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Pothole Detection and Cost Estimation -A Survey Paper

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Abstract

In this paper, An advanced pothole detection method is proposed in this project with accurate calculation of the dimensions of the potholes, estimation of their volume, and determination of the filling cost of these potholes by using video inputs from road surfaces. Our system uses model object detection models to process every video frame to precisely identify potholes, and then me the dimensions as concerning length, breadth, and depth by using depth estimation model. Specifically, the system applies a technology known as monocular depth estimation, which allows for the estimation of the precise depth of every pothole directly from the feed obtained from one camera, enabling the calculation of volume to be repaired. Calculating the volume of each pothole, it computes the cavity volume and uses this volume to estimate the repair cost. Thus, detection, measurement, and cost estimation are fully automated in this solution. Consequently, the road inspection process becomes more streamlined and less laborious as compared to labor-intensive traditional inspection methods. This method is more accurate for pothole detection while it allows for assessment and planning for such extensive infrastructure maintenance works.
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Keywords:
Pothole detection, depth estimation, Volume calculation, Repair cost estimation, Cost-effective solution

1. Introduction

Potholes are a significant concern for road safety and infrastructure maintenance, leading to vehicle damage, accidents, increased and traffic congestion. The presence of potholes not only compromises the safety of drivers but also contributes to traffic jams, resulting in longer travel times and reduced efficiency on the roads. The prevalence of potholes highlights the urgent need for effective monitoring and maintenance strategies to ensure safe driving conditions and faster mobility. Traditional methods of pothole detection often rely on manual inspections or static imaging techniques, which can be time-consuming and prone to human error chances of false repairing and corrruption. This project introduces an innovative approach to address these challenges through the development of a system that utilizes video input for real-time pothole detection and dimension calculation. By employing the YOLOv8 object detection model, the system processes video frames to accurately identify potholes and calculate their dimensions using monocular depth estimation techniques.

The estimated dimensions allow for the calculation of the volume of each pothole, which is essential for determining the cost of repairs.

By automating the detection and assessment of potholes, this project aims to provide a cost-effective tool for authorities, significantly reducing the risk of false calculations and corruption in road maintenance operations. This ensures that resources are allocated efficiently, leading to improved transparency in infrastructure management. Ultimately, the project contributes to calculate a resonable repair expenditure.

2. Existing Systems in Automated Medicine Dispensing

There are many automated pothole detection systems. Current systems use the benefits of both hardware and software in detecting potholes. They can primarily be classified into three different types:

1. Sensor-based detection: This method measures road surface irregularities through height differences. Even though it provides a low-cost solution, it suffers from resolution problems and most of the times misses the smaller or shallower potholes.
2. Accelerometer-based detection: In this solution, accelerometers mounted on a moving vehicle are used. In this case, accelerometers sense the sudden change in heights when vehicles cross over the potholes. However, with this solution, the vehicle must run over the pothole for the detection process to take place.
3. Software-based approaches: In software-based approaches, the need for dependency on hardware is removed. The following are some of the existing software-based approaches: edge detection methods. Some of the edge detection methods include the Canny edge algorithm. This algorithm helps detect potholes by locating the irregularities along their edges. Recently, some traditional CNN-based approaches applied in the detection of potholes. However, these do not ap-

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ply methodologies concerning depth estimation or cost estimation. Some of the YOLO-related approaches such as YOLOv8 and YOLOv4 are applied without considering methodologies for depth and cost estimation.

While these systems deliver significant outcomes, they suffer from some limitations. None of the approaches might address depth detection or repair cost estimation appropriately. In addition, it is extremely difficult to detect potholes in real-time using live video due to complex lighting, road texture, and other environmental conditions. Simple sensors would not work this way properly, while hardware sensor usage introduces the need for validation, which may eventually cause scalability issues and human error.

3. Proposed System

Hence, our completely automated solution realizes the removal of these above-mentioned constraints through the real-time detection of potholes and measurement of their dimensions along with an estimation of the repair costs using advanced deep learning. Our algorithm uses YOLOv8 for accurate pothole detection and MiDaS realizes the depth estimator for volumetric evaluation of potholes. This allows for precise estimates of fill material and sound cost estimates. The system assesses potholes according to depth, width, and volume so that enough repair resources may be decided upon.

It is built around a scalable architecture designed for speed, with each module fully optimized for real-time performance. It automates the calculation of cost and supports estimates of repair time and costs with actual calibrated material costs per unit volume. Such detailed reporting aids in proper planning of maintenance and estimation of budget, while the decisions can be made based on data through metrics about road conditions and needs for maintenance.

Unlike the usual systems dependent on manual procedures or only able to capture surface issues, our proposed solution removes human error and variability to enhance detection accuracy through automation. The system reduces human-interference-related corruption and increases the accountability of serving in road maintenance. These technical merits make it a top tool for the sustainable management of infrastructure, together with optimizing resources and improving safety reliability on roads.

3.1. Methodologies and Techniques

- Data Preprocessing

Frame Extraction: Video frames are divided for the scope of frame by frame analysis of each frame as YOLOv8 and MiDaS would separately process each frame such that nothing was missed. Image Preprocessing: Resize every frame and convert it into grayscale. Converting a frame into grayscale reduces the amount of computational resources used, obviously without loss of detection accuracy. Standardizing the preprocessing of frames ensures the compatibility of images with both detection models and depth estimation models.
Noise Reduction: We employ filtering techniques to remove noise in images, especially in videos taken in extremely low light conditions or motion-sensitive settings. This renders detection more robust and accurate in various circumstances.

- Object Detection

This deals with pothole detection and create a bounding box on it by using Yolo v8 because of its efficiency and high accuracy in real-time object detection with varying shapes and sizes of potholes. Model will be able to process the video frames one by one. Functionality: model identifies and locates potholes by drawing a bounding box around each recognized pothole. The length and breadth measurements of the pothole in the image are obtained directly from these bounding boxes as approximations.
Training and Fine-Tuning: We fine-tune the YOLOv8 on a dataset that is annotated with images of potholes. This fine-tuning assures that the model classifies potholes well, regardless of road conditions, textures, and change in illumination.
Error Detection: Incorporates feedback loops and real-time monitoring to detect dispensing failures, aiming for improved reliability beyond current fail-safe mechanisms like weight sensors.

- Estimation of length and breadth

he dimensions of the bounding box, width and height, at the end are mapped to the length and breadth of a pothole. These measurements are pixel-based, and assuming that there is known reference in the scene, such as distance from the camera to the road or an object of known size, such measurements can be translated to real-world metrics.
Scaling Factor: With the right conversion, we used a scaling factor acquired from the camera calibration parameters. The scaling factor changed the dimensions of the bounding box to reflect measurements in the real world. It could result in the length and breadth of estimation being consistently carried out regardless of varying camera heights and angles. Perspective correction works to apply the method of perspective correction to the system to incorporate any angle in the video footages with potential skewing of measurements.
Correcting the perspective ensures that length and breadth values obtained are consistent with real road surface dimensions.

- MiDaS for Depth Estimation

Model Selection: MiDaS (Monocular Depth Estimation) was used to obtain information relevant to depth from a single image. This model is specifically suitable for the outdoors as lighting conditions and surface textures are mixed. Hence, it is reliable in terms of road conditions.
Depth Estimation: A detected pothole bounding box from YOLOv8 is passed to MiDaS to get the depth. Based on certain

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monocular cues, MiDaS calculates depth and employs prediction algorithms that evaluate it to determine how deep the hole is, which is a requirement for the accurate computation of volume.
Volume Estimation: The system calculates volume by combining length, breadth, and depth of every pothole. Volumetric information can help establish the amount of fill material needed precisely.

- Cost Estimation Model

Material Computation: Based on the volume estimate, our cost estimation model computes the quantity of fill material needed for each pothole. These would comprise length, breadth, and depth values in further computation, hence giving a comprehensive quantity of material requirement.
Automating Cost Estimation The system will make dynamic variation of the repair cost estimates through predetermined material costs per volume. This volume data along with the associated factors of cost gives an accurate real-time projection of cost for each pothole identified.

3.2. *Key Features*

1. New approach to detect the pothole through video input with high accuracy
2. Dimension calculation
3. Automated Cost Calculation
4. high accuracy and adaptibility
5. End-to-End Automation
6. Improved Transparency in cost calculation
7. Reporting, total volume of pothole , estimated cost of repair

3.3. *Diagram in project*

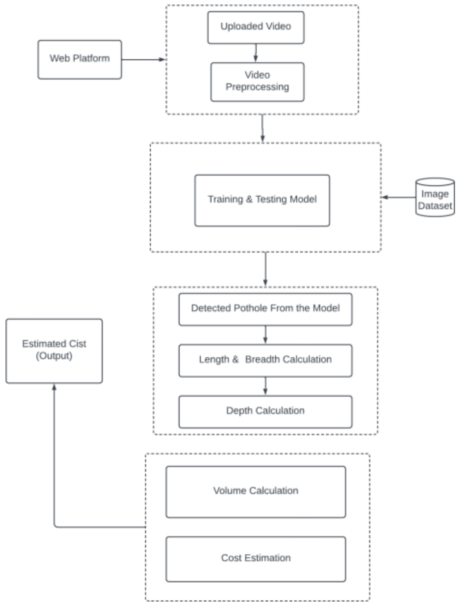

Figure 1: Architecture Diagram

4. Differences in approach and methodologies

1 .Detection Technology Existing Systems: Most of the existing systems employ basic sensor technology, such as accelerometers, ultrasonic sensors, or edge detection algorithms. The approaches are predominantly low-resolution, unable to distinguish between potholes and other road surface irregularities, and also induce false positives
Our System: To attain real-time pothole detection at a high level of precision, we utilize the object detection model , based on deep learning. Since is optimized for continuous processing, the video frames can easily be identified in any shape or size and under a variety of environmental conditions; this shall further increase the accuracy of the system by ensuring it works efficiently for various road conditions.
2. Dimensional Estimation Existing Systems: Depth or volume is not measured in the traditional systems; they could be very specific to merely measure the potholes' surface area. When the depth is measured, there are complicated setups involving LiDAR or stereo cameras, which are expensive and hard to deploy in large number configurations.
Our System: Our system is based on the application of MiDaS to estimate depth from a monocular view. Potholes can be now calculated based on length, breadth, and depth, and one camera alone is sufficient. Since MiDaS provides depth estimation based on monocular cues integrated with model bounding box values, we now stand ready to estimate the volume for each pothole. Estimation of depths helps in estimating better severity levels for potholes and also the required materials for repair.
3. Cost Estimation Existing Systems: In the traditional systems, most of them just work on detection and do not go further to estimate the cost. This means that although potholes may be detected, maintenance teams still have to depend on people's estimates of the costs of repairs, which is taking

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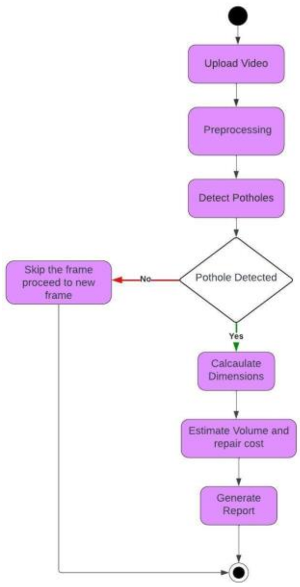

Figure 2: Activity Diagram

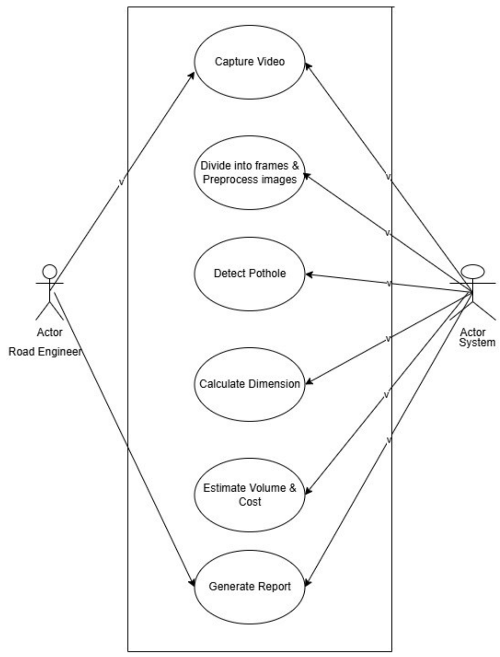

Figure 3: Use Case Diagram

quite a lot of time and with a likelihood of increasing errors in calculation

Our System: Our system has implemented an automated cost estimation module based on the volume of each pothole. This estimation module calculates the quantity of material required to repair it. With a predefined rate of material per cubic unit, the system provides accurate estimates of the repairing costs and makes budgeting and resource allocation straightforward for road maintenance.

4. Automation and Scalability Existing Systems: Most of these existing solutions depend on human verification and recalibration periodically; thus, they are only scalable up to a very limited level and are labor-intensive in their employment. Sensor-based solutions will also have calibration and data integration problems, making them rather less suitable for large-scale, real-time applications.

Our System: Our end-to-end approach gives full automation to the pipeline in terms of video processing, pothole detection, dimension measurement, and cost estimation. With full automation, we therefore minimize chances of human

Conclusion

Our innovation is the complete, end-to-end system for detecting potholes and cost estimation, addressing some of the biggest issues in road maintenance and infrastructure management. Our system uses YOLOv8 object detection in real-time video capture to track potholes, giving it a high accuracy rate and adaptation in response to changing road conditions. The inclusion of MiDaS in the system for monocular depth estimation enhances the capability of the system to provide high-precision depth information from which it can further measure the length, breadth, and depth of potholes. This subsequently calculates the volume of each of the potholes based on measurements by length, breadth, and depth, assisting in determining the quantity of the material needed for repair and estimating the cost.

Being a strong cost estimation model, the system translates volumetric data into meaningful repair costs in terms of predefined material rates thus providing immediate feedback toward proper budgeting by maintenance teams. It ensures minimal intervention by humans and their errors; it provides consistency and transparency in road maintenance processes, and its feature of automatic reporting to make data-driven decisions possible by making available the relevant information on road conditions and necessary repairs to stakeholders.

Overall, our project improves the safety of roads by correctly identifying hazardous potholes while optimizing the maintenance efforts that are cost-effective, efficient, and scalable. In doing so, it becomes the safest asset under sustainable infrastructure management to deal with possibly the biggest challenge in road safety and maintenance today that addresses this issue with a reliable and intelligent approach.

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