THE GPS CAMERA APPLICATION FOR THE EFFICIENCY IMPROVEMENT OF THE BRIDGE INSPECTION

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ABSTRACT

In this paper, we focus on the periodical data acquisition using GPS camera and stereo camera for bridge maintenance. Firstly, we took up some elements to take same photos. Additionally, we took photos under those elements and evaluated those photos. From experimental results, we have confirmed that we can take photos from same positions using GPS camera at the previous inspections. Secondary, we had already been able to acquire 3D data corresponding to close visual inspection. Therefore, we verified whether can accurately extract the cracks in 3D measurement at far position. As a results, we have defined condition constrains in a stereo measurement to acquire an accurate 3D data in periodical data acquisition. Finally, we have mentioned that our proposed methodology can evaluate a progress of bridge structure deterioration using photos.

Keywords: Bridge inspection, Visual inspection, Position data, GPS camera, Stereo camera.

1. INTRODUCTION

Recorded sketches and photos indicate significant data to understand a progress of structure deterioration in maintenance working of bridge. Moreover, a deterioration situation can be evaluated using a periodical acquisition of sketches and photos. Additionally, 3D measurement is required to evaluate the periodical acquisition of sketches and photos automatically. In the current state, the sketches and photos are acquired in a visual inspection. However, these records have no precise location data and geometrical information in a general maintenance working. Thus, an evaluation of deterioration progress is difficult to be conducted efficiently. Therefore, we propose an approach using GPS camera and stereo camera to improve efficiency in visual inspection for structure maintenance. Firstly, we propose some elements, technologies and equipments for taking "same photo". Secondary, we also propose an approach using long-range stereo for a crack measurement. We have already developed closed-range stereo to acquire a crack (Kobayashi et al. 2012). Using the long-range stereo can faster inspection work.

2. METHODOLOGY

In the current visual inspection, deteriorated points are recorded in manual, such as a sketch or image acquisition using a digital camera. An approximate position is also recorded in the inspection.

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However, the approximate position is difficult to navigate inspectors to the same position in the next inspection. Currently, studies to obtain the GIS data using GPS camera have been made (Yamamoto et al. 2007). The image acquisition acquired by GPS camera includes the coordinate of latitude and longitude in EXIF data. Therefore, we focused on the bridge inspection utilized this technology. Additionally, an image acquisition approach using GPS camera to conduct an automated location record.

Next, we focus on human errors in a crack measurement. Recently, automated measurements are applied to avoid the human error (Nishimura et al. 2012). However, the crack extraction is not completely automatic. Thus, the system which can extract cracks and draw in semi-automatically have constructed. Therefore, in our approach, we focused on stereo camera can extract crack in completely automatic.

2.1. Image acquisition for bridge inspection using GPS camera

Location, orientation, elevation and focal length are required to take the same image at a position in the previous inspection. Here, we focus on GPS camera as a low-priced sensor to acquire these data. However, multipath problem is remained in position data acquisition at a place surrounded high-rise buildings.

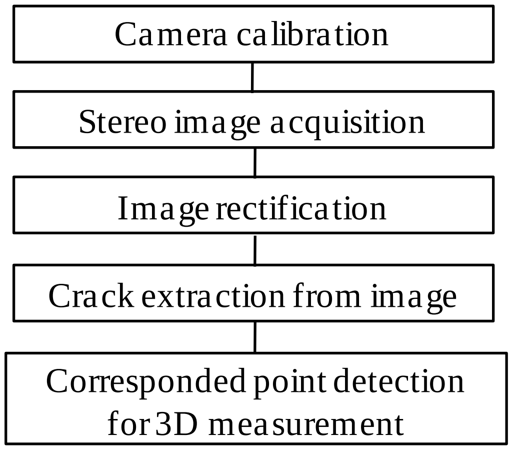

Figure 1: Processing flow for a crack extraction.

2.2. Crack extraction using stereo camera

Our proposed flow is shown in Figure 1. First, a stereo camera is calibrated. Next, stereo images are acquired. Then, stereo images are rectified using calibration parameters. After that, crack was extracted from stereo images. Finally, 3D data are generated using stereo images with corresponded points.

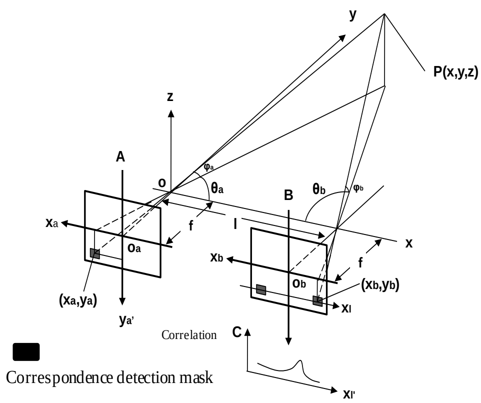

Figure 2: Stereo camera model.

We conducted a stereo measurement using a fixed-baseline stereo camera without known reference points. We applied Zhang's calibration approach to our fixed-baseline stereo (Zhang Z 2000). This approach estimates interior camera parameters using projection transformation parameters into multiple planes. Specifically, we minimize the following Equation (1) to estimate interior parameters ($\mathbf{A}$, k_1, k_2) and external parameters ($\mathbf{R_i}$, $\mathbf{t_i}$).

$$\sum_{i=1}^{n}\sum_{j=1}^{m}||m_{ij}-\breve{m}\left(\mathbf{A},k_1,k_2,\mathbf{R_i},\mathbf{t_i},\mathbf{M_j}\right)||^2 \quad (1).$$

Stereo measurement can obtain 3D position using corresponed points in stereo images, as shown in Figure 2.

3. EXPERIMENTS

3.1. Image acquisition for bridge inspection using GPS camera

In our experiments, we used GPS camera (Casio Exilim EX-H20G), as shown in Table 1. Our experiments consisted of image acquisition and image reference to simulate a daily infrastructure inspection using GPS camera. Firstly, photos are taken to prepare reference data in the image acquisition procedure, as shown in Figure 3. Secondary, navigation using taken photos is examined in the image reference procedure, as shown in Figure 4. Images were acquired at 30 points in three areas (a road level, river level under the bridge and river level around the bridge) around a road bridge across a river. Finally, we evaluated the navigation examination, as shown in Table 2. In the case of Figure 5, the original photo is Figure 6, the photo includes the object (crack) about 80%. Additionally, the photo includes something other than the object about 50%. Therefore, “A relevance ratio” is 2 points and “Something other than the object” is 2 points. As for other items, we scored in a similar way.

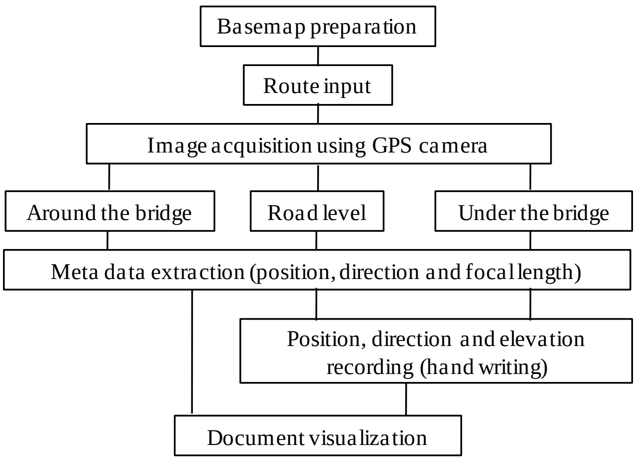

Figure 3: Image acquisition procedure.

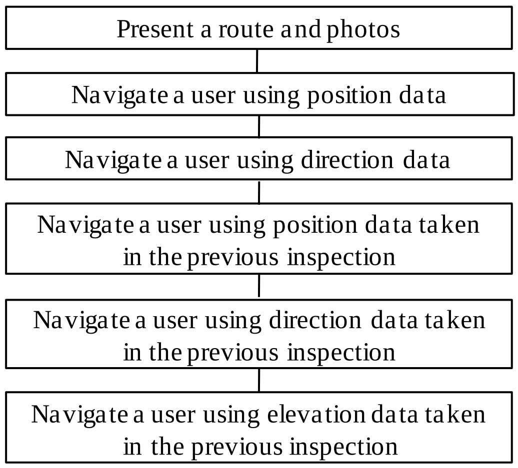

Figure 4: Image reference procedure.

Table 1: Specification of GPS camera

Name	Casio Exilim EX-H20G
Pixel count	14.1 million pixels
Recorded format	JPEG
Positioning accuracy	±10 m
Focal length	4.3～43 mm

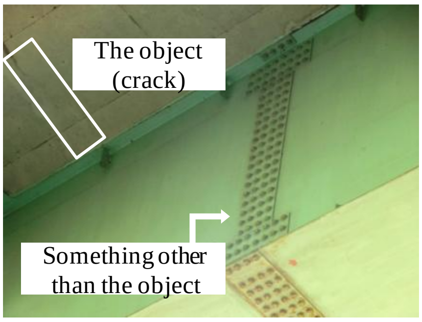

Figure 5: Image Acquisition (Using position data).

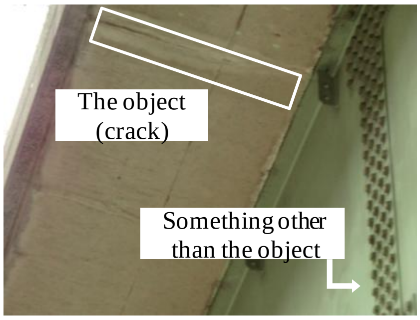

Figure 6: Original image.

Table 2: An example of table style

A relevance ratio	Score [points]
100% (Include the object)	3
50～90% (Include the object)	2
0～50% (Include the object)	1

Something other than the object	Score [points]
0% (Include the others)	3
30～50%(Include the others)	2
50～100%(Include the others)	1

The direction of the object	Score [points]
Equivalent	3
Inverse or left-right reversal	2
Inverse and left-right reversal	1

Brightness	Score [points]
Same	3
Bright or Dark	2
Too bright or dark	1

3.2. Crack extraction using stereo camera

An actual crack inspection requires 0.1mm spatial resolution to recognize a crack. Measurement accuracy is also required less than 0.1 mm. Thus, we assembled our stereo camera system with 0.2 mm spatial resolution. Moreover, we applied subpixel image estimation to improve the spatial resolution virtually. Then, we estimate 3D coordinate values with 0.033 mm accuracy at 5 m distant. Figure 7 shows our experiment environment. The specification of our stereo camera is shown in Table 3.

Table 3: Stereo camera specification

Name	NIKON D300 (two cameras)
Lens	AF-S NIKKOR 200mm
Recorded format	TIFF
Recorded size	2144×1424px

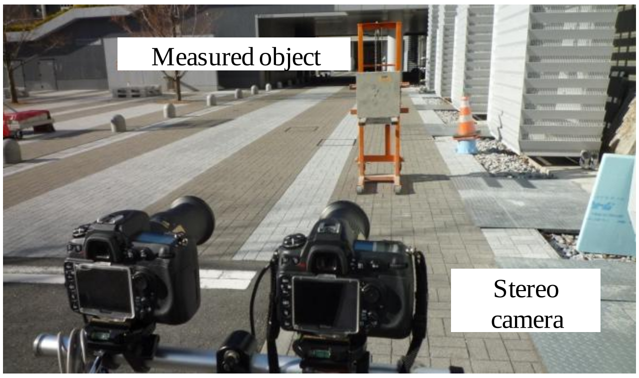

Figure 7: Experiment environment.

4. RESULTS AND DISCUSSION

4.1. Image acquisition for bridge inspection using GPS camera

Based on our definitions, we evaluated the images with location data taken in our experiment, as shown in Table 4. Position data were acquired using GPS receiver mounted on GPS camera well. In the evaluation result of “Around the bridge”, 11 images scored over 10 points. However, location data acquisition was difficult to achieve “the same position detection” with high accuracy under the bridge, because of multipath affects. Therefore, in the “Under the bridge”, there is only 1 images scored over 10 points. From these results, we have clarified that an acquisition of “same photo” is difficult to be conducted using only position data. Therefore, we tried to take photos with reference notes and position data using GPS camera. Taken images evaluated based on our definitions, as shown in Table 5. In the evaluation result of “Under the bridge”, 8 images scored over 10 points. Thereby, we could confirm accuracy enhancement also “Under the bridge” using position data and reference notes.

Table 4: Photos scored over 10 points (GPS camera data)

Around the bridge	Under the bridge	Road level
69% (11/16)	13% (1/8)	63% (5/8)

Table 5: Photos scored over 10 points (image acquisition procedure)

Around the bridge	Under the bridge	Road level
	100% (8/8)	88% (7/8)

From experimental results, we have confirmed that GPS camera has an advantage in a bridge inspection. We can expect that GPS camera can improve efficiency in bridge inspection. However, an inspection using GPS depends on a GPS signal condition and environment. Therefore, we try to avoid these restrictions in the use of GPS camera.

4.2. Crack extraction using stereo camera

Table 6: Stereo measurement results

Baseline length [cm]	Camera arrangement	Measurement accuracy (RMSE) [mm]
16	Parallel	0.116
21	Parallel	0.139
16	Gaze	0.097
21	Gaze	0.099
26	Gaze	0.085
36	Gaze	0.089

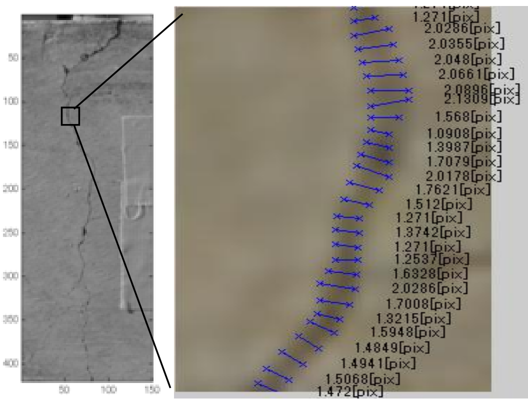

Figure 8: Extracted crack boundaries from image at 5 m distant.

The result of the baseline, direction of camera and measuring accuracy are shown in Table 6. Moreover, we have confirmed that cracks can be extracted at 5m distant (Figure 8). Camera parameter estimation was stable in gazing camera arrangement. However, lens distortion parameter estimation depends on overlapped area in stereo images in our system. Therefore, in parallel camera arrangement, the camera parameter estimation was unstable, because of small overlapped area in stereo images. We can extract a crack with a robust feature tracking approach based on feature extraction from images. Generally, threshold is prepared to detect crack features in manual in conventional approaches. However, our approach can estimate a threshold to detect crack features on concrete surface automatically.

5. CONCLUDION

In this study, we have confirmed a practicality of monitoring using GPS camera and stereo camera for a bridge inspection. Firstly, we have confirmed that GPS camera can refer to a position data taken from GPS receiver to acquire a photo at the same position in the previous inspection. Secondary, we have confirmed that stereo measurement can obtain each crack width. We have also defined condition constrains in the stereo measurement to maintain high accuracy. Through the use of these techniques, we have proposed the approach to evaluate a progress of bridge structure deterioration using photos. Finally, we have clarified that the inspection can be improved more efficient and effective.

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