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A Deep Learning Survey for Pothole and Crack Classification and Detection

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ABSTRACT—

Roads serve as one of the main sources of transportation for people and goods. But such roads are damaged due to various factors, which leads to accidents. Road hazards like potholes, cracks, etc. are formed due to traffic and weather, which affect the road's condition and also cause accidents. So, identification and detection of such road hazards is a crucial task. To address these challenges, a deep learning approach is proposed for the recognition of such road hazards. A two-step approach is used for accomplishing this task. Initially, a ResNet50 algorithm is used to classify the road surfaces as potholes, cracks, and potholes. Subsequently, a YOLOv8 detection algorithm is used for detecting the location and severity of potholes and cracks. The existing work achieved an accuracy of 90% for classification, which needs to be increased by the proposed model.

Keywords— Classification, Detection, Hazards, Potholes, Cracks

Introduction

Roads are major infrastructure that facilitates the mobility of goods and people. Due to its transportation, it also contributes to the country's economy. However, due to its regular use and exposure to various climate conditions, the road quality decreases. This deterioration leads to the formation of potholes and cracks on roads.

Potholes and cracks are the depressions caused on the road surface due to various factors, including weather, traffic, etc. These road hazards, when left unaddressed, may cause road accidents and pose a severe risk to motorists and pedestrians. So, to overcome these challenges a deep learning approach is proposed.

Deep learning, a subset of artificial intelligence, offers various techniques for classifying and detecting those road hazards by leveraging its ability to learn complex patterns from diverse datasets. The integration of deep learning in road hazard recognition not only offers a robust solution to improve road safety but also paves the way for more efficient road maintenance practices. Hence deep learning models like ResNet50 and YOLOv8 are used for accurate classification and detection of road hazards in real time scenarios.

To measure how well our method works, we employ rigorous evaluation metrics such as accuracy and loss for classification and Mean Average Precision(mAP) for detection.

Related Works

The authors build a custom pavement distress dataset consisting of distress and non-distress images. The dataset consists of 6 types of pavement distresses. They trained a binary classification and multi classification models to classify those distresses. They used SSD model to detect the location and size of distresses in the images. Various training techniques are used to increase accuracy of the model. ResNet50 model got higher accuracy of 96% in binary classification and 90% in multi classification models. They need to explore the model's performance on diverse datasets as future work [1].

The authors used a distress dataset of 45,788 images for classification of distresses. They adopted a YOLO network to predict distress locations and categories. The detection accuracy achieved was 73.64% which is greater than other approaches. Future work involves integration of YOLO network with other techniques for better accuracy [2].

The authors proposed a pothole classification model using edge detection in road images. This method converts RGB images to gray-scaled images to reduce computation. This removes all the background objects in the images other than potholes. Potholes are then detected and classified using the YOLO algorithm. The proposed method achieved a mean square error (MSE) of 0.2-0.44 and the structural similarity index map (SSIM) was evaluated as 0.71-0.82 [3].

The authors introduced an attention-based multi-scale convolutional neural network (A+MCNN) for the automated classification of distress and non-distress objects in pavement images. A+MCNN is trained and tested with four distress classes, five non-distress classes, and two pavement classes. The AMCNN achieved an average F-score of 92 on entire objects, outperforming all other approaches. Future work involves use of diverse datasets to perform well in real-world scenarios [4].

The authors proposed a YOLOv3 object detection model for accurate detection of potholes. They used various techniques like data augmentation, structural optimization etc to improve model accuracy. They used ResNet101 model to extract features from YOLOv3 model. Achieved a detection mean average precision (mAP) of 89.3% and an F1-score of 86.5% [5].

The authors proposed a hybrid framework using deep learning to detect and classify road damages. Initially, data is collected from various sources and pre-processed to enhance the contrast of the images and remove the noise using histogram equalization algorithm. Then damage present in the image is detected using segmentation process. Features from the segmented method are extracted using Laplace edge detection techniques etc. The proposed model achieved an accuracy of 98.815$ on the dataset which is better than other comparison classifiers [6].

The authors collected the potholes images under challenging Indian traffic conditions. The model is trained using sequential convolutional neural network model and You only Look Once3 (YOLOv3) models. The model obtained an accuracy of 98% using CNN and precision of 83% using YOLOv3. Future work involves finding the depth, volume etc. of the potholes using vision-based method [7].

The authors made an attempt to classify road images using transfer learning approaches like fine tuning, feature extraction is used for model building. These techniques are employed on various CNN architectures namely VGG16, VGG19, ResNet50, Inception, Densenet121 etc. Three pre-processing tasks namely data labelling, image resizing, and data augmentation are performed to improve efficiency and accuracy of the model. Achieved highest precision of 95% on SEResNet-50 model. Future work involves performing the classification of subtypes of each road surface anomaly class [8].

The authors collected the pothole data using an IOS smartphone installed on car dashboard. The preprocessing techniques used are data augmentation, resampling and labelling. The model used for training is 1D-CNN for classification. The model's accuracy varied in the range of 95%. Future work involves further refinement of proposed approach and also use of diverse datasets [9].

The authors generated a dataset of thermal images of potholes under various weather conditions through manual capturing. They analyzed the feasibility and efficiency of using thermal images for pothole detection by utilizing CNN techniques. Preprocessing steps used are augmentation, resizing and cropping. The proposed model achieved an accuracy of 97.08% which is higher compared to other models. Future work can be extended to detect the region and severity of potholes [10].

The authors aim to analyze the newly developed YOLOX algorithm for pothole detection. The YOLO model was trained on the pothole dataset. The model achieved an Average Precision (AP) value of 85.6%. Future work involves further refinement of proposed approach [11].

The authors presented a new method to detect potholes based on location-aware convolutional neural networks, which focuses on the discriminative regions in the road surface. Preprocessing techniques involve resizing and cropping. The proposed method achieved high precision of 95.2%, recall of 92.0% simultaneously, outperforming other approaches. Future work involves dataset of other road surfaces other than asphalt [12].

The author presents an end-to-end system called PotSpot for real-time monitoring of road surfaces. The proposed system integrates pothole detection using a Convolutional Neural Network (CNN) model with real-time pothole-marked maps produced from Google maps AI. The proposed custom CNN model proposed in the paper achieves better accuracy of 97.6% and a higher Area Under the Curve (AUC) value of 0.97. Future work involves enhancement of proposed approach to other road hazards like cracks, speed bumps etc. [13].

The authors proposed a deep learning approach for automatic road surface monitoring and pothole detection. The paper applies different deep learning models, including convolutional neural networks (CNN), LSTM networks, and reservoir computing models. This model obtained an accuracy, precision, recall, and F -measure of 0.85. Future work will focus on analyzing other types of road surfaces [14].

The authors proposed a top-down scheme for the detection and localization of potholes in the pavement images. The proposed approach aims to categorize pavement images using Bag of Words (BoW) approach and then undergo detection. The model achieved an accuracy of 95.7%. Future work involves detection of other road hazards lie cracks [15].

Results

The accuracy obtained for classification of potholes, cracks and plain roads using ResNet50 model is 95%.

Our proposed model got an accuracy more than the existing model which is 90%.

For detection, the YOLOv8 model is performing well on the validation set, with an overall fitness score of 0.5485.

The mAP scores for the two classes are also high, at 0.5994 for crack and 0.4416 for pothole.

Conclusion

Potholes and cracks on road surfaces pose severe risk by causing road accidents and disruptions in transportation. This survey paper leverages various deep learning approaches to classify and detect potholes and cracks. By using various datasets available for pothole and crack classification and detection we employed ResNet50 for accurate classification and YOLOv8 models for precise detection.

Future work involves enhancement of our proposed model to other classes of road damages like cracks, sink holes etc.

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