The 2018 Structures Congress (Structures18)
Songdo Convensia, Incheon, Korea, August 27 - 31, 2018

Study on Image Quality Assessment and Processing, Damage Diagnosis of Crack for Bridge Inspection based on Unmanned Aerial Vehicle

*Jin-Hwan Lee[1] , Sung-Sik Yoon[1], In-Ho Kim[2] and Hyung-Jo Jung[3]

[1], [2], [3] *Department of Civil and Environmental Engineering, KAIST, Daejeon 34141, Korea*
[1] *archi_tensai@kaist.ac.kr*
[3] *hjung@kaist.ac.kr*

ABSTRACT

The Identification and diagnosis of crack is one of the most important evaluation factors for the old bridge inspection and causes the destruction, deformation and collapse of bridges. Although general bridge diagnosis is performed through visual inspection by the inspector, there is a problem that the reliability of the result is lowered and the inspector is threatened. Unlike the conventional method, the crack detection method using Unmanned Aerial Vehicle (UAV) not only increases the accessibility of the inspection area, but also has an advantage that the reliability of the inspection result is very high. However, the quality of the images taken using the UAV is very unstable, and it is necessary to presuppose that a very high quality image and a proper Field of View (FOV) should be secured in order to quantify the width of the cracks as desired. Therefore, in this study, we propose a method of evaluating and improving the quality of images acquired by using imaging device mounted on UAV, and propose the algorithms for searching crack region and for quantifying width of crack based deep learning. The goal of study is to diagnose actual bridges and to detect the width of crack in 0.3-mm unit.

1. INTRODUCTION

In recent years, studies and examples of using UAVs to conduct inspection of bridge structures have increased. The bridge inspection method by using UAV is widely known to show efficient performance in various aspects than the existing methods. In particular, as the area of inspection is increased due to long span bridges, it is considered to be an alternative method to overcome the limitations of the existing visual inspection method, and various researchers and organizations have been studying the

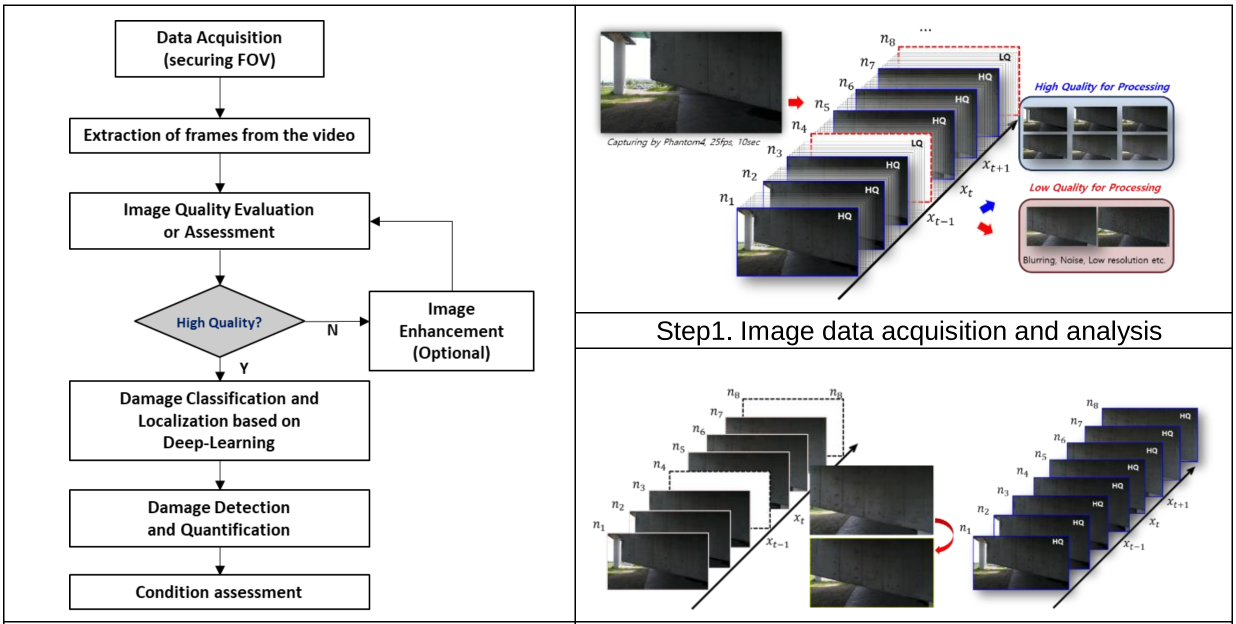
---

[1] Ph.D. Student
[2] Postdoctoral Researcher
[3] Professor

inspection technology of bridges using UAVs. As a representative example, Oregon and Minnesota DOT in the United States conducted an inspection on the aged bridges using UAV and identified the damage of bridges through images of various types of damage such as cracks, bolt damage, efflorescence of concrete and rust on steel (Lovelace and Wells 2017). The UAV equipped with CCD and IR vision sensors were able to capture various members and also detect damage to members that are difficult to access. However, many UAV-based bridge inspection methods, including the above case, still have issues to overcome in terms of technology and application. In particular, the procedures for bridge inspection methods have not been established and most cases are at the level of demonstration or pilot application. Therefore, in this study, we will summarize the bridge inspection procedure using UAV, and propose the application technique for each step and perform technical verification through field experiment.

2. PROPOSED METHODOLOGY

The goal of this study is to propose a scenario for checking a bridge inspection, perform each step of applying technical methods and verification. The following figure shows the proposed methods in this study. It consists of 4 steps, and the details are described below in figure 1. First, the selection of the target bridge and the appropriate FOV are secured and a step of extracting multiple frames from the video file is performed. Next, the measure of quality assessment to each extracted unit frame is used to determine whether or not the level to be passed to the next step is satisfied. If the quality level is low or blurring at this stage, it is solved by improving the image. Because of the large inspection area and the large size of the extracted image, a detection method based on deep learning is applied for efficient detection of cracks. Then, a quantification algorithm can be selectively applied to the detected region to identify the crack as 0.3-mm unit.



Step1. Image data acquisition and analysis

Proposed overall procedures of inspection

Step2. Image quality assessment

Fig1. Outline of the proposed methodologies

2.1 Data Acquisition

In order to inspect the bridge using the UAV, the FOV size within the Region of Interest(ROI) must be secured considering the distances from the target structure, the size of the image sensor, and the focal length of the lens. The data is stored as a video file, and a step of extracting an image frames in accordance with conditions is performed. The table below shows the change in FOV size based on a 2.5m separation distance when a 4K camcorder (Sony AX-700) is mounted on UAV system.

Sony AX-700			
Sensor size	*CMOS 35.6 x 23.8mm*		
Separation distance	*2.5m*		
Focal length	*24mm*	*35mm*	*50mm*
Pixel resolution	*0.30mm*	*0.20mm*	*0.15mm*
Field of View	*1,152 x 648mm*	*768 x 432mm*	*576 x 324mm*

2.2 Image Quality Assessment and Enhancement

Acquisition of images through the UAV is exposed to the risk of wind, vibration, and blurring. Therefore, it is necessary to evaluate whether the acquired image is suitable for applying the crack detection algorithm. In this study, it was evaluated as the value for gray intensity.

$$G(Horizontal, Vertical) = \frac{\sqrt{\left(G(i,j)-G(i,j+1)\right)^2+\left(G(i,j)-G(i+1,j)\right)^2}}{\sqrt{Image\ size^2}} \quad (1)$$

The quality of the frame is classified into high quality and low quality frame based on the value calculated through the above measure. In this process, we applied the enhancement algorithm to improve the image quality when it is judged that it is a low quality frame. In the case of UAV imaging, blurring often occurs on the data due to the influence of the motion blur of the drone. Therefore, we applied the de-blurring method of kernel estimation at this stage.

2.3 Damage Detection using R-CNN

Regions with Convolutional Neural Networks (R-CNN) which shows good performance of object detection in order to confirm not only classification but also position of crack. Therefore, in this study, R-CNN based crack detection algorithm is applied to evaluated frames. Input layer is 50,000 image with 32 x 32 x 3 pixel resolution and convolution layer has 32 filters with 5 x 5 size of kernel. Transfer learning method was used to perform cropping and labeling based 348 pieces of crack images because of insufficient dataset, and bounding box regression was performed for each region proposal feature.

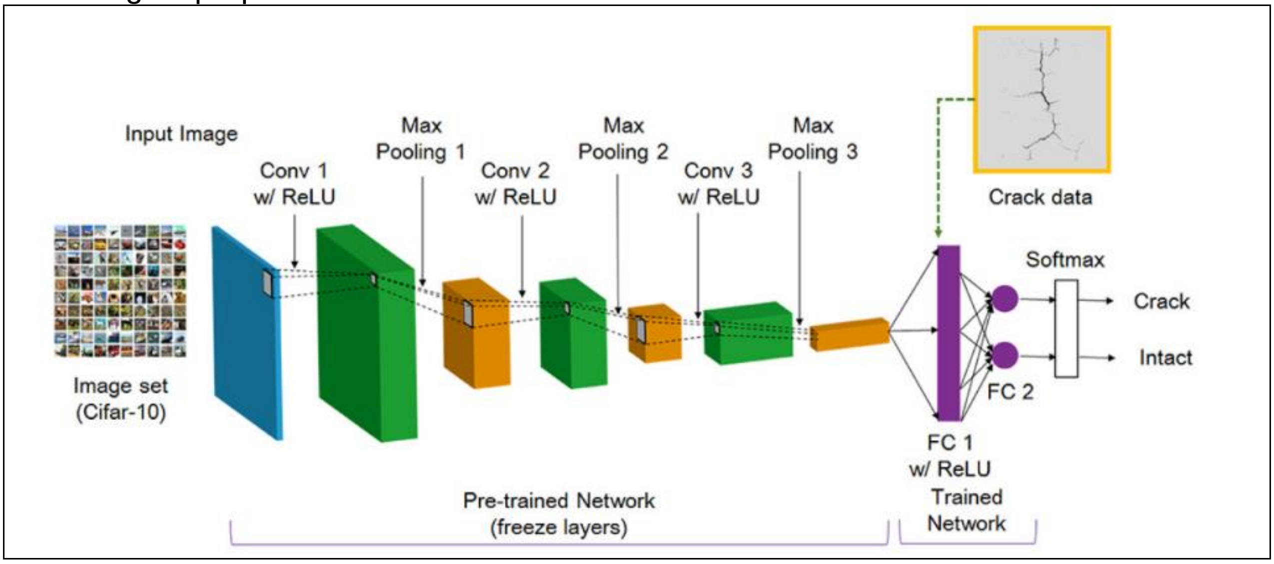


Fig 2. Schematic of the deep learning architecture and information of each layer (Kim et al. 2018).

2.4 Damage Quantification

A crack quantification step using Image Processing Techniques(IPTs) is performed on a crack image stored in box form through R-CNN. The crack quantification algorithm is based on morphological processing and proceeds through 7 steps (Lee et al. 2018), gray scale conversion, binary conversion and elimination of noise on images. Finally, the size of the crack can be quantified by using size of FOV and the pixel resolution.

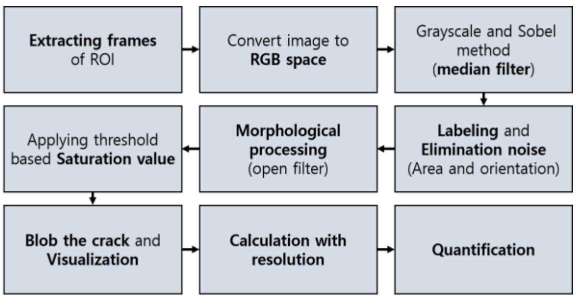


Fig. 3 Overall architecture of detection algorithm

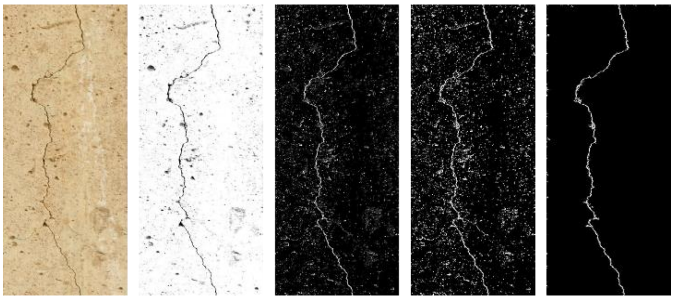


Fig. 4 Example of applying IPTs

3. VALIDATION (FIELD TEST)

The verification of the proposed method was performed by using UAV equipped with video equipment for actual bridges. The target bridge is a combined type with PSCB and STB, which has a span length of 50 m and height of 10 m. The ROI is set as the side of the pier. The target bridge was inspected according to the proposed scenarios and the data obtained through shooting were saved in each frame as a total of 6,000 images. Among them, only 103 frames that can cover ROI were extracted and image quality assessment was performed. The 7 frames of a 103 frames were determined as low-quality frames, so we applied the de-blurring algorithm to enhance the quality. Figure 6 shows the results.

Fig. 5 Details of target structure and setup of UAVs

Fig. 6 Data acquisition and Quality assessment

After evaluating the image, the low-quality frames are selected and improved and stored in box form as shown in figures 7(a) and 7(b) through R-CNN based detection and classification.

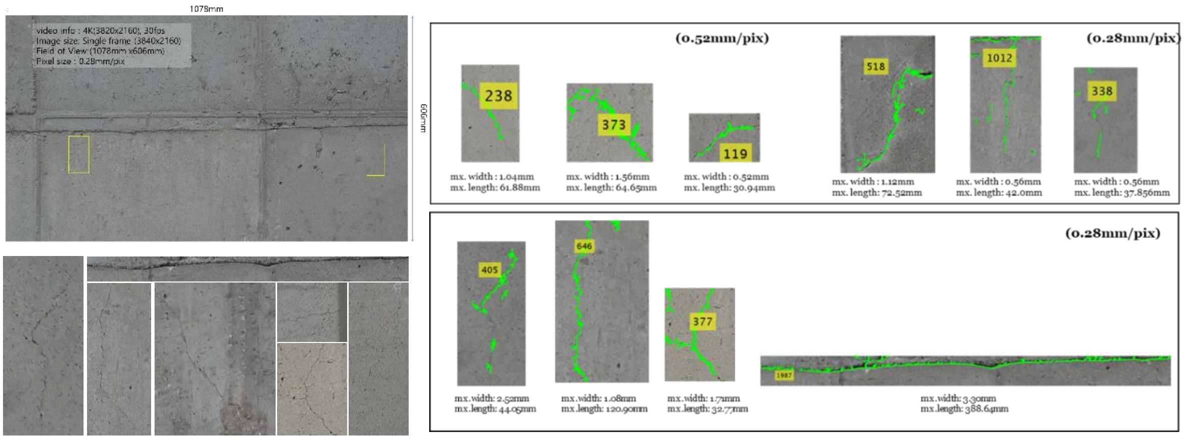


Fig. 7 (a) Detection based R-CNN, (b) Stored images of cracks, (c) Results of quantification

The crack width and length were calculated under the condition that the resolution of 0.28 mm/pix was satisfied as shown in figure 7(c).

4. CONCLUSION

In this paper, we have developed and applied element technology for a series of inspection scenarios including image acquisition, processing and crack detection using UAVs. The algorithm was verified through field experiments, and the inspection scenarios were checked. As a result, crack width detection of 300 micrometers was validated. In the future, we will study not only crack, but also application of technology to various types of damage. Furthermore, if a system of bridge condition evaluation system using UAVs is established through active related research, fully automated and unmanned bridge inspection will be performed.

ACKNOWLEDGEMNET

This research was supported by Construction Technology Research Program funded by Ministry of Land, Infrastructure and Transport (MOLIT) of Korean government, grant number 18SCIP-C1167873-03.

REFERENCES

Lovelace, B. and Wells, J. (2017), “Unmanned Aircraft System Bridge Inspection Demonstration Project Phase 2”, Minnesota Department of Transportation Research Services & Library, Project report.

Kim, I.H., Jeon, H.M., Baek, S.C., Hong, W.H. and Jung, H.J. (2018), "Application of Crack Identification Techniques for an Aging Concrete Bridge Inspection Using an Unmanned Aerial Vehicle", Sensors, 18(6), 1881.

Lee, J.H., Yoon, S.S., Kim, I.H. and Jung, H.J. (2018), “Diagnosis of crack damage on structures based on image processing techniques and R-CNN using unmanned aerial vehicle(UAV)”, Proc. SPIE 10598, Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems.