Visvesvaraya Technological University

BELAGAVI, KARNATAKA - 590 014.

PROJECT PHASE-II REPORT

ON

"Potholes And Humps Detection System in Real-Time"

Submitted By

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Submitted in partial fulfillment of the requirement for the award of degree of

BACHELOR OF ENGINEERING

IN

COMPUTER SCIENCE AND ENGINEERING

Under the Guidance
of

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PES Institute of Technology and Management

Department of Computer Science & Engineering

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(Affiliated to Visvesvaraya Technological University, Belagavi)

Department of Computer Science and Engineering

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CERTIFICATE

Certified that the project work entitled "***POTHOLES AND HUMPS DETECTION SYSTEM IN REAL-TIME***" carried out jointly by

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bonafide students of ***PES INSTITUTE OF TECHNOLOGY & MANAGEMENT*** in partial fulfillment for the award of Bachelor of Engineering in ***COMPUTER SCIENCE & ENGINEERING*** of the Visvesvaraya Technological University, Belgaum during the year ***2023-24***. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the department library. The project phase-I report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said Degree.

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DECLARATION

We, Anusha Manjappa Jogihalli (4PM20CS013), Bhoomika S P (4PM20CS023), Bindu K H (4PM20CS025) and Inchara M M (4PM20CS043) students of 8th semester B.E. in Computer Science & Engineering, PESITM, Shivamogga hereby **declare** that the final year B.E. major project report entitled **POTHOLES AND HUMPS DETECTION SYSTEM IN REAL-TIME** which is being submitted to the **PESITM, Shivamogga** during the year 2023-24 is a record of an original work done by us under the supervision of Mr. Shivanand Maradi, Assistant Professor, Dept. of CSE, PESITM, Shivamogga. This Project work is submitted in partial fulfilment of the requirements for the award of the Degree of **Bachelor of Engineering** in **Computer Science and Engineering**. The material contained in this report has not been submitted to any University or Institution for the award of any degree.

(Anusha Manjappa Jogihalli 4PM20CS013) **(Bhoomika S P 4PM20CS023)**

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Place: PESITM, Shivamogga.
Date: May 25, 2024

Abstract

Potholes are formed as a result of unavoidable wear, tear and weathering of roads. It causes uneasiness to the travelers and may also lead to death due to vehicle accidents. The main purpose of the project is to prevent the road accidents occurring in and around the world. Many people do not slow down as they fail to recognize the potholes and humps on the road while driving, which leads to life hazard or vehicular damage. The proposed method involves the usage of cameras and sensors to collect the data, identify and distinguish between the humps and pothole region and alert the driver with different buzzer sounds. The pothole detection can be achieved using YOLOv4 algorithm, which is efficient in spotting the potholes. The hump detection is carried out using the ultrasonic sensor and Arduino. Therefore, in order to avoid accidents in significant number we have come up with the pothole and hump detection project for social good.

Acknowledgement

It is our pleasure to express our heartfelt thanks to Prof. Mr. Shivanand Maradi, Assistant Professor, Department of Computer Science and Engineering, for his supervision and guidance, which enabled us to understand and develop this project.

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List of Acronyms

mAP	mean Average Precision
DNN	Deep Neural Network
R-CNN	Region-based Convolutional Neural Network
SSD	Single Shot MultiBox Detector
IMU	Inertial Measurement Unit
YOLO	You Only Look Once
USB	Universal Serial Bus
UNO	University of New Orleans
PWM	Pulse Width Modulation
ICSP	In-Circuit Serial Programming
AC	Alternating Current
DC	Direct Current
HC-SR04	High-Conductance ultrasonic sensor
CNN	Convolutional Neural Network
IDE	Integrated Development Environment
OpenCV	Open-Source Computer Vision
GUI	Graphical User Interface

CHAPTER 1

INTRODUCTION

The project addresses the critical issues of road safety and vehicle maintenance by minimizing the risks associated with road hazards. The Indian government said total 4,775 and 3,564 accidents occurred in the years 2019 and 2020 respectively, due to potholes 3.6 thousand accidents are occurred in 2021 and 4,446 accidents are occurred in 2022.The number of accidents due to potholes decreased and its share in the total causes of accidents due to road features had also decreased over the years.

Potholes are not only dangerous, but they are also a major source of frustration and inconvenience for commuters. Potholes are caused by a variety of factors, including poor quality of construction materials, lack of proper maintenance and repair, heavy rainfall, and high traffic volume. The challenge at hand is to develop an advanced Pothole and Hump Detection System leveraging machine learning and image processing techniques, integrated with real-time alerting mechanisms for vehicles. The primary objective is to create a system that can accurately detect the presence of potholes and humps on roadways, and then transmit timely alerts to vehicles. This method involves the use of cameras and sensors to collect data on road conditions, analyze the data and identify areas with humps or potholes. we can achieve this using tensor flow lite model. Tensor-flow lite models are lightweight and require minimal processing power, making them suitable for deployment on even low-powered mobile devices like smartphones or dedicated hardware attached to the two-wheeler.

Tensor-flow lite model can be adapted to specific needs, focusing on detecting potholes, humps, or even debris and other road hazards, allowing drivers to react in time, ultimately improving road safety and reducing vehicle damage.

1.1 Motivation

The motivation for developing a real-time pothole and humps detection system can be driven by several critical factors:

Road Safety Improvement:

Potholes and humps pose significant hazards to two-wheeler riders, increasing the risk of accidents, injuries, and fatalities. Real-time detection and alert systems can help riders avoid these hazards, thereby enhancing overall road safety.

Vehicle Maintenance and Cost Reduction:

Potholes can cause severe damage to vehicle tires, suspensions, and other components, leading to high repair costs. By detecting and avoiding potholes, the system can reduce the wear and tear on vehicles, leading to lower maintenance costs for users.

Enhanced Riding Experience:

A smoother ride with fewer unexpected jolts from potholes and humps improves the overall riding experience for two-wheeler users. This can lead to increased satisfaction and comfort for riders.

Efficient Municipal Response:

The system can provide valuable data to municipal authorities about the locations and severity of potholes and humps. This information can help prioritize road maintenance and repairs, leading to more efficient use of resources and timely interventions.

Contribution to Smart City Initiatives:

Integrating the detection system with smart city infrastructure can enhance urban mobility solutions. It aligns with the goals of smart city projects, which aim to improve urban living through the use of technology and data-driven decision-making.

Reduction in Traffic Congestion:

Real-time alerts about road conditions can help riders choose alternative routes, reducing traffic congestion in areas with poor road conditions. This can lead to better traffic flow and reduced travel times.

1.2 Problem Description

The project aim is to address road safety and vehicle maintenance concerns by mitigating the risks posed by and hump road hazards. The key objective is to develop a robust system that can accurately detect and classify potholes and humps, communicate this information to vehicles, and issue timely alerts to drivers by providing a notification sound. **Problem statement: "The challenge is to create a Pothole and Hump Detection System capable of identifying road imperfections, such as potholes and humps, and providing real- time alerts to two wheelers vehicles."**

1.3 Objectives of the project

- To collect pothole images, label and annotate it.
- To train, test and detect the pothole on road.
- To design and develop an alert system for two-wheeler drivers when a hump or pothole is detected.
- To store the pothole detected output video file in the result folder which will be useful for municipal corporation department and smart city projects for road maintenance.

1.4 Scope and limitations

Scope

- **Enhanced Road Safety:**
  Pothole and hump detection systems play a crucial role in enhancing road safety by leveraging advanced sensor technologies to detect road irregularities in real-time. These systems provide immediate alerts to drivers, allowing them to adjust their speed and trajectory to avoid potential hazards. By alerting drivers to the presence of potholes and humps, these systems help prevent accidents, vehicle damage, and injuries, thereby significantly improving overall road safety for both drivers and pedestrians.

- **Infrastructure Maintenance:**
  Prompt identification of potholes and humps enables authorities to prioritize maintenance efforts effectively. By addressing these road irregularities in a timely manner, authorities can prevent further deterioration of the road surface and minimize damage to vehicles. Additionally, targeted maintenance based on data

collected by detection systems helps extend the lifespan of roads, reducing the frequency and cost of major repairs or reconstruction projects.

- **Accident Prevention:**
  Potholes and speed humps are potential hazards that can lead to accidents, especially if drivers are not aware of them or are unable to react in time. The detection system plays a crucial role in accident prevention by continuously monitoring road conditions and identifying these hazards in real-time. By alerting drivers to the presence of potholes or humps ahead, the system provides them with valuable information to adjust their driving behaviour accordingly, such as slowing down or changing lanes to avoid the hazard.

Limitations

- **Varying Road Conditions:**
  Road conditions can vary significantly, affecting detection systems. Surface texture, curvature, and gradient impact system performance. Algorithms trained on one surface may struggle on others. Speed and traffic density also matter; high-speed vehicles may miss detections, and heavy traffic can create noise. Environmental factors like weather and lighting add complexity, obscuring sensor readings. Obstacles like debris or parked cars can interfere with sensors. Regular sensor maintenance and calibration are crucial for accuracy. Finally, compliance with regulations and addressing legal concerns is essential for deployment.

- **Vehicle Speed and Traffic Density**
  Vehicle speed and traffic density influence detection system effectiveness. High speeds can cause missed detections as vehicles pass too quickly. Heavy traffic congestion poses challenges, making it hard to distinguish road irregularities. Sensors must quickly process data to keep up with varying speeds and densities. Safety depends on accurate and timely detection, especially at high speeds. Congestion adds complexity, requiring precise detection amidst crowded conditions. Balancing speed and accuracy is critical for system performance. Adaptive algorithms can help adjust to changing traffic dynamics.

- **Adverse Weather Conditions:**
  Extreme weather conditions such as heavy rain, snow, or ice can significantly affect the performance of pothole and hump detection systems. Reduced visibility,

slippery road surfaces, and altered vehicle dynamics during adverse weather events can challenge the accuracy and reliability of sensor-based detection systems. Developing robust algorithms and sensor technologies capable of operating effectively in various weather conditions is essential to mitigate these challenges.

1.5 Organization of the report

The report is organized as follows.

Chapter 2: Literature Survey - The chapter includes a review of the existing research and gaps or areas for further study.

Chapter 3: System Analysis-The chapter covers the existing system, disadvantages, proposed system and its advantages.

Chapter 4: System Requirements and Specification -The chapter covers the software and hardware requirements along with system tools.

Chapter 5: System Design- The chapter covers the proposed architecture and methodology.

Chapter 6: System Implementation- The chapter covers pseudo code and method explanation.

Chapter 7: Result and discussion- The chapter covers the project findings and analysis of the results.

Chapter 8: Conclusion and future scope- This chapter covers the recapitulation of how the objectives were achieved and recommendations for future research.

CHAPTER 2

LITERATURE SURVEY

Road safety faces a serious threat due to puddles and bumps causing serious vehicle damage. Researchers are actively looking for space tracking systems to solve this problem. Deep learning appeared to be at the forefront, with YOLOv3 and YOLOv7 achieving high accuracy (up to 98%) in identifying these hazards from images captured by cameras in cars and even smartphones. This model has the potential to make our roads safer by creating instant notifications to drivers and police.

However, other methods such as measurements based on the use of smartphone accelerometers offer good solutions, while technologies such as 3D point clouds Deep learning can provide accurate information, but at the price of complexity and sophistication. The future of hole exploration lies in combining the advantages of these different approaches. Combining the power of deep learning with understanding sensor data such as accelerometers holds great promise for stronger pothole detection in real-world driving.

Different data for further research is important to improve the generality of these systems. The integration of various methods, lighting changes and pit mode into the training material allows this model to work well in the complexities of the real world. As artificial intelligence and computer vision continue to advance, the vision of monitoring on a smart basis is also becoming increasingly common. Imagine a future where vehicles automatically scan and report puddles, enabling efficient road maintenance. This not only makes the road smoother, but also safer and more enjoyable for all drivers. Finally, defining the lake with new technologies such as YOLOv4 Tiny model will pave the way for safer and more efficient transportation, paving the way for the future of reducing accidents and increasing the road safety system.

2.1 Surveyed papers

Several projects were carried out in regard to potholes and humps detection in recent years, here are a few papers.

Title: "A Real-time Pothole Detection Based on Deep Learning Approach" [1]

Authors Name: Yeoh Keng Yik, Nurul Ezaila Alias, Yusmeeraz Yusof and Suhaila Isaak.

Year:2020.

Description:

The paper proposes a real-time pothole detection system using the YOLOv3 deep learning algorithm. The system aims to address the significant safety hazards posed by potholes, which contribute to numerous accidents and vehicle damage. Overall, this paper presents benefits with respect to safety, efficiency, and cost reduction in road infrastructure management.

Advantages:

The system can detect potholes instantly with a frame rate of 4 FPS. The webcam and software approach are more affordable than existing methods like Ground Penetrating Radar vehicles. The system can be installed in public transport or taxis for broader coverage and improved pothole monitoring.

Drawbacks:

The model's accuracy could be improved with more training data. Real-time inference requires a decent GPU for smooth processing. Some non-pothole features might be incorrectly identified. Installation depends on integrating the system with vehicles.

Gaps identified:

The carried-out project achieves more than 65.05% average accuracy (mAP) with the YOLOv4-Tiny model in detecting the source. The project also solves the problem of small data by integrating comprehensive and diverse data. Use the YOLOv4-Tiny model to ensure program efficiency and compatibility with a variety of hardware. In addition, the project provides a solution to the detection of bad roads by not only searching in potholes but also covering bumps. Together, these advances increase the power and versatility of the engine compared to the limitations of previous versions.

Title:“Learning to automatically catch Potholes in worldwide road scene images”

Authors Name: J. Javier Yebes , David Montero and Ignacio Arriola.[2]

Year:2021.

Description:

The system uses cameras on cars to "see" potholes and trained on a large dataset of images. Four different Deep Neural Networks were tested, with Faster R-CNN Resnet101 performing best with 82% accuracy. The system was deployed on a real vehicle and reported potholes to an Internet of Things platform.

Advantages:

Early detection of potholes helps prevent accidents and vehicle damage caused by them. Automated pothole detection allows for quicker and more efficient identification and repair of damaged roads, leading to better overall road quality. This system eliminates the need for manual road inspections, saving time and resources. This technology aligns with the advancements in autonomous driving by providing crucial information for safe navigation.

Drawbacks:

DNN models require high processing power, which can be a challenge for real-time implementation on embedded systems in vehicles. There are still instances of misdetection, including mistaking manholes for potholes, and vice versa. Accurate detection becomes difficult at high speeds (>60 km/h) due to image blur. The system's performance might be affected by lighting conditions, shadows, and road debris.

Gaps identified:

The carried-out project presents several advances in Yebes et al.'s (2021) work. Using the YOLOv4 algorithm can exceed 75% average accuracy, thus improving the accuracy of base detection. The YOLOv4-Tiny model increases computational efficiency while larger datasets increase flexibility for multiple road and pothole types. Integrating bump detection from ultrasonic sensors with Arduino expands the scope of the system. Yebes et al. research, this project addresses facts, data diversity and resource use issues as solutions to road safety.

Title:"A Transfer Learning-Based System of Pothole Detection in Roads through Deep Convolutional Neural Networks" [3]

Authors Name: Jhon Michael C. Manalo, Alvin Sarraga Alon, Yolanda D. Austria, Nino E.Merencilla , Maribel A.Misola , Ricky C. Sandi.

Year:2022.

Description:

The pothole detection is crucial for road safety and maintenance, with potholes causing damage and affecting autonomous vehicles. Deep learning techniques like YOLOv3 prove effective, achieving high accuracy (95.43%) in pothole detection YOLOv3 algorithm offers a balance between low error rate and processing complexity. Pre-trained models and transfer learning improve training speed and precision. Accurate detection on Indian roads enables faster, safer autonomous vehicle operation. Deep learning and computer vision are key for identifying objects in the environment. Further research with larger datasets and diverse models is necessary for real-world application.

Advantages:

Deep learning models like YOLOv3 achieve impressive accuracy rates. Early detection of potholes prevents accidents and vehicle damage. Automated systems facilitate faster and more efficient pothole repair. Accurate pothole information enhances autonomous vehicle navigation.

Drawbacks:

Smaller datasets can affect accuracy and generalizability. Existing technologies might not process data fast enough for immediate notification. Lighting, shadows, and debris can affect detection performance. Accurate detection becomes difficult at higher speeds.

Gaps identified:

The project represents significant progress in the work outlined in this article. Although this study achieved a high mAP of 95.43%, its reliance on a data limit of 300 images may affect generalizability. Greater integration and more diverse information could solve this problem, thus increasing the power of the system. Additionally, in video testing, the paper's accuracy dropped to 40-60%, revealing its limitations in poor conditions. The project will solve this problem by making it better than standard photography. The project monitored the computational efficiency of the YOLOv4-Tiny model, making the device accessible on multiple platforms. Additionally, the project expands the work by providing a more comprehensive solution to rough roads by combining bump detection. Incorporating the mAP metric into the evaluation can improve the understanding of detection accuracy. These advances go beyond operational use, making the program stronger and more effective at improving road safety.

Title: "An Intelligent Convolutional Neural Network based Potholes Detection using Yolo-V7" [4]

Authors Name: Madarapu Sathvik, G.Saranya , S.Karpagaselvi.

Year:2022.

Description:

The paper proposes a CNN-based pothole detection system using YOLOv7 deep learning. The system uses smartphone cameras and location data to detect and map potholes in real-time. Instead of expensive methods, YOLOv7 learns from a dataset of pothole images to detect them accurately. With a high F1 score (0.51) and efficiency boost with more training. It helps authorities maintain roads efficiently. YOLOv7 outperforms other models (YOLOv4, v5, YOLOR) in speed and accuracy, making it a powerful pothole-fighting tool.

Advantages:

YOLOv7 offers faster inference speed and higher accuracy compared to other object detectors. Requires lower hardware resources and trains quickly on smaller datasets. Leverages affordable smartphone technology. Provides immediate information about road conditions. Helps prevent accidents caused by potholes. Creates maps of pothole locations for infrastructure maintenance.

Drawbacks:

Relies on the Roboflow dataset of 289 images, which may not represent all pothole variations. Requires users to actively participate in data collection. Location data collection raises privacy concerns for users. Smartphone cameras may not always provide sufficient image quality for accurate detection.

Gaps identified:

The presented paper demonstrates advancements in pothole detection with YOLOv7, but the project surpasses it in key aspects. Utilizing YOLOv4 potentially offers higher accuracy, while a larger and more diverse dataset improves real-world effectiveness. Additionally, hump detection via an ultrasonic sensor and Arduino expands the scope. Prioritizing computational efficiency with YOLOv4-Tiny makes it suitable for diverse hardware, potentially overcoming compatibility limitations. Furthermore, including the mAP metric provides a comprehensive evaluation, enhancing its effectiveness. These advancements make the project a robust and versatile solution for enhancing road safety compared to the limitations of the other paper.

Title: "Research on Pothole Detection Method for Intelligent Driving Vehicle" [5]

Authors Name: Fuzeng Zhang, Askar Hamdulla.

Year:2022.

Description:

The research paper explores various methods for detecting potholes in real-time, specifically for intelligent driving vehicles. It highlights the importance of accurate pothole identification in preventing accidents and improving road maintenance. Five main categories of detection methods are analyzed: manual, vibration-based, computer vision, 3D reconstruction, and 3D point cloud deep learning. Each method has its own advantages and drawbacks, with advanced techniques like 3D vision and deep learning offering real-time detection and accurate mapping but facing challenges in cost, complexity, and data requirements. Overall, the paper paints a promising picture for the future of pothole detection, potentially leading to smoother and safer roads through the use of intelligent pothole patrols.

Advantages:

Real-time detection alerts drivers and autonomous vehicles immediately. Accurate mapping helps authorities prioritize road repairs. Safer roads for everyone.

Drawbacks:

3D vision and laser scanning require specialized sensors. Deep learning models can be resource-intensive. Training robust models requires large datasets of labeled potholes.

Gaps identified:

The carried-out project goes beyond the literature review on the discovery framework with a detailed analysis of specific technologies and evaluation of deep learning models. It also made specific recommendations for future research and provided methods for advancing pit machine research. These programs make the project important in its creation to ensure that the organism is strong.

Title: “A Modern Pothole Detection technique using Deep Learning” [6]

Authors Name: Abhishek Kumar, Chakrapani, Dhruba Jyoti Kalita, Vibhav Prakash Singh.

Year:2023.

Description:

The paper tackles the critical issue of road accident prevention in India, where poor infrastructure plays a significant role. It proposes a modern pothole detection system using Transfer Learning and Faster Region-based Convolutional Neural Network (F-RCNN) Inception-V2 architecture. This method offers real-time pothole detection and alert systems for both drivers and authorities.

Advantages:

Effectively identifying most potholes and minimizing false alarms. Alerts drivers instantly about oncoming potholes, promoting safer driving. Pothole locations are uploaded to a map, warning other users and helping prioritize road repairs. Efficiently repurposes existing knowledge from pre-trained models, saving training time and resources.

Drawbacks:

Deep learning models require substantial processing power, potentially limiting implementation. The model's performance relies on the size and quality of the training dataset. Complex neural networks may not be easily deployed on low-cost hardware. Current setup focuses on mounted cameras, neglecting alternative sources like smartphones.

Gaps identified:

The project which is being carried out addresses the main limitation found in the Faster R-CNN Inception-V2 pothole detection method. Paying attention to the computational efficiency of the YOLOv4-Tiny model, it is suitable for the installation of different devices. Combining larger and more diverse data leads to more general models, while fine-tuning techniques improve performance. Investigating other types of sensors or fusion techniques could improve system robustness in many areas. Additionally, strategies to reduce vulnerability and address privacy concerns can help create more effective and focused privacy practices. These advances make the program more powerful and widely used in pothole detection.

Title: "Deep Learning Based Pothole Detection" [7]

Authors Name: D Rohit Rajan, Mohammad Khaja Faizan, Rajinikanth Kundelu, Neha Nandal, Vasu Sena Gunda.

Year:2023.

Description:

The project tackles the widespread problem of road potholes causing discomfort and accidents. It aims to develop a real-time pothole detection system using the YOLO algorithm and car-mounted cameras. This system alerts drivers to uneven road surfaces, potentially reducing traffic congestion, accidents, and fuel usage.

Advantages:

Alerts drivers instantly to avoid potholes, improving safety. Leverages the YOLO algorithm and car cameras, minimizing hardware costs. Offers efficient pothole detection with minimal impact on processing speed.

Drawbacks:

YOLO might not achieve the highest accuracy compared to other algorithms. System relies on clear visuals, potentially struggling in poor lighting or weather conditions. Needs further research to handle extreme road conditions and unusual camera angles.

Gaps identified:

The project addresses the main limitation of using YOLO for pothole detection. Using the YOLOv4 algorithm can achieve greater accuracy and reduce false positives and negatives. Integrating larger data sets can improve overall patterns, while techniques such as image processing can reduce artifacts. The YOLOv4-Tiny model plays an important role in computing and can be used on different devices. Detection sensor fusion can increase power in different situations and make the solution more reliable in improving security.

Title: "Image-based Road Pothole Detection using Deep Learning Model" [8]

Authors Name: Priyanka Gupta, Manish dixit.

Year:2023.

Description:

The Existing pothole detection methods like manual, sensor-based, and image processing have drawbacks. Deep learning models offer better accuracy and reduced human intervention. The research aims for 98% accuracy in pothole detection using image data. Pre-processing, augmentation, and a CNN model are key aspects of the proposed method. ResNet50 with transfer learning achieved the highest reported accuracy of 98.05%. The work can be extended to segment and localize potholes within images. Various research papers and datasets on pothole detection are mentioned. Deep CNNs, vision-based algorithms, and dilated convolution are discussed approaches. A specific paper on deep residual learning for image recognition is cited. Access details and restrictions for the cited paper are provided.

Advantages:

Achieves 98% accuracy using ResNet50 and transfer learning. Automates pothole detection compared to manual methods. Applicable for real-time road inspection with further development.

Drawbacks:

Requires a diverse dataset with various lighting and road conditions. Deep learning models can be computationally expensive to train. Current version only detects potholes, not their size or depth.

Gaps identified:

The carried project has the advantage of identifying the pit and addressing major limitations. Using larger datasets may improve overall patterns, while inclusion of other groups and regional findings may provide more detailed information. The YOLOv4-Tiny model plays an important role in computing and can be used on different devices. Additionally, using a more efficient strategy allows performance to be measured effectively. These improvements provide effective and efficient solutions for rock detection and road safety.

Title:“Machine Learning Combined with Thresholding – A Blended Approach to Potholes Detection” [9]

Authors Name: Noor Jeohan Ashaari Muhamad, Vazeerudeen Abdul Hameed, Muhammad Ehsan, Hrudaya Kumar Tripathy.

Year:2023.

Description:

The Potholes damage roads and inconvenience drivers. Traditional detection methods are expensive and slow. Motion sensors (accelerometers, gyroscopes) in smartphones or dedicated devices can automatically detect potholes. Accelerometer/gyroscope data collected from smartphones or attached sensors. Cost-effective, real-time pothole detection enables efficient road maintenance and prioritization of repairs. Crowdsourcing apps like Waze and sensor networks contribute to pothole data collection and patching based on severity.

Advantages:

Motion sensors offer a faster and more affordable way to assess road conditions compared to traditional methods. Machine learning models can achieve up to 97% accuracy in detecting potholes, leading to better infrastructure management. Utilizing readily available sensors in smartphones lowers the cost of implementation

Drawbacks:

Sensor data can be influenced by vehicle speed, requiring correction techniques like linear regression or envelope demodulation. Sudden changes in acceleration or uneven road surfaces can lead to misclassification of potholes. Manual labeling of pothole events can be time-consuming and expensive.

Gaps identified:

The data analysis of the carried project has many advantages. Exploring alternative enrollment options, such as transfer study or part-time study, will make the task easier. It also helps with road maintenance by going beyond simple visual inspection to determine the size of potholes. Methods such as data standardization or outlier detection can compensate for other factors, thus increasing the robustness of the model. Focusing on the performance of the YOLOv4-Tiny model, the project overcomes the power and sensor capacity limitations of the smartphone. It also explores more abstract methods and transforms learning to enhance change. These advances address key limitations in analysis, providing better solutions for road safety.

Title: “Real time detection of humps and potholes” [10]

Authors Name: Tejas B S, V Pavan, Rohith H, Pranam J, Veena N. Hegde.

Year:2023.

Description:

Emphasizing the importance of identifying road hazards for safety and maintenance. Various approaches using computer vision, deep learning, sensor data, and combinations thereof. Technical specifics of hardware, software, and algorithms used in different systems. Performance evaluations and accuracy measurements for identifying bumps and potholes. Improvements and existing studies on pavement condition monitoring.

Advantages:

Proposed solutions using deep learning and sensor fusion achieve around 90% accuracy in detecting humps and potholes under various conditions. Compared to traditional methods, camera and sensor-based solutions can be more cost-efficient in the long run, especially for large road networks. Timely detection of potholes and humps helps prevent accidents and damage to vehicles, leading to improved road safety.

Drawbacks:

Some solutions require dedicated hardware like cameras, sensors, and processing units, increasing initial setup costs. Deep learning models can be computationally demanding, requiring powerful hardware or optimized frameworks for real-time implementation. vision-based approaches might be affected by poor lighting conditions.

Gaps identified:

The project addresses the key limitations identified in the review. Greater accuracy can be achieved using the YOLOv4-Tiny model, while larger data can improve the overall model. Improved detection range and depth sensitivity are important when monitoring the computational efficiency of the YOLOv4-Tiny model. Advanced sensor calibration techniques and data filtering techniques increase reliability and provide better solutions for road safety.

2.2 Outcome of the literature review

The project represents a significant advancement in pothole detection methods, addressing key limitations identified in previous approaches. It prioritizes computational efficiency through the utilization of the YOLOv4-Tiny model, enabling deployment on diverse hardware while overcoming the processing power demands of models like Faster R-CNN. By incorporating larger and more diverse datasets, it enhances model generalizability and robustness to various road conditions and pothole appearances. Advanced fine-tuning techniques optimize model performance, while exploration of alternative sensor modalities ensures broader applicability across diverse environments. Moreover, the project implements strategies to minimize false positives and addresses privacy concerns, further enhancing the practicality and reliability of the pothole detection system. Overall, these advancements solidify the project's position as a more comprehensive, efficient, and privacy-conscious solution for real-world pothole detection and road safety enhancement.

CHAPTER 3

SYSTEM ANALYSIS

3.1 Existing System

Drone-Based Systems: Drones with high-resolution cameras and LIDAR sensors survey roads, with data processed to identify road defects.

GPS-Based Systems: GPS can be used to track the vehicle's position and speed. Changes speed or sudden deceleration can indicate the presence of speed humps or potholes.

Pothole Detection using Smartphone Sensors: Some systems leverage smartphone sensors like accelerometers and GPS to detect potholes. These systems use the accelerometer data to detect sudden drops (indicative of a pothole) and GPS data to mark the pothole's location.

3.2 Disadvantages of the System

- Drone-based systems are limited by the range and flight time of the drones. This can restrict the area that can be surveyed in a single flight, requiring multiple flights to cover larger areas.

- Not all smartphones may have the necessary sensors or capabilities required for accurate pothole detection. This can limit the reach and effectiveness of the system, especially in regions where smartphones with advanced sensors are less common.

- GPS-based systems rely on a network of satellites and ground stations, which may not be available or reliable in all locations. This can limit the effectiveness of the system in remote or rural areas.

3.3 Proposed System

The proposed system combines computer vision and sensor-based approaches for real-time pothole and hump detection. For pothole detection, YOLO (You Only Look Once) can be used due to its efficiency in object detection. YOLO can analyze live video feed from a camera mounted on a vehicle and detect potholes on the road surface.

For hump detection, an Arduino Uno microcontroller can be connected to an ultrasonic sensor mounted on the front of the vehicle. The sensor can measure the distance between the vehicle and the road surface. When a hump is detected, the Arduino Uno can trigger an alert system to notify the driver.

The alert system can be implemented using a combination of visual and auditory signals. For example, a buzzer can sound to alert the driver of the detected pothole or hump. This system aims to improve road safety by providing real-time alerts to drivers, allowing them to take necessary precautions and avoid potential damage to their vehicles.

3.4 Advantages of the System

Real-Time Detection: Combines computer vision (YOLO) and sensor-based approaches for immediate detection and alert, enhancing road safety.

High Efficiency: YOLO's fast object detection capabilities ensure quick identification of potholes from live video feeds.

Cost-Effective: Integrates affordable components like Arduino and ultrasonic sensors, making the system more accessible compared to high-end solutions.

Enhanced Alerts: Provides both visual and auditory notifications, ensuring drivers are promptly informed about road hazards.

Comprehensive Coverage: Addresses both potholes and humps, unlike many systems that focus on only one type of road anomaly.

CHAPTER 4

SYSTEM REQUIREMENT SPECIFICATION

The Software Requirements Specification (SRS) outlines the essential requirements for developing a real-time pothole and hump detection system. This system leverages the YOLOv4 Tiny model for efficient object detection and employs various software tools and frameworks to process video feeds, detect road hazards, and alert users promptly. By providing a detailed specification of both functional and non-functional requirements, the SRS ensures a comprehensive understanding of the system's objectives and deliverables among all stakeholders. This document serves as a critical reference for developers, project managers, and clients, facilitating the successful development and implementation of a robust and efficient road hazard detection system.

4.1 Hardware Requirements

4.1.1 Webcam

A webcam is a small digital camera device that connects to a computer, typically via USB. Webcam consists of an image sensor, a lens, and a processor. The image sensor captures video footage, while the lens focuses the light onto the sensor. The processor then converts the captured information into a digital format that can be transmitted over the internet. The webcam is connected to a computer, which processes and displays the video feed. It captures both still images and motion video, commonly used for video calls, live streaming, and recording. Webcams are compact, easy to install, and come with built-in software for video transmission. They are designed to be compact and portable, making them easy to set up and use with computers or laptops. Webcams are essential components for real-time video capture in projects like pothole, providing a cost-effective solution for monitoring and analysing road conditions.

Figure 4.1: Webcam

4.1.2 Arduino UNO

Arduino UNO is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. The crystal oscillator present in Arduino UNO comes with a frequency of 16MHz. It also has a Arduino integrated WiFi module. Such Arduino UNO board is based on the Integrated WiFi ESP8266 Module and ATmega328P microcontroller. The input voltage of the UNO board varies from 7V to 20V. Arduino UNO automatically draws power from the external power supply. It can also draw power from the USB. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. In this project Arduino uno is interfaced with ultrasonic sensors for hump detection and control buzzer alerts upon detection.

Figure 4.2: Arduino Uno Board

4.1.3 HC-SR04 Ultrasonic Sensor

HC-SR04 stands for High-Conductance ultrasonic sensor, which consists of a transmitter and receiver. This sensor is used to find out the distance from the objective. The sensor measures how far things are without touching them, and it uses sound waves to get the measurements right. The HC SR04 ultrasonic sensor, a compact device compatible with Arduino, is designed to measure distance. Its operational concept resembles SONAR, a technology used by ships for underwater navigation. The sensor calculates distance by emitting and detecting sound waves. First, it emits sound waves and then captures the returning waves. The transmitter pin is responsible for emitting the sound waves, while the receiver pin is connected to the circuit ground. Ultrasonic sensors play a critical role in detecting humps on the road surface by emitting high-frequency sound waves and measuring the time taken for the waves to bounce back.

Figure 4.3: HC-SR04 Ultrasonic Sensor

4.1.4 Buzzer

A buzzer is an electronic device that emits a beep or buzzing sound when activated. It is a type of audio signalling device and unlike a speaker, it cannot produce a wide range of sounds. Buzzers are often used in circuits to provide audible alarms or confirmations. It includes two pins namely positive and negative. The positive terminal of this is represented with the '+' symbol or a longer terminal. This terminal is powered through 6Volts whereas the negative terminal is represented with the '-' symbol or short terminal and it is connected to the GND terminal. Buzzers are typically powered by a low voltage DC source, such as a battery or a regulated power supply. They are very simple to use and can be driven by a microcontroller or other electronic circuit. The buzzer serves as the output device for providing real-time alerts to drivers upon hump detection.

Figure 4.4: Buzzer

4.2 Software Requirements

4.2.1 YOLOv4 Tiny Model

The YOLOv4 Tiny model is a lightweight variant of the You Only Look Once (YOLO) object detection algorithm, designed for real-time inference on resource-constrained devices. Its architecture consists of a convolutional neural network (CNN) backbone followed by detection layers responsible for predicting bounding boxes and class probabilities. Trained on annotated datasets containing labelled examples of potholes, the YOLOv4 Tiny model learns to detect these road hazards with high accuracy and efficiency. We chose YOLOv4 Tiny for pothole detection due to its superior speed and performance compared to other object detection models, making it well-suited for real-time applications with limited computational resources.

4.2.2 Arduino IDE

The Arduino Integrated Development Environment (IDE) serves as the primary programming environment for developing and uploading code to the Arduino UNO board. Its user-friendly interface and extensive library support enable us to write, compile, and upload sketches (programs) to the Arduino Uno with ease. Within the Arduino IDE, we can access various programming concepts such as digital and analog input/output, sensor interfacing, and control structures to implement our detection algorithm and interface with sensors and actuators. By providing a step-by-step walkthrough of the Arduino IDE setup process and common programming concepts, we empower to customize and extend the functionality of our hump detection system according to their specific requirements.

4.2.3 PyCharm IDE

PyCharm is the integrated development environment (IDE) of choice for our project, providing a robust and feature-rich platform for Python development. Its user-friendly interface, advanced code editing tools, and seamless integration with version control systems make it an ideal environment for developing and debugging our pothole detection algorithm. Within PyCharm, we can write, test, and optimize Python code for real-time video processing, leveraging the power of OpenCV and other libraries to implement our detection algorithm efficiently. By utilizing PyCharm, we enhance our productivity and streamline the development process, enabling rapid prototyping and iteration of our pothole detection system.

4.3 About the Tools Used

Ultrasonic Sensor (HC-SR04)

The ultrasonic sensor, comprising a transmitter and receiver, emits high-frequency sound waves that bounce off objects and return to the sensor. The Arduino calculates the distance based on the time it takes for the sound waves to return. Specifically, the Arduino sends a trigger pulse to the sensor, which emits a sound wave. When the wave hits an object, it reflects back, and the sensor sends a signal to the Arduino, which measures the pulse duration and calculates the distance.

Arduino Uno

The Arduino, an open-source microcontroller platform, serves as the project's brain. It reads inputs from the ultrasonic sensor through its digital I/O pins, processes the data, and controls the buzzer accordingly. The code initializes the pins connected to the sensor and the buzzer, continuously sends trigger pulses, reads the duration of the returned signal, and computes the distance. If the distance is less than a predefined threshold (e.g., 20 cm), the Arduino activates the buzzer, alerting the presence of a nearby object. This setup is commonly used in applications like obstacle detection, automatic parking systems, and robotic navigation, demonstrating the practical synergy between the ultrasonic sensor and the Arduino.

4.4 About Programming Languages

Python

We used python language in our project in potholes detection system. Python is an interpreted, object-oriented, high level programming language with dynamic semantics. Its high-level built in data structures, combined with dynamic typing and dynamic binding, make it very attractive for Rapid Application Development, as well as for use as a scripting or glue language to connect existing components together. Python's simple, easy to learn syntax emphasizes readability and therefore reduces the cost of program maintenance. Python supports modules and packages, which encourages program modularity and code reuse. The Python interpreter and the extensive standard library are available in source or binary form without charge for all major platforms, and can be freely distributed.

Python's features include:

- Easy-to-learn: Python has few keywords, simple structure, and a clearly defined syntax. This allows the student to pick up the language quickly.
- Easy-to-read: Python code is more clearly defined and visible to the eyes.
- Easy-to-maintain: Python's source code is fairly easy-to-maintain.
- A broad standard library: Python's bulk of the library is very portable and cross-platform compatible on UNIX, Windows, and Macintosh.
- Interactive Mode: Python has support for an interactive mode which allows interactive testing and debugging of snippets of code.
- Portable: Python can run on a wide variety of hardware platforms and has the same interface on all platforms.
- Extendable: You can add low-level modules to the Python interpreter. These modules enable programmers to add to or customize their tools to be more efficient.
- Databases: Python provides interfaces to all major commercial databases.
- GUI Programming: Python supports GUI applications that can be created and

ported to many system calls, libraries and windows systems, such as Windows MFC, Macintosh, and the X Window system of Unix.

- Scalable: Python provides a better structure and support for large programs than shell scripting.

C++

C++ is a high-level, general-purpose programming language known for its efficiency, flexibility, and versatility. In our project for hump detection in real time, we utilize C++ programming language within the Arduino IDE to program the Arduino Uno board.

Features of C++:

- Object-Oriented: Supports classes, objects, inheritance, and polymorphism for modular and readable code.
- Efficiency: Known for performance and optimization capabilities for real-time and resource-constrained environments.
- Standard Library: Offers a rich set of functions and data structures for common tasks, enhancing productivity.
- Portability: Highly portable across platforms and architectures, enabling cross-platform development.
- Community Support: Large and active developer community provides extensive documentation and resources for assistance.
- Low-level Manipulation: Allows direct memory manipulation through pointers, enabling efficient handling of hardware interfaces and system-level programming.

CHAPTER 5

SYSTEM DESIGN

System Design is the process of designing the architecture, components, and interfaces for a system so that it meets the end-user requirements. A well-structured approach is essential for system design in building and engineering. Effective system design necessitates considering all infrastructure components, from hardware and software to data storage and management. Hardware and software components together form system design.

5.1 Proposed Architecture

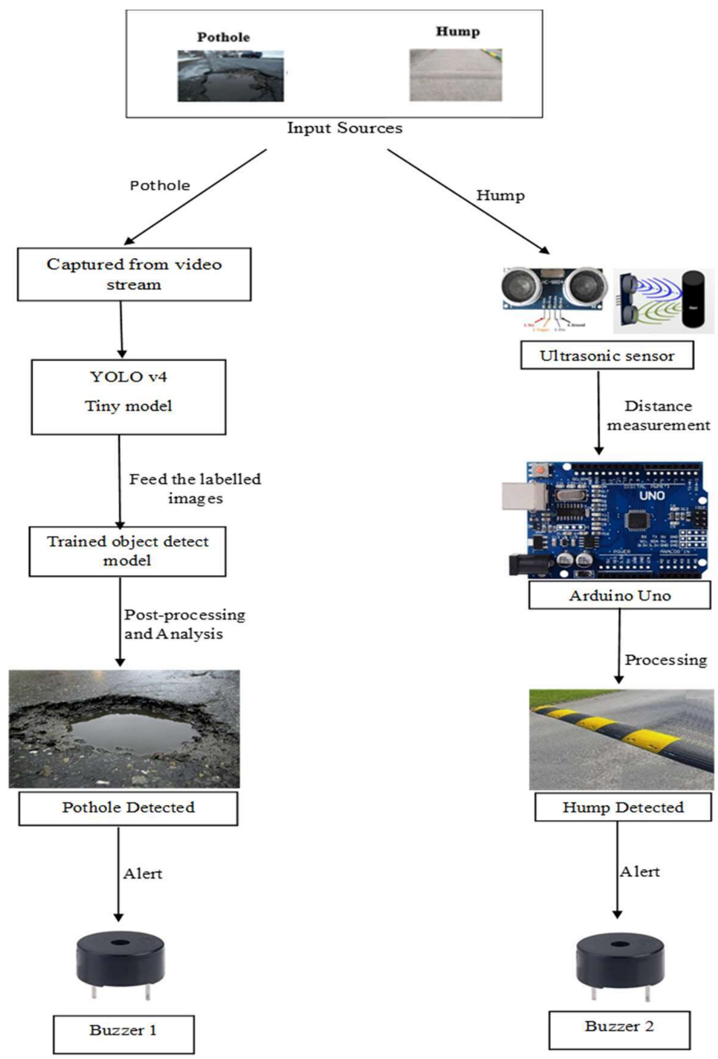

Figure 5.1: System Architecture

The above figure represents the flow diagram of the project where the live video of the road is captured by webcam and it is analyses by YOLOv4 Tiny model. On detecting the potholes, the system will provide the alert and the output video file is also stored in the result folder. HC-SR04 ultrasonic sensor will detects the humps on the road and provide the buzzer sound as an alert.

Pothole

- Input Source: The system captures a video stream as the input source.
- YOLO v4 Tiny Model: The video stream is fed into a pre-trained convolutional neural network model called YOLO v4 tiny model. This model is specifically designed to identify potholes in images.
- Labelled Images: The YOLO v4 tiny model was trained on a dataset of labelled images containing potholes. During training, the model learned to recognize the features of potholes in images.
- Object Detection: When the YOLO v4 tiny model processes a frame from the video stream, it outputs a bounding box around any potholes it detects in the frame.
- Post-processing and Analysis: Check the size and shape of the bounding box around the pothole. Consider a confidence score from the model to see how certain it is about the pothole. Analye detections across multiple video frames for consistency.
- Pothole Detected: A pothole is likely detected when the model identifies darker areas with sharp edges and significant depth, along with irregular shapes or shadows cast within the depression
- Buzzer 1: The buzzer is an alerting device that emits a sound when a pothole is detected. The above figure represents the flow diagram of the project where the live video of the road is captured by webcam and it is analyzed by YOLOv4 Tiny model. On detecting the potholes, the system will provide the alert and the output video file is also stored in the result folder. HC-SR04 ultrasonic sensor will detects the humps on the road and provide the buzzer sound as an alert.

Hump

- Ultrasonic sensor: The ultrasonic sensor emits 40Hz waves and waits for their return. When a wave hits an object, it bounces back and is detected by the receiver. By measuring this time, the sensor calculates distance accurately.
- Distance measurement: The Arduino Uno receives the signal from the ultrasonic

sensor and uses it to calculate the distance of the object.

- Hump detected: If the distance measurement is below a certain preset threshold value, it indicates that a hump has been detected.
- Processing: The Arduino Uno processes the signal from the ultrasonic sensor and determines whether a hump has been detected based on the distance measurement.
- Alert: When a hump is detected, the Arduino Uno will activate an alert.
- Buzzer 2: The buzzer is a device that emits a sound to alert when a hump is detected

5.2 Methodology

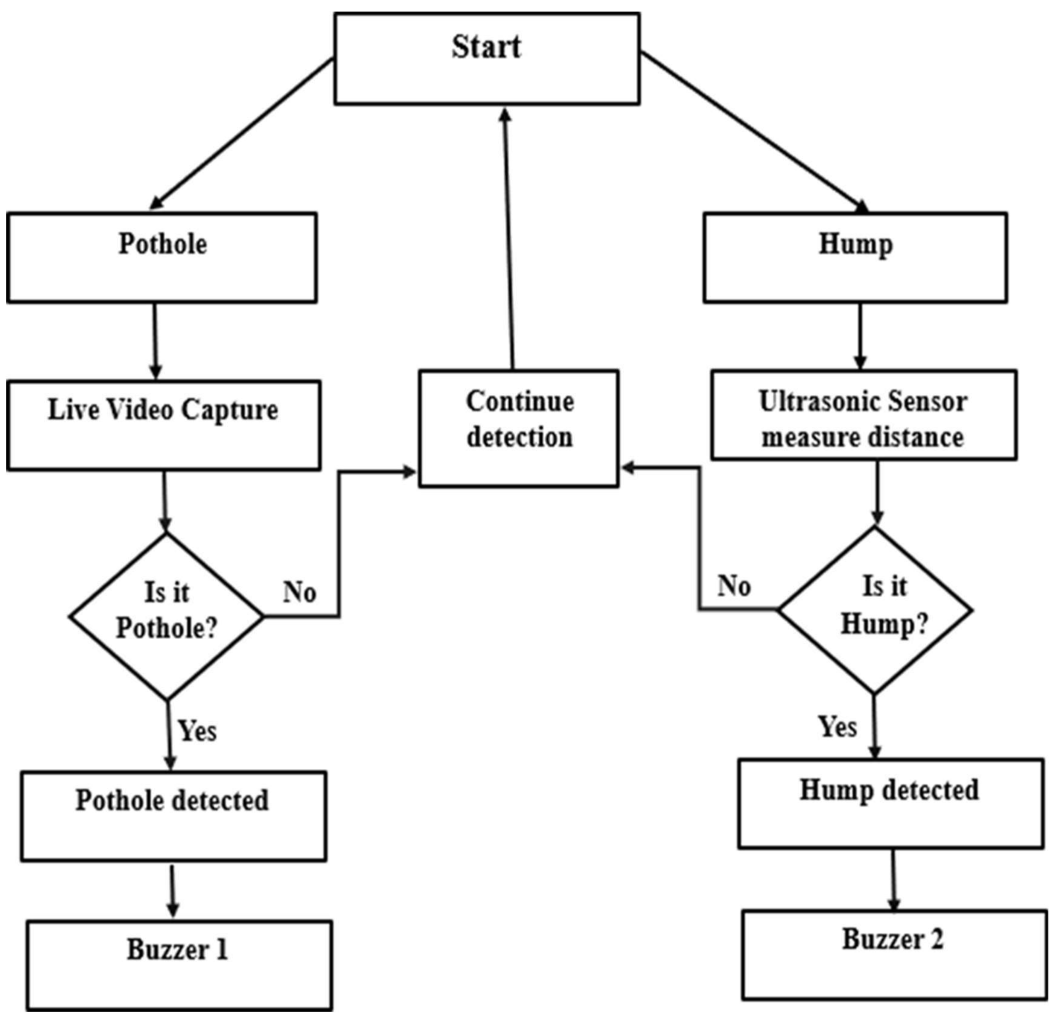

Figure 5.2: Methodology

The project proposes a real-time system for detecting potholes and humps on roads using a computer vision approach specifically leveraging the YOLOv4-Tiny object detection algorithm. YOLOv4-Tiny is a powerful yet compact version of the YOLOv4 model, making it ideal for real-time applications on resource-constrained devices.
Here's a breakdown of the methodology:

Data Collection: The project will involve collecting a large dataset of road images containing potholes and humps. This dataset will be crucial for training the YOLOv4-Tiny model to effectively recognize these road imperfections.

Data Annotation: Each image in the dataset will be meticulously annotated with bounding boxes around the potholes and humps. This annotation process tells the YOLOv4-Tiny model what features to look for when identifying these objects in future images.

YOLOv4-Tiny Model Training: The annotated dataset will be used to train the YOLOv4-Tiny model. During training, the model will learn to recognize the patterns and features that distinguish potholes and humps from other road elements.

Real-Time Detection: Once trained, the YOLOv4-Tiny model will be integrated into a real-time system. A camera mounted on a vehicle or infrastructure will capture live video footage of the road. Each frame of the video will be fed into the YOLOv4-Tiny model, which will then analyse the image and identify any potholes or humps present.

Output and Applications: The system will output real-time information about the detected potholes and humps. This information could include location data, severity (depth/height), and timestamps. This data can be used for various applications.

Detailed Process for Hump Detection Using Arduino and Ultrasonic Sensor

Hardware Setup:
Components: Arduino microcontroller, ultrasonic sensor (e.g., HC-SR04), power supply, and mounting hardware.
Installation: Secure the ultrasonic sensor to the front of the vehicle or on roadside infrastructure at a fixed height above the road surface.

Sensor Calibration:

Initial Calibration: Measure the distance from the sensor to the road surface under normal conditions to establish a baseline measurement.

Threshold Setting: Determine the threshold distance that indicates a hump (e.g., if the sensor detects a sudden rise of 5 cm or more from the baseline, it indicates a hump).

Real-Time Data Processing:

Continuous Measurement: The Arduino continuously reads distance measurements from the ultrasonic sensor.

Hump Detection Logic:

If a measurement shows a significant decrease in distance (within the threshold range), the Arduino registers a hump detection.

Calculate the height of the hump by comparing the current distance measurement with the baseline distance.

Alert System:

Upon detecting a hump, the Arduino can trigger a buzzer (Buzzer 2) to alert the driver or log the event with a timestamp and location data.

By combining the YOLOv4-Tiny model for pothole detection with an Arduino and ultrasonic sensor for hump detection, this system offers a robust and comprehensive solution for real-time road condition monitoring. This dual approach ensures accurate detection and classification of road imperfections, enhancing road safety and maintenance efficiency

CHAPTER 6

SYSTEM IMPLEMENTATION

The currently proposed project discusses about detection of potholes and humps in real time. We collected the datasets of potholes and trained the model to detect the pothole and to provide beep alert. Then we used this pre-trained model for the detection of potholes. YOLOv4 Tiny, a lightweight object detection model is used for potholes detection. For humps detection in real time, we used ultrasonic sensor integrated with Arduino uno.

6.1 Pseudocode

Potholes

Step 1: Read Frame

Read the next frame from the video feed using OpenCV's VideoCapture object.

Step 2: Object Detection

Object Detection: Use the pre-trained YOLOv4 Tiny model to detect objects in the frame. Pothole Check: Determine if any of the detected objects are classified as potholes.

Step 3: Pothole Detection

If a pothole is detected, play a beep sound using the winsound library to alert the user. Draw a bounding box around the detected pothole using OpenCV's rectangle function. Add a label to the bounding box indicating that a pothole has been detected.

Step 4: Save Results

Save the frame with pothole detection and save the frame as an image file using OpenCV's imwrite function.

Step 5: Display Frame

Display the frame with pothole detection in a window using OpenCV's imshow function.

Step 6: User Interaction

Continuously monitor for keyboard input using OpenCV's waitKey function. If the 'q' key is pressed, exit the loop and terminate the program.

Humps

Step 1: Initialize Hardware and Variables

Initialize the buzzer pin (Buzzer) and ultrasonic sensor pins (trigPin and echoPin). Declare variables for duration and distance.

Step 2: Setup Function

Set the pinMode for the buzzer pin and ultrasonic sensor pins as OUTPUT and INPUT respectively. Initialize serial communication at 9600 baud rate.

Step 3: Loop Function

Enter an infinite loop.

Step 4: Ultrasonic Sensor Operation

Generate a 10 microseconds pulse on the trigger pin (trigPin) to trigger the ultrasonic sensor. Measure the duration of the echo pulse using the pulseIn function. Calculate the distance based on the duration of the echo pulse.

Step 5: Distance Output

Print the distance measured by the ultrasonic sensor to the Serial Monitor.

Step 6: Pothole Detection

Check if the measured distance is less than 20 centimeters. If the distance is less than 20 centimeters, activate the buzzer by setting the Buzzer pin to HIGH.

Step 7: Delay

Add a delay of 100 milliseconds to control the frequency of distance measurements.

6.2 Method Explanation

Module 1: Detecting the Humps via Ultrasonic sensor

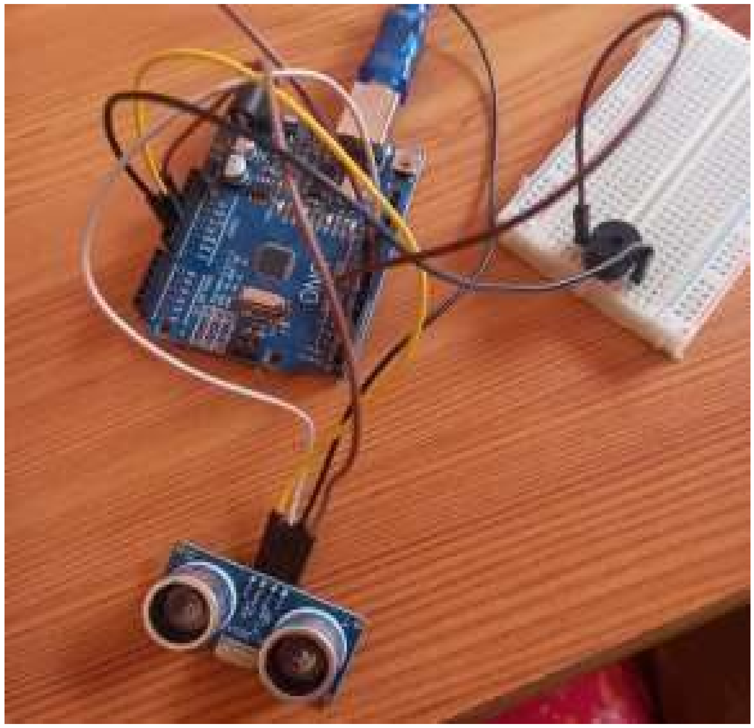

Figure 6.1: Arduino UNO, HC-SR04, Buzzer connection

In this module we are detecting the humps using Ultrasonic sensors. HC-SR04 ultrasonic sensor is used to detect humps on the road. These sensors emit ultrasonic waves and measure the time it takes for the waves to bounce back from the road surface. Ultrasonic sensors emit sound waves at frequencies that are typically above the range of human hearing. These sensors operate in the frequency range of tens of kilohertz (kHz) to several hundred kHz, well above the 20 kHz upper limit of human hearing.

Method of detecting the humps on the road:

- The ultrasonic sensor emits sound waves that travel until they encounter a hump. These waves then reflect back to the sensor, which calculates the time taken for the round trip.
- Using the speed of sound and the time measurement, the Arduino UNO calculates the distance of the hump from the sensor.
- If the calculated distance falls within the predefined range for a hump, the sensor considers it as a hump detection.

- Upon detection, the Arduino UNO sends a signal to activate the buzzer, which emits an audible alert to notify the presence of a hump.

This module is crucial for real-time hump detection and alerting the driver or system to take necessary action. The ultrasonic sensor's ability to detect objects in its path makes itan ideal choice for this application. The Arduino UNO serves as the central processing unit that interprets sensor data and controls the buzzer based on the detection results.

Module 2: Detecting the Potholes via YOLOv4 Tiny model

In this module we are detecting the potholes with the help of YOLOv4 Tiny model by capturing the real time videos via webcam. The YOLOv4 Tiny model, short for "You Only Look Once version 4 Tiny," is a state-of-the-art deep learning architecture specifically designed for real-time object detection tasks. It is a compact variant of the YOLOv4 model, optimized for efficiency and speed while maintaining high accuracy. As each frame of the video is fed into the YOLOv4 Tiny model, it performs inference to detect potholes present in the scene. Detected potholes are outlined with bounding boxes and labelled with corresponding confidence scores, providing a visual indication of their presence in the video along with the alert beep.

Method of detecting the potholes on the road:

- The system starts by capturing real-time video from the webcam. Each frame of the video is processed independently.
- For each video frame, the YOLOv4 Tiny model is applied. It identifies objects in the frame, including potential potholes. The model provides bounding boxes around detected objects along with confidence scores.
- The system sets a confidence threshold (e.g., 0.5). If the confidence score for a detected object (e.g., a bounding box) exceeds this threshold, it is considered a valid detection.
- If a bounding box corresponds to a pothole (based on the class label), it triggers an alert. When a pothole is detected, the system generates a beep sound using the winsound library.
- The system can also log the geolocation coordinates of detected potholes.
- The entire process happens in real time, allowing continuous monitoring of road conditions. As the vehicle moves, the webcam captures new frames, and the system

detects potholes accordingly.

- The system also stores the output video file in the results folder. This information can be useful for maintenance crews to prioritize repairs.

CHAPTER 7

EXPERIMENTAL RESULTS AND ANALYSIS

7.1 Snapshots and Results

Test Scenario	Condition	Detection Accuracy
Scenario 1	Pothole	85-90%
Scenario 2	Water filled Pothole	80-90%
Scenario 3	Potholes during night time	70-75%

Table 7.1: Pothole detection accuracy under different conditions

The table shows the detection accuracy of a pothole detection system under different test scenarios. The scenarios include potholes on dry surfaces, water filled potholes, and potholes at night. The system performs best in well-lit conditions, with an accuracy of 85-90% for detecting potholes on dry surfaces. The accuracy drops to 80-90% when detecting water filled potholes, and to 70-75% for potholes at night.

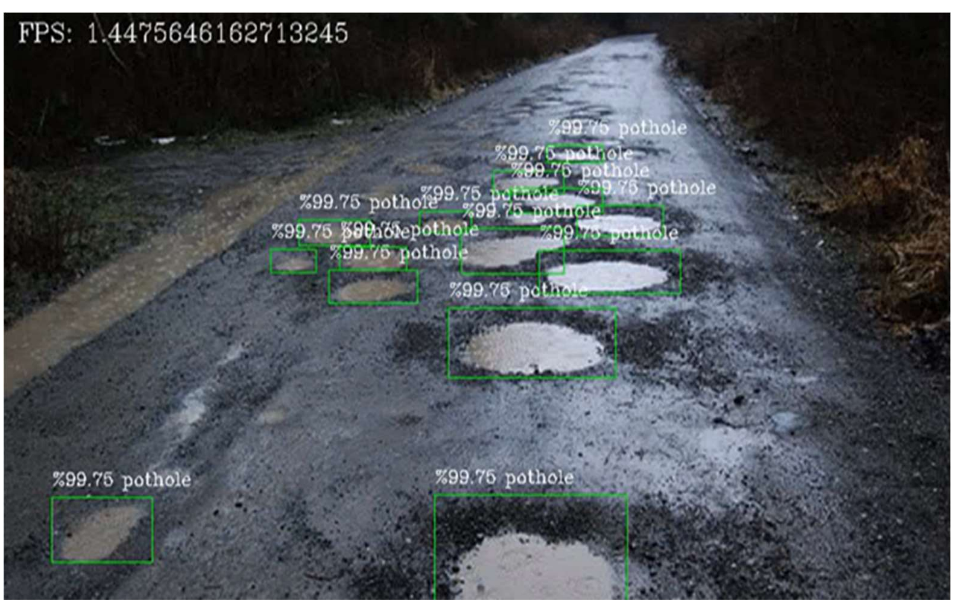

Figure 7.1 Water filled potholes detected

The Figure 7.1 This indicates that the pothole detection model has successfully identified water-filled potholes in the image with a high accuracy of 92.2%.

Figure 7.2 Potholes detected

The system makes use of the YOLOv4 Tiny model's pothole detection capabilities in real-time. A bounding box precisely encloses the identified pothole, accompanied by a confidence score of 8.17. This high score suggests the model is highly confident in its detection. Notably, the YOLOv4 Tiny architecture achieves this with impressive speed, potentially reaching frames per second. This efficiency makes it suitable for real-time applications on embedded systems with limited resources. Further evaluation with various image sets containing potholes under diverse conditions will solidify these initial findings.

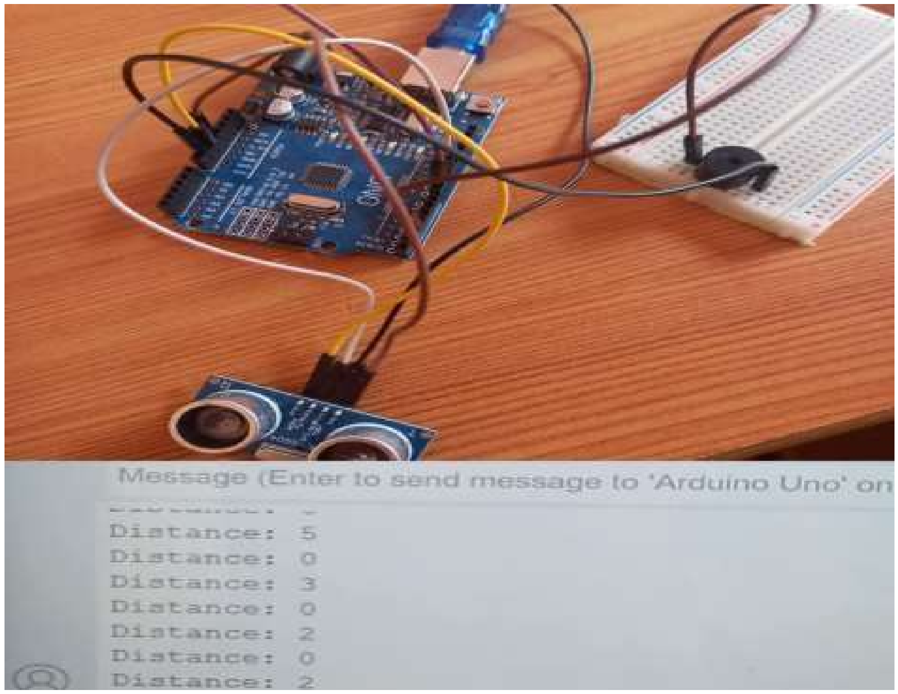

Figure 7.3 Prototype for hump detection

The Arduino UNO and HC-SR04 ultrasonic sensor successfully measured the distance to a hump in the test scenario. The LCD display indicated a distance of 2 centimetres, signifying that the ultrasonic sensor is very close to the obstacle. This demonstrates the feasibility of using an ultrasonic sensor to detect the presence of a hump. Further testing under controlled conditions with various hump sizes and distances is recommended to determine the optimal placement and sensitivity of the ultrasonic sensor for robust hump detection in real-world applications.

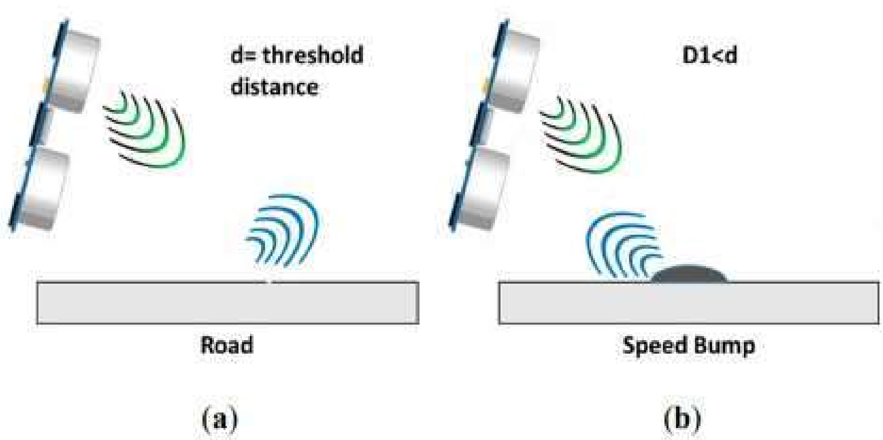

Figure 7.4 working of ultrasonic sensor, (a)Plain Road, (b) Speed bump

The picture shows how a sensor can be used to detect bumps on a road. Imagine a sound wave being shot out and bouncing back - on a flat road, the bounce back takes longer because there's no bump. But when there's a speed bump the bounce back is quicker because the sensor is closer to something. By comparing this distance to a set limit, the system can tell if there's a bump ahead.

7.2 Analysis of Results

Objective 1: Collection, Labeling, and Annotation of Pothole Images

To achieve this objective, we collected pothole images from various sources, including online databases, publicly available datasets. We made sure to gather a variety of pothole images that showed different road situations, types of potholes. Upon collection, each image underwent labelling process where potholes were identified and annotated with bounding boxes using labelling tool, LabelImg.

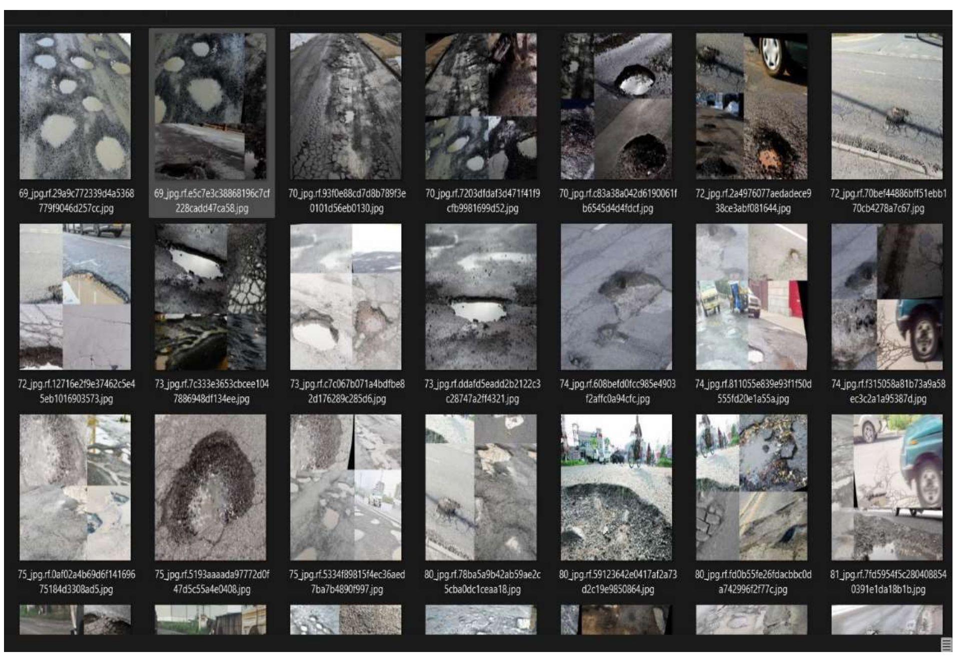

Figure 7.5: Data collection images for potholes

The Figure 7.5 shows an image of data collection done for potholes. The data collected from various means which includes manual collection, roboflow and online sources. There is total of 1700 images collected in all.

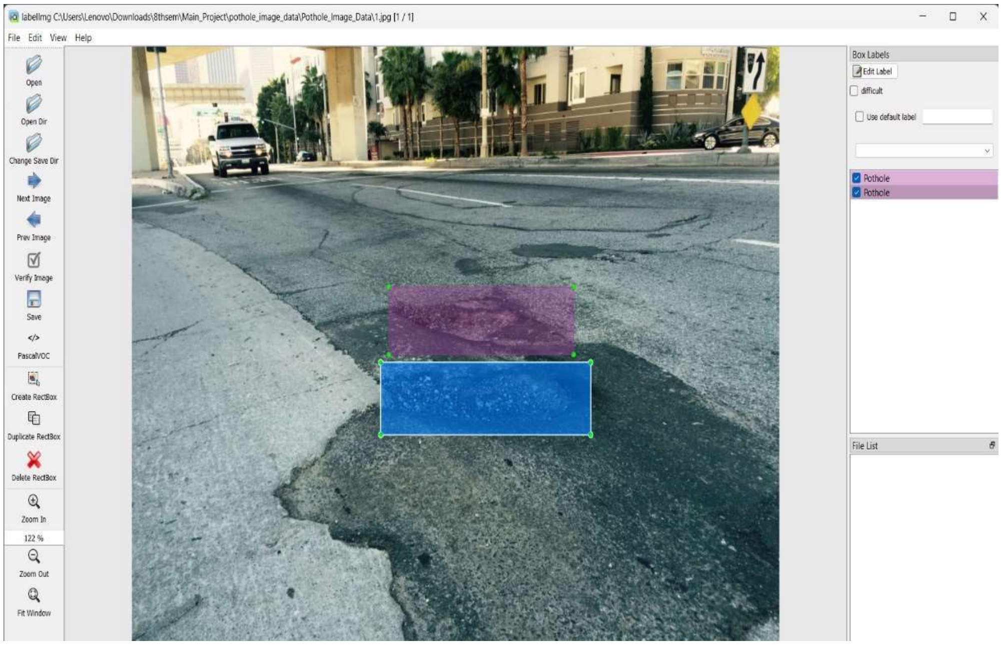

Figure 7.6: Pothole annotation using LabelImg

Objective 2: Training, Testing, and Detection of Potholes on Road

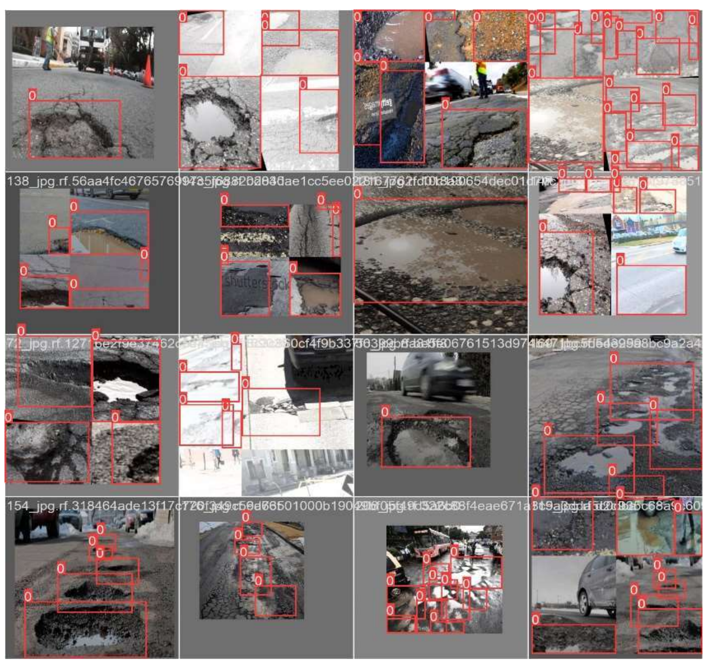

Figure 7.7: Trained batch of pothole images

The training phase commenced with the preparation of the annotated dataset, which was split into training and testing sets to ensure unbiased evaluation. Utilizing the YOLOv4 Tiny model architecture, the training process involved fine-tuning the pre-trained model on the annotated dataset to optimize pothole detection performance. Rigorous testing was conducted on the trained model using real-time video streams captured by a webcam under various environmental conditions and road surfaces. Performance metrics such as accuracy, precision, recall, and F1-score were computed to assess the model's effectiveness in detecting potholes accurately and reliably.

Objective 3: Design and Development of Alert System for Two-Wheeler Drivers

The objective of designing and implementing an alert system for two-wheeler drivers upon detecting humps or potholes was achieved by integrating ultrasonic sensors for hump detection and the YOLOv4 Tiny model for pothole detection. Upon detecting a hump or pothole, the system triggers a buzzer to emit an audible alert, ensuring timely notification to drivers.

Objective 4: Storage of Pothole Detected Output Video Files

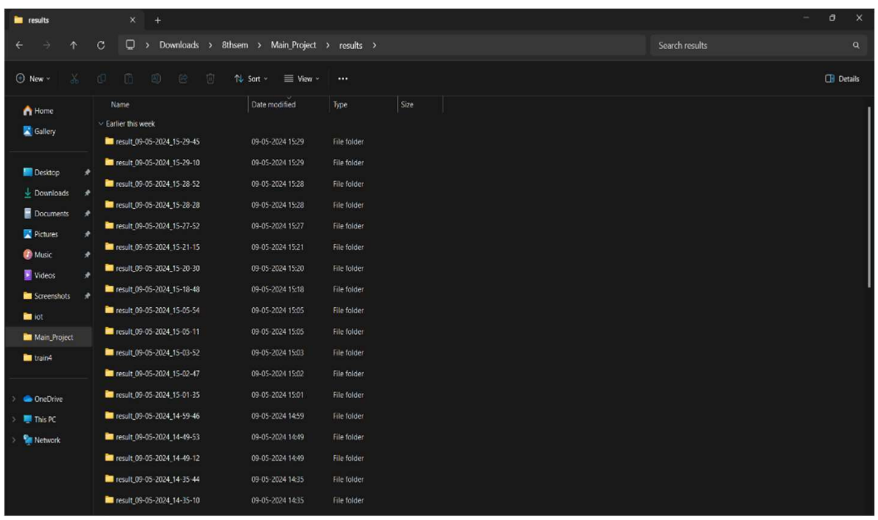

Figure 7.8: The output video files stored in a results folder

To achieve this objective, output video files containing detected potholes were systematically stored in a designated result folder using file management techniques in Python. Each video file was timestamped and organized to facilitate easy access and retrieval for municipal corporation departments and smart city projects. The stored videos served as valuable resources for road maintenance activities and infrastructure planning, providing visual documentation of potholes detected in real-world conditions for informed decision-making and resource allocation.

CHAPTER 8

CONCLUSION

This project Integrates YOLOv4-Tiny, ultrasonic sensors, Arduino, and a webcam creates a real-time system for pothole and hump detection. YOLOv4-Tiny identifies potholes, while ultrasonic sensors detect road humps, ensuring comprehensive road surface analysis. The fusion of image processing and sensor data enables accurate hazard identification and localization. Custom object detection enhances pothole identification, facilitating prompt maintenance. Arduino's integration with sensors allows reliable hump detection, contributing to safer driving experiences.

8.1 Future scope

- Implement an adaptive alerting system that adjusts alert frequency based on vehicle speed, road conditions, and hazard proximity for context-aware warnings to drivers.
- Utilize GPS Road data to optimize routes, offering drivers alternative paths to avoid potholes or humps through navigation systems, thereby enhancing safety and efficiency.
- Develop advanced image processing algorithms capable of simultaneously detecting both humps and potholes within a single frame.

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APPENDICES

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Potholes and Humps Detection System in Real-Time

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Abstract: *Potholes are formed as a result of unavoidable wear, tear and weathering of roads. It causes uneasiness to the travelers and may also lead to death due to vehicle accidents. The main purpose of the project is to prevent the road accidents occurring in and around the world. Many people do not slow down as they fail to recognize the potholes and humps on the road while driving, which leads to life hazard or vehicular damage. The proposed method involves the usage of cameras and sensors to collect the data, identify and distinguish between the humps and pothole region and alert the driver with different buzzer sounds. The pothole detection can be achieved using YOLOv4 algorithm, which is efficient in spotting the potholes. The hump detection is carried out using the ultrasonic sensor and Arduino. Therefore, in order to avoid accidents in significant number we have come up with the pothole and hump detection project for social good.*

Keywords: potholes, humps, accidents, cameras, sensors, YOLOv4 algorithm, buzzer, ultrasonic sensor, Arduino

I. INTRODUCTION

Roads are the most dependent mode of transport in India. Road transport is the main cause, accounting for about 87% of passenger transport in the country. However, maintaining road safety and vehicle safety is an important aspect of road transport. The Indian government said a total 4.4 thousand accidents occurred in the year 2022 due to potholes. Potholes are caused due to small surface cracks, heavy rainfall, high traffic volume, and also due to lack of proper maintenance. Some humps are present without any warning, which will lead to accidents and vehicle damage. Major challenge is to develop an advanced Pothole and Hump Detection System using machine learning and image processing techniques, integrated with real-time alerting mechanisms for vehicles. Existing methods for pothole and hump detection lack real-time capabilities. Therefore, the primary aim is to create a system that can accurately detect the presence of potholes and humps on roadways, and then provide timely alerts to vehicles. This in turn reduces the risks associated with road hazards. Pothole and hump detection can be done in real time. Detection of potholes is done using Yolo algorithm and ultrasonic sensor, Arduino is used for hump detection. Advantages over existing system are easy to implement, maintain and cost effective.

II. BACKGROUND

Road infrastructure faces constant challenges from wear and tear, leading to issues like potholes and humps. Potholes are caused as aresult of by traffic, weather, and water, pose a significant threat to road safety. They can cause sudden jolts to vehicles, potentially leading to accidents and damage for drivers and pedestrians. Conversely, humps, also known as speed bumps, are intentionally built to slow down traffic and enhance safety, particularly in residential areas, school zones, and parking lots. While both potholes and humps impact road safety, they do so in contrasting ways.

Traditional methods for pothole and hump detection rely on manual inspections, a time-consuming and subjective process. To address this limitation and improve overall road safety, automated detection systems using deep learning algorithms have emerged. This project proposes a real-time pothole and hump detection system utilizing the YOLOv4-Tiny algorithm.

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YOLOv4 is a powerful object detection algorithm known for its accuracy and real-time processing capabilities. However, the standard YOLOv4 model can be computationally expensive for deployment on resource-constrained embedded systems. This is where YOLOv4-Tiny comes in. This lightweight and efficient variant is specifically designed for real-time applications on mobile devices or Internet-of-Things (IoT) platforms. By leveraging YOLOv4-Tiny, this project aims to develop a cost-effective and efficient detection system for potholes and humps. Trained on a specifically curated dataset capturing various lighting and weather conditions, the system will be able to identify these road irregularities in real-time. This real-time detection capability holds immense potential. Early identification of potholes allows for prompt repairs, minimizing accident risks and vehicle damage. Similarly, detecting humps in advance ensures their effective integration into traffic management systems, optimizing their role in maintaining safe driving speeds. Ultimately, this project strives to contribute to a safer and more efficient transportation network by implementing a proactive and cost-effective pothole and hump detection system using the YOLOv4-Tiny deep learning algorithm.

III. SYSTEM DESIGN

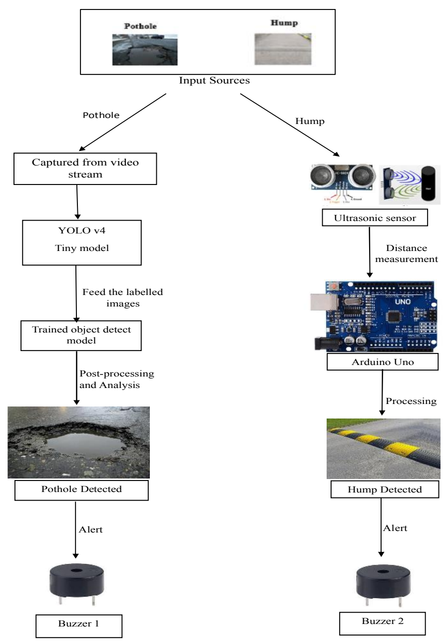

Fig.1.System Architecture

Pothole

- **Input Source:** The system captures a video stream as the input source.
- **YOLO v4 Tiny Model:** The video stream is fed into a pre-trained convolutional neural network model called YOLO v4 tiny model. This model is specifically designed to identify potholes in images.
- **Labelled Images:** The YOLO v4 tiny model was trained on a dataset of labelled images containing potholes. During training, the model learned to recognize the features of potholes in images.
- **Object Detection:** When the YOLO v4 tiny model processes a frame from the video stream, it outputs a bounding box around any potholes it detects in the frame.
- **Post-processing and Analysis:** Check the size and shape of the bounding box around the pothole. Consider a confidence score from the model to see how certain it is about the pothole. analyze detections across multiple video frames for consistency.
- **Pothole Detected:** A pothole is likely detected when the model identifies darker areas with sharp edges and significant depth, along with irregular shapes or shadows cast within the depression
- **Buzzer 1:** The buzzer is an alerting device that emits a sound when a pothole is detected.

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Hump

- **Ultrasonic sensor:** The ultrasonic sensor emits 40Hz waves and waits for their return. When a wave hits an object, it bounces back and is detected by the receiver. By measuring this time, the sensor calculates distance accurately.
- **Distance measurement:** The Arduino Uno receives the signal from the ultrasonic sensor and uses it to calculate the distance of the object.
- **Hump detected:** If the distance measurement is below a certain preset threshold value, it indicates that a hump has been detected.
- **Processing:** The Arduino Uno processes the signal from the ultrasonic sensor and determines whether a hump has been detected based on the distance measurement.
- Alert: When a hump is detected, the Arduino Uno will activate an alert.
- **Buzzer 2:** The buzzer is a device that emits a sound to alert when a hump is detected.

IV. METHODOLOGY

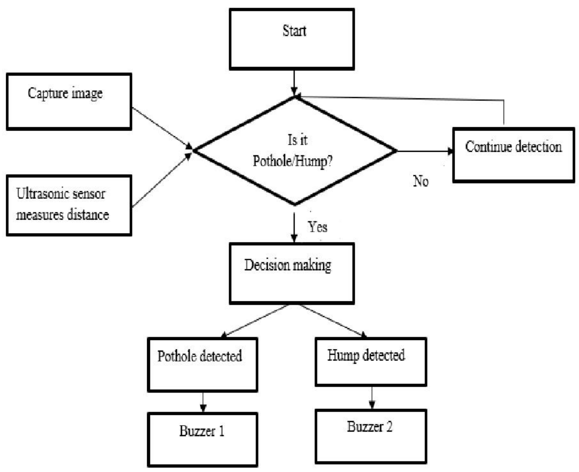

Fig. 2. Flow Chart

The beginning of the pothole and hump detection is marked by start. The pothole and hump detection is carried out independently. Firstly, live video is captured in potholes detection and each frame from the video is analysed using the YOLOv4 tiny model. If the object identified matches the pothole criteria then the system alerts the driver with a distinct buzzer sound. On the other hand, hump detection is carried out using a hardware setup comprising of ultrasonic sensor integrated with Arduino. If the object detected is with protrusions on the road surface, then it is identified as hump and an alert is given to the driver with another distinct buzzer sound.

Hardware Implementation:

Prototype Development includes the following hardware tools like Arduino UNO, Ultrasonic sensor, Buzzer, Camera. The Arduino uno contains a set of analog and digital pins that are input and output pins which are used to connect the board to other components. Arduino Uno is integrated with ultrasonic sensor and buzzer. Ultrasonic sensor is placed at end of prototype to detect the presence of hump on the road. Ultrasonic sensor measures the distance between road and the bike and it is received by Arduino. The distance between the road and the bike will be fixed, if the distance detected is less than the fixed value then it will be detected as hump. Upon detection of hump, buzzer will provide the alert. Camera will be mounted on the top of the model in such a way to capture the road ahead. Camera will provide the video of road as an input for the system. By analysing the video with the help of YOLOV4 algorithm system will provide the alert, if pothole is detected.

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V. RESULTS AND DISCUSSION

Fig 3. Potholes detected

The system makes use of the YOLOv4 Tiny model's pothole detection capabilities in real-time. A bounding box precisely encloses the identified pothole, accompanied by a confidence score of 85%. This high score suggests the model is highly confident in its detection. Notably, the YOLOv4 Tiny architecture achieves this with impressive speed, potentially reaching frames per second**.** This efficiency makes it suitable for real-time applications on embedded systems with limited resources. Further evaluation with various image sets containing potholes under diverse conditions will solidify these initial findings.

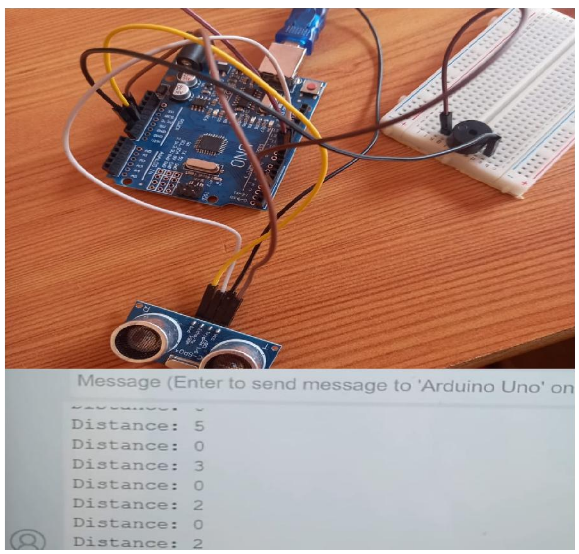

Fig 4. Prototype for hump detection

The Arduino Uno and HC-SR04 ultrasonic sensor successfully measured the distance to a hump in the test scenario. The LCD display indicateda distance of 2 centimeters, signifying that the ultrasonic sensor is very close to the obstacle. This demonstrates the feasibility of using an ultrasonic sensor to detect the presence of a hump. Further testing under controlled conditions with various hump sizes and distances is recommended to determine the optimal placement and sensitivity of the ultrasonic sensor for robust hump detection in real-world applications.

VI. CONCLUSION

This project developed is based on real-time potholeand hump detection system using a YOLOv4-Tiny algorithm, ultrasonic sensors, Arduino, and a webcam. This innovative approach combines the strengths of image processing and sensor data to accurately identify and locate potholes and humps on the road. The custom object detection YOLOv4-Tiny algorithm has been implemented to detect potholefrom live images captured by the webcam and humps are detected using ultrasonic sensor and Arduino.

VII. FUTURE SCOPE

- **Smart Infrastructure Integration:** Pothole and hump detection systems will be integrated with smart city infrastructure, such as IoT sensors embedded in roads and traffic lights. These interconnected systems will enable automated maintenance workflows, where detected road defects trigger immediate repair requests or adjustments to traffic flow to minimize congestion around damaged areas.
- **Water-Filled Pothole Detection**: Future pothole detection systems will include specialized sensors capable of detecting water-filled potholes. These sensors may utilize technologies such as sonar or conductivity measurements to identify areas where water has accumulated within potholes, alerting authorities to potential safety hazards caused by reduced traction or road instability.
- **Traffic Flow Optimization:** By integrating real-time hump detection with traffic management systems, authorities can optimize traffic flow by adjusting signal timings or routing vehicles to alternate routes to minimize delays caused by speed humps. This can lead to smoother traffic flow and reduced congestion, benefiting both commuters and the environment.

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