Examination of Efficiency of Bridge Periodic Inspection Using 3D Data (Point Cloud Data and Images)

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Abstract –

Many of Japan's bridges built during the period of high economic growth are deteriorating and require proper maintenance. However, due to the shortage of specialist in the field of civil engineering as well as the declining birthrate and aging population, the current bridge periodic inspection the proximity visual inspection and the preparation of inspection reports require a lot of work by each inspection engineer. To promote bridge inspection using robots such as UAVs, we have been improving efficiency in on-site inspection and the documentation of inspection results. The current challenges in this effort are the management of a vast number of images, image analysis and damage detection, and the accurate recording of damage locations. In this report, we present the results of the accuracy test of 3D bridge data generated by Structure from Motion (SfM) and explain the management of images using 3D data.

Keywords –

Bridge maintenance; Bridge periodic inspection; Inspection robot(UAV); Structure from Motion(SfM); 3D data(Point cloud data)

1 Introduction

Many Japanese bridges constructed during the period of high economic growth are aging and require proper maintenance. Due to the shortage of specialist in the field of civil engineering as well as the declining birthrate and aging population, realization of more efficient bridge inspection is an urgent issue for proper maintenance of bridges.

Bridge periodic inspections every five years in Japan require a lot of labor, time and cost, and for on-site visual inspection and preparation of inspection reports. MLIT (Ministry of Land, Infrastructure, Transport and Tourism) which manages bridges, has published Guidelines For Using New Technology for the purpose of streamlining bridge inspections, and is actively promoting the use of inspection robots.

In that case, it is necessary to efficiently perform, Managing the tremendous amount of images acquired from robots, Recognizing degradation in image, and Accurate recording of degradation position.

In recent years, UAVs and computer vision have been utilized in various fields of civil engineering.[1] Among these technologies, we focused on SfM, which automatically estimates the shooting position and shooting direction of images shot continuously in 3D space, generates 3D data of the shooting target.

In this paper, in order to improve efficiency the field work and record creation work of the bridge periodic inspection, we report the status of the examination up to now regarding bridge inspection using 3D data.

2 Research Content

In order to verify the possibility of bridge inspection using robots and 3D data, we examine the following three processes for the South Loop Bridge on the site of PWRI(Public Works Research Institute).

1. Efficient image shooting by a bridge inspection robot
2. Generation of 3D data of bridge by SfM
3. Image management method using 3D data

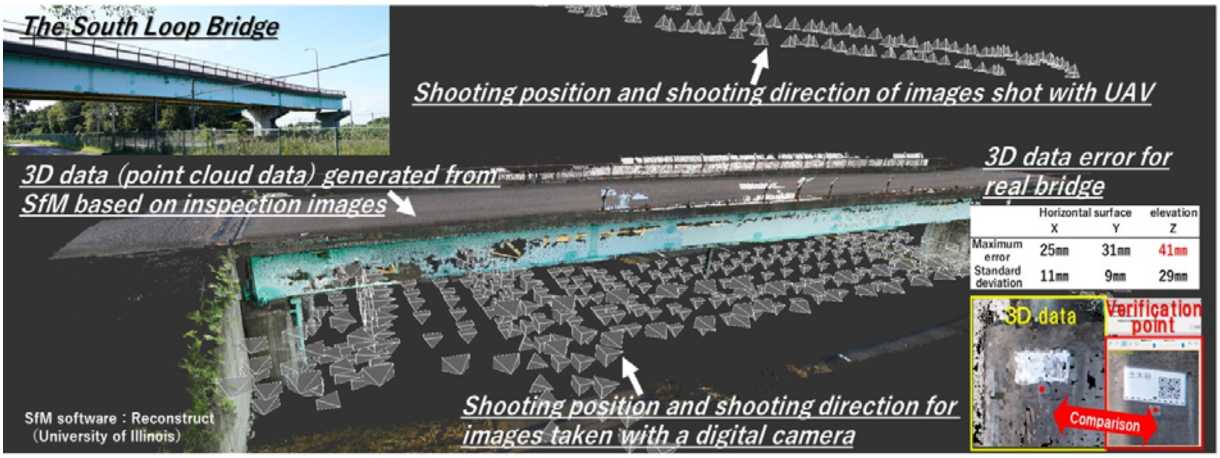

Figure 1. 3D data of South Loop Bridge generated from SfM

a) Development of infrastructure inspection system using semi-autonomous multi-copter equipped with flexible electrostatic adhesive device

b) Development of UAV for Observing and Hammering Aged Bridges at Short Range

Figure 2. Example of bridge inspection robot developed by SIP[3]

3 Generation of 3D Data and Image Management Using Images of Bridge Inspection Robots (UAVs, etc.)

3.1 Accuracy Verification of Generated 3D Data

In this paper, the bridge was shoot with a UAV (Phantom4Pro made by DJI) and a digital camera (α7R2 made by SONY). It was confirmed that the 3D data of the bridge can be generated by SfM from the shooting image and that the position and direction of the captured image can be expressed in the 3D space. ‘Figure 1’

The coordinates of the verification points on the actual bridge obtained from the survey criteria and the coordinates of the verification points on the 3D data were compared. The error of all verification points was within 5 cm, which satisfied the quality control standard defined by MLIT. ‘Figure 1’ [2]

3.2 Applicability to Bridge Inspection Robot

Figure 1 shows 3D data generated from images of general UAVs and digital cameras. Furthermore, by utilizing the robots specialized for advanced bridge inspection developed by the Cabinet Office's SIP (Cross-ministerial Strategic Innovation Promotion Program), more detailed bridge photography can be performed. ‘Figure 2’ [3]

By generating 3D data from the images taken by such a bridge inspection robot, it becomes possible to manage images taken of the damage conditions inside members and girders.

3.3 Management Example of Image Shooting Position Using 3D Data

3.3.1 Bearing

As shown in ‘Figure 3 a)’, the area around the bearing is often complicated due to abutments, floor slabs, main girders, and various piping. This area is generated as 3D data by SfM, and the shooting

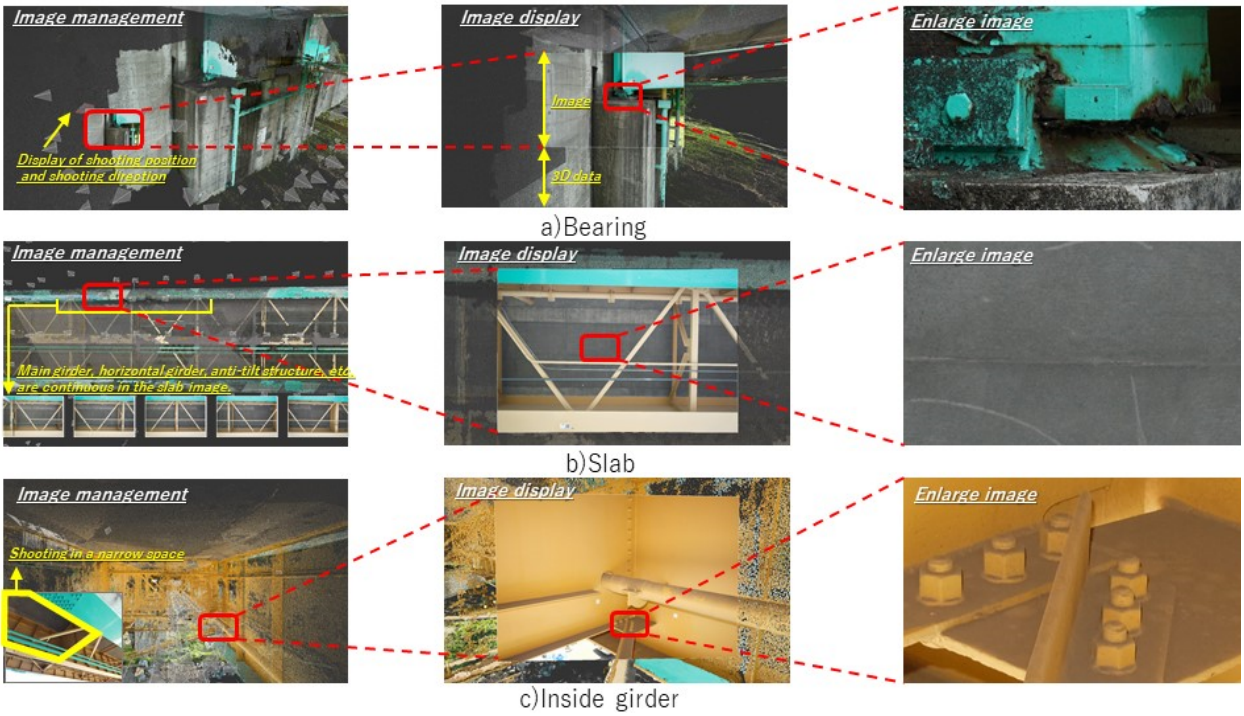

Figure 3. Image management example using 3D data

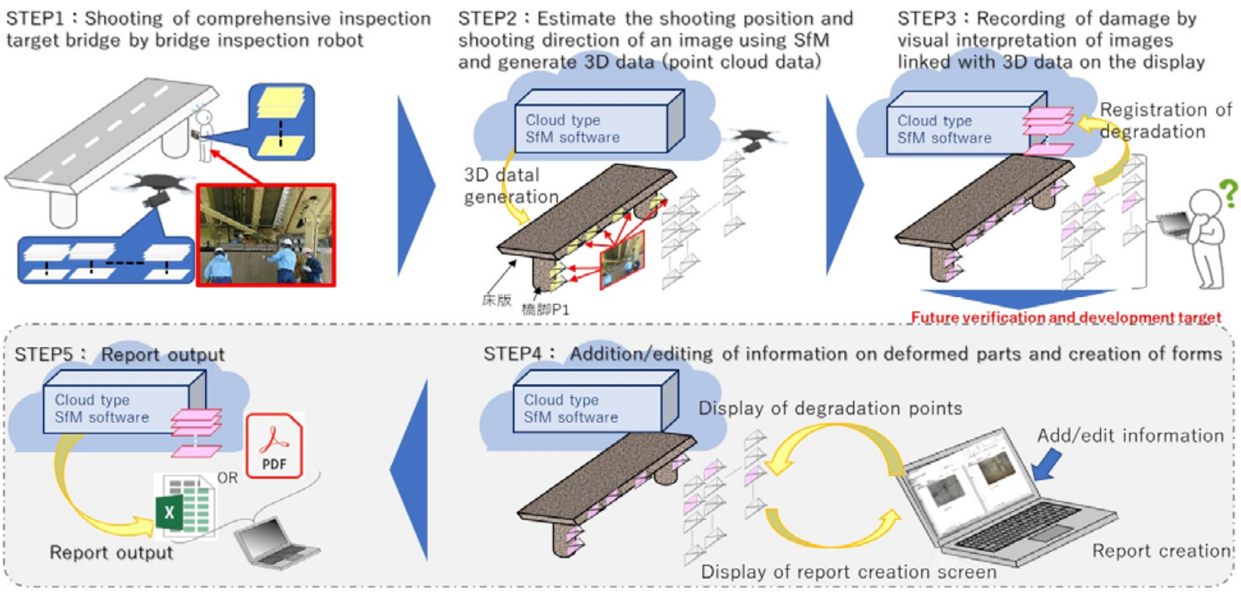

Figure 4. Bridge periodic inspection method utilizing 3D data

position and direction of the image can be expressed as a quadrangular pyramid in 3D space.

When the image of the bearing is displayed, it is displayed so as to match the 3D data, and the accuracy of the automatically estimated shooting position and shooting direction can be confirmed.

3.3.2 Slab

As shown in 'Figure 3 b)', the inspection results of slab in the current bridge inspection are managed by span. When the slab is continuously and comprehensively photographed, slab, main girders, horizontal girders, and the like are repeated, so a large number of images with the same contents are stored,

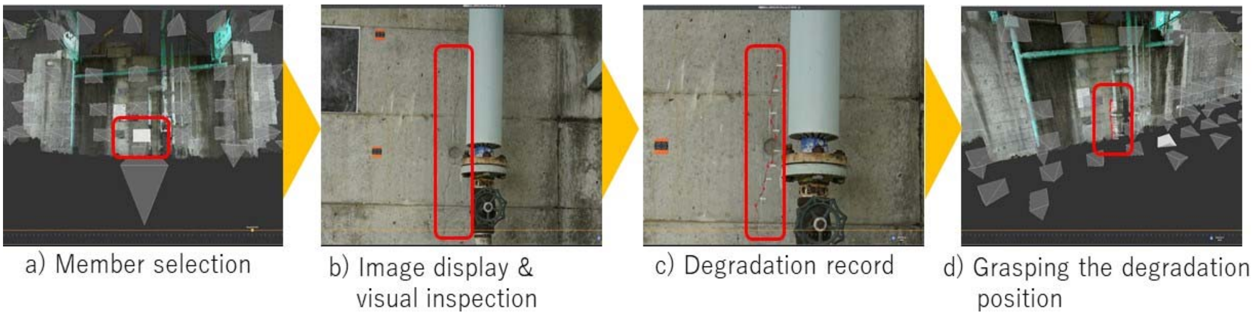

Figure 5. Visual confirmation of image degradation and recording example

and it becomes difficult to estimate the shooting positions of them later.

However, SfM's automatic image shooting position estimation and automatic association of 3D data with images can improve the efficiency of such continuous-image management.

3.3.3 Inside Girder

As shown in ‘Figure 3 c)’, It is difficult to manually record the image inside girder in the image shooting direction. The reason is that the shooting is focused on checking the condition of slab, the main girder, the anti-tilt structure, etc., and that the shooting is performed in a narrow space surrounded by the main girder and the horizontal girder.

By automatically estimating the shooting direction of the image with SfM, it is possible to manage the image of only the local part such as the bolt inside the girder and the corrosion condition of the anti-tilt structure.

4 Bridge Periodic Inspection Utilizing 3D Data

4.1 Proposal of Bridge Periodic Inspection Method Utilizing 3D Data

Based on the examination results to date, we propose a bridge periodic inspection method that uses 3D data generated by SfM as a solution to the problem which are Efficiency of inspection work, recording accuracy of deformed position of bridge inspection. ‘Figure 4’ This study does not limit the generation of 3D data, the estimation of the shooting position, direction of images to SfM in consideration of future technological development and development of this inspection method.

Since this inspection method generates 3D data by SfM, it is premised and important that robots shoot a comprehensive image of the bridge. After that, the inspection engineer will visually inspect only the areas where the degradation can be confirmed from the images taken by the bridge inspection robot and the areas where it was difficult to take images. The characteristics of the inspection method are as follows.

4.1.1 Efficiency Improvement of Visual Inspection for Actual Bridge

When the degradation of the member is confirmed on the image, the position of it can be grasped by referring to 3D data. In addition, an engineer will visually inspect the actual bridge depending on the condition of the degradation.

Therefore, it is possible to narrow down the scope of visual inspection on-site by the engineer in advance in the office.

4.1.2 Enhancing the Record of Changes in Visual Inspections by Engineers

The scope of visual inspection by the engineer is narrowed down, and more detailed degradation inspection can be performed on the degradation, so the contents of the recording of the degradation status are enriched.

4.1.3 Upgrading of Degradation Management by Utilizing 3D Data

By managing images and degradations by associating them with the three-dimensional data of the bridge, the shooting position and shooting direction will become clear, and it will be possible to guide the degradation shooting with the same angle of view in later years. In addition, by comparing images having the same shooting angle of view, it is possible to contribute to highly accurate progress grasp of aged deterioration.

4.2 Degradation Recording Example on Image

One of the merits of utilizing 3D data in bridge inspection is the possible to check and record the state of degradation on images managed in association with 3D data.

After 3D data is generated from the image by SfM, the image of the member to be confirmed is displayed, and the content of the degradation is recorded on the image for which the degradation can be confirmed. 'Figure 3 a)~c)' The degradation is recorded in association with the 3D data, and the position of the degradation can be grasped on 3D data even when the image is not displayed. 'Figure 3 d)'

5 Summary

This paper reported the research results on the method of utilizing 3D data for the purpose of improving the efficiency of periodical bridge inspection. As a concrete content, the basic verification result of the 3D data accuracy of the bridge generated by SfM was shown, and the image management method using the 3D data was proposed. This paper is summarized as follows;

1. We proposed a bridge periodic inspection method using 3D data as a solution to the problems of bridge inspection (many image management, accurate recording of degradation position) when using robots.
2. It was shown that the 3D data of bridges generated by SfM from the images taken continuously and automatically by UAV satisfy the quality control standards set by MLIT.
3. We proposed an image management method and a degradation confirmation method using 3D data. The feasibility of periodical bridge inspection using 3D data was also shown by introducing application examples.

The information generated by the proposed method in this paper, such as a set of image angles and perspectives and 3d structure by SfM, has not been applied in bridge inspection phase. Utilizing those infomation to improve the whole management cycle, which is not limited to the inspection, will contribute to improvement of the productivity in the entire construction field. Future research contents assume points listed below;

1. Confirmed to the bridge manager and the inspection engineer "Recording method for image degradation and expression method on 3D data" and "Delivery standard and management method for products of bridge periodical inspection utilizing 3D data" To do. Based on the results, we will study the workflow, functional requirements and related standards for social implementation.
2. It takes a great deal of effort to grasp the degradation on the image because the engineer performs visual inspection. Therefore, we will study support technologies that can efficiently detect degradations from images (automatic extraction of degradations by AI, emphasis on degradations by image processing).
3. By managing the images at the time of completion using this method, we will examine the utility of this method during emergency inspections such as grasping the displacement and degradation of the bridge structure after an earthquake.

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