them using different parameters, namely accuracy, F1 score, precision, and recall. These parameters were chosen because they are widely used in machine learning to assess the performance of classification models. By evaluating our models using these parameters, we aimed to determine their effectiveness in accurately predicting and classifying data.

4.1 Obtained Results

In our study, we utilized different machine learning models to identify and detect objects. Through our evaluation process, we found that among all the models tested, YOLOv8 provided the most accurate and efficient results. This outcome indicates that YOLOv8 is a promising model for object detection in our specific application. However, it is important to note that the selection of the best model may vary depending on the nature of the dataset and the specific requirements of the application. Therefore, further evaluation and comparison of various models may be necessary to identify the most suitable one for a particular task.

Here are some output results of YOLOv8-

Figure 4.1: This is a figure of our model detecting speed breaker and pothole

4.2 In-Depth Result Analysis

Precision, Recall, and F1-Score are essential concepts that provide a more comprehensive understanding of a classifier's performance compared to solely focusing on overall accuracy. These metrics enable us to gain a more nuanced idea of how well a classifier is performing rather than just looking at the overall accuracy.

Confusion Matrix-

A confusion matrix aids in visualizing the results of a classification task by providing a table arrangement of the various outcomes of the prediction and findings.

The associated parameters of a confusion matrix are –

TP (True Positive)- Positive cases which are predicted as positives.

TN (True Negative)- Positive cases which are predicted as negatives.

FP (False Positive)- Negative cases which are predicted as positive.

FN (False Negative)- Negative cases which are predicted as negative.

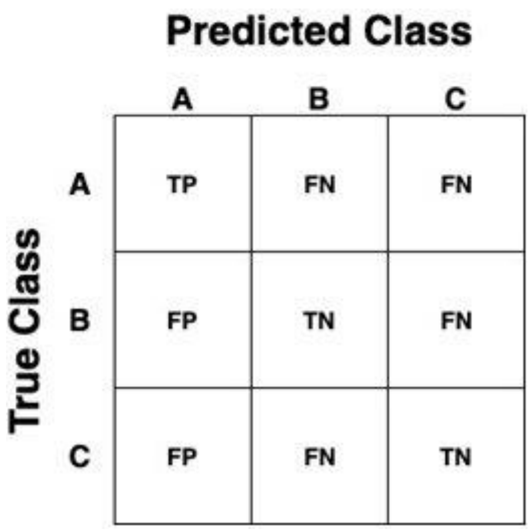


Figure 4.2: This is a figure of a 3*3 confusion matrix

Precision: The proportion of significant outcomes that your model provides is known as precision. Instead of returning any results that may be construed as being a match to what you're looking for, it assesses how good your model is at finding the proper response.

Precision = True Positives / (True Positives + False Positives)

Recall: The recall is determined as the proportion of Positive samples that were properly identified as Positive to all Positive samples. The recall gauges how well the model can identify positive samples. The more positive samples that are identified, the larger the recall.

Recall = True Positive/True Positive + False Negative

<u>F-1 Score</u>: An F-score is the harmonic mean of a system's precision and recall values. It can be calculated by the following formula:

2 x [(Precision x Recall) / (Precision + Recall)].

The model's name, along with its accuracy are following,

Yolov5:

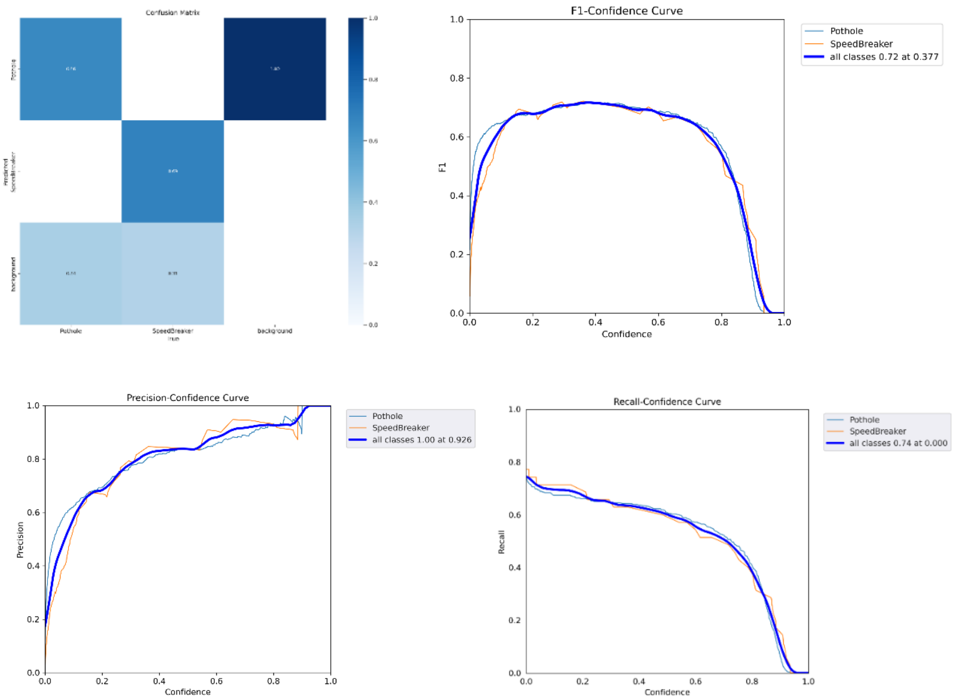


Figure 4.3: Result of yolov5

Yolov7:

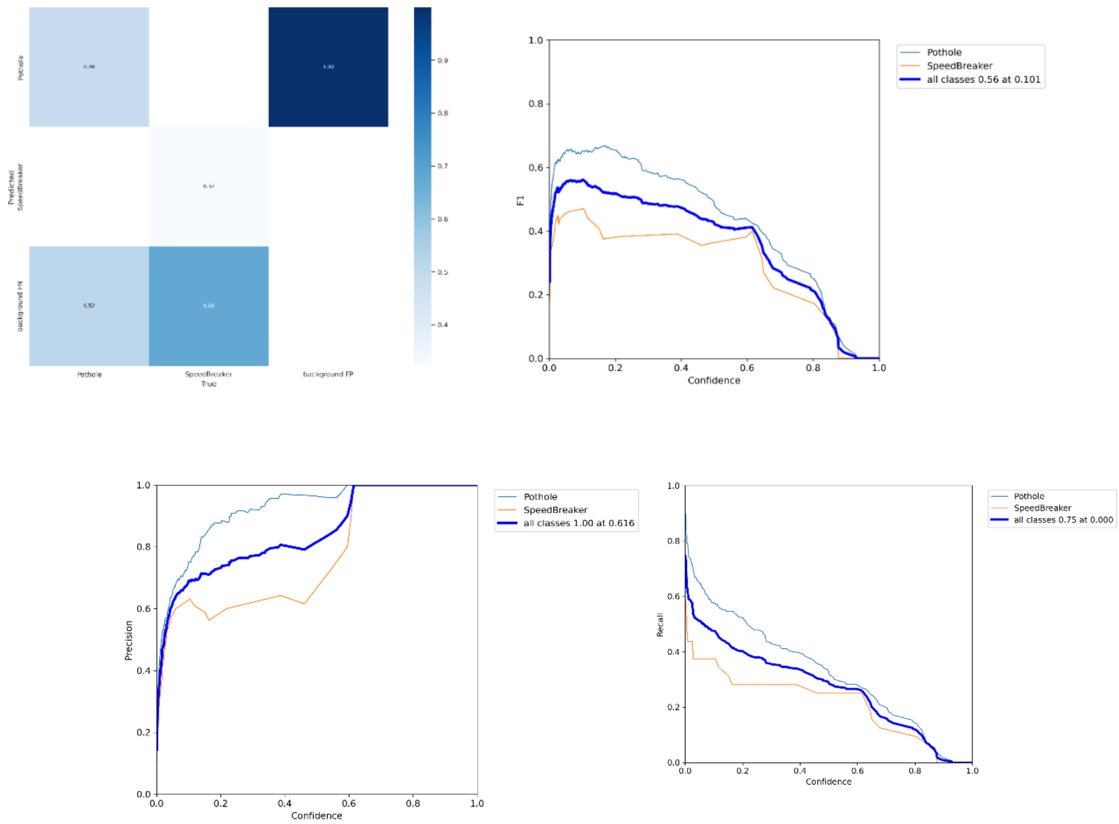
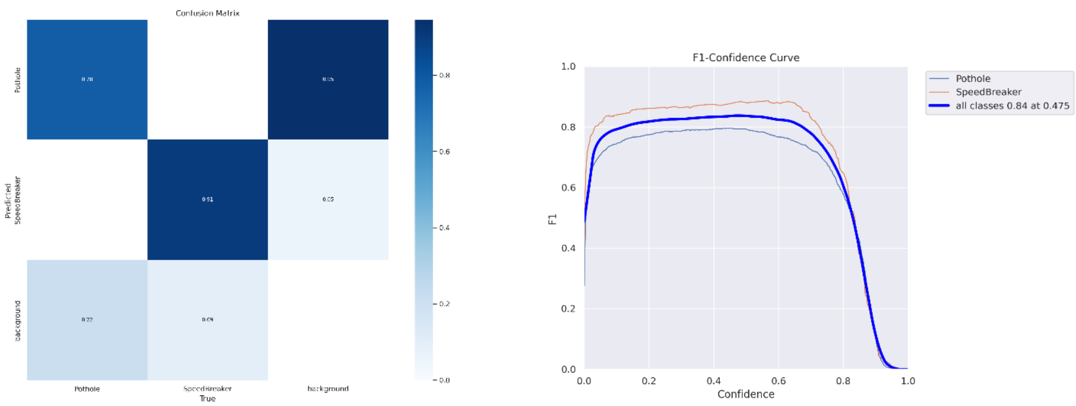


Figure 4.4: Result of yolov7

Yolov8:



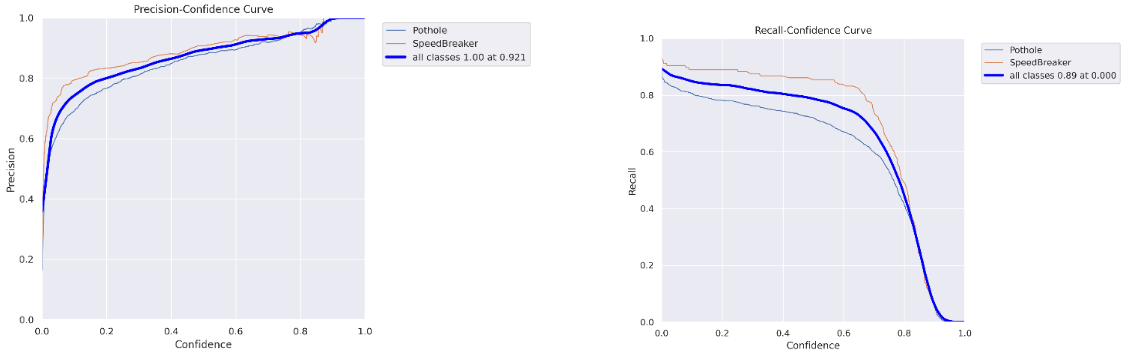


Figure 4.5: Result of yolov8

Faster-RCNN:

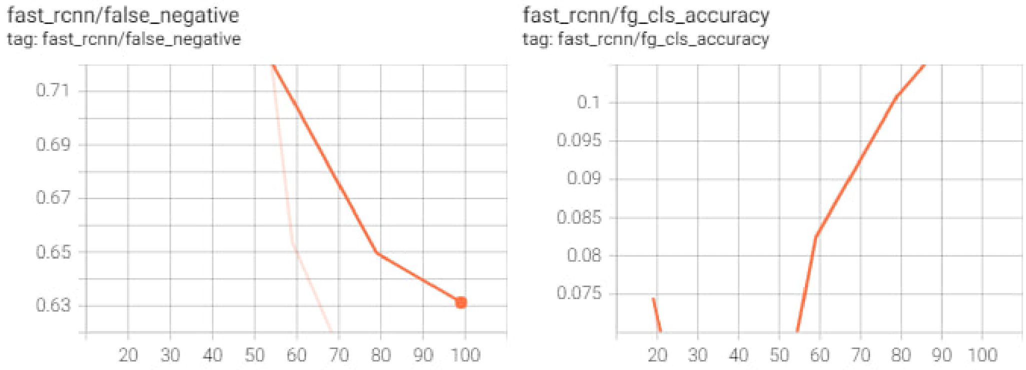


Figure 4.6: Result of faster rcnn

4.3 Performance Evaluation

Object Detection Models	Precision Score	Recall Score	F1-Score	Accuracy Score
Yolov5	1.00	0.74	0.72	84%
Yolov7	1.00	0.75	0.56	80%
Yolov8	1.00	0.89	0.84	88%

Faster-RCNN	1.00	0.83	0.87	92%

4.4 Discussion

YOLOv8 showed a precision of 1 and a recall of 0.89, along with an F1 score of 0.84, this indicates that the model performed very well in detecting the objects of interest. A precision of 1 means that all the detected objects were relevant, which is a desirable outcome as it indicates that the model did not falsely detect any irrelevant objects. A recall of 0.89 indicates that the model was able to detect 89% of the total objects present in the dataset, which is a good measure of the model's sensitivity in detecting objects.

The F1 score of 0.84 is a harmonic mean of precision and recall, which is used to measure the overall performance of the model. A higher F1 score indicates that the model has a better balance between precision and recall, which is desirable for object detection applications. Therefore, based on these metrics, it can be concluded that YOLOv8 is a reliable and efficient model for object detection in the given dataset.

4.5 Summary

Both YOLOv8 and faster R-CNN provided a good result. But overall yolov8 was selected. YOLOv8 is known for its fast object detection speed, making it suitable for real-time applications. Since our project required detecting objects in real-time, YOLOv8 was a better choice. Additionally, YOLOv8 has a simpler architecture compared to Faster R-CNN, which makes it easier to train and use. This simplicity had been a factor in our decision as our project had limited resources or time for training and deployment.

Chapter 5

Conclusion

5.1 Overall Contributions

This project is the development of a system that can detect speed breakers and potholes on the road using deep learning algorithms, as well as an Android application that can alert the user about these obstacles while driving.

The use of deep learning algorithms like Faster-RCNN and YOLOv5, YOLOv7, and YOLOv8 has allowed for more accurate and efficient detection of obstacles, improving road safety and we use YOLOv8 in this project. Additionally, the development of an Android application that can alert drivers to the presence of obstacles can help prevent accidents and injuries caused by sudden jolts or unexpected shocks to the vehicle.

Overall, the project's contributions lie in the development of a cost-effective, accurate, and efficient system that can improve road safety by detecting speed breakers and potholes, which can ultimately contribute to reducing accidents and injuries on the road.

5.2 Limitations and Future Works

5.2.1 Limitations

The given research project has several limitations that must be considered. One significant limitation is the lack of computational resources available to the researchers. The object detection model could only be trained on a limited number of images, which could affect the accuracy and performance of the system. Additionally, the researchers were unable to utilize more sophisticated equipment such as the NVIDIA Jetson due to cost limitations, which could further limit the system's potential.

Another limitation of the research project is the accuracy of GPS data. While the system can detect obstacles like speed breakers and potholes, the accuracy of their location data may be affected by weak or inconsistent GPS signals. This could be compounded using less sophisticated devices that are not optimized for GPS accuracy. Furthermore, the researchers' attempts to save the location data of the detected obstacles in Firebase were unsuccessful, which could further limit the utility of the system.

In summary, the research project has several limitations that could impact the accuracy, performance, and utility of the system. The limited computational resources available to the researchers, the accuracy of GPS data, and the inability to save location data in Firebase are some of the major limitations that must be considered.

5.2.2 Future Works

In the future, this research holds promising potential for further expansion and development. Specifically, incorporating more complex and combination of models can lead to even higher accuracy in the detection of speed breakers and potholes. With more powerful devices and proper hyperparameter tuning, researchers can fully utilize the trained models to their maximum potential.

Furthermore, the research can be further expanded to detect the obstacles' location utilizing the object detection model. The integration of a chatbot within the system could also prove highly useful, offering additional features such as notifications for necessary traffic signs and over-speeding alerts. These additional features can significantly enhance the application's utility, increasing its value proposition for users.

In addition to these, there are promising possibilities for the model to be developed into a business model, where additional features can be offered at a cost. With the growing demand for safer and more efficient driving, this application can serve as a valuable tool for drivers to navigate the roads more safely and efficiently.

In conclusion, the future prospects of this research project are vast and exciting. The integration of more advanced models, location-based detection, and chatbot integration can significantly enhance the utility of the application. Furthermore, the potential for the model to be developed into a business model can create significant value for both the users and the developers.

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Appendix

Mapping of Course and Program Outcomes

CSE400-A

Program Outcomes:

PO1 (Engineering Knowledge): Our project in Computer Science and Engineering is a demonstration of our proficiency in utilizing engineering knowledge. Specifically, it pertains to the sub-fields of data science and intelligent systems, and software engineering, and addresses a pressing issue in our country. We have applied both our existing expertise and newly acquired knowledge to its solution. Programming languages have been a crucial component of our approach. In addition to our prior engineering knowledge, we have also sourced information from external resources.

PO4 (Investigation): A significant requirement for initiating a new research or project is to peruse a substantial number of papers. This is necessary as it is impossible to contribute novel ideas to a field without being cognizant of previous works. In pursuit of a better comprehension of the approaches, instruments, and hardware employed to achieve objectives, we analyzed more than 15 papers published in prominent conferences and journals related to our work. This research necessitated a thorough investigation for discovering pertinent papers. We meticulously explored topics including laws, models, hardware, software, and the requisite tools.

CO	Details	Knowledge Profile (K)	Engineering problem (EP)
CO2	Examine various problem domains (literature review), define the problems, and formulate the objectives for the capstone project	**(i) Related Works [K8**] From previous studies, we have identified their limitations and defined our objectives	Related Works [EP1] After learning in-depth engineering knowledge at the level of K3, K4, K5, K6, or K8, a fundamental-based, first principles analytical method is possible Objectives [EP2, EP6, EP7] We overviewed the causes of road accidents due to speed breakers and potholes. We discussed with stakeholders such as BRTA officials and drivers about the road accidents caused by speed breakers and potholes. We have the freedom in our project to work on high-level problems. (ii) Planned Methodology [EP2, EP6] We discussed with the stakeholders about the technical, engineering, and other issues to detect speed breakers and potholes with a smart and efficient system.

CSE400-B

Program Outcomes:

PO2 (Problem Analysis): The project team demonstrated strong problem analysis skills by identifying the challenges associated with detecting speed breakers and potholes. They developed a suitable solution based on this analysis.

PO3 (Design/Development of Solutions): They developed an innovative solution for detecting speed breakers and potholes using computer vision and machine learning and designed and developed an Android app that provides real-time alerts to the user, enhancing road safety, demonstrating the team's ability to integrate multiple technologies into effective solutions.

PO5 (Modern Tool Usage): The project team demonstrated proficiency in modern tools for computer vision, machine learning, and Android app development. They utilized state-of-the-art libraries and framework such as YOLOv8 and Android Studio to develop an accurate and efficient solution.

PO6 (The Engineer and Society): The project team has developed a solution that has significant potential for improving road safety and reducing accidents caused by speed breakers and potholes. The project demonstrates the team's awareness of the social impact of their work and their commitment to using their engineering skills to benefit society.

CO	CO Descriptions	K	EP
CO3	**Analyze** various aspects of the objectives for designing a solution for the capstone project.	**(i) Problem Analysis [K1, K2, K3, K4]** **K1: Theory-based natural sciences:** In our capstone project, we emphasize on the risks caused by the undetected potholes and speed breakers and studied deep to minimize the risks and come up with a solution. **K2: Conceptually-based mathematics, numerical analysis, statistics, and formal aspects of computer and information science: -** Our strategy makes use of numerical techniques, mathematics, and statistics to help create or apply models that accurately represent 'real world' behavior. To determine the properties of our dataset, we have performed statistical and mathematical analysis. **K3: Theory-based engineering fundamentals:**	**(i) Problem Analysis [EP1, EP2, EP3, EP6, EP7]** **EP1: Depth of knowledge required: -** After gaining in-depth engineering knowledge at the level of one or more of K3, K4, K5, K6, or K8, allowing for a fundamental-based, first principles analytical approach. In our system, we use our extensive engineering experience. It is difficult to achieve the aim of detecting speed breakers and potholes and predicting the output without in-depth engineering expertise at the level of one or more of K3, K4, K5, K6, or K8. **EP2: Range of conflicting requirements: -** Our system is cleaner, smarter, and error-free for spotting speed breakers and potholes and anticipating the best

		- The main source of real knowledge in the key domains of basic engineering knowledge that are relevant to our engineering discipline is data science. In order to build several types of models to identify speed breakers and potholes, we used our in-depth understanding of deep learning in our capstone project on the detection of speed breakers and potholes. **K4: Forefront engineering specialist knowledge for practice: -** Our method provides a significant depth of knowledge to enable the practice of identifying speed breakers and potholes owing to deep learning. For the best results, our project is designed around various deep learning models.	results since we combine a broad variety of possibly contradictory technological, engineering, and other issues, such as data augmentation techniques and many types of models. **EP3: Depth of analysis required: -** We required abstract reasoning and analysis to create suitable models for our project and find the obvious answer in order to put the system in place. As the focus of this project is the identification of speed bumps and potholes, we started by thoroughly analyzing the issue before developing a solution. **EP6: Extent of stakeholder involvement and conflicting requirements: -** Our technology, which can identify speed breakers and potholes and anticipate results, may involve a wide range of stakeholders, each with specific needs. We may, for instance, include specialists into our programs and solicit professional advice. **EP7: Interdependence: -** In our effort to identify potholes and speed breakers, we are free to work on high-level problems with several component parts or sub-problems.

CO4	Design and develop solutions for the capstone project that meet public health and safety, cultural, societal, and environmental considerations.	**(i) Design and Implementation [K5]** **K5: Engineering design: -** To properly recognize speed breakers and potholes and to foresee the results before putting them into action, we acquire knowledge. We studied YouTube videos, online classes, and our academic course to acquire technical knowledge, design strategies, and pertinent tools and resources to create parts, systems, or procedures that satisfy certain requirements. After thoroughly examining all of our alternatives, we researched various strategies like CNN and created a product that will be extremely beneficial to humanity. Our project entails the importation of several tensor flow and open source pytorch packages, data pre-processing, data augmentation, statistical analysis of the two types of datasets, deployment of the CNN model, and detection and prediction of the target.	**(i) Design and Implementation [EP1, EP2, EP4, EP5, EP6, EP7]** **EP1:** Depth of knowledge required: - A fundamentals-based, first-principles analytical approach is achievable after acquiring in-depth engineering knowledge at the level of K3, K4, K5, K6, or K8. We use our extensive engineering abilities, which we have acquired over the course of a year at our university, in our method for locating speed breakers and potholes, and then we project the results. **EP2: Range of conflicting requirements: -** We used a variety of deep learning models in our project to detect speed breakers and potholes, as well as pre-processing that conflicted with our engineering design. **EP4: Familiarity of issues: -** When detecting speed breaker and pothole locations and forecasting the results, we try to take uncommon situations into account. **EP5: Extent of applicable codes: -** We put a lot of effort into keeping the code standard up so that outside concerns are handled by professional engineering standards and best practices. so that the user may easily

			obtain the results of the detection of speed breakers and potholes. **EP6: Extent of stakeholder involvement and conflicting requirements: -** Our method for identifying speed breakers and potholes may involve a wide range of stakeholders, each with its own unique set of needs. We may, for instance, include specialists into our programs and solicit professional advice. **EP7: Interdependence: -** In our effort to identify potholes and speed breakers, we are free to work on high-level problems with several component parts or sub-problems
CO5	**Identify** and **apply** modern engineering and IT tools for the design and development of the capstone project.	**Materials and Devices [K6]** **K6: Engineering Practice (technology): -** We need to investigate several Deep Learning algorithms in order to apply deep learning as a method of detection and prediction. Different methods have been devised by researchers particularly for object detection of various categories. We have examined these algorithms as well. Finally, we employ a variety of deep learning methods and convolutional neural network (CNN) techniques. We use the most recent tools and features to	**Materials and Devices [EP1, EP2, EP4, EP5]** **EP1: Depth of knowledge required: -** Although we use different packages to review experiments, implement different algorithms, and implement tools and features, we still need to have extensive fundamental engineering knowledge at the level of K2, K3, K4, K5, and K6 in order to use the tools and features correctly and analyze the results. We need extensive conceptual AI understanding to deploy the most recent algorithms

		carry out these operations and analyses. We require a high-performance computer with a GPU system since we must deal with photos. We put a lot of effort into delegating tasks equally throughout the staff.	and software in our situation. **EP2: Range of conflicting requirements: -** We encountered several unusual problems throughout the implementation phase in order to train the dataset and get accurate results. To solve the problem, we use theory-based as well as fundamental scientific and engineering reasoning at the K3, K6, K7, and K8 levels. **EP4: Familiarity of issues: -** For a more precise and enduring detection-prediction outcome, we strive to employ datasets with rare photos of speed breakers and potholes while training the system. We try to cover problems in our system that aren't frequently seen. **EP5: Extent of applicable codes: -** We make effort to keep a professional tone when coding. We also put a lot of effort into using ethical, logical, and rational problem-solving techniques at the K4, K5, and K6 levels while upholding professional standards to reduce errors in our detection and prediction stages.

CO6	**Assess** and **address** societal, health, safety, legal, and cultural aspects related to the implementation of the capstone project considering the relevant professional and engineering practices and solutions.	**Social and Environmental Impact of Engineering [K7]** **K7: Comprehension of engineering in society: -**. We didn't use any language or software that was unlawful in our project. No unfavorable effects of social or environmental engineering are present in our system. We updated our system's workflow using cutting-edge, environmentally friendly technology. Our approach is risk-free, and the details we offer are precise, reliable, and true with reliable references. We make sure the system is secure and that our actions are suitable for human health. The program is safe when used in testing, experimental, and lab settings.	**Social and Environmental Impact of Engineering [EP2, EP5, EP6]** **EP2: Range of conflicting requirements: -** We look at many facets of how potholes and speed breakers affect the environment and society, and we try to think of uncommon problems that our system could be able to handle. At the K3, K4, and K7 levels, we incorporate findings through analysis and debate. When developing our capstone project, we encountered a number of model conflicts, but we were able to resolve them. **EP5: Extent of applicable codes: -** We concentrated on simplifying our system and maintaining the code standard such that external concerns are handled by professional engineering standards and guidelines. We concentrated on simplifying our system and maintaining the code standard such that external concerns are handled by professional engineering standards and guidelines. **EP6: Extent of stakeholder involvement and conflicting requirements: -** We integrate a wide variety of stakeholders into our system, each with specific needs. For instance, we could employ experts in our

			programs to research the system we are developing and provide appropriate feedback.

CSE400-C

Program Outcomes:

PO7 (Environment and Sustainability): The project team has taken into consideration the environmental impact of their solution, as it can reduce fuel consumption and vehicle emissions caused by unnecessary braking and acceleration due to speed breakers and potholes. The project demonstrates the team's commitment to sustainability by developing a solution that can contribute to reducing environmental harm caused by transportation.

PO8 (Ethics): The project team has considered ethical implications such as privacy and data security in the development of their Android application. The project demonstrates the team's commitment to ethical principles in engineering and their ability to develop solutions that adhere to ethical guidelines.

PO9 (Individual Work and Teamwork):

The project team has demonstrated effective teamwork by collaborating on the development of the solution, sharing responsibilities, and communicating effectively. The project demonstrates the team's ability to work both independently and collaboratively, highlighting their individual strengths and the collective abilities of the team.

P10 (Communication): The project team has effectively communicated their solution by developing an Android app that is user-friendly and provides real-time alerts to the user. The project demonstrates the team's ability to communicate complex engineering concepts in a clear and concise manner, and to develop solutions that meet the needs of the end-users.

P11 (Project Management and Finance): The project team has effectively managed the project by establishing clear goals, timelines, and milestones, and by using project management tools to monitor progress and ensure timely completion. The project demonstrates the team's ability to manage project resources effectively, including time, budget, and personnel, and to develop solutions that meet project requirements within these constraints.

P12 (Life-Long Learning): The project team has demonstrated a commitment to lifelong learning by continuously updating their knowledge of emerging technologies, including computer vision and machine learning, and incorporating these into their solution. The project demonstrates the team's ability to adapt to changing circumstances, to identify and address knowledge gaps, and to develop innovative solutions that push the boundaries of their current knowledge and skills.

CO	**Details**	**Knowledge Profile (K)**	**Engineering Problem (EP)**
CO7	Analyze and interpret data and develop insights and recommendations for improving road safety.	**(i) Societal and environmental contexts [K7]** **K7:** The team has considered the impact of their project on society and the environment and developed a solution that promotes sustainability and social responsibility.	**(i) Societal and environmental contexts [EP2, EP5, EP6]** **EP2: Range of conflicting requirements**: The team successfully navigated the conflicting requirements to develop a solution that meets the needs of both safety and user experience. **EP5: Extent of applicable codes:** The project team has demonstrated a strong understanding of applicable codes and regulations related to road safety and mobile application development. **EP6: Extent of stakeholder involvement and conflicting requirements:** The team will consider and address

			conflicting requirements, and develop appropriate strategies to manage stakeholder expectations and ensure project success.
CO8	Demonstrating an understanding of professionalism and ethical behavior by adhering to professional standards and codes of conduct, and conducting themselves with integrity throughout the project	**(i) Ethical principle and practices [K7]** **K7: Comprehension of engineering in society**: The team will recognize the impact of the project on the environment and the potential for promoting sustainable transportation systems.	
C09	involves the ability to apply critical thinking and problem-solving skills to identify and evaluate potential solutions, as well as to use relevant technologies and tools to implement and test these solutions		
CO10	Ability to integrate computer vision and machine learning technologies to develop innovative solutions for enhancing		

	road safety and improving transportation infrastructure.		
CO11	Ability to apply modern tools and technologies for developing a solution to a real-world problem		
CO12	Ability to apply knowledge and skills to solve complex engineering problems		