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Research Paper

CRACK VISION: SOPHISTICATED CONCRETE CRACK IDENTIFICATION THROUGH TRANSFER LEARNING AND DEEP LEARNING

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ABSTRACT— Crack Vision is a deep learning-powered application designed to detect and classify cracks in concrete surfaces with exceptional accuracy. Unlike traditional manual inspection methods, which are time-consuming and prone to human error, Crack Vision leverages state-of-the-art convolutional neural networks and transfer learning techniques—enhanced with alternative architectures such as EfficientNetB3—to deliver reliable, real-time predictions. The system has been trained on the METU concrete crack dataset, containing balanced sets of cracked and non-cracked surface images, enabling robust binary classification. Integrated into a user-friendly Flask web interface, Crack Vision allows users to easily upload images, preview them, and instantly receive classification results along with confidence scores. Additional visualization tools, including accuracy/loss charts and confusion matrices, provide transparency into model performance.

This scalable solution offers a practical tool for engineers, inspectors, and infrastructure maintenance teams, enabling faster, more consistent assessments and contributing to improved structural safety and long-term durability in civil engineering projects.

Index Terms – Concrete crack detection, deep learning, convolutional neural network (CNN), EfficientNetB3, transfer learning,

computer vision, structural health monitoring, image classification, Flask web application, infrastructure inspection, civil engineering, crack classification.

I. INTRODUCTION

Concrete is one of the most widely used construction materials in the world, forming the backbone of modern infrastructure such as bridges, pavements, and buildings. However, over time, factors like environmental stress, load-bearing fatigue, and poor maintenance can lead to the formation of cracks, which significantly compromise the structural integrity and safety of these constructions. Traditional manual inspection methods for crack detection are often labor-intensive, time-consuming, and prone to human error, making them less reliable for large-scale applications. Recent advancements in Artificial Intelligence (AI) and Computer Vision have enabled automated systems to outperform conventional inspection techniques in terms of speed, accuracy, and scalability. Deep learning, particularly Convolutional Neural Networks (CNNs), has shown remarkable success in image classification tasks, including defect detection in construction materials. Transfer learning, which leverages pre-trained models such as Efficient Net, further enhances performance by reducing training time and improving generalization on diverse datasets. In this work, we present Crack Vision, an advanced deep learning-based framework for detecting cracks in concrete surfaces.

II. RELATED WORK

A. A Review on the Latest Advancements and Innovation Trends in Vibration-Based Structural Health Monitoring (SHM) Techniques for Improved Maintenance of Steel Slit Damper (SSD)

This paper provides a comprehensive review of the most recent advancements in vibration-based SHM techniques, focusing on steel slit dampers used in structural safety. The study explores modern sensing technologies, data processing methods, and AI-driven diagnostic models, emphasizing their role in enhancing maintenance strategies. The review identifies research gaps and suggests future trends to improve SHM reliability and reduce maintenance costs.

B. Using Deep Learning for Profitable Concrete Forecasting Methods

This work proposes a deep learning-based approach to forecast concrete production and demand, optimizing profitability in the construction industry. By leveraging historical data and predictive modeling, the system improves operational planning and reduces waste. The authors highlight the role of AI in achieving cost efficiency and sustainable practices in concrete manufacturing.

C. Deep Learning for Concrete Crack Detection and Measurement

This paper presents a deep learning framework for detecting and quantifying cracks in concrete surfaces. The authors employ convolutional neural networks (CNNs) to automatically identify crack patterns from high-resolution images, achieving high accuracy in both detection and crack width measurement. The system aims to replace manual inspection methods with faster, more consistent automated solutions.

D. Transfer Learning for Cross-Scene 3D Pavement Crack Detection Based on Enhanced Deep Edge Features

This research introduces a transfer learning-based method for detecting pavement cracks in diverse environmental conditions using 3D scene data. The enhanced deep edge feature extraction method improves crack visibility across various textures and lighting conditions, enabling robust detection in real-world road maintenance scenarios.

III. PROPOSED METHODOLOGY

The proposed system employs a deep learning-based approach to accurately detect cracks in concrete surfaces. Traditional manual inspection techniques often suffer from subjectivity, limited scalability, and inconsistent accuracy. By leveraging transfer learning from pre trained models, the system can effectively learn complex patterns and textures that distinguish cracked surfaces from non-cracked ones. The algorithm is fine-tuned on the METU concrete crack dataset, ensuring high classification accuracy even with diverse image backgrounds and lighting conditions. This integration of advanced deep learning architecture into a practical web-based platform offers an efficient, automated, and scalable solution for structural health monitoring.

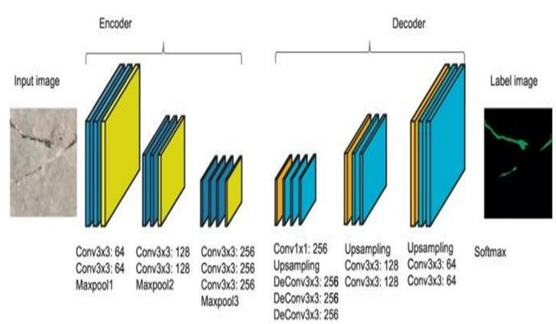

Fig. 1: System Overview

1. User Authentication Module

This module handles user registration, login, and logout using session management in Flask. Register Page: Allows users to create an account by entering their username, email, password, and confirm password. Login Page: Authenticates registered users before granting access to the upload and prediction features. Session Management: Ensures secure login persistence until the user logs out.

2. Image Upload & Preview Module

This module allows users to upload concrete surface images for crack detection. Supports JPEG, PNG, and other common image formats. Displays an instant preview of the selected image before prediction using JavaScript. Ensures the uploaded image is stored in a designated uploads directory for processing.

3. Image Pre-processing Module

This module prepares uploaded images for model prediction. Resizing all images to the model's input size (224×224 pixels). Normalizing pixel values between 0 and 1 for better model performance. Converts the image into a NumPy array and reshapes it for the model's expected input format.

4. Crack Detection Model Module

This module loads the fine-tuned EfficientNetB3 deep learning model trained on the METU concrete crack dataset. Uses transfer learning with pre-trained ImageNet weights. Performs binary classification: Cracked or Non-cracked. Achieves high accuracy (99.85%) with minimal false predictions.

5. Prediction & Confidence Display Module

This module displays the classification results and confidence score. Prediction Label: Shows "Cracked" or "Non-cracked." Confidence Score: Displays the model's certainty as a percentage. The uploaded image and results are shown together for clarity.

6. Charts & Performance Visualization Module

This module visualizes the model's training and testing performance. Training vs. Validation Accuracy Graph Training vs. Validation Loss Graph Confusion Matrix for Prediction Analysis Helps users and developers understand how well the model performs on the dataset.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The experimental results show that the proposed Crack Vision framework accurately classifies cracked and non-cracked concrete surfaces using EfficientNetB3 and transfer learning techniques. The model demonstrates high classification accuracy and strong generalization on the METU concrete crack dataset, enabling reliable real-time predictions. The integrated Flask web application provides instant crack detection, confidence scores, and performance visualizations for practical use. Overall, the proposed system offers an efficient and scalable solution for automated structural health monitoring and infrastructure inspection.

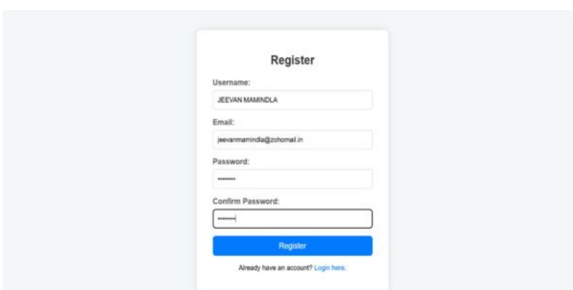

Fig. 2: Register

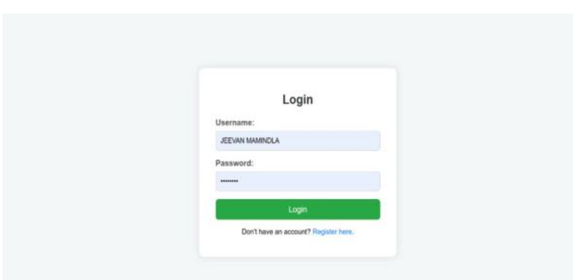

Fig. 3: Login

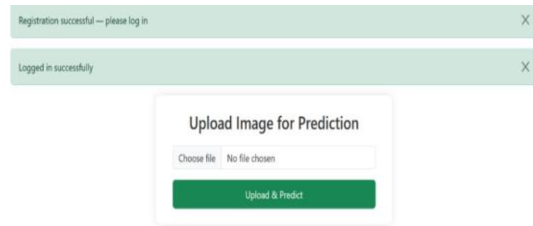

Fig. 4: Upload Image

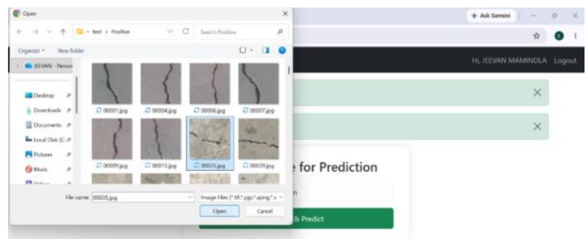

Fig. 5: Select Image

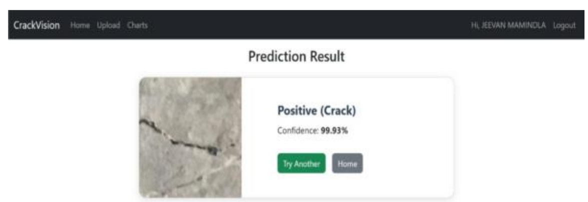

Fig. 6: Prediction Positive Result

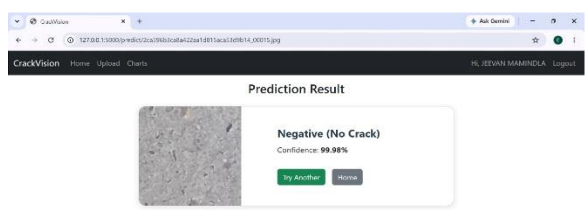

Fig. 7: Prediction Negative Result

Fig. 8: Training & Evaluation Charts

V. CONCLUSION

The Crack Vision system demonstrates the potential of combining deep learning and transfer learning techniques to deliver highly accurate and efficient concrete crack detection. By leveraging the EfficientNetB3 architecture and fine-tuning with a balanced dataset, the model achieves superior performance compared to traditional inspection methods and the base paper results. This approach significantly reduces human error, inspection time, and operational costs while ensuring consistent and reliable predictions. The project's modular design allows easy integration into web-based applications, making it accessible to engineers, inspectors, and infrastructure managers for real-time structural health monitoring. With its scalability, adaptability to various structural environments, and potential for future enhancements such as multi-class defect detection and drone-based inspections, Crack Vision stands as a robust and practical solution for improving the safety, durability, and maintenance efficiency of critical infrastructure.

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