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Automated Inspection of Structures using High-resolution Imaging System and Deep Learning Model

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ABSTRACT

In this study, a high-resolution imaging system and a deep learning model were developed to automatically inspect the exterior of large structures such as bridges. The imaging system was designed to automatically capture an image optimized for the input of a deep learning model. The deep learning model analyzes the captured image and automatically finds the information of damage, such as cracks, efflorescence, spalling, and rebar exposure. The imaging system consists of a DSLR camera equipped with a telescopic lens to detect even the smallest crack width (0.1mm) of the structure, translating and rotating motors to control the position and angle of the camera to capture the images with appropriate overlapping required for image stitching, a laser displacement meter to record the imaging distance, and a frame with a controller. The images of the entire structure using the above hardware are automatically stitched using commercial stitching software. The stitched image is input to the Cascade Mask R-CNN model trained using the images containing damages, and the location and size of the cracks, efflorescence, spalling, and rebar exposure are displayed as the result. The developed system was implemented for the inspection of highway bridges, and the results were compared with the results of labor-based inspection to show performance of the developed system.

1. INTRODUCTION

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Recently, in many developed countries, the demand for technology to efficiently manage old bridges has emerged. Concrete structures need careful management after 30 years of public use. In the United States, where full-scale social overhead capital (SOC) structures were constructed from the economic growth period of the 1920s and the postwar 1950s, more than 20% of structures have entered old aged stage since 1960s. In South Korea, there are up to 270,000 structures that requires regular inspection annually. However, the budget and number of inspectors are decreasing gradually. Considering this social background, it is urgent to develop equipment and systems to efficiently manage the growing old structure.

In order to develop an efficient and rapid structure inspection system, it is necessary to develop equipment capable of automatically photographing the structure surface and technology capable of detecting damage in the captured image. One of the examples using image capturing system and image processing is a damage detection system using an unmanned aerial vehicle. For example, Kim et al. (2017) succeeded in detecting cracks narrower than 0.1mm in concrete walls using UAV. Currently, structural damage detection systems using UAVs have shown high accuracy at laboratory level or in small area of structures. However, since most of UAV batteries last only for 20-30 minutes, it is unpractical to use UAVs for real structure inspection. In addition, blur appearing in images due to the shaking of an UAV decreases the detection accuracy of relatively small damages such as cracks.

In order to overcome the limitations of recent structure damage detection researches using UAVs, this study proposes a novel damage detection system using imaging equipment that can easily shoot high-rise structures using telephoto lenses while installed on the ground. This system is composed of imaging equipment with telephoto lens and DSLR and damage detection using state-of-the-art deep learning model. In this paper, we describe the damage detection framework using the proposed equipment and deep learning model and introduce the real structure damage detection case using this system.

2. PROPOSED STRUCTURE DAMAGE DETECTION FRAMEWORK

The damage detection framework proposed in this paper consists of four steps, as shown in Fig. 1. The proposed inspection scenario is composed of four steps as explained below. First, acquire images from structure surfaces using the automated image capturing device developed in this study. Second, merge the captured images to display entire surface of a structure element with one image. Third, detect concrete damages using a deep learning model trained for multiple concrete damage detection. Fourth, convert the concrete damage detection results into a form of inspection report.

The automated image capturing device in this paper consists of a distance sensor for measuring the distance between the camera and the structure, a displacement sensor for measuring the absolute position of linear transfer part, and an angle sensor for measuring the absolute angle of rotation part as shown in Fig. 2. The linear transfer part moves the installed camera in the vertical and horizontal directions, and the rotation part rotates the camera vertically and horizontally, so that the camera can capture images of the various types of concrete structures such as bridges, tunnels or buildings.

The captured images are matched to one image using a commercial image stitching program. In this study, the bridge surface images were merged into one image using Photoshop's image stitching module.

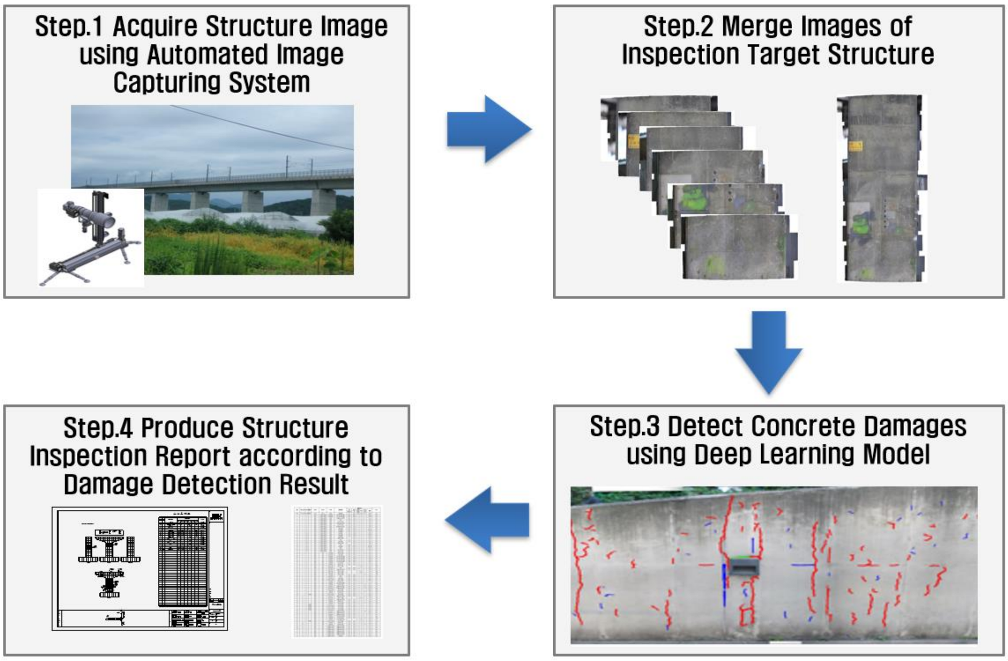
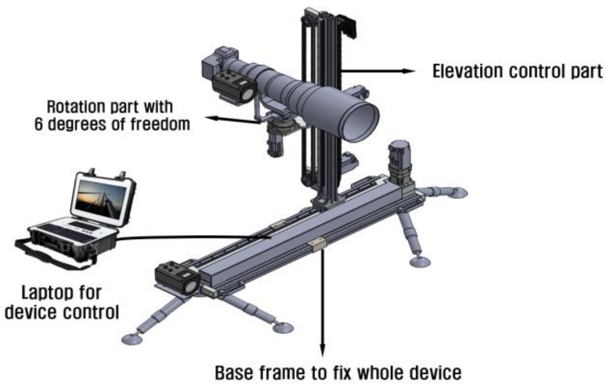


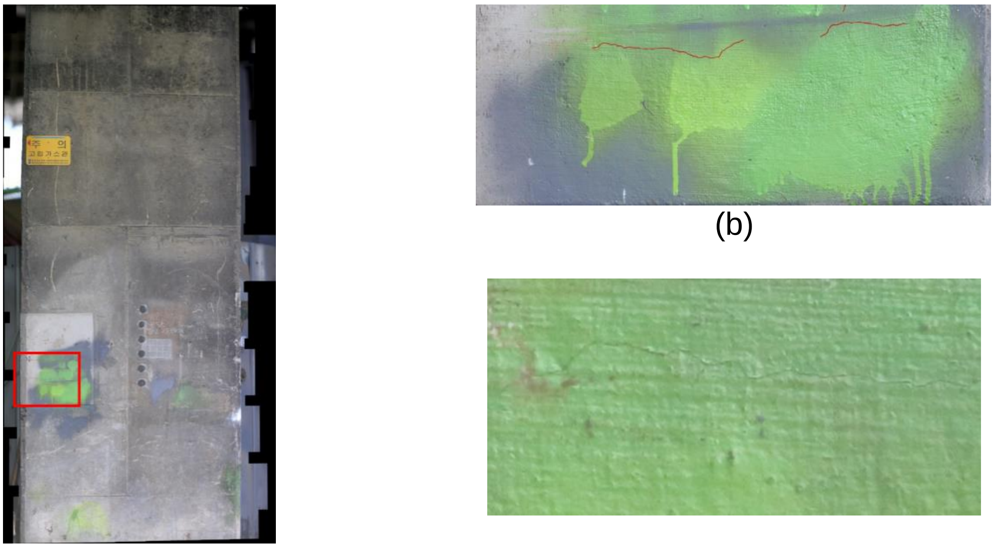
Fig. 1. Overall Concrete Damage Detection Framework using an Automated Image Capturing Device and Deep Learning Model.



(a)

(b)

Fig. 2. Automated Image Capturing Device: (a) Concept Drawing and (b) Image of the device in use.



(a) (b) (c)

Fig. 3. Example of Damage Detection using the Proposed System in a Real Structure: (a) Bridge Pier Image, (b) Concrete Damage Detection Result (Red area denotes crack area) and (c) Image of the area with crack detection

The proposed damage detection system is applied to a real structure located in Guro-gu, Seoul, South Korea. A total of 80 high-resolution images were acquired using the automated image capturing system, and the acquired images were merged into one image as shown in Fig. 3(a) using the image merging module of Photoshop. In the merged image, concrete damage detection is conducted using a deep learning model trained for concrete damage detection. The concrete damage detection model is Cascade Mask R-CNN (Cai et al., 2019) that are trained with 1500 crack images captured from concrete bridges. The trained model successfully detected 0.1mm wide crack on the concrete pier.

3. CONCLUSIONS

This paper proposed a robust concrete damage detection framework using an automated image capturing system and a state-of-the-art deep learning model, Cascade Mask R-CNN. The proposed Framework is used to conduct bridge pier inspection and succeeded to detect 0.1mm wide crack.

REFERENCES

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