A Drone-Based Concrete Crack Inspection System by Using Morphological Component Analysis and Sub-Pixel Width Estimation

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Abstract

Social infrastructure inspections were relying on human experts, and then a recent topic is a possible implementation to realize an automated inspection based on machines and sophisticated software algorithms. We have studied an advancement of Morphological Component Analysis (MCA) to apply the concrete-crack position estimation especially for submillimeter-width cracks, which are highly difficult for traditional methods to detect finely. We demonstrated a concrete crack detection from images obtained from proximity cameras attached a specialized multi-copter, by using the MCA-based crack position estimation and the linear regression-based sub-pixel width estimation. It will contribute to the actual field work not only for the concrete crack detection but also various social infrastructure inspections.

Keywords Morphological Component Analysis (MCA), multicopter, concrete crack detection, sub-pixel estimation

1. Introduction

In the consideration of the sustainable society, the social infrastructure maintenance is highly important issue, such an early-stage detection of cracks in the concreate buildings[1][2][3][4][5]. Traditionally, human experts have been devoted to careful inspections; however, the inspection work in high places has a certain risk on accidents and the height safety for human workers requires special cares and huge costs. Therefore, a recent trend is to provide an automated and remote detection of flying systems, known as a drone. In the national research project in Japan, called “SIP Infrastructure Regional Implementation Support Teams: Promoting Innovation in Regional Infrastructure Maintenance,” innovative inspection systems were developed in a competitive style of teams organized by academic-industrial partnerships [6]. We have contributed to the project in a team of the project as a part of academic advancement [7], by using Morphological Component Analysis (MCA) [8] for the concrete-crack detection and position estimation, particularly for submillimeter-width cracks, which are highly difficult for traditional methods. We demonstrated not only a concrete crack detection from images obtained from proximity cameras attached a specialized multi-copter, but also the length and width estimation, which is crucial for the completion of the inspection report associated with a database to record a secular change. In this study, the sub-pixel estimation method for lengths and widths of concrete cracks was proposed to adapt to the direction of extension of cracks even they were wandering.

The remainder of this paper is organized as follows. After giving brief introduction of our work in section 1, in section 2, the hardware and software systems were explained as the overview of the inspection procedure from the image acquisition to an inspection report. In section 3, the proposed method was described and in section 4 experimental results were described, which is followed by conclusion in section 5.

2. Inspection System Design Using a Multicopter

2.1. *Hardware design*

In this study, we used a multicopter, or simply drone, with high proximity camera as shown in Figure 1. The video image can be clearly obtained with the same distance *L* between the camera and the concrete surface.

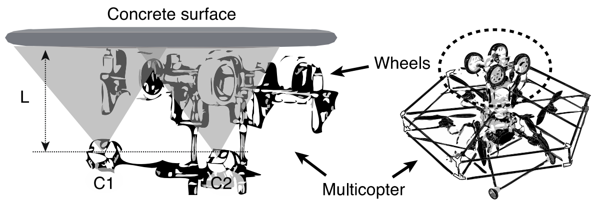


Fig. 1. The multicopter inspection system with wheels to keep the same distance *L* between cameras (*C1* and *C2*) and the monitoring surface (illustrated as a redraw version from [7]).

2.2. *Software design*

As illustrated on Figure 2, acquired images in the form of videos is converted to split images as snapshots of the target concrete surface. Large (more than 1mm width; Fig. 3 (a)), middle (about 1mm width) and minor cracks (less than 1 mm width; Fig. 3 (b)) were detected by using multiple methods with image morphology (IM), anisotropic diffusion filter (AD) and MCA methods as Dixit and Wagatsuma reported [9][10]. After the estimation of crack positions, an accurate gauging is necessary for making a fine inspection report as well as reports provided by human experts.

In this study, we focused on the possible method for the sub-pixel estimation method for lengths and widths of concrete cracks. The problem is that most of cracks are not simply extending straightforward and those extend in a zig-zag manner, which prevent an appropriate measurement.

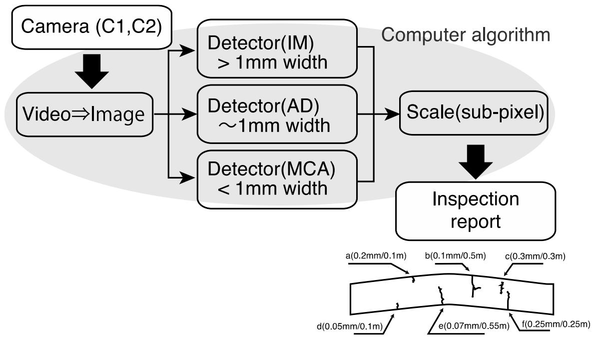
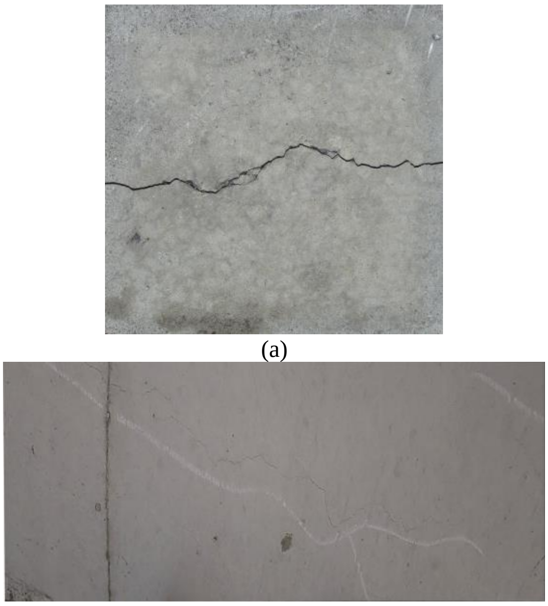


Fig. 2. The whole workflow of the information processing from the image data acquisition to the inspection report.



(a)

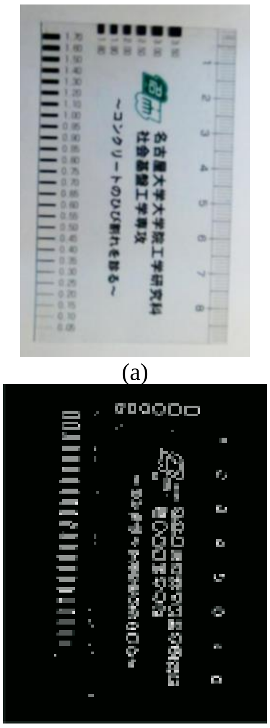
(b)

Fig. 3. Example of concrete cracks. (a) >1mm width and (b) <1mm width.

3. Proposed Method

In the consideration of the crack-width estimation, which is traditionally performed by the human expert with the crack gauge (Fig. 4(a)), an edge detection is necessary to estimate the gap of normal regions to represent a crack and then a tangential section is required for an appropriate estimation of the width as illustrated in Figure 5. According to those requirements, the sub-pixel estimation method was proposed as a procedure with steps:

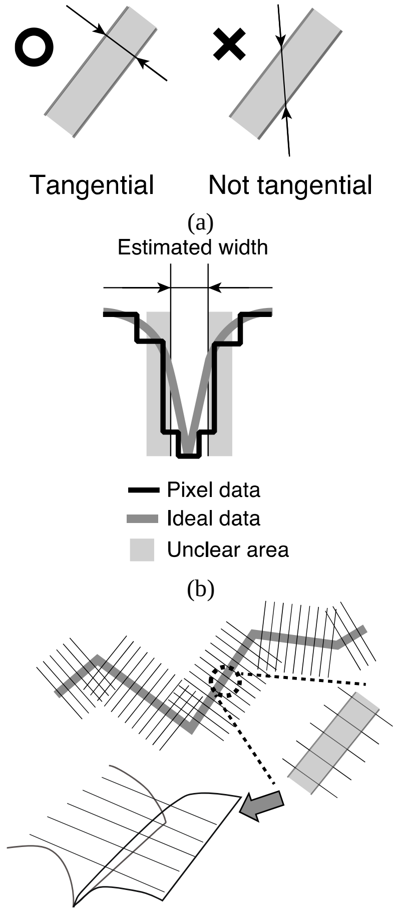
1) Extract a pre-straight line as target
2) Estimate the tangential angle against the target line (Fig. 5 (a))
3) Provide a curve fit, which trace the discrete stair-like color difference due to pixel-based representation in the image (Fig. 5 (b) as the ideal data)
4) Obtain a transition point in the fitted curve, which represents the crack in the form of the negative valley of the brightness of the color (Fig. 5 (b) as the estimated width)
5) Plot the width and length of the crack at the position of the detected crack for making an appropriate inspection report (Fig. 5 (c))



(a)

(b)

Fig. 4. The traditional crack gauge and a processed result by using AD filter described in Fig. 2 [9][10].

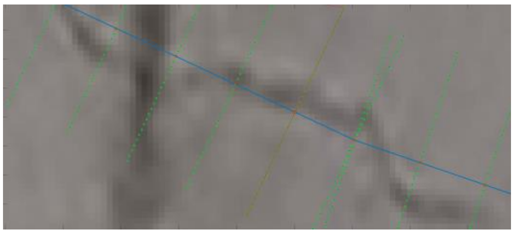


(a)

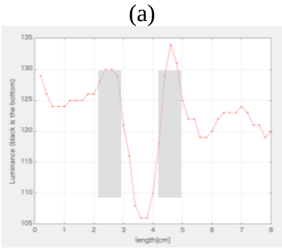
(b)

(c)

Fig. 5. The proposed sub-pixel width estimation method for an appropriate measurement.



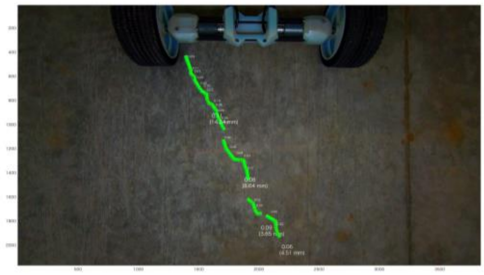
(a)



(b)

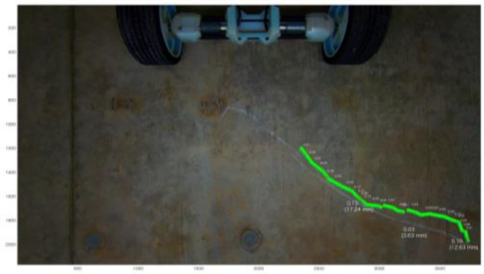
Fig. 6. An example of the tangential section of the target crack to estimate the width of the crack.

(a)



(b)

(c)



(d)

(e)

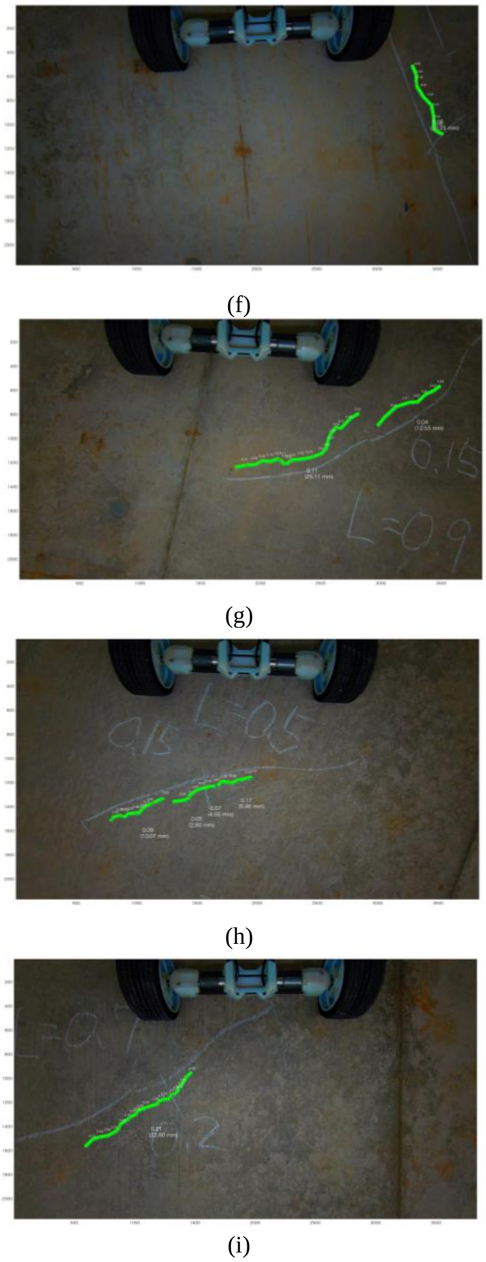


Fig. 7. Estimated widths and lengths of cracks superimposed on target images. The human measurement was described by chalk lines.

4. Results

The proposed method was applied to the real environment data that collected by the specialized multicopter [7]. After the crack detection (Fig. 2; Detectors), the gauging of the width and length was done successfully. The evaluation was verified with the human expert data provided by Shin-Nippon Nondestructive Inspection Co., Ltd. The numerical analysis and visualization were derived from the programming code with MATLAB. Fig. 7 showed the results.

5. Conclusion

We demonstrated the length and width estimation of concrete cracks by proposing the sub-pixel estimation method to adapt to the direction of extension of cracks even they were wandering. In further analyses, full automated concrete detection and estimation is expected [11-20].

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