The 2022 World Congress on
Advances in Civil, Environmental, & Materials Research (ACEM22)
16-19, August, 2022, GECE, Seoul, Korea

Crack Quantification Method for Concrete Tunnels with RGB-D

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ABSTRACT

For the convenience of transportation and life, concrete tunnels are used for various purposes. Specifically, concrete structures of infrastructure, such as road tunnels and utilities, deteriorate over time, necessitating accurate and efficient management. To this end, research is being conducted on systems or methodologies utilizing computer vision, sensor networks, etc., that are distinct from the existing human resource-based methods. In particular, with the advance in computer vision-based technology, research is being actively conducted to accurately detect cracks, leaks, and damage, which are deterioration factors of tunnel structures. Among those factors, cracks can be used more easily for deep learning-based research since crack data created in roads, bridges, and tunnels are shared relatively more than other degradation factors data.

However, in order to apply the developed technology to the tunnel and enable efficient management, it is essential to derive quantitative results such as crack length and width based on the detected results. Therefore, in this study, in light of the tunnel's spatial characteristics, a segmentation-based measurement method with RGB-D cameras is proposed and analyzed. The results of this study are expected to be used as a baseline for the development of crack quantification methods in the tunnel condition evaluation system in the future.

1. INTRODUCTION

Concrete tunnels are used for various purposes in the form of road tunnels, utility tunnels, and underground spaces, which play a major role in improving the convenience of transportation and living (Song *et al.* 2022). However, because of the material properties of concrete, the structure deteriorates over time. In particular, concrete structures of infrastructure such as road tunnels and utility require accurate and efficient

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management, as inadequate management of the deterioration that happens over time can result in catastrophic catastrophes. In Korea, periodic safety inspections are conducted on facilities such as tunnels and utility tunnels for this reason. It monitors and evaluates several factors connected to the structure's deterioration, including cracks, water leakage, fracture, carbonation etc. The majority of these metrics are measured and assessed using manpower-based techniques.

In an effort to automate processes, research is being performed on methods utilizing computer vision and sensor networks that differ from existing methods relying on human resources (Munawar *et al.* 2021). In particular, as computer vision-based technology advances, intensive research is being performed for the accurate detection and evaluation of tunnel deterioration factors such as cracks, leaks, and damage. Among them, crack image data created in roads, bridges, and tunnels is particularly vast compared to other deterioration elements, so it can be utilized for deep learning-based study more readily. However, since the method using computer vision has a limitation in that it derives results in units of pixels, additional information to calculate actual values is required.

Therefore, in this study, a segmentation-based measurement method using RGB-D camera was proposed considering the applicability of the tunnel. And the limitations and necessary research directions were additionally presented by analyzing the proposed method.

2. CRACK QUANTIFICATION

2.1 Quantification process

In order to apply the developed technology to the tunnel and to enable efficient management, it is essential to derive quantitative results such as crack length and width based on the detected results (Fig. 1). Using the acquired image of the tunnel's surface, cracks are found using a segmentation algorithm, and their width in pixels can be determined using an image processing technique. It is important to compute the size of a pixel in order to determine the width of the measured value.

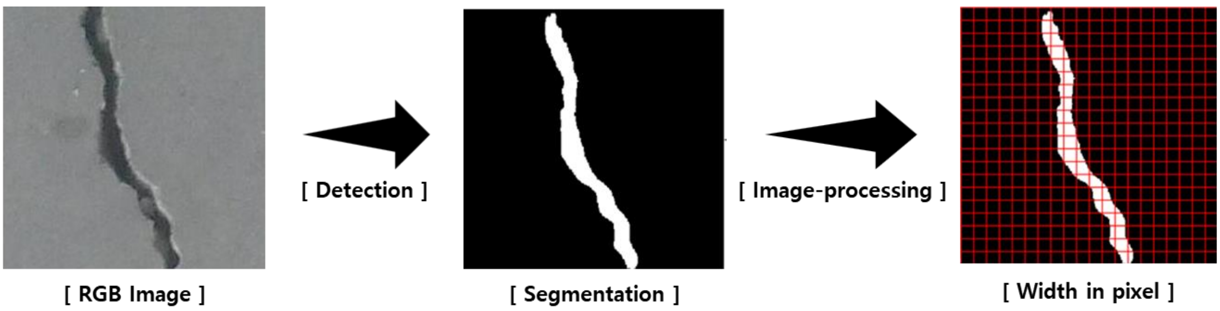


Fig. 1 Overview of crack quantification

There are several ways to calculate the size of a pixel. Using the working distance and the camera's resolution, the size of a pixel may be calculated (Kim *et al.* 2018; Dang *et al.* 2022). However, if the image is not taken accurately from the front, a large error occurs, and since the size of the crack occupies a very small part of the acquired image, there is a limit that it can be greatly affected by the error. Another way is to use a reference instrument that can calculate the size of one pixel. This has the advantage of reducing the error of one-pixel size, but its applicability is limited. In this study, in order to address the limitations of these two approaches, we suggest a method for crack quantification that is less impacted by shooting conditions and does not require the installation of additional equipment, such as a reference measuring instrument, by employing an RGB-D camera.

2.2 Crack quantification with RGB-D

The camera used in this study is a combination of an infrared camera and an RGB camera (Fig. 2). The resolution of the RGB image is 1920 × 1080, and the resolution of the depth map derived through the infrared camera is 1280 × 720.

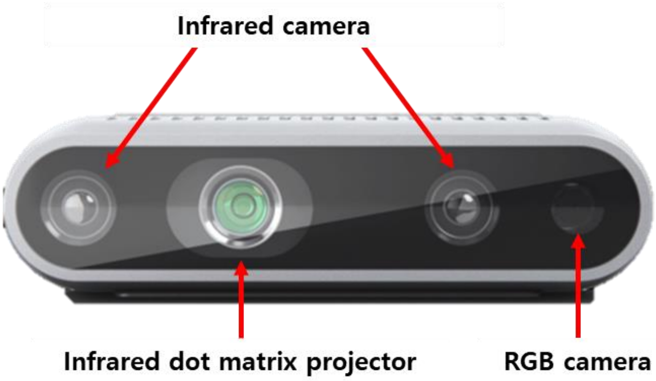


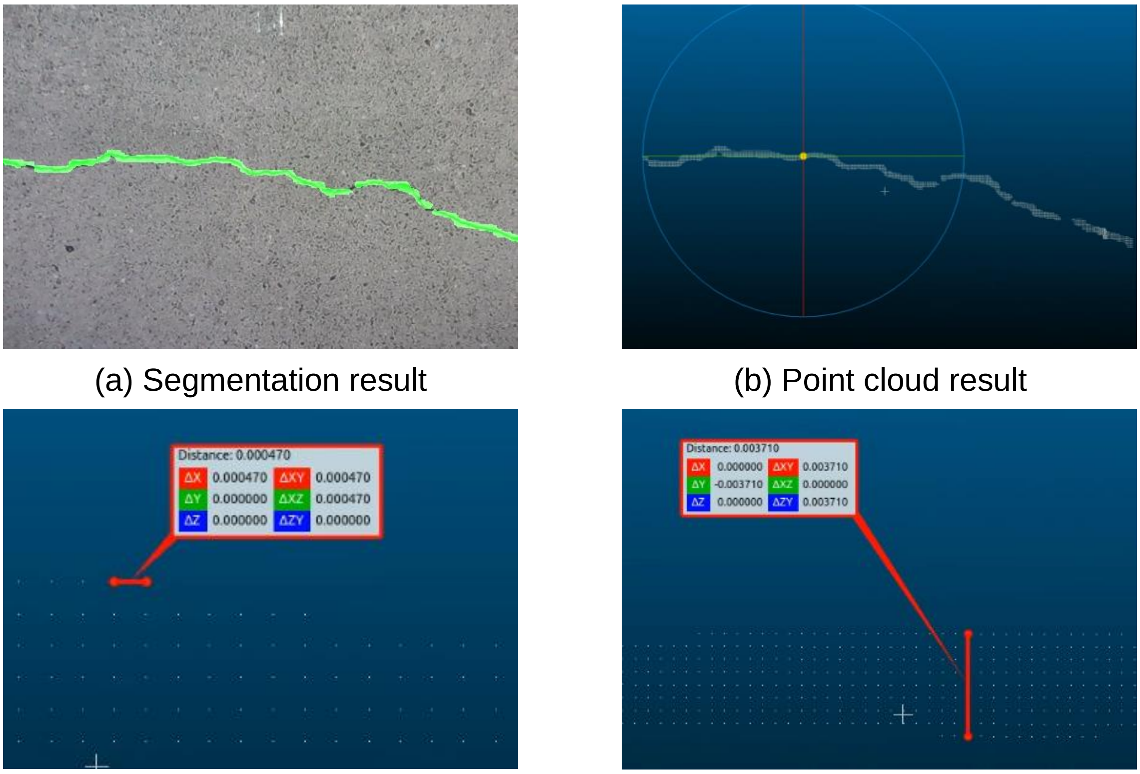
Fig. 2 RGB-D camera (Intel® RealSense™ Depth Camera D435i)

Crack detection and quantification are performed based on RGB images. Similar to the original segmentation approach, crack detection on RGB images is conducted. Similarly, for the depth map, only the numerical value for the crack portion is retained, while the remainder is deleted. The (x, y, z) coordinates of each point are obtained as a point cloud for the crack portion.

3. RESULTS AND DISCUSSIONS

The crack detection and point cloud results are shown in Fig. 3. The algorithm used for crack detection in this study is CGNet (Wu *et al.* 2020). The visualization of the point cloud utilized a program known as Cloudcompare (Girardeau-Montaut 2016). From this, it can be seen that the coordinates can be derived for the cracked part without additional equipment.

However, when evaluated at a working distance of 40 cm, the size of one pixel is approximately 0.4 mm, which is relatively large compared to the highest standard for safety diagnosis of 0.1 millimeters. In addition, the working distance of 40 cm is too short to cover a wide tunnel area, so it is necessary to secure a small pixel size even at a greater distance.



(a) Segmentation result (b) Point cloud result

(c) Pixel size (d) Width of crack

Fig. 3 Crack quantification results

4. CONCLUSIONS

In summary, in order to automate crack evaluation in underground structures such as tunnels and utilities, it is necessary to define a method for quantifying cracks beyond crack detection. Depending on the shooting conditions, the RGB image changes drastically, which has a significant effect on the measuring results. In addition, the tunnel is lengthy, and investigation must be performed over a broad range. Therefore, in this study, a method for quantifying cracks was presented that overcomes the sensitivity problem to shooting conditions and considers tunnel properties. The quantification results were inspected for actual cracks, and the limitations that need to be overcome for future automation were confirmed.

ACKNOWLEDGEMENT

This work is supported by "Ministry of the Interior and Safety" R&D program (20018374). And this work is financially supported by Korea Ministry of Land, Infrastructure and Transport (MOLIT) as「Innovative Talent Education Program for Smart City」.

REFERENCES

Dang, L.M., Wang, H., Li, Y., Park, Y., Oh, C., Nguyen, T.N., and Moon, H. (2022), "Automatic tunnel lining crack evaluation and measurement using deep learning", *Tunnelling and Underground Space Technology*, **124,** 104472.

Girardeau-Montaut, D. (2016), "CloudCompare", *France: EDF R&D Telecom ParisTech*, **11,**

Kim, I., and Lee, C. (2018), "Development of video shooting system and technique enabling detection of micro cracks in the tunnel lining while driving", *Journal of the Korean Society of Hazard Mitigation*, **18,** 217-229.

Munawar, H.S., Hammad, A.W., Haddad, A., Soares, C.A.P., and Waller, S.T. (2021), "Image-based crack detection methods: A review", *Infrastructures*, **6,** 115.

Song, L., Sun, H., Liu, J., Yu, Z., and Cui, C. (2022), "Automatic segmentation and quantification of global cracks in concrete structures based on deep learning", *Measurement*, 111550.

Wu, T., Tang, S., Zhang, R., Cao, J., and Zhang, Y. (2020), "Cgnet: A light-weight context guided network for semantic segmentation", *IEEE Transactions on Image Processing*, **30,** 1169-1179.