Research and Development of Innovative Operation Technology for Access Network Infrastructure

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Abstract

The Optical Access Network Project underway at NTT Access Network Service Systems Laboratories involves research and development on access network technology. This article is based on a lecture given at the NTT Tsukuba Forum held in October 2016; it introduces the research and development designed to innovate access network operation and the areas of development planned for the future.

Keywords: innovation of operation, equipment/facility inspection, Tsukuba Forum

1. Introduction

The NTT Group has built and operates huge numbers of telecommunications facilities in Japan, and this is continuing with the spread of telephone networks and optical broadband services nationwide. In order to continuously provide safe and secure social infrastructure services, a lot of effort and resources are required for operation and maintenance, and thus, the cost of maintaining and operating these facilities is extremely high. NTT Access Network Service Systems Laboratories (hereinafter referred to as AS Labs) has undertaken initiatives to reform the operation of these huge numbers of telecommunications facilities. We aim to streamline the process of inspecting equipment and facilities through innovation.

AS Labs has been studying the equipment inspection techniques in cooperation with NTT EAST and NTT WEST in order to improve efficiency. Inspection work in the future, however, will require technical innovation. This will involve checking and evaluating equipment structures quantitatively and in a planar manner with centimeter-order precision by maximizing the use of robotic technology such as mobile mapping systems (MMS). An MMS is a tool for acquiring point cloud data and images that is installed on measuring vehicles equipped with a high-density laser, camera, and GPS (Global Positioning System). This technology is already being used in the civil engineering construction industry and in the mapping industry. The reflection of a laser beam emitted at 1 million points per second from a high-density laser onto the measuring equipment in the measuring vehicle produces white trace data called point cloud. Each point in a point cloud has coordinates, so accurate position information can be acquired, thus enabling spatial data of equipment to be acquired together with image data obtained by the camera (**Fig. 1**).

In addition, AS Labs has been developing technology to model the point cloud data measured by MMS and automatically detect the condition of a piece of equipment. For example, in the case of a utility pole, modeling is achieved by extracting aggregates of circles from point cloud data and then removing noise (**Fig. 2**). Once the modeling is done, it is possible to detect the presence/absence of abnormalities such as inclinations and deflections, and to determine what the extent of the abnormality is. For example, in the field photograph on the far left in Fig. 2, the telephone pole appears to be leaning. When modeling is done using the above-mentioned technique, we see that it

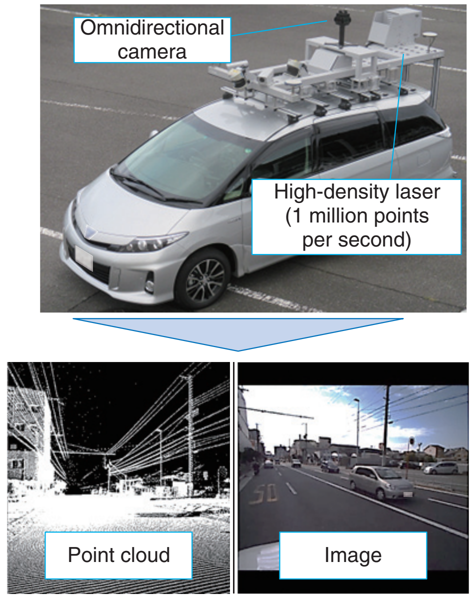

Fig. 1. MMS measuring vehicle and acquired data.

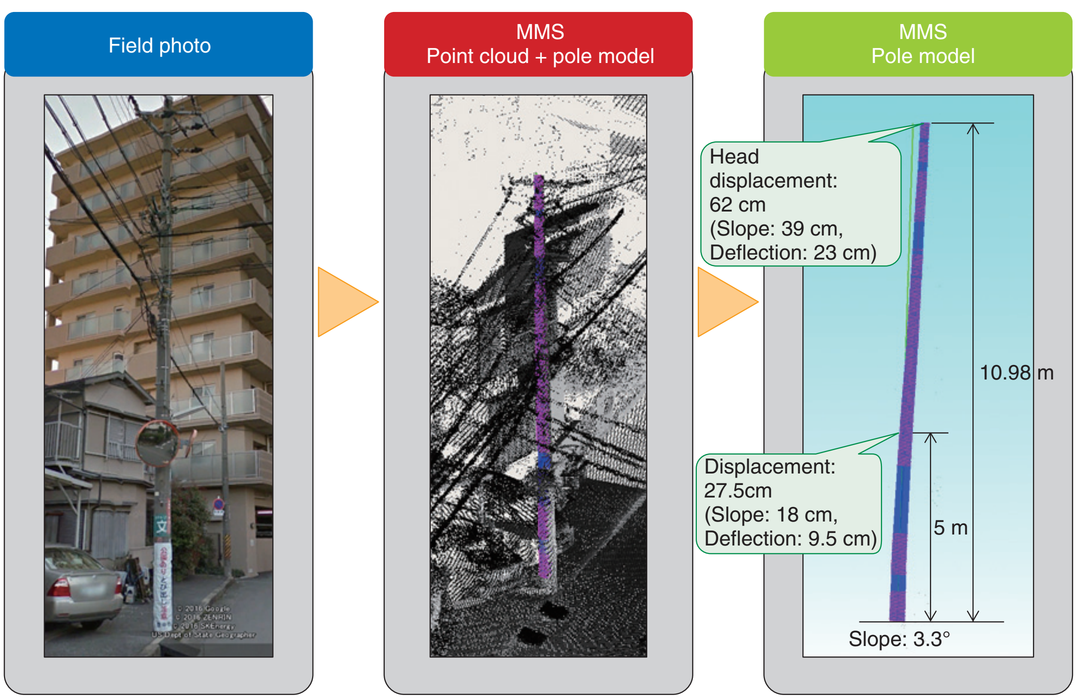

Fig. 2. Automatic detection of poles and three-dimensional modeling.

has shifted to the right from the center position by 62 cm at the head of the utility pole and 27.5 cm at the aerial position of the cable. Furthermore, we can determine that the deviation of 62 cm at the head of the utility pole is caused by a 39-cm inclination of the utility pole and a 23-cm deflection of the utility pole itself. As with the case of the utility pole, the MMS can measure the distance to the ground from the cable

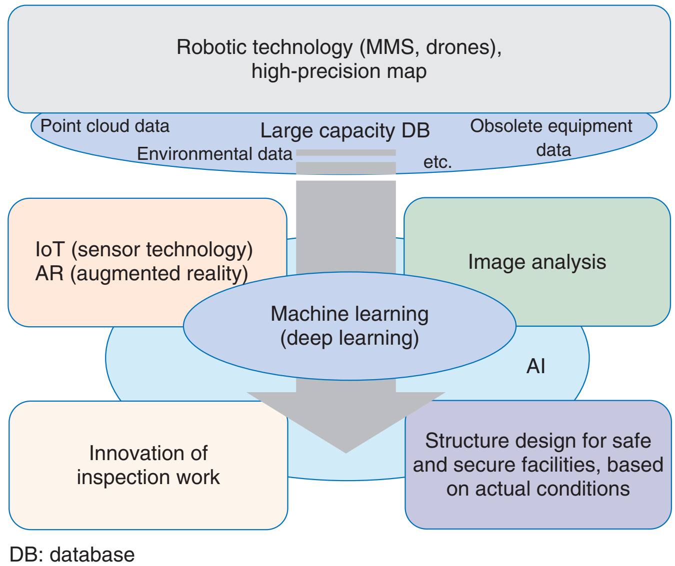

Fig. 3. Technology category related to inspection innovation.

attached to the utility pole. Therefore, the shortage of the distance to the ground from the cable, which is one of the problems in facility operation, will be possible to grasp, and concrete measures to rectify it can be implemented.

We experimentally measured and analyzed facilities using an MMS in the Koiwa area of Tokyo in March 2016. The Koiwa area has about 10,000 telephone poles. In MMS measurement, safety is an important factor, so the range of safe traveling (in terms of speed and time) of the measuring vehicle is taken into consideration. Thus, we were able to safely measure 2000 poles per day. The measurement results indicated that most utility poles were found to have a deflection of 5 cm or less. A deflection of 20 cm will likely lead to cracking, and cracks will enable water to penetrate the pole, resulting in possible deterioration of the rebar. None of the utility poles in this measurement area had deflections as large as 20 cm, so they were in relatively good shape.

To utilize data acquired by MMS, we first need to develop a high-precision map. The map currently being used has a scale of 1:2500, with a reported error of about 2 m. Utilizing the data acquired with MMS makes it possible to generate a highly accurate map with a scale of 1:500. A map at this scale has an error of about 30 cm, so the equipment position can be grasped very accurately. Moreover, in addition to facility inspection, we believe that with such a map we can improve services such as selecting equipment with greater precision when providing NTT services.

This article thus far has focused on robotic technology using MMS, which is a method of inspecting objects from the ground. However, we are also considering using drones to obtain an aerial viewpoint, and we are planning to utilize the high-precision map based on the coordinate positions obtained by drones.

2. Inspection innovation for a safer society

Five technological fields are considered to be key areas in designing safe and secure telecommunications facilities that reflect the innovation and the actual conditions of inspection work. These fields are the Internet of Things (IoT), augmented reality (AR), image analysis, machine learning, and artificial intelligence (AI). These are very trendy terms; however, since a wide range of operational services are provided in business, we would like to realize a society in which telecommunications facilities are continuously monitored (watched over) by promoting innovation through the use of the technologies in these fields (**Fig. 3**).

2.1 IoT and fiber sensing

After the MMS is used to grasp the equipment condition, it will be necessary to immediately repair or replace any equipment determined to be in poor condition. Equipment with progressing deterioration but not at a stage requiring immediate renewal will be

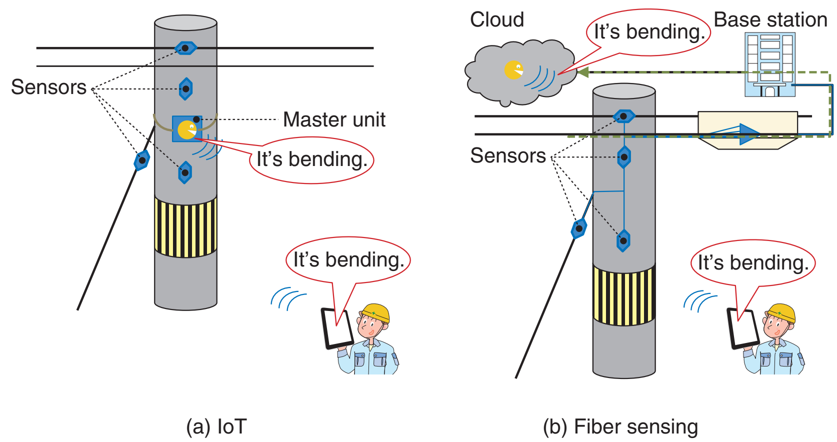

Fig. 4. IoT and fiber sensing technology.

recorded as needing a follow-up observation. It is currently only possible to increase the frequency of manual inspections by workers. However, installing a sensor (IoT technology) on equipment that needs such follow-up observations will enable the equipment state to be sent automatically any time someone approaches the equipment. In addition, fiber sensing is expected to be used for equipment in poor condition, with notification of the equipment condition being automatically sent to the appropriate department. Such remote monitoring will make it possible to detect dangerous conditions and their signs at an early stage (**Fig. 4**).

2.2 AR

The year 2016 saw everyone talking about Pokémon GO, a virtual monster-like character that appears on a map with AR technology. We can represent the equipment information obtained using robotic technology and IoT on a map by applying AR technology with a smartphone application. In this way, we aim to provide a fun way for experts and other members of society to be able to watch over society and to create a system that can accumulate useful data. In terms of watching over society, we can imagine using the system to keep an eye on elderly people who may have a tendency to wander, but we would like to use the system to monitor NTT facilities (i.e., equipment and buildings), which are also aging in our aging society.

2.3 Image analysis

The image analysis feature involves using the photos taken by MMS of corroded branching hardware, rusting equipment, lateral cracks of utility poles, and other such defects in order to assess the degree of damage and to plan for repairs. As camera technology advances, we will need to adapt how we proceed with maintenance work. The current use of this technology to detect wear in manholes is steadily progressing at AS Labs.

2.4 Machine learning

It is also important to be able to apply machine learning (deep learning) of images. For example, NTT Media Intelligence Laboratories is advancing machine learning of images, and even if an object is placed at an angle that is different from the registered image, it can be identified and detected. We aim to utilize this technology to determine the appropriate time to replace equipment such as closures, branching hardware, and lead-in lines installed in outdoor facilities (**Fig. 5**).

We will continue to innovate inspection work by combining the technologies introduced so far. The next task is to examine what the entire structure is like (**Fig. 6**). When measuring structures using MMS, we can see the routes of communication cable lines and suspension wires. It is also possible to determine whether or not a branch line or support pillar is necessary depending on the wire route situation. In this way, monitoring the entire facility situation such as the arrangement and state of the utility pole, the communication cable lines, the wire route, the branch line, and the support pillar as one system, and by seeing the balance of the whole system, it will likely be possible to analyze and predict any imbalance or distortion of such facilities. There is no problem when the balance of the entire system is sound. However,

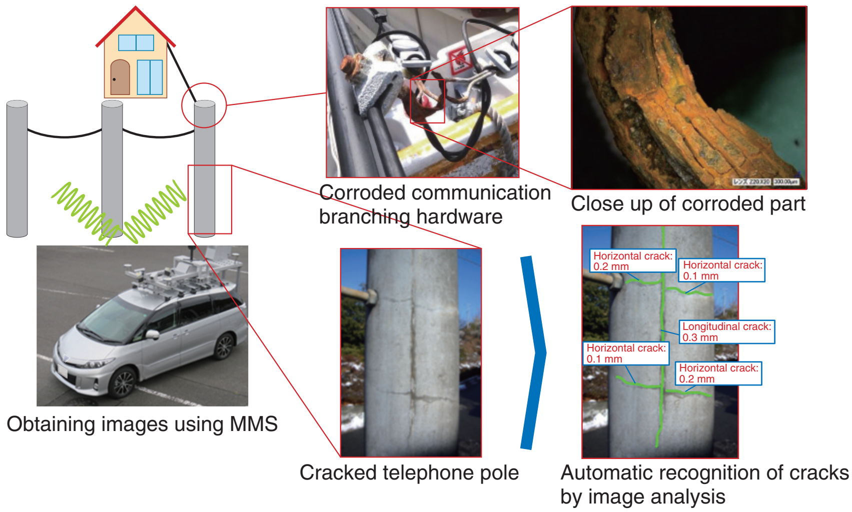

Fig. 5. Image analysis technology.

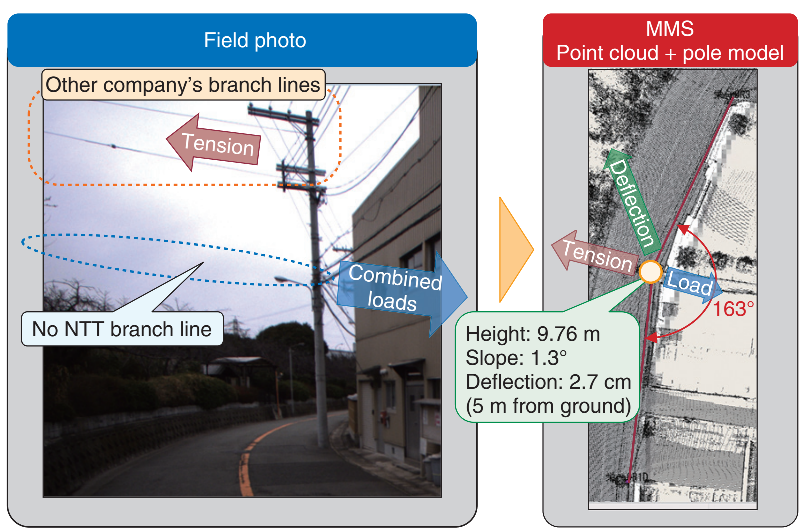

Fig. 6. Evaluation image of structure.

most of the existing facilities are 30 to 40 years old, so some of them are structurally unbalanced. Consequently, it is preferable to confirm the safety and security of such facilities according to the structural design reflecting the actual situation.

2.5 AI

Until now, we have investigated the new approach based on information on the structure and material of equipment, but further innovation of inspection work will not reach a sufficient level unless external information (external factors) is also taken into consideration. External factors include environmental indicators such as information on other companies' equipment, temperature, humidity, and other environmental data. It is important to combine these indicators to determine when to replace NTT equipment so as to avoid unnecessary capital investment by using equipment for as long as possible. AI technology can comprehensively support experts in deciding how to utilize the acquired data when updating or maintaining equipment. Therefore, we intend to further develop

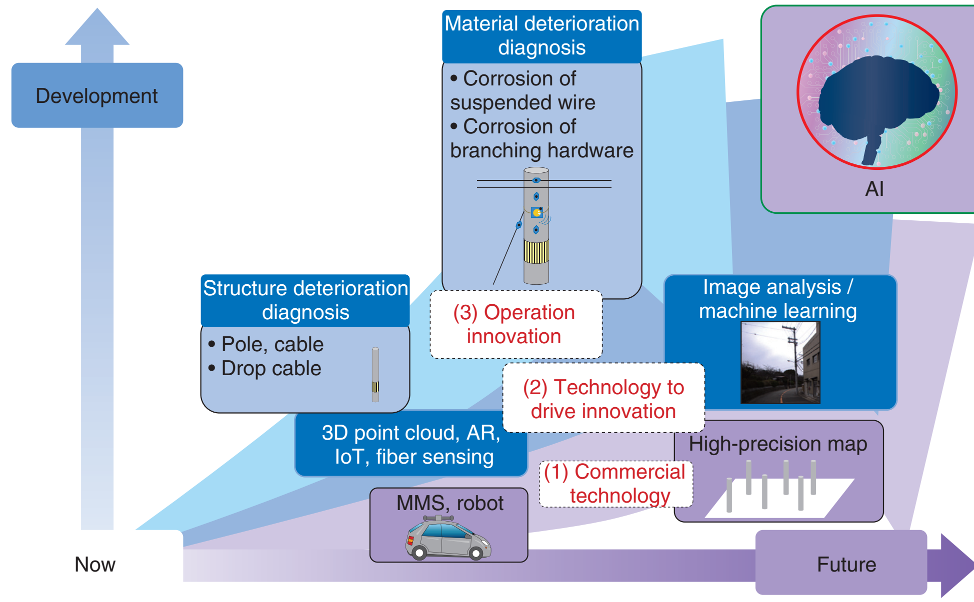

Fig. 7. Three pillars of inspection innovation.

AI technology in collaboration with partners both inside and outside the NTT Group.

We can summarize the above inspection work as being the three pillars of inspection innovation (**Fig. 7**).The base involves using general-purpose technologies such as MMS, robots, and high-precision maps ((1) in Fig. 7). The end goal is to improve the accuracy of technology applied for diagnosing the deterioration of structures and materials and to improve the efficiency of operations ((3) in Fig. 7). The element connecting these is to combine the 3D (three-dimensional) point cloud we are now researching and developing and the technology described here ((2) in Fig. 7). Our goal is to continue to expand these three pillars of inspection innovation from now on. We have manufacturing know-how that we have acquired at AS Labs for this effort, but our future efforts will not be realized unless we create new operation methods and techniques by collaborating with others in this field. The capability of field personnel is NTT's valuable asset. My aim is to improve the efficiency of NTT's business operations by successfully combining the element that improves efficiency through technology development with the element that increases the professional ability of field personnel.

3. Future deployment of services

In the environment surrounding ICT (information and communication technology), the demand for optical communication, which was always the center of equipment construction, is showing a tendency of saturation. As we pursue the Hikari Collaboration Model (wholesale fiber access service), various uses such as IoT, cloud formation, and the fusion of wired and wireless services are progressing, and the deployment of new services is expected. The NTT Group must operate facilities and services with the optimal number of personnel, while maintaining the quality of the equipment in order to take advantage of new business opportunities.

To achieve innovation of equipment/facility inspection, it is necessary to change not only the operation technology but also the current network to some extent. The optical network that NTT has built and expanded in Japan is another valuable asset of the NTT Group and ultimately of Japan, and it is therefore necessary to improve it so that it is more efficient and economical.

There are two necessary elements for updating access networks. One is our new access system architecture called FASA (Flexible Access System Architecture), which enables us to modularize and combine the functions of the access network equipment so that we can provide various services flexibly and promptly.

Another is the need for a new ground design for the optical fiber network. One example is to simplify the access network (e.g., aggregation of function points). We are currently placing splitters in optical networks and placing optical line terminals in public switched telephone networks in small buildings and considering how we can aggregate some of them. We would like to expand the scope of remote maintenance and increase the efficiency of operations by reducing the amount of maintenance done on site. This is referred to as equipment renovation at AS Labs. We plan to research the innovation of operation and equipment renovation and the way the network should improve in the future.

In our vision of the future access network infrastructure that expands optical network services to every person, thing, and business and continues to support society as a safe infrastructure beyond the age *anywhere*, *any business*, *any period*, we aim to deepen our cooperation with those we are collaborating with and strive to realize the results of research and development in a timely manner.

■ **Author profile**

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He joined NTT in 1989. During 2002–2005, he was with NTT Access Network Service Systems Laboratories as a Senior Research Engineer, where he worked on the development of the optical access system. During 2007–2014, he was a General Manager at NTT EAST, where he helped develop the operation system for the optical access network.