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A SURVEY ON PAVEMENT CRACK AND POTHOLE DETECTION USING DEEP LEARNING METHODS

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Abstract
One of the key reasons for road accidents is potholes, cracking, which is a frequent indicator of the condition of the road construction. If cracks continue to deteriorate, accidents may occur that have a significant negative impact on people's safety and property.
We trained our model using CNN algorithm as the base architecture of faster-RCNN and trained it with dataset consisting of images of pavement cracks and potholes as the two classes. Images of pavement cracks and potholes are used to train and test the model. We annotated the images of both cracks and potholes using labelimg software and stored them as xml files and then converted them into csv files to perform the training. Object-detection in CNN is one of the most efficient methods and faster-RCNN as the Neural Network Architectures provides a better output compared to other methods because they contribute to maintaining a low error rate much deeper in the network. A web interface is created and deployed so that the users can manually test the model with a test image and the output will be displayed showing whether the image consists of pavement cracks or potholes or both with the confidence score displayed on the screen. In future, the proposed algorithm can be further embedded in cameras of vehicles and can be used to report the pavement cracks and potholes to the respective authorities so that they can take the necessary actions and ensure road user safety.

Keywords: Python module, Anaconda Navigator, Faster-RCNN, CNN, Django, Labelimg, Web Interface.

Introduction
Pavement crack and pothole detection using deep learning methods is a project which majorly addresses the problem of potholes and cracks on roads which are a threat to the road user safety and it's important to take steps to reduce the accidents occurring because of potholes and cracks on the roads. If cracks continue to deteriorate, accidents may occur that have a significant negative impact on people's safety and property. Higher standards are thus set for the road's sustainability and safety.

Anaconda Navigator: Anaconda Navigator is a popular graphical user interface (GUI) that comes with the Anaconda distribution of Python. It provides a convenient and user-friendly way to manage packages, environments, and software dependencies for data science and machine learning projects.

Anaconda Navigator makes it easy to install, update, and manage packages that are required for building deep learning models, such as TensorFlow, PyTorch, and Keras.

This can save time and effort compared to installing packages manually. Anaconda Navigator allows users to create isolated environments for different projects, which can help avoid conflicts between different packages and versions. This is particularly

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useful for deep learning projects, which often require specific versions of packages and dependencies. Jupyter notebooks are a popular tool for building and testing deep learning models. Anaconda Navigator provides an easy way to manage Jupyter notebooks and launch them in a web browser.

Faster-RCNN: We have used faster-RCNN (region-based convolutional neural network) in training our model. Faster R-CNN (Region-based Convolutional Neural Network) is a popular deep learning architecture used for object detection tasks. The architecture of Faster R-CNN consists of two main components: a region proposal network (RPN) and a Fast R-CNN detector. The RPN is used to generate region proposals by sliding a small network over the convolutional feature map of the input image. The Fast R-CNN detector takes the region proposals generated by the RPN and extracts features from them using a shared convolutional network.

The architecture of Faster R-CNN has several advantages over previous object detection models. First, it eliminates the need for external region proposal methods, making the model end-to-end trainable. Second, it achieves state-of-the-art accuracy on several object detection benchmarks while maintaining real-time performance. Finally, it is a flexible architecture that can be adapted to different object detection tasks, such as instance segmentation and keypoint detection.

CNN: Faster R-CNN is actually a specific architecture for object detection that uses a convolutional neural network (CNN) as its algorithm. CNNs are a type of deep neural network that is particularly effective at image recognition tasks. In the context of object detection, CNNs are used to extract features from the input image, which are then used to identify objects and their locations within the image.

The Faster R-CNN architecture builds on top of the basic CNN algorithm by incorporating a region proposal network (RPN) to generate object proposals. The predicted objectness scores and bounding box offsets are then used to generate a set of object proposals that are fed into the CNN for further analysis.
Once the object proposals are generated, the CNN is used to classify the proposals into object categories and to refine the bounding boxes. This is done by extracting features from each proposal using the same shared convolutional layers as the RPN, and then passing the features through a set of fully connected layers to output class probabilities and bounding box offsets.

The combination of a CNN algorithm with the Faster R-CNN architecture has proven to be highly effective for object detection tasks, achieving state-of-the-art performance on a number of benchmarks.

Labelimg: In pavement crack and pothole detection using deep learning methods, we have used labelimg software. Basically, LabelImg is a graphical image annotation tool that allows users to label object bounding boxes in images. It is an open-source software written in Python and Qt, and it is compatible with Windows, Linux, and macOS. With LabelImg, users can easily label object bounding boxes in their images for object detection and recognition tasks. The software provides various annotation tools, such as rectangular and circular bounding boxes, polygons, and points, to enable users to precisely mark the boundaries of objects.

LabelImg also supports various annotation formats, including PASCAL VOC, YOLO, and Create ML, and it allows users to save and export annotated images and annotations in these formats. Moreover, LabelImg has a user-friendly interface that simplifies the annotation process, making it an ideal tool for researchers, developers, and data scientists working on computer vision projects.

Django: We have used Django in the backend of the web-interface designed for the project. Django is a popular Python web framework that is often used in the backend of web applications.

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In the frontend, HTML, CSS, and JavaScript are typically used to create the user interface and design of a web application. HTML provides the structure of the webpage, CSS is used to style the elements of the page, and JavaScript is used for interactivity and dynamic content.

To connect a deep learning model to the web interface, Django can be used to build a RESTful API that exposes the deep learning model's functionality to the frontend. The API can be created using Django Rest Framework, which provides a simple way to serialize Django models and respond with JSON data.

Once the API is created, the frontend can make HTTP requests to the API to send data to the deep learning model and receive the results. The frontend can be built using modern JavaScript frameworks like React or Vue, which provide a robust set of tools for building responsive and interactive user interfaces.

Overall, using Django in the backend with HTML, CSS, and JavaScript in the frontend provided a powerful and flexible platform for building web applications that can connect to deep learning models like the one we have trained here.

Web Interface: Here is a step-by-step process for using the web interface designed for pavement crack and pothole detection model using deep learning methods:
Step 1: Go to the website by clicking on the url generated.
Step 2: Input a test image.
Step 3: Click on predict button to display the output
Step 4: The model receives the request from the user and tests the given image and displays the output.

Scope
The scope of Pavement crack and pothole detection using deep learning methods is quite significant. Here are some of the key benefits and applications of such a model:
1.Accessibility: Anyone can access the web interface that is designed to test whether a image consists of a crack or a pothole and the model displays the output on the screen labelling the cracks and potholes in the image using the annotations and with the confidence score.
2.Ease of Use: The web interface is very simple and anyone can use it without facing any trouble.
3.Overall, pavement crack and pothole detection using deep learning methods has the potential to improve the conditions of roads and ensure the safety of the users by making sure to reduce the number of accidents that occur because of cracks and potholes.

Purpose
One of the key symptoms of road problems is cracking, which is a frequent indicator of the condition of the road construction. If cracks continue to deteriorate, accidents may occur that have a significant negative impact on people's safety and property. Higher standards are thus set for the road's sustainability and safety.

Problem Statement
The problem statement for a pavement crack and pothole detection using deep learning methods is to address the difficulties the people face while travelling on the roads containing cracks and potholes and which are eventually leading to accidents being occurred. It is important to address these problems and take necessary measures to get rid of potholes and cracks and makes the roads safer for people to travel from one place to another with safety as the first and foremost priority for everyone.

Comparative study about various algorithms for Pavement Crack and Pothole Detection using Deep Learning methods:

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S.no	Title of the paper	Authors	Advantages	Disadvantages
1	Pothole detection in asphalt pavement images	Christian Koch, Ioannis Brilakis	The method can be used for pavement condition assessment, which is important for road network maintenance	Limited to asphalt pavement images, not suitable for other materials.
2	Efficient pavement crack detection and classification	A. Cubero-Fernandez, Fco. J. Rodriguez-Lozano, Rafael Villatoro, Joaquin Olivares and Jose Palomares	Cross-validation technique was used in the learning process provides a more accurate and reliable result.	Error rate of 20% in crack classification.
3	Efficient Convolutional Neural Networks for Mobile Vision Applications	Andrew G. Howard, Menglong Zhu, Bo Chen, Dmitry Kalenichenko, Weijun Wang, Tobias Weyand Marco Andreetto, Hartwig Adam	MobileNets use depthwise separable convolutions which results in smaller model size and less computational complexity.	The training process of MobileNets might be computationally expensive, as it requires significant computational resources to train such models.
4	Detection of Asphalt Pavement Potholes and Cracks Based on the Unmanned Aerial Vehicle Multispectral Imagery	Yifan Pan, Xianfeng Zhang, Guido Cervone, and Liping Yang	Spatial features (i.e., texture and geometry) contributed much more to the accuracy of the cracks and potholes detection.	Because of the spatial resolution limitation, the UAV pavement images used in the paper still cannot capture the cracks that width are less than 13.54 mm.
5	Automated Vision-Based Detection of Cracks on road Surfaces Using DL Technique	Byunghy-unKim and Soojin Cho	Analyses the crack morphology by eliminating the interrupting objects in an image in prior.	Few which have relatively irregular shapes are classified as cracks
6	Self-adapting Framework for U-Net-Based Medical Image Segmentation	Fabian Isensee, Jens Petersen, Andre Klein, David Zimmerer, Paul F. Jaeger, Simon Kohl, Jakob Wasserthal.	The nnU-Net automatically adapts its architectures to the given image geometry.	They only submitted once and reported the results of a single submission.
7	Structural crack detection using deep learning–based fully convolutional networks	Xiao-Wei Ye, Tao Jin, Peng-Yu Chen	The proposed FCN exhibits a better performance over the edge detection methods in structural crack detection	The model is less accurate in detecting the images with thin crack and classify whether it is a crack or not.
8	Improving the Efficiency of Encoder-Decoder Architecture for Pixel-Level Crack Detection	Hanshen Chen, Huiping Lin, Minghai Yao	Here SWM (Switch module) is built and integrated into the architectures to reduce computation complexity.	The method cannot achieve notable speed acceleration under a scenario where the object in the image has a consistent ratio against the background.

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9	Pothole Detection based on Disparity Transformation and Road Surface Modeling	Rui Fan, Umar Ozgunalp, Brett Hosking, Ming Liu, Ioannis Pitas	To achieve greater processing efficiency, GSS and DP were utilized to estimate the transformation parameters.	The parameters set for pothole detection cannot be applied to all cases. Therefore, we need to train a deep neural network to detect potholes from the transformed disparity map.
10	Deep Learning Approach to detect potholes in real time using smartphones	Shebin Silvister, Dheeraj Komandur, Shubham Kokate, Aditya Khochare	Accelerometer and gyroscope detection uses a custom trained Deep Feed Forward Neural Network.	System performance should be improved over time.
11	Pothole Detection Using Computer Vision and Learning.	Amita Dhiman and Reinhard Klette	The LM2 model is capable of real-time pothole identification, the LM1 model can accurately and reliably identify a pothole in adverse weather circumstances.	Detection accuracy is not very high. Cannot identify a pothole when there is sunlight or shadows of trees in the image.
12	A Research on an improved Unet-based concrete crack detection algorithm	Lingxin Zhang, Junkai Shen, Baijie Zhu	The detection results of six images show that CrackUnet15 and CrackUnet19 can detect cracks under complex conditions.	CrackUnet cannot accurately detect cracks from images with strong illumination shadows.
13	Deep Learning Based Pothole Detection and Reporting System	Ganesh Babu R, Chellaswamy C, Surya Bhupal Rao M	The classification result of 99.2% was achieved by CNN-DL, 95.4% was achieved by KNN, and 89.3% was attained by the Kirchhoff method.	More number of dataset images can be added, to further push the accuracy achieved by CNN-DL.
14	A Comparative Evaluation of the Deep Learning Algorithms for Pothole Detection	Archit Kashyap, Shubham Jindal and Saurabh Pahwa	The proposed architecture has a high precision (0.87) and recall (0.89) compared to the other models tested, making it an effective tool for pothole detection.	The Modified YOLO v2 architecture is complex, requiring specialized expertise and computing resources for implementation and optimization.
15	Attention-Based Convolutional Neural Network for Pavement Crack Detection	Haifeng Wan, Lei Gao, Manman Su, Qirun Sun, and Lei Huang	C.R.A.N- good segmentation. The result was extremely close to ground truth.	Cnet and FCN misclassified few backgrounds. SegNet and ExFuse misclassified some cracks.

Literature Survey

1. Christian Koch, Ioannis Brilakis, "Pothole detection in asphalt pavement images", ELSAVIER, 2011, describes a methodology for automatically identifying and assessing the severity of potholes in asphalt pavement using a combination of image segmentation, form extraction, and texture comparison techniques. The proposed method was tested on 70 photographs of pavement, achieving an overall accuracy of 86%, precision of 82%, and recall of 86%. The

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paper notes that existing methods for identifying pavement defects are time-consuming, expensive, and heavily influenced by subjective and experiential factors. The proposed method offers an automated and more efficient alternative, which can be implemented using existing recording equipment.

2. A. Cubero-Fernandez1, Fco. J. Rodriguez-Lozano "Efficient pavement crack detection and classification", EURASIP journal on image and video processing, 2017, describes a system for detecting and categorizing cracks in pavement using image processing and a decision tree algorithm. The system was tested on 400 images, and achieved an average success rate of 88% in detecting cracks.

3. Howard, Andrew G., et al, "MobileNets: Efficient Convolutional Neural Networks for Mobile Vision Applications", arXiV:1704.04861v1[cs.CV], 17 Apr 2017, presents a new model architecture called MobileNets, which are designed to be very tiny and low latency, making them suitable for real-world applications with constrained processing resources. The authors compared various MobileNets to well-known models and showed their superior size, speed, and accuracy features.

4. Yifan Pan, Xianfeng Zhang, "Detection of Asphalt Pavement Potholes and Cracks Based on the Unmanned Aerial Vehicle Multispectral Imagery", IEEE, 2018, presents a new approach for detecting cracks and potholes on asphalt roads using UAV multispectral pavement photos and machine learning algorithms such as SVM, ANN, and RF. The paper suggests that the adaptable UAV platform equipped with multispectral remote sensors can be a useful instrument for monitoring the status of asphalt pavements. Therefore, the approach can be further improved by using better quality pavement photos.

5. Byunghyun Kim, Soojin Cho, "Automated Vision-Based Detection of Cracks on road Surfaces Using DL Technique", MDPI, 2018, describes a deep learning-based method for automated crack detection in concrete structures using computer vision. The proposed method involves training a CNN on a large dataset of images of cracked and uncracked concrete surfaces, including various objects that may be mistaken for cracks. The trained network is then used for crack detection and classification, and a probability map is created to improve the sliding window detection method's resiliency.

6. Isensee, Fabian, et al, "nnU-Net: Self-adapting Framework for U-Net Based Medical Image Segmentation." Bildverarbeitung für die Medizin 2019. Springer Vieweg, Wiesbaden, 2019. 22-22, introduces the nnU-Net, a segmentation system for medical images based on the U-Net architecture. The authors focus on creating an automated training process for the U-Net models and adapting them to the unique characteristics of the given dataset, without the need for manual input.

7. Ye, Xiao-Wei, Tao Jin, and Peng-Yu Chen, "Structural crack detection using deep learning-based fully convolutional networks", Advances in Structural Engineering 22.16 (2019): 3412-3419, proposes the use of a fully convolutional network called Ci-Net for identifying structural cracks in civil infrastructure. The Ci-Net is trained using pixel-level tagged image data obtained through online data collection. The study shows that Ci-Net performs better than edge detection approaches in detecting structural degradation, with good robustness in crack detection and crack geometry demonstration. However, there are some false negative results for thin cracks.

8. Chen, Hanshen, Huiping Lin, and Minghai Yao", Improving the efficiency of encoder-decoder architecture for pixel-level crack detection", IEEE Access 7 (2019): 186657-186670, proposes a technique which uses a switch module named SWM, which determines if an input image contains cracks or not. The proposed technique was evaluated on the CrackTree206 and AIMCrack datasets and was found to improve efficiency without compromising accuracy.

9. Rui Fan, Umar Ozgunalp, "Pothole Detection based on Disparity Transformation and Road Surface Modeling", IEEE, 2019, propose an algorithm that uses stereo vision-based pothole detection to identify potholes on roads accurately and efficiently. The

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experimental results show that the proposed approach has an overall successful detection accuracy of 98.7% and an approximate pixel-level accuracy of 99.6%. The authors conclude that their proposed pothole detection technique cannot be used in every situation since not all road surfaces can be considered quadratic.

10. Shebin Silvister, Dheeraj Komandur, “Deep Learning Approach to detect potholes in real time using smartphones”, IEEE, 2019, presents a mobile application that uses deep learning-based technology to identify potholes in real-time, which can help prevent accidents caused by road damage. The user mounts their smartphone on a mobile holding stand in their car and launches the application, which shows previously identified potholes on the route.

11. Amita Dhiman, Reinhard Klette “Pothole Detection Using Computer Vision and Learning”, IEEE, 2019, assess the accuracy of the models using precision and recall measures, and they report accuracy, recall, and precision of 86%, 86%, and 82%, respectively. The LM2 model can detect potholes in real-time, while the LM1 model is reliable in adverse weather conditions.

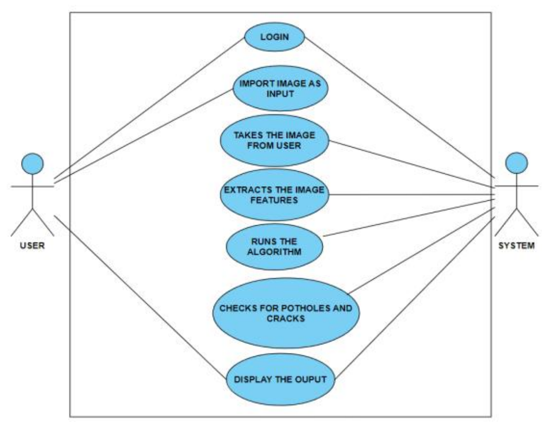
12. Zhang, Lingxin, Junkai Shen, and Baijie Zhu, "A research on an improved Unet-based concrete crack detection algorithm", Structural Health Monitoring 20.4 (2021): 1864-1879, introduces a deep learning-based approach called CrackUnet for identifying surface fractures in concrete structures at the pixel level. The method uses an enhanced Unet-based architecture and a novel loss function to improve accuracy and generalization. The proposed model has higher precision, recall, and F1 score than other cutting-edge approaches on the CrackForest Dataset.

13. Ganesh Babu R, Chellaswamy C, Surya Bhupal Rao M “Deep Learning Based Pothole Detection and Reporting System”, IEEE, 2020, proposed a highway pothole detection and information system using a CNN-DL algorithm. Overall, the proposed CNN-DL algorithm demonstrated higher accuracy and better performance compared to the other two benchmark techniques, making it a promising approach for pothole detection on highways.

14. Archit Kashyap, Shubham Jindal and Saurabh Pahwa," A Comparative Evaluation of the Deep Learning Algorithms for Pothole Detection", IEEE,2020, aimed to evaluate the performance of different neural network algorithms for identifying potholes on the road. The study also proposed a modified version of YOLOv2 to address the issue of class imbalance between "pothole" and "normal road" classes. The study concluded that the suggested architecture could be implemented in manual and autonomous vehicles

15. Wan, Haifeng, et al. "Attention-Based Convolutional Neural Network for Pavement Crack Detection", Advances in Materials Science and Engineering, HINDAWI, 2021 (2021), proposed ResNet-34 as the encoder and suggested incorporating attention modules after each encoder layer to condense distant context data which helped to improve information extraction and increase prediction accuracy.

Proposed Model:



A proposed model for a Pavement Crack and Pothole Detection using deep learning methods could involve the following components:

1. LABELIMG software: LabelImg is a graphical image annotation tool that allows users to label object bounding boxes in images. It is an open-source software written in Python and Qt, and it is compatible with Windows, Linux, and macOS.

With LabelImg, users can easily label object bounding boxes in their images for object detection and recognition tasks. The software provides various annotation tools, such as rectangular and circular bounding

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boxes, polygons, and points, to enable users to precisely mark the boundaries of objects.

2. FASTER-RCNN (Region-based convolutional neural network): We have used faster-RCNN (region-based convolutional neural network) in training our model. Faster R-CNN (Region-based Convolutional Neural Network) is a popular deep learning architecture used for object detection tasks.
3. CNN: The combination of a CNN algorithm with the Faster R-CNN architecture has proven to be highly effective for object detection tasks, achieving state-of-the-art performance on a number of benchmarks. Therefore, we have built the faster RCNN architecture on top of the CNN (convolutional neural network).

4. ANACONDA NAVIGATOR: Anaconda Navigator is a popular graphical user interface (GUI) that comes with the Anaconda distribution of Python. It provides a convenient and user-friendly way to manage packages, environments, and software dependencies for data science and machine learning projects.

5. DJANGO: We have used Django in the backend of the web-interface designed for the project. Django is a popular Python web framework that is often used in the backend of web applications. In the frontend, HTML, CSS, and JavaScript are typically used to create the user interface and design of a web application. HTML provides the structure of the webpage, CSS is used to style the elements of the page, and JavaScript is used for interactivity and dynamic content.

6. WEB INTERFACE: Here is a step-by-step process for using the web interface designed for pavement crack and pothole detection model using deep learning methods:
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Step 2: Input a test image.
Step 3: Click on predict button to display the output
Step 4: The model receives the request from the user and tests the given image and displays the output.

In conclusion, a pavement crack and pothole detection using deep learning methods model could provide the web interface which is very simple and anyone can use it without facing any trouble to use it. Overall, pavement crack and pothole detection using deep learning methods has the potential to improve the conditions of roads and ensure the safety of the users by making sure to reduce the number of accidents that occur because of cracks and potholes.

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Here are references that might be useful in building a “Pavement Crack and Pothole Detection
Model using Deep Learning methods”:

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[2] A. Cubero-Fernandez1, Fco. J. Rodriguez-Lozano “Efficient pavement crack detection and classification”, EURASIP journal on image and video processing, 2017.
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