MLIT's Initiatives for Promotion the Efficient Construction and Inspection by using new Technologies such as AI and Robots in Japan.

Kenichi Watanabe

Deputy Director for AI and Robotics for Construction and Maintenance, Policy Planning and Coordination Division for Public Works Project, Policy Bureau, The Ministry of Land, Infrastructure, Transport and Tourism, Government of Japan
E-mail: watanabe-k2q2@mlit.go.jp

Abstract –

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is promoting the use of drones and other robots to improve the construction and management processes and improve the efficiency of infrastructure inspections, and is preparing an AI development environment that supports "human judgment." Specifically, MLIT is preparing "teaching data" which necessary for AI development and provides it to AI developers. In order to create an annotation rule for preparing teaching data, MLIT have started the working group of Industry-academia-government collaboration and are proceeding with discussions. At present, teaching data for cracks in bridges and tunnels has been prepared. MLIT is going to realize future advanced inspection, such as accumulating and using high-definition photographs with positional information taken by robots and inspection records in a 3D model. This will be possible to grasp the secular change of damage and deformation easily.

Keywords –

AI; Inspection; Teaching data; Drone; Bridge; Tunnel

1 Introduction

Currently, many of Japan's infrastructure is aging, while there is increasing risk of natural disasters such as typhoons and floods due to climate changes related to global warming. Japanese people are also in the face of challenges such as low birthrate and aging population. Under such situation, maintenance of infrastructure needs to be performing more effective and efficient, while the development and introduction of robot technology which support the work is required to proceed rapidly and intensively.

Therefore, MLIT and the Ministry of Economy, Trade and Industry (METI) in Japan have considered the needs of robots in a situation of social infrastructure survey, construction, maintenance and disaster management, including different needs from other industry fields in Japan and overseas such as IT, manufacturing, and so on. In order to consider measures for practical application such as clarifying the development and introduction fields of robots in, the "Next Generation Social Infrastructure Robot Development and Introduction Study Group" was established on July 16, 2013, "Next Generation robots for infrastructure development and introduction priority areas (5 key areas)" was formulated on December 25, 2013 (as shown in Figure.1).

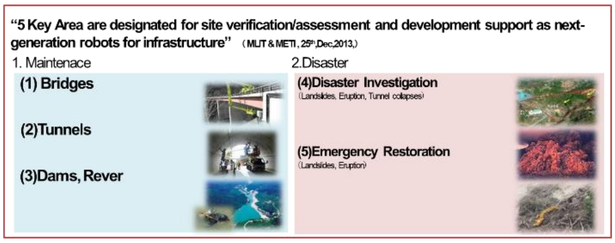

Figure 1. Next Generation social infrastructure for robot development and introduction priority areas (5 key areas)

Therefore, MLIT had decided to establish "the on-site robot verification committee for the next generation social infrastructure" (hereinafter referred to as "the on-site verification committee") in 2014 February, to experiment on-site for the purpose of evaluating the robots. It was also the purpose to facilitate the development and introduction robots in the maintenance and disaster management field of social infrastructure.

The on-site verification committee had 5 subcommittees, 3 as the maintenance (the bridge, the tunnel, and dams and river), and 2 as the disaster management (the disaster investigation and the emergency restoration). Experiments were conducted for each of the five priority areas.

The robots for maintenance of social infrastructure can take photographs which can detect damages of infrastructure such as cracks or corrosion. This can reduce the time which an engineer work on-site, and this can be also expected to reduce the time lost due to traffic closed for construction or inspection. But it is needed for an engineer to look at each photo for detecting the damage.

For further improving the efficiency of inspection work, it can be worth considering that creating three-dimensional model which shows the overall structure of the inspection object from inspection photos and organizing large amounts of photos on the 3D model. It can be also useful for grasping the changing over time of the infrastructure. Furthermore, it can be an efficient technique for such inspection to create and use artificial intelligence (AI) which can automatically detect damages on infrastructure from inspection photos.

In this paper, I show you "Initiatives and results of the on-site verification committee" in section 2," Efforts to further improve the efficiency of inspection work" in section 3, and "Conclusion" in section 4.

2 Initiatives and results of the on-site verification committee

In fiscal year 2014 and 2015, MLIT had researched various robot technologies like drones or ROV related to five priority areas (FY2014: 67 techs, FY2015: 70 techs). MLIT had taken technological verification and evaluation for improving and promoting these technologies. For disaster management, two years verification and evaluation initiatives have made these robot techs to be used in site. On the other hand, the robot techs for the maintenance had many difficulties on achieving inspection efficiency and accuracy which were required, so it was decided to continue the verification and evaluation initiatives beyond year.

In FY2016 and FY2017, the situation and performance level to be achieved for practical use were set, while some of these robot techs were re-verified and re-evaluated the accuracy and the economic efficiency caused by shortening of work time (FY2016: 16 techs, FY2017: 16 techs). Figure 2 shows examples of the verified robot techs.

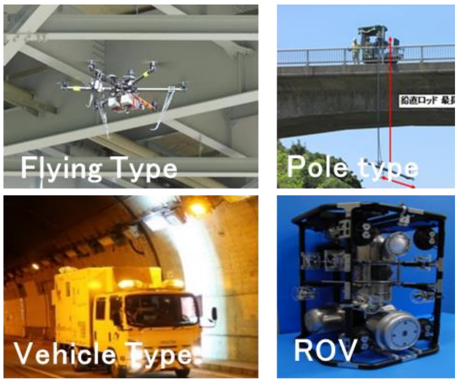

Figure 2. Examples of the verified robot techs

In FY2018, MLIT have written the manuals which described the method to use these robot techs in each situation such as bridge maintenance or disaster investigation. It has made the robot techs to be used in site.

The manual regarding road (bridge, tunnel) maintenance is described in detail below.

2.1 Road (Bridge, Tunnel) Maintenance Manual Using Robots

For the road infrastructures in Japan, The Ministerial Ordinance Revising Part of Road Law Enforcement Regulations has been issued and enforced in 2014 behind the rapid increase in aging road infrastructures. Therefore, regular inspections of road bridges and tunnels are conducted once every five years by close visual inspection, while evaluating its healthiness in stages.

The first round of inspections was completed in FY2018, and the road bridge periodic inspection guideline was revised in 2019, February through discussions on the revision of the periodic inspection guideline by the Road Subcommittee of the Council for Social Capital Development Road Subcommittee . The road tunnel regular inspection procedure was revised in March of the same year.

In addition, in the process up to the revision of the periodic inspection procedure, the direction was shown to utilize these technologies for periodic inspections. "Inspection support technology" such as infrastructure inspection robots will be determined by a professional engineer who has the knowledge and skills which are necessary for inspection of the parts, members, scope, and purpose of using these technologies.

Therefore, MLIT has established standard performance evaluation items that show the performance of inspection support technology, and then "the catalog" was made in 2019 February for the performance values submitted by the developer through on-site verification.

Moreover, "the guideline" was compiled in same time. For professional engineers of the order and the contractor, the guideline shows the process of decision making to use these technologies on periodic inspection work.

3 Efforts to Further Improve The Efficiency of Inspection Work

The inspection support technology, shown in above section, can take photographs from which a professional engineer can detect damages of infrastructure such as cracks or corrosion. This can reduce the time which a professional engineer work on-site like marking with chalk or measuring with crack scale, and this can be also expected to reduce the time lost due to traffic closed for construction or inspection. However, it is needed for a professional engineer to look at each photo for detecting the damage.

For further improving the efficiency of inspection work, it can be worth considering that creating 3D model which shows the overall structure of the inspection object from inspection photos and organizing large amounts of photos on the 3D model. It can be also useful for grasping the changing over time of the infrastructure. Furthermore, it can be an efficient technique for such inspection to create and use AI which can automatically detect damages on infrastructure from inspection photos.

Two methods that MLIT is currently studying about AI are shown in below.

3.1 Damage Representation above 3D model

In the current inspection work in Japan, the contractor is not needed to deliver all of the photographs taken by inspection support technology, and it is often enough to deliver the photographs of the places where damage is recognized and damage information with the form defined.

The inspection support technology can take high quality and large images which can use to generate a 3D model. If it could record and accumulate accurate damage location above such 3D models, deformation of aging structure changing over time can accumulate inspection records of the structure in comparable form. The more information amount of inspection results is, the more useful diagnosis by a professional engineer can be expected.

The deliverable for making 3D model needs photos which show shape and location of damages, metadata of positional information of taken photos, and damage shape data added to the 3D model. If the standard which defined these data items and specification did not exist, it might make a situation that the damage 3D model only depended on the application which was used and managed the data. Incompatible and discontinuous data might store in that cases.

Therefore, MLIT have stipulated common data items and specifications related to the data required to create a 3D model. MLIT have also shown the method how to deliver the result of inspection through an application that creates a 3D model from photos taken by inspection support technology. So, " 3D deliverables manual for tunnel or bridges by inspection support technology (image measurement technique) " have created in 2019, March.

MLIT is going to verify the 3D model creation method using photographs are taken through the periodic inspection work. MLIT is also going to revise the manual while researching the inspection scene in which we can use 3D model efficiently. Through these initiatives, MLIT leads inspection work to improve.

I will explain the 3 types of deliverables that are defined in this manual: "inspection photo", "damage shape data", "Inspection photo metadata".

Each of the details are as follows.

3.1.1 Inspection Photo

This is raw data of photos taken by inspection support technology. For creating 3D model, photos should be taken not only of the damaged part but also whole of the structure including the sound part.

It is necessary for inspection photos to carry out appropriate quality control based on shooting condition which defined to secure the accuracy. In this manual, the conditions of inspection photos taken will be described referring to shooting conditions for teaching data which is essential to create AI. (As shown in Table 1.)

Table 1. Conditions for taking photos for the preparation of teaching data for bridges

<table>
<tr><td colspan="3">When a crack of 0.1mm width is detected, the width shall be 0.3mm/pixel or less.
The field of view size should be determined according to the camera used.
Field of view size in longitudinal direction (mm) = Number of camera pixels in longitudinal direction x 0.3mm
Size of vertical field of view (mm) = Number of camera pixels in vertical direction x 0.3mm</td></tr>
<tr><td></td><td>specification</td><td>points to remember</td></tr>
<tr><td rowspan="4">Camera model</td><td rowspan="4">Mirrorless camera or equivalent</td><td>Necessary to ensure stable image quality</td></tr>
<tr><td>Sensor size: APS-C or larger</td></tr>
<tr><td>Do not use contrast AF</td></tr>
<tr><td>Necessary for depth of field</td></tr>
<tr><td>ISO sensitivity</td><td>ISO200 or less</td><td>Increasing the ISO sensitivity may smooth the image and make it impossible to detect cracks</td></tr>
<tr><td>Lap rate</td><td>Overlap and side-lap percentages are both over 30%</td><td>Necessary for compositing to the planar development</td></tr>
<tr><td>Shooting angle</td><td>Confronting directly (in principle)</td><td>Depends on the environmental conditions, but generally up to 10 degrees</td></tr>
</table>

3.1.2 Damage Shape Data

This is the information of damage position, shape, and area. When we create this data, we can choose two methods: 3D model or the layer structure drawing file

(2D). The damage shape data on 3D model is expressed by 3D polylines (cracking, etc.), a polygon (corrosion, free lime, etc.) which are described on 3D-CAD.

On the other hand, the damage shape data based on the layer structure drawing file (2D) is created by showing polylines and polygons indicating damage on 2D drawing that is superimposed with a layer structure that can be separated from the inspection photos. This corresponds to the data delivered as a damage diagram in the conventional inspection record.

3.1.3 Inspection Photo Metadata

This is the text data (CSV file) in which describes the information of coordinate system in which inspection target structure is located, and of the position coordinates and angle of inspection photo or camera.

The position coordinates and angle information are necessary to express at which position and angle the photo exists in 3D space. Representation methods of this information can be 3types: (1) center position coordinates and angle of the inspection photo, (2) center position coordinates of the camera and angle, and (3) four corner coordinates of the inspection photo.

This manual defines the representation methods of these metadata, and one example is shown in Table2.

Table 2. Conditions for taking photos for the preparation of teaching data for bridges

Item	Input condition	Description
Position Coordinate Entry Method	Required	Enter 0 if the positional coordinates are the center positional coordinates of the photo, 1 if it is the center positional coordinates of the camera, and 2 if it is the four corner coordinates of the photo.
Position Coordinate	Required (When the positional coordinate input method is "0")	XYZ coordinates (x, y, z) to show the center position of the inspection photo. Eulerian angle (α, β, γ) or quaternion (q0, q1, q2, q3) that represents the slope of the inspection photo.
	Required (When the positional coordinate input method is "1")	XYZ coordinates for the center position of the camera (x, y, z) Eulerian angles (α, β, γ) or quaternions (q0, q1, q2, q3) that represent the inclination of the camera.
	Required (When the positional coordinate input method is "2", 3 points or more)	XYZ coordinates (xUR, yUR, zUR, xUL, yUL, zUL, xDR, yDR, zDR, xDL, yDL, zDL) of the four corners of the inspection photo (top right, top left, bottom right, bottom left)

3.2 Automatic Interpretation of Damage Using AI

As previously described, from many photos obtained using the current inspection support technology, damage of structure has been read by hand. By utilizing AI, this damage reading procedure can be done automatically. It can be also a great help for the work of those who create inspection records. A future image of inspection procedure is shown in Figure 3.

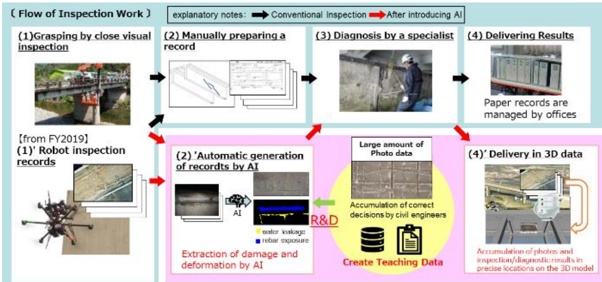

Figure 3. Future Images of Inspection Procedure

In conventional inspection procedure, a professional engineer needs to get closer to the structure to be inspected and check with his/her own eyes. So, inspection records (output) have been created from the visual information (input).

If this procedure is going to be achieved by AI, first, it will be needed to create the teaching data which is based on photos (input) and records(output) which have been acquired and made by a professional engineer.

These teaching data contains the tacit knowledge and know-how of the professional engineers of inspection. AI learning algorithm needs to learn based on teaching data like these.

The learned AI can infer results from inputs, so it can automatically interpret damages of the structure to be inspected from photos acquired by inspection support technology. To develop such AI, and to improve automatic interpretation by such AI to higher precision, it is necessary to prepare a large amount of teaching data. The teaching data is created by simply tagging (annotating) where in the photo acquired by inspection the damage is on the photo.

The inspection photo is owned by the manager of the structure like MLIT, and annotating requires the knowledge and skills of inspection professional engineers. So that, MLIT prepares teaching data as a cooperative area. MLIT is confident that this initiative can be a great help for firms to create AI needed in the fields of inspection.

An image of AI learning and utilization is as shown in Figure 4.

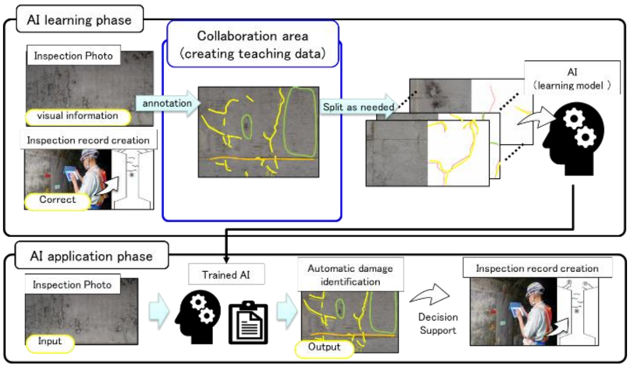

Figure 4. An image of AI learning and utilization

MLIT is considering the establishment of "AI Development Support Platform" for the purpose of creating teaching data, giving the data to AI developers, and evaluating the performance of the developed AI (Figure 5).

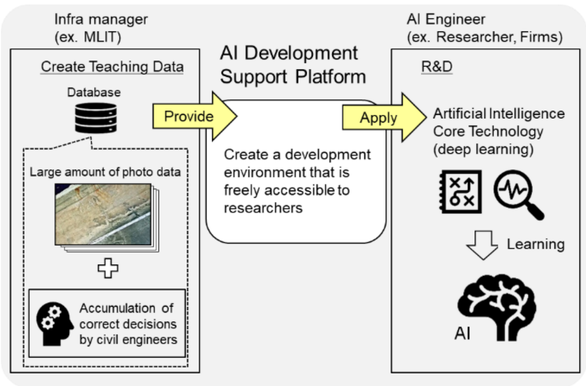

Figure 5. Outline of AI development Support Platform

MLIT have established the industry-academia-government collaboration working group for AI towards the establishment of the platform. In this WG, MLIT and WG members have considered a good quality and efficient way to create and deliver teaching data, and examined the ideal way of a data infrastructure that facilitates the acquisition, storage, analysis, and utilization of inspection data.

This WG has been held 3 times so far. The WG members have discussed specifications for the original photo used as teaching data, specifications of annotations, rules regarding provision of teaching data, sharing of schedule for future teaching data provision and prototype AI development, opinions exchange on prototype teaching data, and review of specifications of teaching data.

In addition, in order to improve the accuracy of AI, it is necessary to accumulate more inspection photos. MLIT is going to verify how to take a picture of the structure based on the technological progress of inspection support technology continuously, and "3D deliverables manual for tunnel or bridges by inspection support technology (image measurement technique) " should be revised as appropriate.

4 In Conclusion

In Japan, the skilled worker in construction site is decreasing, the infrastructure is aging, and it is important to maintain existing infrastructure effectively and use them longer.

MLIT initiatives will contribute a variety of inspection support technology development in the robot market, supporting the work of professional engineers in infrastructure inspection, accelerating the development and introduction of robots, and further improving the efficiency and sophistication of the overall infrastructure maintenance management.

MLIT will be contributing to the improvement of productivity of construction industry, while grasping the trend of technology seeds and worksite needs by the social implementation of new technology on construction site.

References

[1] MLIT, Measures to deal with aging roads On-line: https://www.mlit.go.jp/road/sisaku/yobohozen/yobohozen.html, Accessed: 15/June/2020.

[2] MLIT, Robots and AI technology On-line: https://www.mlit.go.jp/sogoseisaku/constplan/sosei_constplan_tk_000028.html, Accessed: 15/June/2020.

[3] MLIT, About the preparation working group for the “AI Development Support Platform” On-line:https://www.mlit.go.jp/sogoseisaku/constplan/sosei_constplan_tk_000034.html, Accessed: 15/June/2020.