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# Surface damage inspection using deep learning and structured light

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## ABSTRACT

Due to the Increase in aging civil infrastructures, the stability assessment by detecting surface damages is becoming increasingly emphasized. In this paper, deep learning has been applied to detect damages on structural surfaces. To quantify the damages, structured light consisting of a vision sensor and two laser sensors have been applied. The Faster RCNN(Region-based Convolutional Network) algorithm has been used for damage detection, and the quantification of the detected damages has been calculated based on the positions of the projected laser beams on the structural surface. To improve the accuracy of quantification, various image processing technique including image stitching method have been applied. The performance of the system has been verified through simulation and experimentations, and the results show that the damages on the structural surfaces are detected and quantified with high accuracy.

## 1. INTRODUCTION

With the increase of aging infrastructure, the stability assessment of structures is becoming more emphasized. Currently, the detection of surface damage on structures is monitored through human’s investigation. In this test method, the results of the investigation are highly dependent on the skill level of the investigator. In addition, there are restrictions on the sections that the investigator can access, so the overall inspection of large structures cannot be conducted. To solve these problems, researches have been carried out to automate the investigation process. Through the development of image processing and machine learning technology, the method for investigation of surface using vision sensor is actively studied. (Cha 2017) have suggested the crack detection method using Convolutional Neural Network(CNN).

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(Park 2020) have proposed the system for crack detection and quantification using You Only Look Once(YOLO) v3 detector and structured light. However, research on surface damage detection using vision sensors is mostly focused on cracks. In addition, there is a limit to the image information of the structure that be obtained at once with the vision sensor. Since surface damage is not captured in one image frame, a problem of poor accuracy occurs. In this paper, the performance of surface damage detection was improved using image processing techniques. In addition, data sets related to spalling are collected, and the deep learning detector is also trained to enable detection of spalling.

## 2. STRUCTURAL DAMAGE DETECTION

In this paper, deep learning is used to detect surface damage of structures. Additional image processing techniques, including stitching, are used to improve the accuracy of deep learning detectors.

### *2.1 Image Processing*

There is a limit to the collection of image information using a vision sensor because it allows segmentation capture of structural damage images. This problem is especially serious for large structures. This problem can be improved by combining multiple image information through image processing. The stitching is used to combine image information as one of the image processing techniques. The stitching is a technique for finding feature points in each image and matching them together. In this paper, the Oriented FAST and Rotated BRIEF(ORB) algorithm combined with various feature extraction techniques is used for feature detection and optimization. After a feature is detected using the ORB algorithm, it matches each feature and attaches the images together to combine multiple image information.

### *2.2 deep learning detector*

The deep learning detection model for detecting surface damage used the Faster Region-based Convolutional Neural Network(R-CNN). The Convolutional Neural Network(CNN) architecture for extracting and classifying the characteristics of the images were used the Inception Resnet v2 and the transfer learning was performed using the coco dataset to enhance the detection performance of the model. For learning, 1,965 cracks and spalling images were collected on the web and on the site. 80% of these data were used as learning data, and the rest were used as data to check the performance of the model. The process of detecting surface damage using the learned detection model is as shown in Fig. 1.  As shown in (a), there is a limit to the image information that a vision sensor can collect in one frame. Thus, through the process of stitching, several image information is combined into a single image, such as (b), so that the overall configuration information of the damage can be obtained. The detection of damage using the Faster R-CNN model can then produce the same results as (c). Finally, through edge detection and crack integration algorithms, integrated crack detection, such as (d), can be performed.

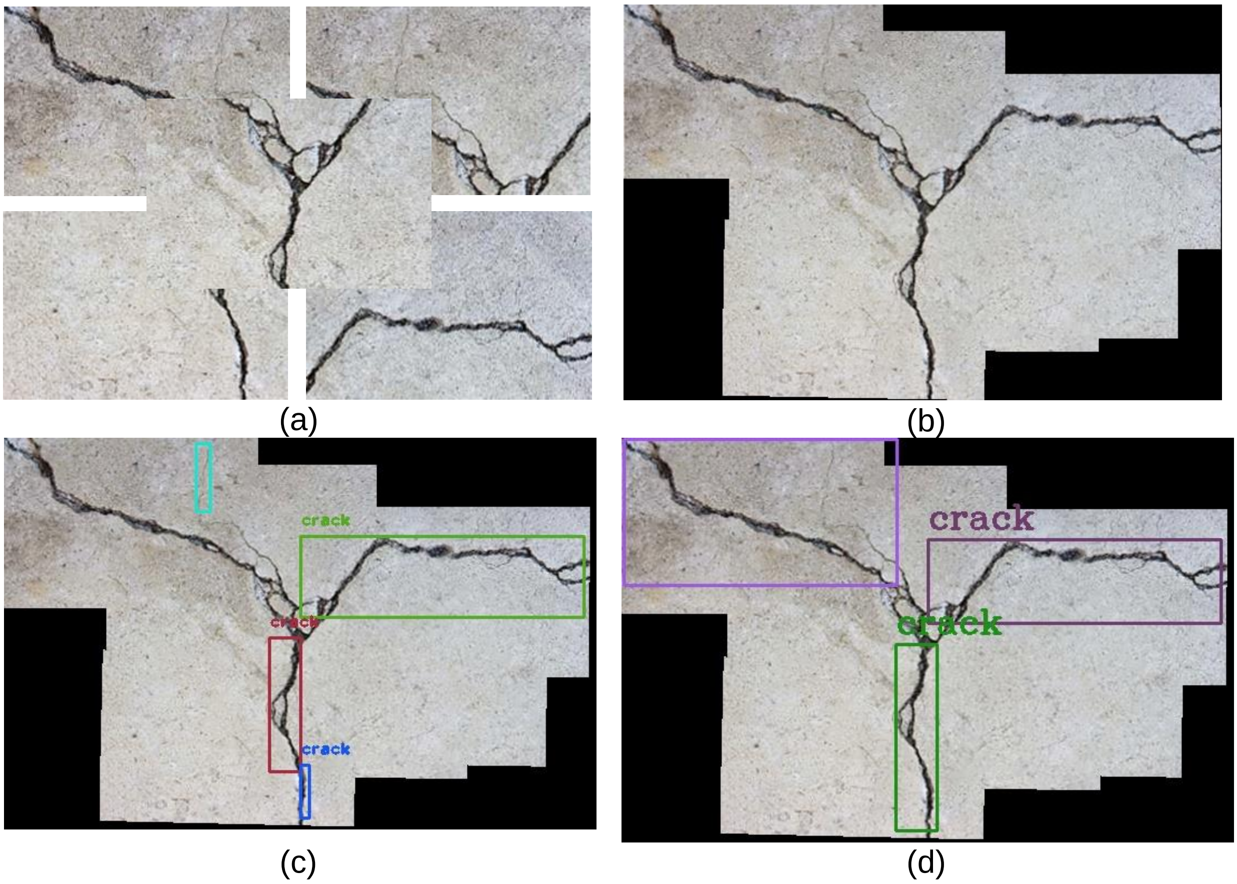


Fig. 1 The process of structural damage detection

### 3. STRUCTURAL DAMAGE QUANTIFICATION

A structured light consisting of a vision sensor and two lasers was used to quantify surface damage. The quantification of damage was performed by obtaining the ratio of the distance between the pixels of the two laser beams and the actual distance. Two lasers projected the beam onto the structure and collected the image information of the laser beam being projected using a vision sensor. When the image information of the laser beam is collected, the laser was extracted by thresholding the image using the difference in brightness of the image. Then, the Circular Hough Transform(CHT) algorithm was used to detect the center of the extracted laser. Through the CHT algorithm, the ratio between pixels and mm units can be calculated using the pixel distance between the center of the explored laser and the mm distance between the actual two lasers. Finally, quantification in mm units is possible through the calculated ratio between pixels and mm units.

## 4. CONCLUSIONS

This study is proposed the structural damage detection and quantification system. The detection system was established using deep learning to detect surface damage and the performance improvement was attempted using image processing techniques. The stitching technique was used to integrate image information of various frames collected through vision sensors to obtain overall configuration information of damage. In addition, a detection model was established by collecting data sets related to spalling and conducting learning. For quantification of surface damage, the system was established to calculate the ratio between pixels and mm units by using a structured light consisting of a vision sensor and two lasers. In future studies, a more systematic and verifiable experimentation will be carried out and a system will be established to quantify the area of the spalling.

## ACKNOWLEDGEMENTS

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