International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING

ISSN:2147-6799 www.ijisae.org Original Research Paper

A Novel Pothole Detection Model Based on YOLO Algorithm for VANET

Dr. Kamalakannan S.*[1], Dr. Navaneethan S.[2], Yogesh S. Deshmukh [3], Dr. Sujay V.[4], Dr. Sivakami Sundari M.[5], Dr. Venkadeshan Ramalingam [6], Dr. Jagadeesan D.[7], Dr. Venkatesh C.[8]

Submitted: 01/11/2023 **Revised**: 20/12/2023 **Accepted**: 02/01/2024

Abstract: The well-maintained highways are essential to the nation's economy because roads serve as the primary means of transport. Locating the potholes is crucial for avoiding accidents and vehicle damage caused by driver distress, as well as minimizing the consumption of fuel. This paper offers a straightforward method for identifying potholes in that regard and preventing collisions and supporting drivers. Deep learning technology is used to detect potholes. Raspberry Pi is used as the controlling device. Using Wi-Fi, the device locates potholes geographically and sends that information to the appropriate authorities for repair. The first action in solving this problem is to design a device that can detect potholes on the road surface continually, warning the driver so drivers can avoid them. The device utilizes the Global Positioning System (GPS) to find the pothole's position. This database is transferred to the cloud by connecting the system to Wi-Fi or 4G technology. The experiments are carried out with a picture database with potholes in different road conditions, different lighting conditions, and real-time video recorded by a speeding vehicle. The You Only Look Once (YOLO) architecture produces a very fast inference time.

Keywords: *YOLO algorithm, Pothole, Deep Learning, GPS, Real-Time Video*

1. Introduction

The biggest concerns in the roadway transport industry include that the roads are congested, of low condition, and underfunded. However, the number of vehicles that the road can handle is constrained and the density of vehicles on the route is rising. Potholes are created as the outcome of severe rainfall and intense traffic on poorly designed roadways. Not only does hitting a pothole harm a car's shocks and suspension [1], but it can also make the driver lose control of the vehicle. Along with the bad road conditions that frequently result in significant vehicle accident casualties, potholes can also cause truck accidents and motorcycle accidents [2]. The proposed system is using the Faster Region-based Convolution Neural Network (F- RCNN), Transfer Learning and Inception-V2. Numerous pothole detection models combine the accelerometer with machine learning methods (without using a dataset), but fewer pothole detection models exist that employ simply these methods.

The findings of this proposed work to demonstrate that the suggested model performs better than other pothole-detecting methods that are currently in use [3]. Examining the results of pothole detection using multiple real-time deep learning algorithms, including YOLOv4-CSPDarknet53, YOLOv3-Darknet53, and SSD-TensorFlow, High precision of 85%, mean Average Precision of 85.39%, and high recall of 81%, were observed using YOLOv4 (mAP). At an image resolution of 832*832, the YOLOv4 processing speed is measured at 20 frames per second (FPS). Additionally, the potholes are found at hundred-meter distances [4]. The results showed better performance in real-time when compared to other cutting-edge techniques [5], [6].

The experiment uses real-time video recorded through a moving car, a collection of images with potholes in various road conditions, and lighting fluctuations. On the picture collection, YOLOv5, YOLOv4, and Tiny-YOLOv4 exhibit the greatest mean Average Precision (mAP) of 85.48%, 95%, and 80.04%, demonstrating the effectiveness of the suggested technique for identifying potholes and implemented for instantaneous detection on OAK-D. Having a 90% recognition rate and 31.76 FPS, the research highlighted Tiny-YOLOv4 as the best system for true pothole recognition [7]-[9]. The purpose of their research is to assess the capacity and practicality of infrared imaging for pothole prediction. After gathering an appropriate volume of data, containing pothole photos in different lighting, weather and applying enhancement Deep learning has been accomplished using convolutional neural networks, which use techniques on the data and is a novel method for solving this issue that makes use of thermal imaging. Additionally, a comparison has been made between a self-built convolutional neural network and

[1,8] KGISL Institute of Technology, Coimbatore – 641 035
[2] Saveetha Engineering College, Chennai – 602 105
[3] Sanjivani College of Engineering, Kopargaon
[4] Krishna University College of Engineering and Technology, AP
[5] Agni College of Technology, Chennai -600 130
[6] University of Technology and Applied Sciences- Shinas, Oman,
[7] The Apollo University, Chittoor, Andhra Pradesh-517127
** Corresponding Author Email: kamalsphd@email.com*

several pre-trained models. The outcomes demonstrated the best residual network model, based on pre-trained convolutional neural networks, was able to properly identify photos with an accuracy of 97.08% [10]. As it is simpler to create and produces more reliable results, deep learning detection using the YOLOv3 method is recommended in contrast to research on machine learning-based detection, image processing or accelerometer detection [11].

After pothole Real-time camera detection will cause employing the API of Google Maps, the position will be captured and shown [12]. To put the pothole detection training model into action, 330 different sets of data were gathered. The model produced 0.41 recall rates, 0.9% accuracy rate, and 65.05 mAP as results. Using GPU with better-specified performances and the ability to sample 1000–10,000 datasets, the YOLOv3 method detection limit may be improved even more [13]. The potholes with a sufficient level of precision using effective deep learning Convolution Neural Networks (CNNs) are developed [14]. This research suggests a modified VGG16 (MVGG16) network to lower the computational cost and enhance training outcomes. Various dilation rates and certain convolution layers [15]. The proposed system concentrates on the pothole identification problem using image-processing methods and information obtained from a vehicle-mounted ultrasonic sensor. Later actions were carried out via the Bluetooth interface found in cell phones [16]. To locate holes and potholes in the road, an IoT-based Road Monitoring System (RMS) is suggested. The ultrasonic sensor's scattering signal has a significant impact on the pathway that the pothole affects [17].

To monitor the fluctuation in the signal, an accelerometer has been added to the ultrasonic sensor and adjusted using the Honey Bee Optimization (HBO) method. The IoT-RMS uses cloud-based location data to automatically update the status of the road. Each car on the road can access the server's information and calculate its speed based on the road's humps and potholes [18]. A simple method for Smartphone-based pothole detection, using Transfer Learning is used for categorization. The experimental finding supports the suggested strategy gives, efficiency in terms of performance and implementation [19]. The secret to keeping an eye on road conditions is to look for irregularities like humps, potholes, and different levels of roughness. These irregularities have a significant impact on both passenger comfort and traffic safety.

2. Methods & Materials

This paper proposes a pothole-detecting method that is both affordable and energy-efficient. To create a perfect road surface, find potholes, and forecast their size, the development of a sophisticated piezoelectric detector in an unorganized ecosystem is based on an imagination method. Additionally, the local server GPS locates the potholes' location. Three different pothole detection techniques exist, including the use of a 3-axis camera sensor, acceleration sensor and laser sensor. Each of these has advantages and disadvantages. The foundation of our suggested solution is an image processing technique utilizing the camera sensor. Identifying potholes based on their characteristics. The potholes have a rounded form, and rough texture, and black area is its distinguishing feature.

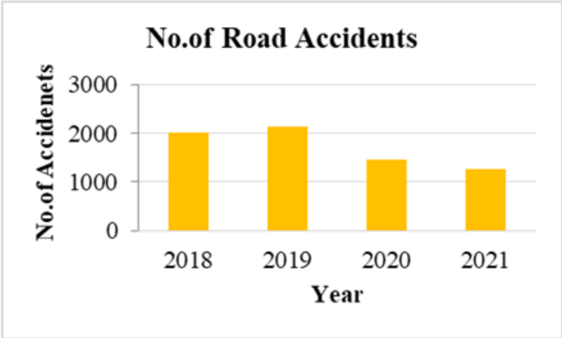

Fig 1. Graph of Accidents due to Potholes

When measuring the height and depth of humps and potholes, ultrasonic sensors are utilized to locate the obstacles. An IoT-based prototype is provided and the block diagram for proposed system is shown in figure 2. A device that can be incorporated with the car to identify potholes and humps can give maintenance authorities immediate information so that the appropriate action can be performed to ensure driver safety. This initiative aims to identify potholes using deep learning technology and a camera. The system uses GPS to send the location of these potholes to authorities, allowing them to take action on road maintenance and assist drivers in avoiding accidents. The alert is delivered via GPS and SMS to the driver.

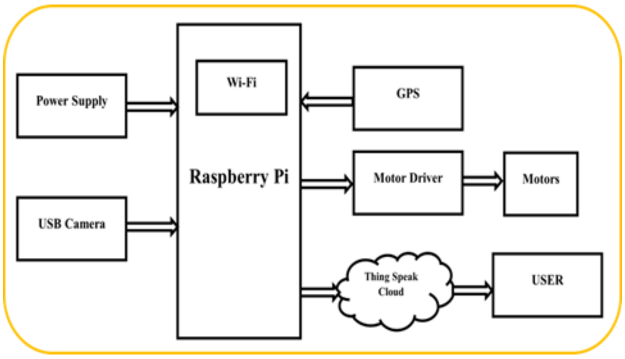

Fig 2: Block Diagram of Proposed Method

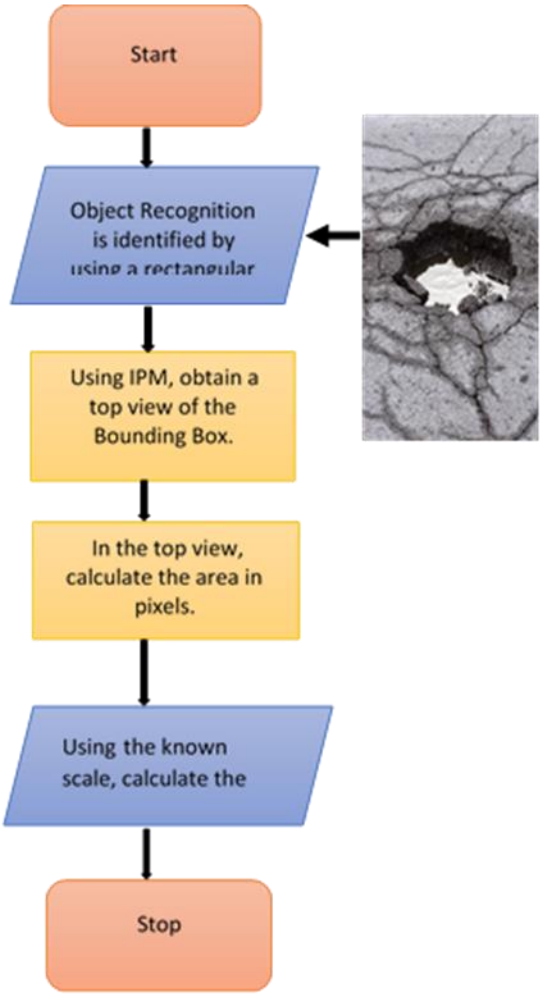

Fig 3. Flow Diagram of YOLO v5s

The system monitors the road continuously by using the USB camera and compares the images of the road with the data set available in the Raspberry Pi by using the YOLO algorithm and the flow diagram is shown in figure 3. After continuous monitoring of the road, whenever a pothole is detected on the road, i.e., the pothole image on the road is matched with the dataset. After finding the pothole the location of the pothole is sent to the driver using GPS and also updated to the cloud/IoT application. For a better understanding of pothole information, the image of that detected pothole on the road is sent to the driver using telegram. So, whenever the driver receives the message or image of the pothole in their telegram, the driver can reduce the speed of the vehicle. By using this system accidents number will decrease and a greater number of lives will be saved.

3. Performance Analysis of Proposed System

The pothole monitoring technology intends to offer a solution for citizens to decrease the frequency of accidents. That system's overall layout is based on the yolov5s model. The USB camera is mounted on the front of the car and is used to continually watch the road. After continuous road monitoring, anytime a pothole is discovered on the road, the pothole picture on the road is compared to the dataset which is already uploaded to the Raspberry Pi. With several photos being taken, the object identification model must recognize potholes as quickly as possible. YOLO v5s (version 5 small) increases operating speed to satisfy real-time detection needs. The dataset serves as the core engine for this application and database, and it is trained using the YOLOv5s model. The collection contains around 600 to 800 photos. The photos in the collection are all unique and have various characteristics. Certain parameters in this dataset are constant, such as pothole proximity, road color, and lighting. The system needs additional capacity to store the dataset, as a result, Raspberry Pi4 with 2GB of RAM is used. It contains a micro-SD card slot for data storage and loading the operating system.

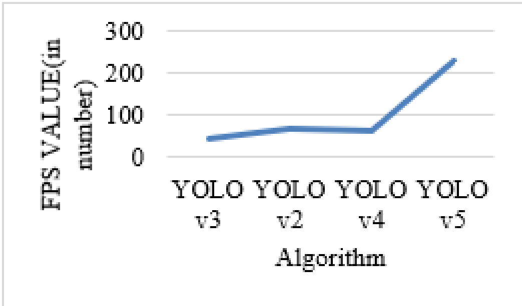

Fig 4: Performance Analysis of Different Yolo Algorithms

The proposed system receives the collected pothole picture from the USB camera and sends it to the Raspberry Pi4. Training and detection are the two stages of YOLO use. Teaching includes both giving the YOLO algorithm practice photographs and training it to identify the assignment. When a new image (one that is not included in the sample image) is introduced, detection attempts to perform the identification job on the new image. Students will be in charge of the training and detection portions of this project. The input picture is compared using YOLOv5s.

Table 1. Comparison of FPS values of different algorithms

Algorithm	*Frames per second value (in number)*
YOLO v3	45
YOLO v2	67
YOLO v4	65
YOLO v5	230

From Table 1, it is observed that the value of FPS of YOLO v5s is very high. this indicates that object detection is quite accurate. Yolov5's approach detects bounding boxes using object detection and then uses IPM to acquire a top view of the bounding box. In the top view, compute the area in pixels and get the estimated areas using the known scale. The input image is stored in the cloud and sent to the driver through Telegram, a mobile application. GPS, which is used to determine a certain position on the pothole, is required for this reason. The GPS is used to inform the driver of the location of the potholes. The system is developed in Python and uses deep learning technologies to process the final pothole dataset.

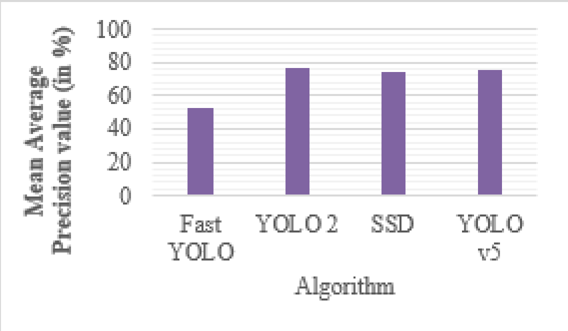

Fig 5. Mean Average Precision Analysis of Different Yolo Algorithms

The YOLO Algorithm is the process used for training and evaluating the model. The YOLOv5s algorithm is trained using an object-detection training set that has been labeled is shown in Fig.5. When the image has been assembled, every bounding box is identified with a Labeling tagged instrument of interest for every individual photograph. The item is captured by the camera for the source image, and the montage is processed frame by frame while monitoring city traffic, where the item is located.

Table 2. Comparison of mAP values of Different Algorithms

Algorithm	*Mean Average Precision value (in %)*
Fast YOLO	52.7
YOLO 2	76.8
SSD	74.3
YOLO v5	75

Object detection is performed on the picture that was taken of the action, expected objects have been shrunk and then the frame is sent through the neural net with the more efficient Darknet 53 convolution operation to the YOLO module.

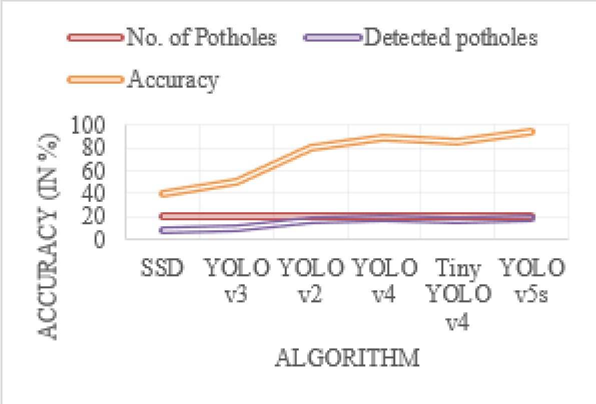

Fig 6. Performance Analysis of Accuracy for Different Yolo Algorithms

The performance analysis of accuracy for different yolo algorithms is shown in figure 6. The input image is divided into an SxS grid using this system. Box bounding with assurance in all of those grid cells, box scores are projected. Each test image is composed of five projections: X, Y, W, H, and reliability.

Table 3. Comparison of the Accuracy metrics for Several Algorithms

Algorithm	*No. of Potholes*	*Detected Potholes*	*Accuracy (in %)*
SSD	20	8	40
YOLO v3	20	10	50
YOLO v2	20	16	80
YOLO v4	20	18	90
Tiny YOLO v4	20	17	85
YOLO v5s	20	19	95

The table compares the performance of different object detection algorithms in identifying potholes. Each row corresponds to a specific algorithm, detailing the total number of potholes in the dataset, the actual number of detected potholes, and the resulting accuracy in percentage. The algorithms include SSD, YOLO v3, YOLO v2, YOLO v4, Tiny YOLO v4, and YOLO v5s. Notably, YOLO v5s demonstrates the highest accuracy at 95%, outperforming the other algorithms in terms of pothole detection. The accuracy values provide insights into the effectiveness of each algorithm in correctly identifying potholes within the given dataset.

4. Conclusion

Based on the YOLO technique, an autonomous pothole detection system is designed. The YOLO regression algorithm recognizes objects in real time and views the entire image at once. The proposed method offers a cost-effective way to find potholes and warn vehicles to avoid potential collisions. An additional benefit of this system is the smartphone app Telegram, which sends out timely information about potholes. The technology also works at night and during the rainy season, when potholes fill with muddy water, and alarms are generated using database data. Performance metrics are measured when the detection is carried out on both photos and videos. The GPS can be used to identify and pinpoint the site of pavement problems as part of a more advanced solution. Using a vision-based approach, the work may be improved to extract pothole properties like depth, volume, etc. This research work proposes a practical, cost-effective solution to the problem of deadly pothole accidents.

5. References and Footnotes

Conflicts of interest

The authors declare no conflicts of interest.

References

[1] R. Shen, T. Zhen, and Z. Li, "YOLOv5-Based Model Integrating Separable Convolutions for Detection of Wheat Head Images," in IEEE Access, Vol. 11, pp. 12059-12074, 2023

[2] H. Shi and D. Zhao, "License Plate Recognition System Based on Improved YOLOv5 and GRU," in IEEE Access, Vol. 11, pp. 10429-10439, 2023.

[3] H. Li, L. Deng, C. Yang, J. Liu, and Z. Gu, "Enhanced YOLO v3 Tiny Network for Real-Time Ship Detection From Visual Image," in IEEE Access, Vol. 9, pp. 16692-16706, 2021.

[4] Z. Long, W. Suyuan, C. Zhongma, F. Jiaqi, Y. Xiaoting, and D. Wei, "Lira-YOLO: A lightweight model for ship detection in radar images," in Journal of Systems Engineering and Electronics, vol. 31, no. 5, pp. 950-956, 2020.

[5] D. S. Kaputa and B. P. Landy, "YOLBO: You Only Look Back Once–A Low Latency Object Tracker Based on YOLO and Optical Flow," in IEEE Access, vol. 9, pp. 82497-82507, 2021.

[6] Aparna, Yukti Bhatia, RachnaRai, VarunGupta, Naveen Aggarwal, AparnaAkula (2022), "Convolutional neural network based potholes detection using thermal imaging", Journal of King Saud University-Computer and Information Science, Vol. 34, No. 3, 2022.

[7] Yeoh Keng Yak, Nurul Ezaila Alias, Yusmeeraz Yusof, and Suhaila Isaak, "A Real-time Pothole Detection Based on Deep Learning Approach", Journal of Physics Conference Series 1828(1):012001, 2022.

[8] Q. Xu, R. Fu, F. Wu and B. Wang, "Roadside Estimation of a Vehicle's Center of Gravity Height Based on an Improved Single-Stage Detection Algorithm and Regression Prediction Technology," in IEEE Sensors Journal, Vol. 21, no. 21, pp. 24520-24530, 2021.

[9] L. Zhou, W. Min, D. Lin, Q. Han, and R. Liu, "Detecting Motion Blurred Vehicle Logo in IoV Using Filter-DeblurGAN and VL-YOLO," in IEEE Transactions on Vehicular Technology, vol. 69, no. 4, pp. 3604-3614, 2020

[10] Kulwant Singh, Sristy Hazra, Chandra Mukherjee, Sushanth. G, Sanjith Gowda, "Iot Based Real Time Potholes Detection System Using Image Processing Techniques", International Journal Of Scientific Technology Research, Vol. 9, No. 2, 2020.

[11] Hyunwoo Song, Kihoon Baek, and Yungcheol Byun, "Pothole Detection using Machine Learning", Advanced Science and Technology Letters, Vol. 150, pp.151, 2018.

[12] Ramsha Suhail, Harleen Boparai, Faraz Ahmed, "Automated Sensor-based Pothole Detection System for Preventing Unfortunate Causality", International Journal of Engineering Research Technology, Vol. 9, No. 07, 2020.

[13] W. -Y. Hsu and W. -Y. Lin, "Ratio-and-Scale-Aware YOLO for Pedestrian Detection," in IEEE Transactions on Image Processing, Vol. 30, pp. 934-947, 2021.

[14] Z. Liu and S. Wang, "Broken Corn Detection Based on an Adjusted YOLO With Focal Loss," in IEEE Access, vol. 7, pp. 68281-68289, 2019.

[15] N. Zarei, P. Moallem, and M. Shams, "Fast-Yolo-Rec: Incorporating Yolo-Base Detection and Recurrent-Base Prediction Networks for Fast Vehicle Detection in Consecutive Images," in IEEE Access, Vol. 10, pp. 120592-120605, 2022.

[16] Y. Dai, W. Liu, H. Wang, W. Xie, and K. Long, "YOLO-Former: Marrying YOLO and Transformer for Foreign Object Detection," in IEEE Transactions on Instrumentation and Measurement, Vol. 71, pp. 1-14, 2022.

[17] K. Liu, "STBi-YOLO: A Real-Time Object Detection Method for Lung Nodule Recognition," in IEEE Access, Vol. 10, pp. 75385-75394, 2022.

[18] Z. Liu, Y. Gao, Q. Du, M. Chen and W. Lv (2023), "YOLO-Extract: Improved YOLOv5 for Aircraft Object Detection in Remote Sensing Images," in IEEE Access, Vol. 11, pp. 1742-1751, 2023.

[19] W. Zhao, M. Syafrudin and N. L. Fitriyani, "CRAS-YOLO: A Novel Multi-Category Vessel Detection and Classification Model Based on YOLOv5s Algorithm," in IEEE Access, Vol. 11, pp. 11463-11478, 2023.