Digital Twin Technology

Utilizing Robots and Deep Learning

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Abstract

Recently 3D management solution utilizing BIM/CIM is expected for construction and inspection management. Especially for inspection utility, big data such as huge number of inspection pictures and sounds should be managed with location data of taking data and should be taken with high quality and resolution on 3D world. This paper describes the total solution for 3D management system using Robots and AI technology.

Keywords –
BIM/CIM; Robot; Deep Learning; 3D

1 Introduction

In recent years, the deterioration of social backbone in terms of industrial infrastructure and social infrastructure has become a social problem. It has become necessary to solve many problems such as increase in the number of inspection and repair locations, aging of workers engaged in maintenance and management and decline in the number of employees, and pressure for reducing the maintenance and management cost. Especially for social infrastructure, in 2014, it became a requirement to carry out close-up visual inspection once in every 5 years for maintenance and management of all bridges, which are said to be 720,000 in total in Japan. In the case of close-up visual inspection conducted by workers based on the old inspection procedure, it is expected that continuing sound maintenance and management in future will be difficult.

As a solution in this situation, various new technologies such as the use of robots and drones and automatic extraction of damage by deep learning are being examined. In addition, research and development of three-dimensional unification technology for the integrated management of enormous amount of information obtained by robots and drones is also underway.

On the other hand, the initiative of i-Construction is underway in the field of construction and civil engineering, and by using BIM/CIM (Building Information Modeling / Construction Information Modeling), three-dimensional models are linked and developed in a series of processes such as planning, research, design, construction, and management, and a mechanism for sharing information at each stage has been developed [1].

In the present paper, in light of the above background, as a method for sustainable infrastructure maintenance and management, we developed a mechanism that uses digital twin technology, automatically extracts damage from various data acquired by inspection robots with deep learning, and associates them with a time axis on a 3D drawing. In addition, by assuming a case of a structure where drawings are lost or a case where there are attached equipment not reflected in the drawings, we also worked on methods such as CAD conversion from three-dimensions points group data obtained by 3D scanner and photogrammetry.

2 Digital twin technology

The digital twin technology [2] proposed by Professor Michael Grieves of the University of Michigan in 2002 is a technology that reproduces the real world in real time in a digital space in a linked manner. It is a technology that makes it possible to contribute to preventive maintenance by using acquired data, such as understanding the current situation digitally and making changes and predictions by conducting various simulations.

For the digital twin in infrastructure maintenance, first of all, it is important to obtain the latest shape and configuration of the structure, and it is necessary to accurately model attached equipment and repair marks that are not yet reflected in the construction drawings. On the other hand, a system that induces third party damage and that increases social losses such as traffic congestion when taking measures such as suspension of sharing in data acquisition is not desirable. At the same time, it is also necessary that is a method for making a complex structure into a detailed three-dimensional structure.

Especially in the case of a large-scale structure, when trying to restore a complex structure in the digital space with an accuracy that contributes to infrastructure maintenance and management, if 3D restoration is done from continuous images with 90% overlap by a drone etc. using photogrammetry technology, the data size of the restored data becomes huge because thousands of images of a few MB size each are joined. The joining process itself takes a lot of time, and at the same time, there are some problems to be solved before putting it into practical use, for example, it requires a high-performance PC for viewing the restored data.

Therefore, in infrastructure maintenance and management, it is necessary to acquire data for understanding the latest shape and configuration of the structure and data of inspection quality required for maintenance and management, and it is necessary to acquire and restore data with the accuracy required for each of them.

In the present paper, the data for understanding the shape and configuration is acquired at a resolution that will allow understanding the shape and configuration, and the data size is further compressed by CAD. Moreover, the inspection data for checking cracks in concrete is acquired at a resolution that can detect the cracks of 0.1 mm size. After that, these data is merged for solving the above problems.

Figure 1 shows a panoramic view of the steel plate girder bridge, and Figure 2 shows a 3D points group obtained by mounting a 3D scanner on the robot Turrets (Figure 3) [3] that can access the girder of the steel plate girder bridge from the back of the bridge.

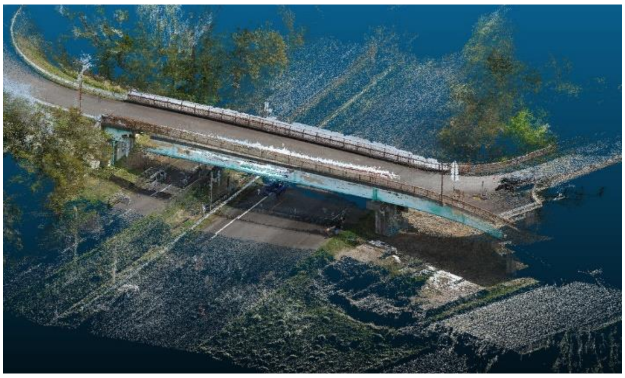

Figure 1. Three-dimensional point groups model of the whole bridge view

Figure 2 . Three-dimensional point groups model in bridge girder

Figure 3. Flange-suspended type inspection robot Turrets

3 Damage extraction by using AI

Recently, AI has been used in various scenarios such as crack extraction of concrete and corrosion extraction of steel structure by using deep learning. Even in infrastructure maintenance and management, the Ministry of Land, Infrastructure, Transport and Tourism is playing a central role for making preparations such as rolling out the "AI development support platform" [4].

As for extracting cracks in the concrete, from the high-quality camera images taken, cracks are extracted by using semantic segmentation, and the cracks are then displayed in different colors according to the crack width and crack length. It is expected that because of this the inspection staff will not miss the inspection of cracks (Figure 4) and it will shorten the preparation of crack diagrams when preparing inspection records (Figure 5).

Turrets is equipped with a high-definition camera that can detect cracks of 0.1 mm size, and it is also equipped with a lighting device to obtain appropriate photographic images even in dark environments. Therefore, it is possible to obtain pictures with good image quality.

Figure 4. Bridge deck crack extraction image

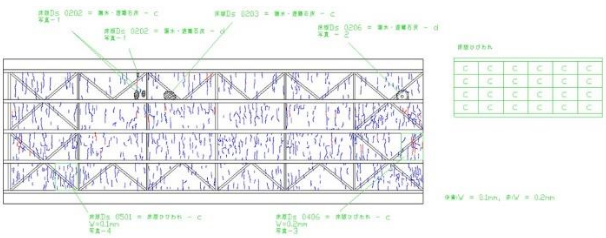

Figure 5. Inspection record

On the other hand, in the case of damage such as corrosion, after the target site is identified, deep learning and image processing technologies are used to automatically calculate the corrosion position, corrosion area, etc.

By associating these deterioration data with 3D drawing data with a time axis, the inspection staff can accurately understand the current state of the structure from a remote location, and it becomes possible to correctly diagnose the state of the structure.

In addition, since it has a time axis, the reusability of data is high, and it is easy to observe changes over time, which can contribute to the planning of future repairs.

4 Three-dimensional model and BIM / CIM conversion

Various types of data for structures including photographic images obtained by robots are often large amounts of data when compared to that of conventional inspections conducted by inspection staff. Therefore, if the various data obtained are randomly stored, the reusability will be poor, and it will take a lot of time to organize the data, which will reduce the advantages of using a robot.

One of the advantages of using robots is that the position information obtained from the sensors used to control the robots can be used as self-position information, and it can be associated with the acquired data to automatically organize the data. In addition, by managing the acquired data with position information in three dimensions, it is possible to intuitively overlook the damage situation in the entire structure compared to the two-dimensional management as shown in Figure 5.

On the other hand, in i-Construction, which is being promoted in the field of construction and civil engineering, integrated three-dimensional data management by using BIM / CIM is progressing. Therefore, integrating maintenance and management information into BIM / CIM not only offers the advantage that the data obtained in maintenance and management operations can be intuitively managed in three dimensions, but it also allows integrated management of design and construction data and maintenance and management data. In that respect, it is very effective that it can be used to estimate the cause of damage.

Give that, a mechanism was developed for unifying the robot's self-position and the BIM / CIM coordinate system, managing various data obtained by the robot in the BIM/CIM coordinate system, and then correlating them with the attribute data IFC (Industry Foundation Classes) used in BIM/CIM. In addition, it is often difficult to correlate with BIM/CIM data when the robot acquires self-position, for example, in the case of structures with old construction without BIM/CIM drawings, structures with attached equipment not reflected in the drawings, and structures that were repaired.

Recently, there is a measuring device called 3D scanner that can acquire the surrounding conditions with high precision in a three-dimensional points group. A method to make a new BIM/CIM by using this was also developed.

Figure 6 shows the Turrets (Figure 3) equipped with a three-dimensional scanner that is scanning while moving over the structure. It was possible to obtain the three-dimensional points group data shown in Figure 1 and Figure 2 by combining the multiple points group data at each measurement position obtained here.

In addition, Figure 7 and Figure 8 show the results of surface estimation from the obtained three-dimensional points group data and CIM conversion.

Figure 6. Turrets equipped with a three-dimensional scanner

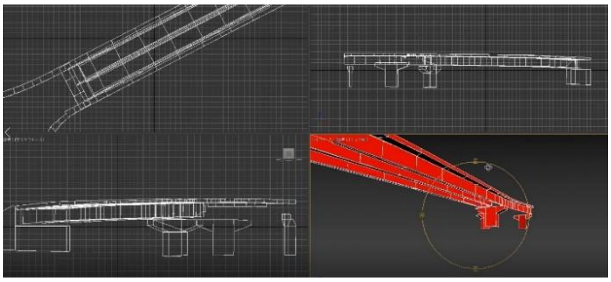

Figure 7. CIM conversion from three-dimensional points group data

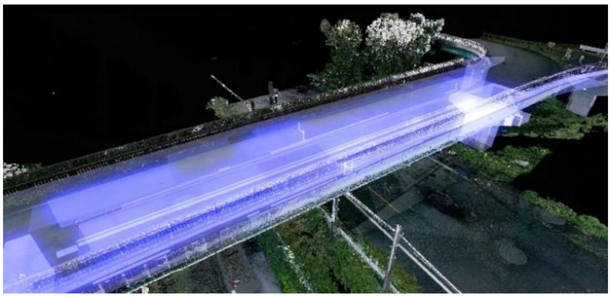

Figure 8. Superimposing three-dimensional points group data and CIM

5 Data superposition for digital twin

Up to the previous section, by correlating various data acquired by the robot with position information, it became possible to automatically extract and automatically measure the damage by using image processing technology and AI such as deep learning. In addition, by mounting a 3D scanner on the robot, three-dimensional points group data of the structure was acquired and converted into CIM. Since all of these data are managed in the BIM / CIM coordinate system, and the acquired data were superimposed on the three-dimensional points group so that they could be correlated with the IFC, which is the attribute data, and the damage condition could be intuitively understood.

Superimposition of the acquired images calculates the shooting position of the robot (camera center) from the postures of each joint of the robot, converts it to the BIM/CIM coordinate system, and measures the distance up to the shooting surface with the sensor mounted on the robot. Furthermore, the image size at that distance is estimated from the camera parameters, and its neighboring points are searched and correlated from the three-dimensional points group.

By the above processing, it became possible to arrange the images on the three-dimensional points group as shown in Figure 9.

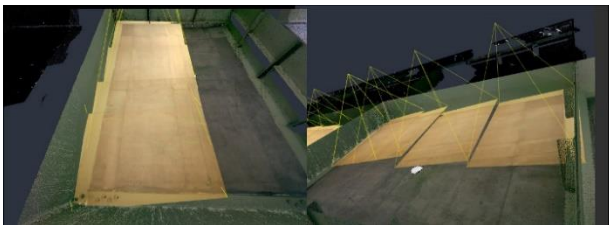

Figure 9. Image superposition on three-dimensional points group data

At this time, since the damage in the image is extracted by deep learning etc. and displayed on the image, the worker can intuitively understand the damage location on the three-dimensional points group on which the image is superimposed (Figure 10).

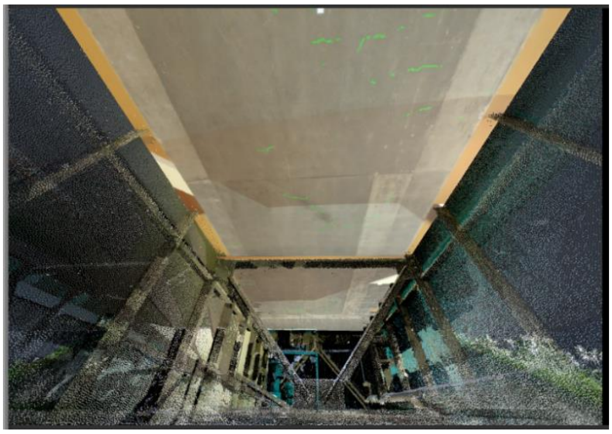

Figure 10. Digital twin data

In addition, since these images associated with IFC can also be associated with other data described in IFC during design and construction, it is expected to contribute to preventive maintenance such as investigating the cause of damage occurrence and estimating future growth of damage from the relationship with design values, materials, and completion inspection data.

6 Conclusion

In the paper, as one of the methods that effectively contribute new technologies such as robots and deep learning to infrastructure maintenance and management work, a digital twin technology based three-dimensional integrated management method was proposed. It is expected that future technological innovations will facilitate appropriate maintenance and management of the infrastructure, where aging has become a social problem.

However, while each technology is expected to be labor-saving, some problem have been pointed out such as the enormous data size and some operational issues like subsequent browsing of the data. Therefore, in this paper, we acquired the data with the required accuracy according to the purpose, converted it into three-dimensional data, and developed a sustainable infrastructure maintenance and management method by making it compliant with BIM/CIM.

In particular, as the number of skilled inspection personnel is expected to decrease in the future, it is necessary to propose to asset owners the diagnostic information that contributes to preventive maintenance from these new technologies. By setting up a mechanism that can correlate the acquired data and the position information and manage this information with a time axis, it is expected that efforts will be made for automation of diagnosis in the future.

In the future, we would like to deepen the digital twin technology that would allow inspection personnel to properly diagnose the infrastructure by accumulating data at various times for structures constructed in various environments.

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