Application and Deployment of Remote Work Support Tool to Realize Real-time Sharing of Remote Field Situations

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In the after-sales services of our products delivered to customers, a problem that always arises is the shortage of resources for skilled staff and experts for on-site work instructions and customer service. This may lead to a decline in customer satisfaction or become a bottleneck in expanding our service business. To address these issues, a remote work support tool has been established. The tool consists of a wearable camera and a web conferencing system, thereby enabling to share the situation happening on-site or in the field with someone at a factory or office in real time. The hurdle in introducing the tool has been lowered by combining commercially available cameras with in-house tools. This allowed us to immediately deploy it in the multiple business divisions. Our capability to provide timely decisions about the situation happening in a remote area has not only improved the in-house service business but has also enabled us to promptly respond to customers.

1. Introduction

Many of the products manufactured by Mitsubishi Heavy Industries (MHI) Group are in operation on customers' premises, which are often called "the site or the field". MHI Group provides after-sales services such as maintenance (e.g., inspections and repairs), remodeling and updates. As the site or field is often located in an area distant from the office (Division bases, works, research and innovation center, etc.), the staff and engineers themselves directly visit there as needed to get the work done, necessitating time and expenses for travel. In addition to the planned on-site work, a problem requiring a quick response may occur. Every time this happens, experienced staff such as skilled engineers and experts need to travel to the site to decide what to do according to the situation. With the aim of enabling such decision-making to be done remotely in a timely manner, a remote work support tool has been developed. Its application concept is shown in **Figure 1**. The development of remote work support tool is effective in not only helping make a timely decision in an urgent situation on the site as described above, but also giving instructions for work in a remote location, monitoring its process or grasping the situation. In fact, the effects are not limited to only the reduced business travel costs; the range of real-time information sharing has also been expanded.

To realize remote work support, the functionalities of commercially available wearable cameras and their applications within MHI Group were investigated. The specified key points for practical use are the stability of communications, low tool cost, and data management of the information handled. A tool that satisfies these requirements was established by combining commercially available equipment with the systems that have been used in-house, and was immediately put on trial for use within MHI Group. As the tool was configured in such a way that the cost and time for introduction can be minimized, "use-it-first" action was enabled. The feedback from the applications on multiple sites and new use cases were obtained.

This report presents a summary of this tool we developed, application cases and prospects of future deployment.

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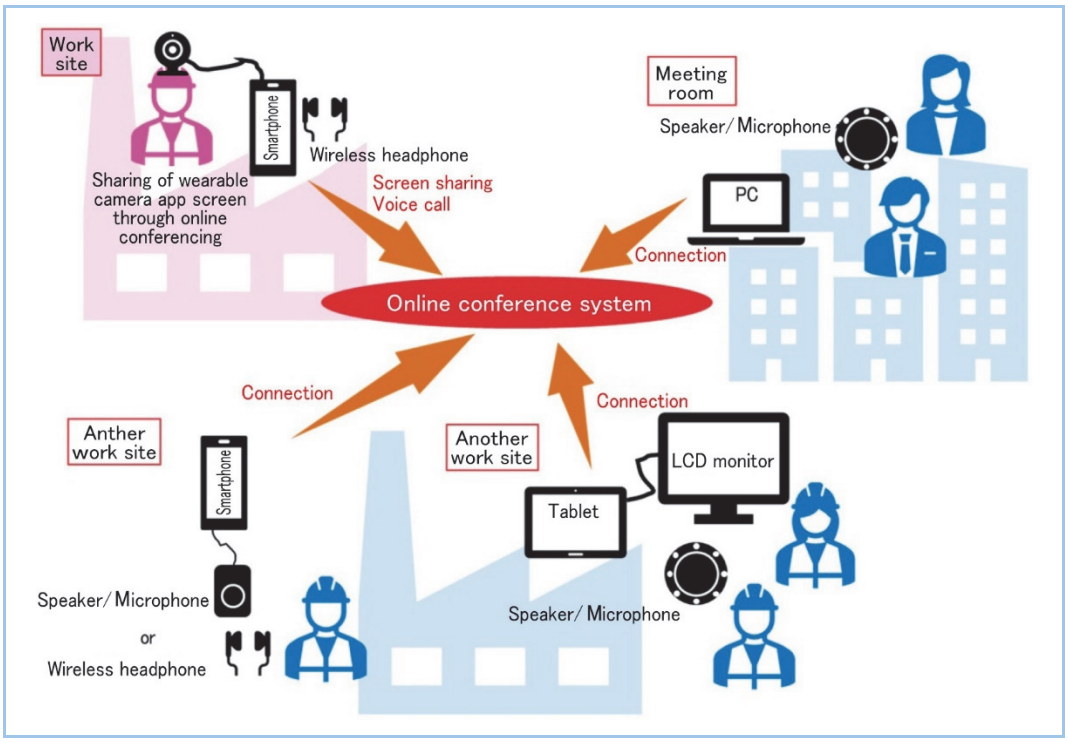

Figure 1 Application image of remote work support tool

2. Summary of remote work support tool

As shown in **Figure 2**, the remote work support tool consists of a wearable camera that captures the field of vision of the worker on the site, an online conference system to share the obtained visual information in real time (live video), and a communication device. Many integrated systems combining these systems and even individual items are commercially available on the market. However, for the introduction to numerous locations, the requirements that need to be satisfied pertain to not only video and communication performance but also costs and availability.

With regard to the performance of the wearable camera itself, the following functions are required in addition to visual quality: predesigned features to keep the horizon steady when worn, camera shake prevention assumed to be mounted by the worker, and waterproof and dustproof features to make it usable in an on-site working environment. In addition, wearing an expensive high-performance camera on the site tends to be avoided from the viewpoint of workability. It is therefore desirable to find a durable, relatively inexpensive, wearable camera that meets these requirements.

Secondary, as a means of sharing the images from the camera at a distant location, the screen sharing function of an online conference system is employed. By utilizing the online conference system that has been regularly used in-house with shared data security management, sharing of visual data has been realized without entering into a new account licensing contract or securing a dedicated data server. In addition, for operating an app to control a wearable camera and screen sharing through online conferencing, the smartphones provided for daily work are used, eliminating the need to obtain dedicated terminals.

In addition, all the equipment required on-site can be ready by preparing the other necessities such as a mounting device to fix a wearable camera to the helmet, connection cables and batteries. On the other hand, the office (or another site) checking remotely the ongoing situation needs to have only an environment to access the online conference system. Therefore, live video can be viewed just by adding, if necessary, a microphone and speaker system to the company's smartphones or PCs.

As the wearable camera in use also has a function to allow the user to change the digital zoom ratio (angle of view) through the app, the camera is set to a wide angle when capturing the overall situation on the site and digital zoom is used to look into the appearance of an object under observation in detail. Necessary visual information can thus be obtained appropriately. The business divisions that actually used the camera responded favorably, pointing out its usefulness in

the examination of dents or coating surface conditions of the object, when compared with the cameras used previously.

Having multiple sets of this tool, the Service Engineering Department of the Research & Innovation Center performs a demonstration at the business divisions and carries out on-site trials, continuing to prepare a manual, upgrade the components of the tool, and identify potential new use cases. The demonstrated applications are presented in the following chapters.

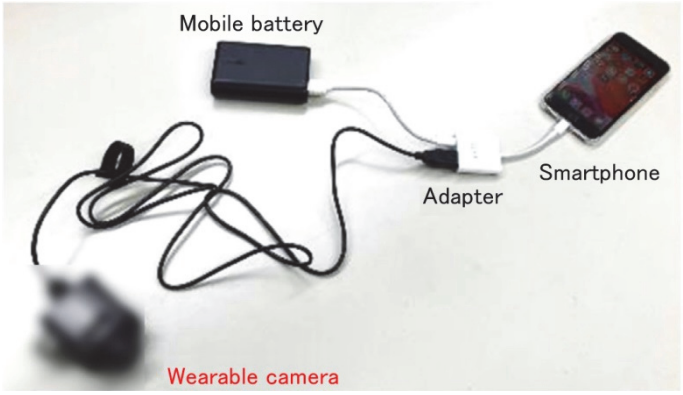

Figure 2 Components of remote work support tool

3. Application case

3.1 Application case 1: "Work instructions from distant location"

Firstly, let us describe the tool's original envisioned application. In the on-site inspections and measurements, there were some cases in which the conditions for data acquisition were adjusted while reading the measurement data. When an expert gave instructions on how to set the measurement equipment, etc., from the meeting room of a distant office, the tool was used both at the site and the meeting room. As shown in **Figure 3**, the screen display of the on-site measurement equipment and the ongoing data collection were placed in the field of vision of the wearable camera. Watching the images therefrom, the expert in the office was able to give instructions for setting the conditions. This way of giving instructions has made it possible by pinpoint for the experts to know exactly what is going on without their actually visiting the site, and reduced the risk of misunderstanding in the case of telephone communication.

Apart from the expert in the meeting room who gave the work instructions, there were actually some other staff members who used their mobile devices or PCs to access the system and watch the ongoing site condition in a timely manner, thereby saving the time and additional work necessary to share the results.

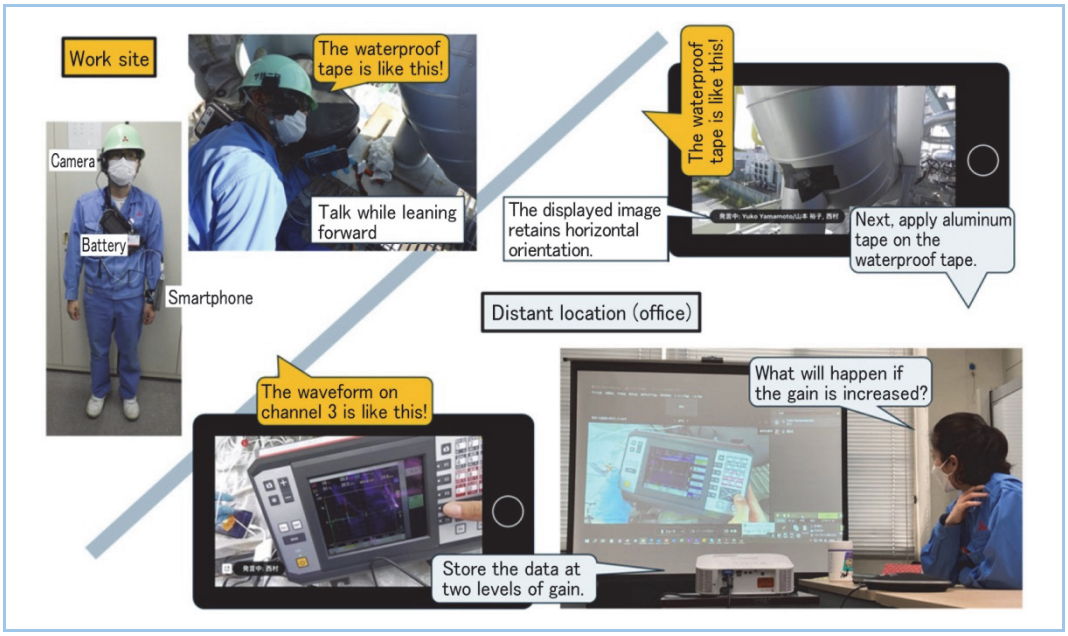

Figure 3 Remote work instructions from distant location

3.2 Application case 2: “Checking condition of regularly patrolled site”

When the site for new construction or remodeling is far from the office, the site manager needs to patrol the site on a regular basis. However, every time patrolling is conducted, the time required to complete the work includes not only the patrolling itself, but also visiting the site and making preparations. This causes delays in office work, for which taking measures has been considered necessary. Therefore, as a remote patrolling trial, whatever or wherever needed to be checked by the site manager was inspected using the remote work visual line tool on the site. Watching from the office, the site manager gave instructions and comments in real time. As shown in **Figure 4**, the site manager in the meeting room was able to see the field of vision of the worker checking the temporary storage site of materials and the notices. In addition to such inspection, other site conditions such as puddles after rain and the degradation of equipment can be checked, indicating the tool’s effectiveness for arranging on-site work processes. It has become possible to choose between actual patrol and remote inspection depending on the degree of importance, reducing the unnecessary work needed for frequent visits.

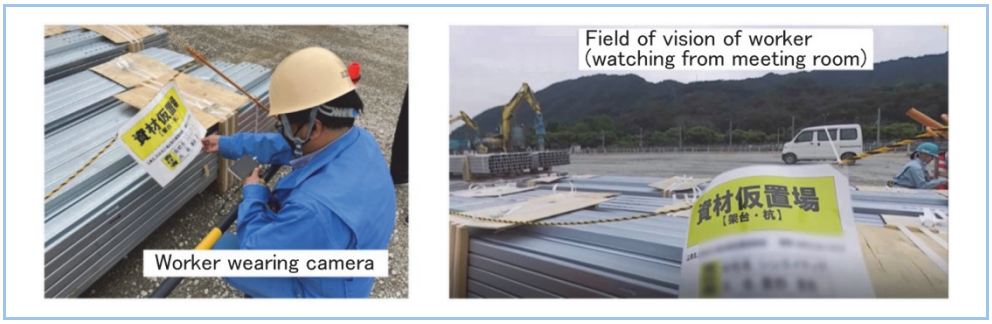

Figure 4 Checking condition of regularly patrolled site

3.3 Application case 3: “Attendance at actual product inspection at partner’s factory or in the field”

On occasions when our delivered equipment needs maintenance or periodic inspection or is under remodeling construction, it is necessary to conduct actual product inspection at the site, which is attended by the inspector. The remote work support tool can be used in this regard to inspect simultaneously from a distant office, thereby allowing only a minimum number of inspectors to be in attendance at the actual inspection site. As shown in **Figure 5**, when inspectors were visually checking the actual products at our partner’s factory, several staff also watched them from the office. With clear images, it was possible to reasonably grasp what was going on there with no time lag. A dent in the object under observation and the coating surface conditions were also able to be examined. Even if the inspectors moved, the displayed image stayed steady, retaining the horizontal orientation without blurring. Inspections from the office were able to be carried out without problems.

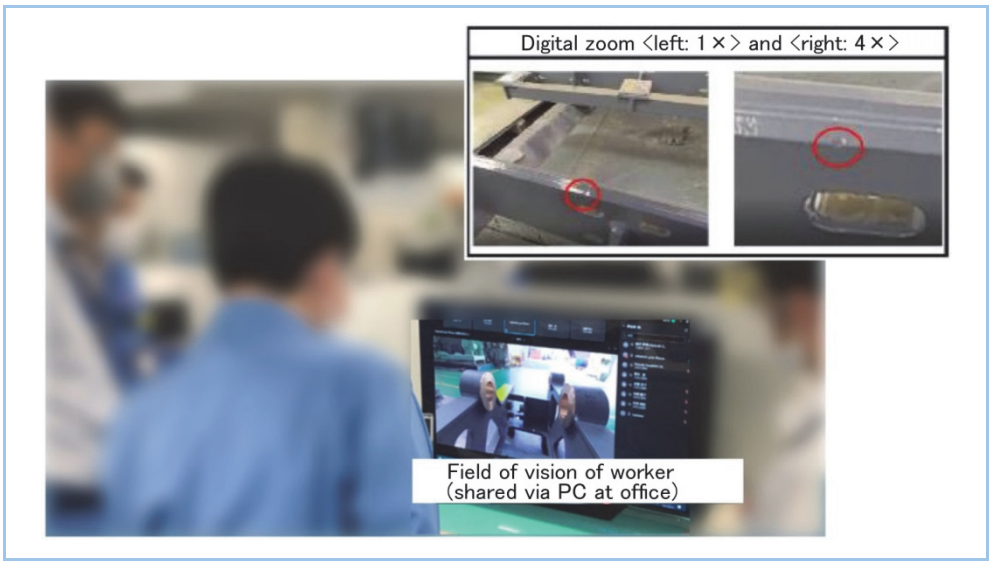

Figure 5 Attendance at actual product inspection at partner’s factory

Furthermore, visual checking is not the only operation carried out for on-site inspections of actual products and materials. It also becomes possible to remotely read the size measurements with digital calipers or convex lens by simply placing the scale into the field of vision of the wearable camera. An on-site demonstration was performed on a customer's premises. In this demonstration, other information such as the marks engraved on the materials could also be observed clearly, indicating the feasibility of using the system for remote attendance at material acceptance inspections.

With regard to these cases described so far, it has been identified what improvements are needed mainly in terms of communication environment, relay method and device wearing depending on the site. We will make improvements to contribute to enhancing customer satisfaction by creating more applicable cases.

3.4 Application case 4: "Customer attendance at inspection at factory"

Finally, we will introduce the tool's application in locations other than distant ones. When customers are in attendance during production inspection or finished product inspection at a factory, the number of people who can enter the site may be limited depending on the site; for example, inspections using an aerial work platform, inside containment areas or in control areas. It is difficult for them all to inspect the site at the same time. When this was the case, as shown in **Figure 6**, one of the inspectors put on a wearable camera and entered a restricted area as a representative, whose field of vision was shared with everyone else outside the restricted area for inspection. It is also possible to divide workers into groups such as those responsible for inspecting the actual object in a restricted area and those for checking technical drawings outside the area. Such use can be applied for OJT (On-the-Job Training) of inexperienced staff.

There were some cases in which preparations were needed at the beginning, including attaching a wearable camera and adjusting any misalignment between the wearer's actual field of vision and the image captured by the camera. However, it was possible to get used to the outfit within a few minutes at any of the sites. The difficulties experienced by those checking the shared images included isolation from ambient noise in an environment other than the meeting room. However, the employment of existing tools such as a highly directional microphone and speaker system and bone conduction microphones in a combined manner helped deal with the problem.

Such on-site improvements should not be special tools whose application is limited to certain locations, but should be general-purpose tools that can be immediately deployed at many locations. It is also desirable for it to be within the budget, inexpensive and compliant with the in-house security policy. The remote work support tool presented in this report, which satisfies these requirements, has been introduced to multiple business divisions for the applications demonstrated by the research division. The tool has also been in use on the sites of customers.

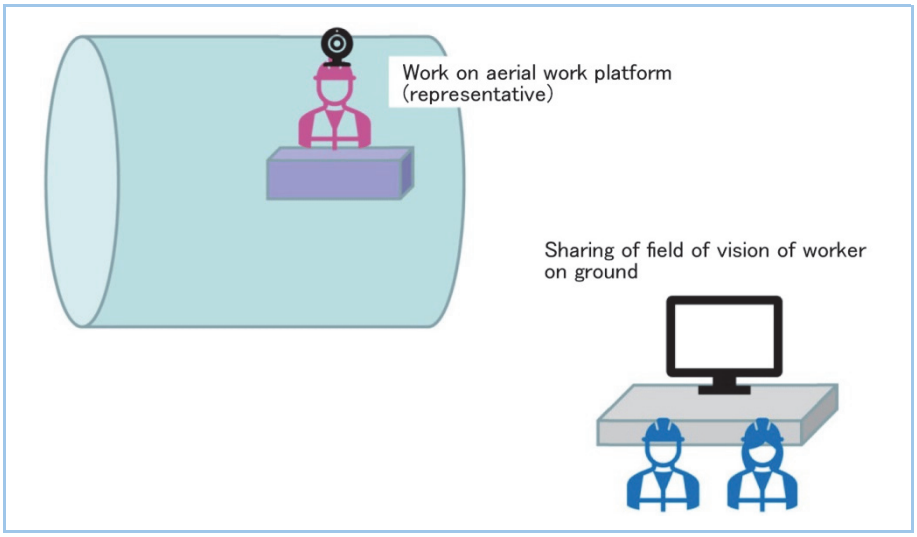

Figure 6 Application during attendance at factory

4. Future prospect

This report presents the MHI Group's applications of a remote work support tool. All of the aforementioned cases could take place on customers' premises to which our products were delivered or in the field. With this tool, it becomes possible to promptly provide an expert's opinion and contribute to rationalizing costs through reducing the number of dispatched staff. Having started as an auxiliary tool for remote patrols, inspections, examinations, measurements, instructions to workers and training, the tool is capable of not only sharing live images of ongoing work at a distant location, but also recording it digitally and sharing it with multiple people. Therefore, remote work support itself can also be provided as a service.

Customization is possible depending on the site, for example, using relays to share because of a poor communication environment or having a simple monitor to check the shared images by the workers themselves. We will consider the packages according to the customer's needs, on-site environmental specifications and operation methods.

5. Conclusion

For customers who have premises in remote areas and MHI Group's business divisions, it has been a challenge to remotely provide an expert's opinion in a timely manner and rationalize the inspections by qualified personnel. In some cases, such problems can be solved using the remote work support tool. The hurdle in introducing the tool has been lowered by combining commercially available wearable cameras, the online conference system approved in-house, and the company's smartphones. The sites of ongoing construction, operations and periodic inspections were actually able to be inspected in real time from the office or another site, during which instructions, advice and necessary judgement were able to be provided while the field of vision of the worker was watched from a distant location. This technology can contribute to not only reducing costs for business travel and dispatch of experts, but also enhancing on-site customer satisfaction because of its capability of providing prompt instructions and decisions. Although it is currently being applied as an auxiliary tool for measurement and inspection, we will continue to propose solutions that enable timely response to on-site needs such as the provision of remote work support as a service.