

Geopolymer Concrete Crack Prediction System Using Machine Learning and Image Processing

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Introduction

Concrete is one of the most commonly used construction materials. However, crack development reduces structural strength, durability, and service life. Geopolymer concrete is an eco-friendly replacement for ordinary cement concrete because it utilizes industrial by-products and reduces carbon emissions. Still, it is vulnerable to crack formation due to shrinkage, loading, temperature variation, and aging. Traditional crack inspection methods are manual, time-consuming, and expensive. Therefore, an automated smart inspection system is required. This paper proposes a machine learning and image processing based crack prediction system for fast and accurate structural analysis.

System Architecture

The proposed system consists of the following major stages:

- Image Acquisition
- Image Preprocessing
- Feature Extraction
- Model Training
- Crack Detection
- Severity Prediction

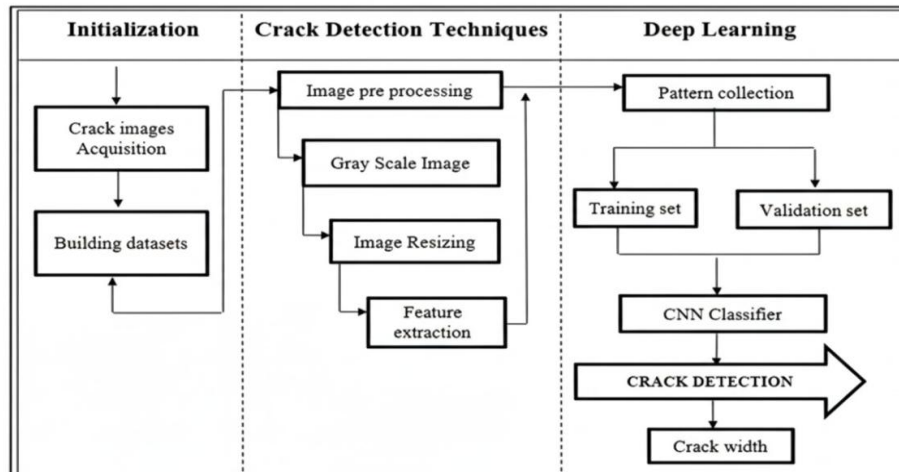


Fig. 1. System Architecture of Proposed System

Methodology

Geopolymer concrete is gaining significant attention as a sustainable alternative to conventional concrete due to its reduced environmental impact and enhanced durability. However, the formation of cracks can adversely affect its structural integrity and service life. To address this challenge, the proposed methodology employs machine learning and image processing techniques for automated crack detection and prediction. The framework consists of data collection, image preprocessing, feature extraction, and model training using CNN, SVM, and Random Forest algorithms to achieve accurate and reliable crack classification.

Data Collection

A dataset of 16,000 geopolymer concrete crack images was collected from laboratory experiments and online sources.

Image Preprocessing

The following preprocessing techniques were applied before model training:

- Grayscale Conversion
- Noise Removal
- Edge Detection
- Image Resizing to 224×224 pixels

Machine Learning Models

- Convolutional Neural Network (CNN)
- Support Vector Machine (SVM)
- Random Forest

Results and Discussion

Performance Metrics

Table 1: Performance Metrics

Metric	Value
Accuracy	94.5%
Precision	92.8%
Recall	93.6%
F1-Score	93.1%

Model Comparison

Table 2: Model Comparison

Model	Accuracy
CNN	94.5%
SVM	91.2%
Random Forest	90.6%

Among all evaluated models, CNN achieved the highest accuracy because of its superior feature extraction and pattern learning capability.

Experimental Output

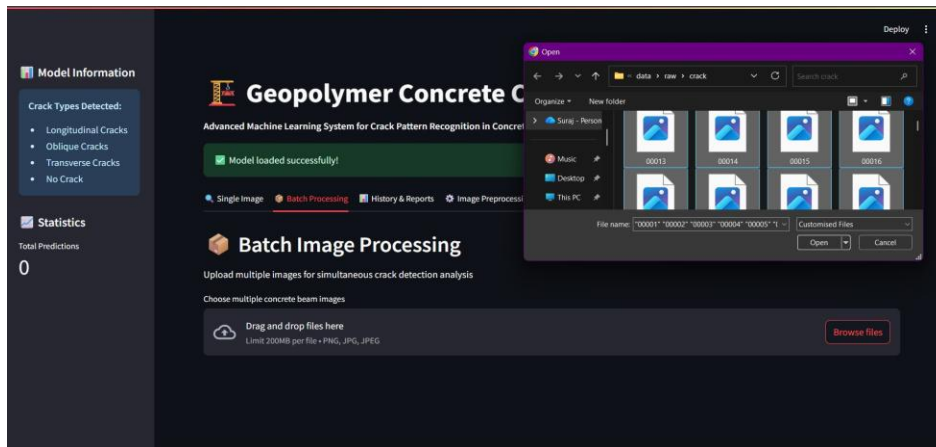


Fig. 2. Crack Detection Interface and Batch Processing Screen

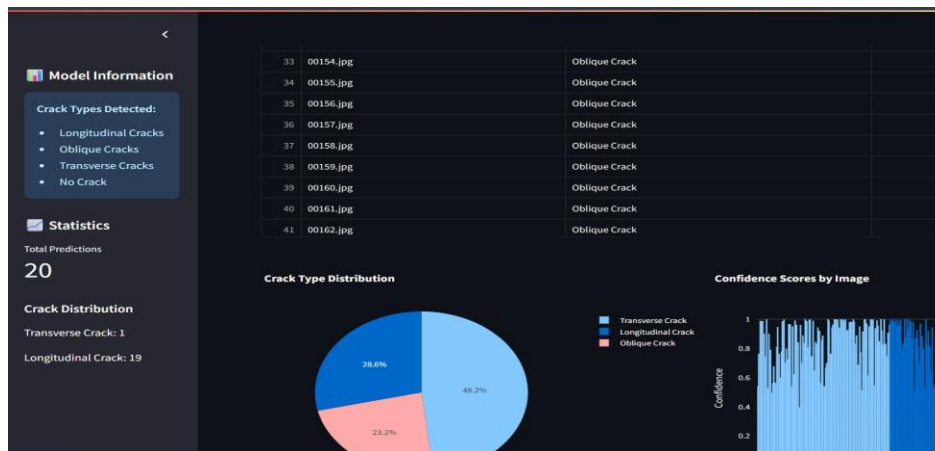


Fig. 3. Crack Classification Results with Analytics Dashboard

Discussion

The proposed system demonstrated excellent performance in identifying crack patterns from geopolymer concrete surfaces. The CNN model outperformed SVM and Random Forest due to its automatic feature extraction capability. The experimental results indicate that the system can classify multiple crack categories with high confidence. This reduces dependency on manual inspection and minimizes human error.

The solution is suitable for structural monitoring, preventive maintenance, and infrastructure safety analysis. However, system performance depends on image quality, lighting conditions, and dataset diversity. Further training with larger real-world datasets can improve robustness.

Conclusion

The proposed system effectively detects and predicts cracks in geopolymer concrete using machine learning techniques. The achieved accuracy of 94.5% demonstrates the effectiveness of CNN based crack analysis. This intelligent system can support engineers in structural health monitoring, maintenance planning, and safety inspection.

Future Work

- IoT based real-time monitoring
- Drone based crack inspection
- Mobile application deployment
- Cloud based prediction system
- Larger real-world dataset training

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