Preliminary Study on Detection of Surface Cracks in Concrete Structures

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Abstract – Crack formation is a major concern in reinforced concrete structures due to its implications for durability, serviceability and safety. This study presents a preliminary image-based approach for crack identification using image processing techniques. Images of concrete surfaces were collected from real-world structures, followed by preprocessing and segmentation using methods such as Canny Edge Detection and Otsu Thresholding. Observations suggest that each techniques provides distinct advantages in detecting fine or broad cracks respectively. This preliminary work is intended to support future studies involving machine learning-based structural health monitoring.

Index Terms — Crack Detection, Image Processing, Canny Edge Detection, Otsu Thresholding, Concrete.

I. INTRODUCTION

Concrete structures are prone to various types of cracking due to environmental stress, shrinkage, aging and external loads. Timely identification of these cracks is crucial to prevent structural failures and costly repairs. Manual inspection methods are labor-intensive, subjective and often unsafe.

Image processing presents a promising, non-destructive and automated alternative for surface crack detection. This study focuses on the comparative performance of two image segmentation techniques: Canny Edge Detection and Otsu Thresholding. These methods are evaluated in the context of surface crack images collected from existing buildings.

Machine Learning (ML) and Deep Learning (DL) are playing a transformative role in detection of cracks by enabling systems to autonomously analyse data, detect patterns, and make informed decisions. These techniques are particularly effective in interpreting complex, high-dimensional data generated from sensor arrays and visual sources.

II. LITERATURE REVIEW

1) M. R. S. Zawad, et al. (2021), have presented a comparative analysis of various image processing-based crack detection methods applied to civil engineering structures. It categorizes the techniques into traditional algorithms and learning-based approaches, evaluating their performance based on accuracy, sensitivity to noise, and computational efficiency. The study underscores the limitations of thresholding and edge detection techniques and contrasts them with the adaptive capabilities of machine learning models. It provides experimental insights and benchmarking metrics, serving as a resource for selecting appropriate methods for specific structural applications.
2) Ms. Kruti Desai, et al. (2024), provides a thorough examination of the current landscape in automated crack detection within structural systems, highlighting the transformative role of image processing, machine learning, and deep learning techniques. Emphasis is placed on the use of convolutional neural networks (CNNs) for feature extraction and classification tasks. The review compares different algorithmic approaches and discusses the challenges of data acquisition, preprocessing, and model generalization. It also identifies gaps in the literature and proposes directions for future research aimed at enhancing the robustness and scalability of automated inspection systems.
3) Beata Nowogońska (2020), outlines a methodological framework for assessing the rehabilitation needs of buildings, integrating diagnostic evaluation, performance indicators, and risk assessment tools. It proposes a structured decision-making process that helps prioritize maintenance activities based on condition severity and functional obsolescence. The

study supports the development of strategic rehabilitation plans and underscores the importance of integrating engineering assessments with socio-economic and environmental considerations.

4) Gomasa Ramesh, et al. (2021), have discussed the principles and practices involved in the repair, rehabilitation, and retrofitting of reinforced concrete structures. It outlines the causes of structural degradation, such as corrosion and mechanical overload, and reviews techniques for strengthening and restoring structural performance. Topics include jacketing, fiber-reinforced polymer application, and load redistribution. The study provides practical guidelines for selecting intervention strategies based on the extent of damage and desired performance outcomes, contributing to safer and more sustainable infrastructure renewal.

III. METHODOLOGY

A. Image Collection

Images were collected from exposed concrete elements of various civil infrastructure systems, including bridges, retaining walls, and columns. A standard mobile phone camera was used for ease of access and practical deployment in real-time inspection scenarios. The dataset encompassed a wide range of crack types — including hairline cracks, wide and deep surface cracks, and branching patterns — to ensure diversity in crack morphology, orientation, and visibility under natural lighting conditions.

Fig.1 – Crack Image 1

Fig.2 – Crack Image 2

B. Preprocessing

To prepare the raw images for segmentation and analysis, the following preprocessing steps were applied:

Grayscale Conversion: Colour images were converted to grayscale to reduce computational complexity and focus on the intensity information critical for detecting cracks. This step also increases the contrast between the cracks and the surrounding concrete surface.

Median Filtering: A median filter was applied to suppress random noise, such as texture or surface artifacts, while preserving important edge details. This process enhances the visibility of crack boundaries and eliminates irrelevant background information, improving the effectiveness of edge detection methods.

C. Segmentation

To isolate and highlight cracks from the background, two primary segmentation techniques were employed:

Canny Edge Detection: This technique identifies the edges of cracks by computing the gradient of image intensity. It is particularly effective for detecting fine and continuous crack lines. The method uses non-maximum suppression and hysteresis thresholding to produce thin, well-connected edge maps that outline the crack geometry.

Otsu Thresholding: This global thresholding method determines the optimal threshold value based on the bimodal histogram of grayscale intensity. It is especially useful for segmenting thicker cracks and regions where there is a sharp contrast between the crack and the concrete surface. Otsu's method improves binary segmentation by adapting to the image's pixel intensity distribution.

IV. OBSERVATIONS

This study focuses on visual evaluations, without numerical metrics. Observed findings include:

a) Canny detection effectively identifies narrow, hairline cracks, but may capture background textures as false positives.
b) Otsu's method produces clean segmentation of more visible, broader cracks, making it preferable for general surface damage assessment.

Both techniques are found to complement each other and can serve as preprocessing filters for advanced AI-driven crack classifiers.

V. DISCUSSIONS

Visual segmentation techniques are not standalone classifiers but are important for early crack detection pipelines. Proper preprocessing enhances the performance of downstream deep learning models. The system can support automated SHM tools to prioritize inspection zones and reduce manual intervention.

Technique	Crack Type Detected	Strengths
Canny Edge	Hairline/Narrow Cracks	Good Continuity, detail capture
Otsu Thresholding	Broad surface cracks	Clean segmentation

VI. CONCLUSION

This preliminary study confirms that even classical image processing techniques can effectively aid in identifying structural cracks in concrete. Future research will extend this work by applying machine learning and deep learning models for crack classification, severity estimation, and real-time monitoring. The combined framework will enable smart infrastructure assessment and timely maintenance action.

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