



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 11, November 2023

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

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An Analytical Review of Deep Learning-Based Pothole Detection System

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ABSTRACT: The quality of the roads that automobiles are driven on is essential to ensuring that every vehicle, manual or automatic, can complete its journey satisfactorily. Road defects such as potholes and speed bumps can lead to car wear and even fatal traffic accidents. As a result, recognizing and characterizing these anomalies helps to reduce the likelihood of crashes and vehicle damage. The identification of street abnormalities is made more difficult by the fact that street pictures are intrinsically multivariate because of significant amounts of duplicated data and heavily contaminated measurement noise. This study offers the automatic color image processing of potholes on highways using a YOLO Deep learning model, either from the video frames or from photos taken with a smartphone camera. Lightweight architecture was chosen to facilitate training and usage more quickly. This is composed of seven properly coordinated and interconnected layers. Every pixel in the original image is used, no resizing involved. We used the conventional stride and pooling procedures to get as much data as we could. This enhances the developed model's capability to identify potholes and alert drivers to the need for cautious driving. In order to accomplish this, the suggested approach examines past research to compile crucial data for pothole detection.

KEYWORDS: Street anomalies, deep neural network, synchronized layers, Pothole detection, YOLO Neural network.

I. INTRODUCTION

The number of vehicles on the road is always growing, which increases the likelihood of traffic and accidents. Road safety is crucial for everyone since it is typically caused by a driver's error or a problem with the structure of the road. A pothole is a section of the road surface where fissures have grown until they create a hole larger than 150 mm in diameter. Potholes pose a serious risk to both pedestrians and automobiles. Roads that are utilized every day may not be inspected as part of every nation's road maintenance program.

When a pothole occurs, fast-moving vehicles would rarely detect it or have time to react. Different drivers respond differently to impending potholes. This could involve the driver making a quick maneuver to avoid a pothole or braking suddenly, which could result in the car rolling over or in a rear-end collision. An investigation was conducted into a pothole detection system to alert drivers ahead of time and prevents unintentional collisions and property damage. Numerous studies and technological advancements have been made to identify and report potholes utilizing a range of tools and methods. A few of these methods make use of vibration-, vision-, and laser-scanning techniques. The purpose of this study is to compare the speed and accuracy of two object identification algorithms: YOLO and SSD, in order to identify road potholes before they become problems. For every algorithm, many models will be trained, and the top performing model will be shrunk to fit on devices with less processing capability. This makes it possible for the models to function properly on embedded systems like Raspberry Pi, which can be utilized in cars or on the driver's mobile device. Based on the findings, transportation companies might equip their vehicles with this technology to lessen the amount of accidents and pothole-related vehicle damage. Alternatively, automakers may implement a system in which the driver is alerted to a pothole and the car slows down while modifying the suspension to avoid it, reducing impact and improving ride quality.

The world's second-largest road network is found in India. As a result, the road system is crucial to the social and economic development of India. As to the research, throughout the past ten years, the GDP of the Road Transport

sector has grown at an average annual rate of nearly 10%, while the overall GDP has grown at an average annual rate of 6%. The Indian government is currently building roads quite quickly. However, because of the inadequate drainage system and the overloaded cars, maintaining the roads is a difficult effort. Potholes form on the road as a result of inadequate road maintenance, which leads to traffic accidents. Based on data provided by the Indian government, between 2013 and 2016, potholes caused 11,836 fatalities and 36,421 injuries. Pothole issues are difficult to fix since nearly every location experiences yearly floods, natural disasters, excessive rain, etc. Even though the system is unable to maintain the roads, it can lower the annual number of accidents.

A pothole is a breakdown in the road's surface structure. Given that it could result in serious traffic accidents and reduce road efficiency, it cannot be disregarded. A survey conducted in 2006 by the Asian Development Bank (ADB) revealed that around 50% of these paved roads are in poor condition. Nearly every developed nation has the same issue. The combination of bad weather and heavy traffic creates potholes. The most crucial stage in maintaining the state of the road is to accurately identify potholes. Numerous experiments have been carried out in recent years to automatically detect potholes in the road. Based on the image's histogram, the image region was recovered, and the pothole was found using a straightforward kernel support vector machine. This strategy allowed for a clear identification of the target. Based on the pictures, potholes and cracks are categorized using deep learning using CNN (Convolutional Neural Network) technology. CNN was used to create a model that was unaffected by noise from improper lighting and shadows.

Potholes have become more common in unusual weather conditions, such as summertime torrential rain and winter, and they have a significant impact on road damage and traffic safety. It results in social problems like car accidents and break-downs, which have a financial cost to society. For effective pothole repair and pavement management, automatic pothole detecting techniques are being researched. Pothole detection techniques now in use can be categorized as vibration-based, 3D reconstruction-based, and vision-based. Accelerometers are used in the vibration-based method to find potholes. However, vibration-based techniques may yield inaccurate results, leading one to believe that potholes are present in the joints and hinges of the road. Pothole detection in real time can be achieved using 3D reconstruction using laser scanning devices.

Equipment for laser scanning is still somewhat expensive, though. Even while vision-based techniques are less expensive than 3D laser scanner techniques, noise in the form of shadows or patches on the road surface may make it challenging to identify potholes. The method known as Light Detection and Ranging (LiDAR) uses the time at which an infrared beam returns from an object to determine its distance. Numerous industries, including unmanned aerial vehicles, atmospheric studies, autonomous vehicles, and space facilities, use laser measuring. LiDAR-based three-dimensional mapping has recently been popular in domains including autonomous running, quadcopter, and distance measuring.

Open source computer vision (OpenCV) is utilized for pothole identification based on videos. A collection of real-time computer imaging applications is called OpenCV. Applications including motion tracking, face, object, and behavior identification use this open-source computer vision code. The development of computer vision applications is supported by the detection that it has numerous image functionalities. The benefit of a 2D LiDAR and camera-based pothole detection system is that it is unaffected by electromagnetic waves or the condition of the road surface. Thus, a cost-effective automatic pothole detecting system employing 2D LiDAR and a camera is developed.

[1] B.-h. Kang and colleagues created a pothole detecting system with a camera and 2D LiDAR. A large portion of the road surface can be more precisely scanned by employing two LiDARs. The system then created an algorithm for detecting potholes that included line extraction, gradient of data function, filtering, and clustering. The pothole detecting system's error rate provides insight on the system's developed performance. Additionally, the system demonstrated that 2D LiDAR may be used for 3D pothole identification. When 2D LiDAR and video data are integrated, pothole identification utilizing the combined data performs more accurately.

[2] P. Ping et al. suggest an effective pothole detection system that uses deep learning algorithms and can identify potholes on the road with just an internet connection and a camera mounted on an automobile's dash. Using preprocessed datasets, four models—YOLO V3, SSD, HOG with SVM, and Faster R-CNN—are trained and tested. The system converts labeled image files to training files after choosing the available data. record that the models will utilize as input. For more precise detection results, pothole sizes are calculated and hyperparameters are adjusted for each of the four models. With an accuracy of 82%, the YOLO V3 model outperformed the other three in the comparison of results. Future work will focus on expanding the detection item to include manhole covers and broken drains, as well as utilizing real-world situation photographs captured from moving automobiles.

[3] A. Kumar et al. suggested a system that would warn the driver to a pothole on the road in front of the car and identify potholes in real-time in photos or videos taken by a camera installed on the vehicle. In addition, the system will locate the pothole and upload it to a map (which will be displayed in an Android app we developed), allowing other users who don't have a camera installed on their car to receive an alert about it through the app alone. Several well-known and intricate CNN architectures, including Inception v1 (GoogLeNet), Inception v2, and lastly Inception v2 in the suggested system, were used in this system. Based on the experiment data, the system performs incredibly well. Experiments to refine the system and simplify it for widespread usage are part of the system's future works (see the section on future works for additional information).

The second half of this literature survey article is devoted to a review of the literature that evaluates earlier studies, and the third portion offers suggestions for more research.

II. LITERATURE SURVEY

[4] The Camilleri group, N. Road potholes were identified using computer vision techniques. The primary goal was to assess several object identification methods and determine the optimal algorithm. The algorithms that performed better overall than other architectures were YOLO and SSD, which were put into practice and trained using the dataset covered in Section. With a map accuracy of 68.83%, the experimental results of this study demonstrate that the YOLOv3 SPP model is the most accurate object detection technique for pothole detection. Compared to the other models, this one took longer to scan the entire image (as shown in Table 1). The architecture's use of the additional convolutional layers could help to explain this. In conclusion, the system reports that the SSD model's inference time is highly promising when compared to TFLite, even on low-power CPUs like the OnePlus 6 and Raspberry Pi. This demonstrates that the model has been implemented on an embedded system and has reached real-time speeds.

[5] This paper's proposal by P. A. Chitale et al. will lessen the need for human labor to maintain roads, particularly in the event of a pandemic. The study demonstrates that in terms of accurate pothole detection, the YOLOv4 based model performs better than the YOLOv3 based model. Pothole dimensions are computed with high precision and a significantly low error rate. When YOLOv4 achieves a higher IoU, it offers an accurate estimate of the potholes' diameters. Subsequent efforts will involve expanding the system to include surveillance vehicles so that exact automated road condition monitoring is possible. Additionally, a GPS module would be installed in these surveillance trucks so that the precise location of the potholes could be noted. The estimated dimensions of the potholes would be useful in determining the amount of road damage as well as the amount of raw materials needed to fill them. As a result, most planning and inspection can be completed remotely.

[6] According to L. Parameswaran et al., When compared to other item detections, such human, automobile, airplane, and so forth, pothole detection is distinct. Potholes are not shaped like other objects are. It is harder to detect as a result. Because of the aforementioned constraint, it is challenging to increase the mean average precision for pothole identification. This research uses different versions of YOLO to train a newly produced dataset of 1500 images. Furthermore, appropriate architectural modifications improve the mean average precision. In the future, a raspberry pi with a camera will be used to implement the system in real-time in a car's dashboard. The road repair crew can greatly benefit from the system's ability to trace the position of potholes that are recognized thanks to an inbuilt GPS.

[7] The pothole detection system, which has excellent accuracy and enhances the bounding box's precision for pothole representation, was proposed by C.-W. Kuan et al. and improved the deep reinforcement learning-based pothole avoidance system, which is capable of successfully avoiding potholes. Furthermore, these systems may be operated in real time and are installed on an energy-efficient edge platform.

[8] Extracting accurate features from the input image is the first stage in creating a successful machine learning model for image segmentation, according to H. K. I. S. Lakmal et al. The research that is being presented focuses on the application of computer vision as a driver aid device for water-filled pothole detection. In order to identify the water surfaces and segment the water region in an input image, this study presents a number of different attributes. In addition, the system has trained a model for the segmentation of the water surface using the Random Forest Classifier for feature ranking. We were able to get testing accuracy of 0.877 and training accuracy of 0.998 with the suggested architecture system.

[9] M. Omar et al. suggest the Pothole Detection paradigm in the Intelligent Transport system, which is primarily carried out by the YOLOv4 algorithm, which is based on deep learning. This work achieves an average IoU of 38.38% by training a dataset of roughly 200 photos for pothole identification. Video samples are also successfully used to detect potholes using the trained model based on picture datasets. This idea may be used in the future by the auto industry and road maintenance organizations to identify different types of road damage.

[10] R. Rastogi and colleagues discuss the It's critical to identify potholes on the road in order to protect people and reduce car damage. A variety of factors, including variations in pothole size, the materials used in road

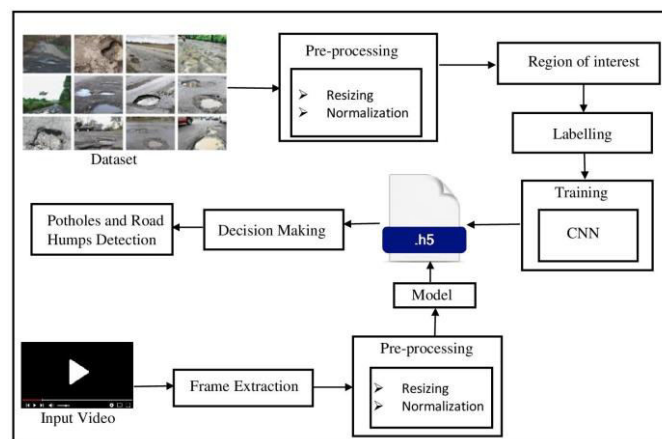
construction, traffic patterns, and meteorological conditions, add complexity to the pothole identification problem. 1300 pothole photos were gathered for this study in order to evaluate different object detection algorithms. To address the class imbalance issue between the "pothole" and "normal road" classes, a modified YOLOv2 model was put forth; it performed better than both the YOLOv2 base model and Faster R-CNN architectures. Due to its great accuracy, the suggested architecture can be put on the dashboard of manual and autonomous cars for real-time pothole detection. It can also be combined with a smartphone camera using a Raspberry Pi. With the advice for safe driving, this will benefit commuters and drivers.

[11] Using depth-based analysis, E. J. Reddy et al. suggested an efficient automatic pothole detecting method. The depth determined by the ultrasonic sensor and the method used in the detecting process are used in the study. In order to determine the position and depth of the pothole and enable the system to display the associated threat, the determined depth is compared against the system's ground clearance. Through the use of a GPS module and an IFTTT server, the location is shared with the maintenance authorities' emails so they may take the appropriate action. The maintenance authorities can identify poor road conditions more regularly and affordably with the aid of this method. By utilizing vehicle-to-vehicle communication inside a designated area, this model can be expanded even further. This way, everyone will be aware of the pothole and able to modify their speeds for their own safety.

[12] Using FDTD techniques, A. Srivastava et al. determined the two-dimensional RCS of potholes through simulations. The system has contrasted the backscatter from a level road with the RCS of air- and rainwater-filled potholes. According to system results, when there is a large fluctuation in the electrical parameters of the pothole material with regard to the properties of the neighboring ground, potholes cause significant backscatter. The RCS values slightly rise as a result of the walls' lower curvature and the pothole's greater dimensions. There is no discernible difference in the backscatter of potholes filled with rainfall and air due to the low dielectric constant and conductivity of rainwater. Potholes with a triangle cross-section may be the simplest to find with look-ahead radar since they produce significantly more backscatter than those with a rectangular cross-section.

[13] A brand-new virtual environment was created by J.-C. Tsai and colleagues to train pothole identification. The created system incorporates a number of contemporary VR and simulation methods, such as deep learning interface, 3D modeling, VR simulation, and automobile simulation. The system proved that virtual images can in fact improve the accuracy of a real pothole detector through a series of experiments carried out on real pothole datasets. In order to train an AI agent to automatically modify a car's suspension system in a variety of weather and road conditions, the system will attempt deep reinforcement learning with CarSim in the future.

Proposed System :



III. CONCLUSION AND FUTURE SCOPE

Due to the utilisation of substandard building materials in the development of road drainage systems, road accident prevention and detection has become an increasingly complex and demanding issue in India. The aforementioned issues lead to early road deterioration and the emergence of potholes, which in turn cause accidents. In India, there are about 4,64,910 accidents annually, according to a 2017 data that was filed by the Ministry of Road Transport and Highways transport research wing New Delhi.

As a result, recognizing and characterizing these anomalies helps to reduce the likelihood of crashes and vehicle damage. The identification of street abnormalities is made more difficult by the fact that street pictures are intrinsically

multivariate because of significant amounts of duplicated data and heavily contaminated measurement noise. This study offers the automatic color image processing of potholes on highways using a YOLO Deep learning model, either from the video frames or from photos taken with a smartphone camera. We used the conventional stride and pooling procedures to get as much data as we could. This enhances the developed model's capability to identify potholes and alert drivers to the need for cautious driving. In order to accomplish this, the suggested approach examines past research to compile crucial data for pothole detection.

The system will be expanded in the future to incorporate surveillance cars, enabling accurate autonomous road condition monitoring. These surveillance vehicles would also be equipped with GPS modules so they could track the exact positions of the potholes. The amount of road damage and the quantity of raw materials required to patch the potholes could both be approximated using the expected sizes of the holes. The majority of planning and inspection can therefore be finished remotely.

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