# XR Applications for Reducing Environmental Impact of Long Distance Travels

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OKI has been researching and developing technologies to improve productivity through the integration of audiovisual communication and XR technologies. The combined technologies enable knowledge transfer of skilled workers, which is difficult to accomplish by means of language. The resulting technologies are the “Remote Work Support System” and “Digital Twin XR,” and they have been publicized in previous OKI Technical Reviews and technical paper[1), 2), 3)].

Development of these technologies began with the aim of improving productivity at manufacturing sites, conveying knowledge, and reducing the physical burden associated with the travel of skilled workers. However, they are also expected to have an effect on reducing environmental impact, which has been a topic of attention in recent years. Until now, in order to support work being carried out at a remote site, it was necessary for a skilled worker to travel to the site. Consequently, ordinary transportation such as automobiles and airplanes were used to reach the site, which inevitably emitted large amounts of $CO_2$. Therefore, if the task can be completed without actually traveling to the site, $CO_2$ emissions resulting from long distance travel can be reduced thus minimizing environmental impact.

This article will first review the background and characteristics of the two technologies then follow with a report on the current progress of development. Finally, the effects of these technologies are evaluated from the perspective of $CO_2$ reduction.

## Background of Remote Work Support System

OKI has developed the Remote Work Support System for use at its manufacturing plants. This technology enables work support between sites that do not or cannot share the same location. In manufacturing, it is often the case that the designer who actually designed the product and understands the design intent is not at the same location as the manufacturer who engages directly in manufacturing. Examples include cases in which the design base and the manufacturing base are located in different parts of Japan, or cases in which production is carried out at an overseas factory after the product is designed in Japan.

When product manufacturing involves multiple bases and a new production line needs be started, it is normal for the designer make several trips to the manufacturing base and even make an extended stay until the line is up and running. However, due to the spread of COVID-19 in 2019, travel within and outside of Japan became restricted, and it was impossible to make actual site visits. The Remote Work Support System can be used under such a situation. The technology enables detailed work instructions to be given to workers performing the labor at the remote site via communication lines.

## Overview of Remote Work Support System

**Figure 1** shows an overview of the Remote Work Support System.

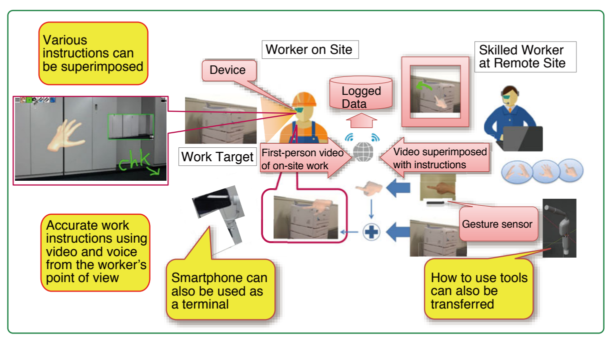


**Figure 1. Overview of Remote Work Support System**

The Remote Work Support System connects the skilled worker at an off-site location with the on-site worker and enables the skilled worker to remotely support on-site “work.” In addition to audiovisual communication similar to that used in common teleconferences and video conferences, it also utilizes a variety of other methods to communicate instructions such as displaying hand images captured by a gesture sensor, described later, and drawing lines called sketches on the screen.

Activities that aim to give instructions and guidance to on-site workers without skilled workers making physical travel are referred to as “remote support.” However, existing research has shown that audiovisual transmission alone does not provide sufficient support. For example, information conveyed through speech accompanied by gestures such as “look here” (while pointing a finger at an object) and “grab like this” (while performing operation) is unmistakably clear when the workers are in the same place. Unfortunately, the same information cannot be conveyed remotely, and gestures become meaningless.

Unlike normal teleconferencing, support for manufacturing work requires instructions referring to real objects rather than digital data since the work target exists in a real space, and gestures mentioned previously is one example. In order to enable such informative instructions, the Remote Work Support System under development acquires the image of the on-site worker, and “gestures,” which are the instructor’s hands and their movements obtained with a gesture sensor, are superimposed on top of that image in real-time using computer graphics. As a result, position to take notice and direction to move (direction to move the camera shooting the image) can be presented in an easy-to-understand manner just by pointing the finger. It is also possible to easily show the form of both hands and their required movements to perform a specific work.

Additional instructions can be provided using a snapshot, which is a single still image cut out from a video, and displaying the above-mentioned gestures on that image. To provide even more detailed instructions, the sketch feature enables characters, symbols and lines to be drawn on the image.

In addition to displaying hands, development is currently underway to display 3D images of tools that are necessary for work. The tools’ images are moved in real-time with a mechanism similar to gestures and can show how to use tools such as a welding torch.

Initially, the technology was aimed at providing detailed work instructions for handling “physical objects” at an on-site location. Therefore, development proceeded with a wearable device as the display terminal to allow workers to use both hands freely (**Figure 2**). However, in recent years, it has become clear that the technology can be applied to other uses, such as having qualified personnel remotely audit the factory of a supplier outside OKI. To adapt the system to other uses, development is being carried out on a configuration that uses smartphones (**Figure 2, right**), which are readily available and come equipped with a high-quality camera at a low cost.

Expand compatible devices from dedicated terminals to smartphones

**Figure 2. Examples of Devices Usable with Remote Work Support System**

## Background of Digital Twin XR

One issue facing the manufacturing industry has been the inability to transfer knowledge of skilled workers, which are difficult language-wise, to the next generation. Problems underlying the issue are the retirement of skilled workers due to aging and the fact that there was no one to transfer the knowledge to in the first place because hiring was held back during the long recession. As a result, the tacit knowledge of skilled workers, which takes time to acquire, has not been transfered to the next generation. If this situation continues, there is a risk that techniques and know-how necessary for manufacturing will disappear along with the resignation or retirement of skilled workers. It is also necessary to create detailed work procedure manuals in order to ensure consistent manufacturing quality regardless of the workers’ skills. However, the needs of consumers have become diversified, and high-mix low-volume production is now required. Since preparing a manual for each product will result in enormous costs, some kind of method is required to remedy the issue. Worksites are considering recording the actions of the skilled workers on video, but the problem with this method is that the information obtained is only from the viewpoint of the video.

The Digital Twin XR currently under development aims to solve these problems by recording the body movements of skilled workers as 3D motion data and displaying them using multiple means. Therefore, even if the skilled workers are absent or unable to travel to a site, it will be possible to learn and train from the accumulated techniques.

## Overview of Digital Twin XR

The Digital Twin XR consists of a 3D motion measurement system (motion capture system) and a 3D image display (visualization system) as shown in **Figure 3**.

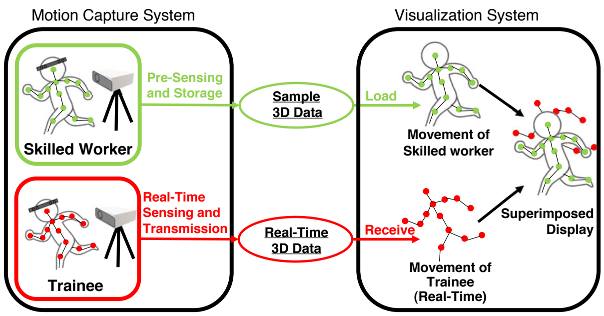


**Figure 3. Overview of Digital Twin XR**

### (1) Motion Capture System

The system records the movements of a skilled worker, that is, a person who will serve as the sample model for the work to be performed. In order for the system to be used in places such as a factory where there are installation constraints and the need to minimize burden on the trainee, focus was placed on configuring the system that uses a combination of inexpensive sensors, is easy to install, and captures information necessary for knowledge transfer. Currently, commercially available optical sensors are being used to capture detailed movements of the body's skeletal structure and hands. Two sensors capture 3D data of a person's movement, which consists of numerical data from a total of 76 joint points, and information of the entire body posture associated with the detailed hand movements is stored. Furthermore, the movements of the trainee can also be captured and superimposed with the stored sample model data to improve the educational effect, as described later.

### (2) Visualization System

In the visualization system under development, a commercially available glasses-free 3D device is used as an information display. The device outputs images that are matched to the viewer's left and right eyes, which then presents 3D images using left-right parallax. Therefore, the viewer is not required to wear a special device for stereoscopic vision. HMD (Head Mounted Display) can also be used as the display device, but considering the increased burden on trainee who must wear them, development at the moment is mainly with glasses-free 3D.

The visualization system reads the 3D data recorded by the motion capture system and using the angle of each joint, it reproduces the captured movements in a form of a 3D humanoid avatar. Since the movements are saved as 3D data, the display method can be easily changed compared to video-recorded instructional content. For example, the position of the virtual camera viewing the avatar can be changed freely and zoomed in for a detailed view of the hand movements, or conversely zoomed out to check the full body posture of the skilled worker. It is also possible to adjust the speed of the movement or stop it, so that the trainee can better confirm the skilled worker's movements.

Additionally, the trainee's movements during training can be captured and superimposed onto the movements of the sample model, allowing the trainee to check his/her own movements. **Figure 4** shows the appearance of an avatar that reproduces the movements of the sample model superimposed with the avatar of the trainee.

In the current implementation, the sample model appears as a male-shaped translucent avatar, and the avatar that reproduces the trainee's movements is a stick avatar with spheres as joint points and cylinders as the links that connect them. Also, around the stick avatar, outline matching the shape of the sample model avatar is displayed[4].

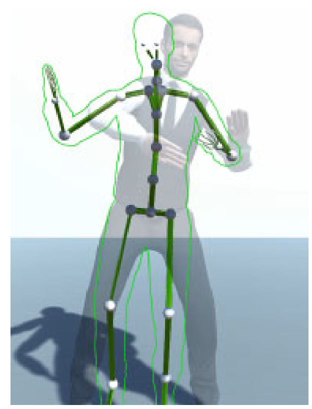

**Figure 4. Appearance of Avatars**

Using both the visualization system and the motion capture system, it is possible to superimpose the trainee's own movements captured in real-time while displaying the movements of the skilled worker. This function makes it easier for the trainee to compare the differences between the skilled worker and the trainee's own movements and enables the understanding of issues in one's movements.

## Effect on $CO_2$ Emissions

The two technologies introduced in this article make it possible to provide on-site work support or training without the need for skilled workers and trainees to travel.

They have the effect of reducing $CO_2$ emissions if the travel required some means of transportation such as automobiles and airplanes. This section will examine the effect on $CO_2$ emissions when the technologies are applied to specific cases within OKI both in Japan and overseas.

The domestic example involves a normal passenger vehicle used to travel between the Numazu Factory in Shizuoka Prefecture and the Honjo Factory in Saitama Prefecture, where communication is necessary for the relocation of a production line. In the overseas example, air travel for providing technical support to ODMT's (OKI Data Manufacturing Thailand) Ayutthaya factory, which is the furthest OKI facility from Japan, is examined.

**• Example of $CO_2$ Emission from Domestic Travel**

The amount of $CO_2$ emission when traveling approximately 400km roundtrip between Numazu City and Honjo City in a normal passenger vehicle is:

153[*1)]g-$CO_2$/km x 400km = 61.2kg $CO_2$

**• Example of $CO_2$ Emission from Overseas Travel**

Using Google's[*2)] calculation based on the latest 2019 algorithm model proposed by the European Environment Agency (EEA), the standard estimated $CO_2$ emission[6)] when traveling via jumbo jet from Tokyo's Narita Airport to Thailand's Suvarnabhumi International Airport is:

296 x 2 (roundtrip) = 592kg $CO_2$

Both of the values above are for a single roundtrip and will increase with the number of trips. Assuming the proposed technologies can reduce the number of domestic trips by five trips and overseas trip by one trip per year, the OKI Group will be able to reduce $CO_2$ emissions by approximately 900kg or nearly 1t per year.

## Conclusion

It was expected that the introduction of the Remote Work Support System and Digital Twin XR would reduce travel and be a solution to the declining number of skilled workers. However, after evaluating the technologies from a different perspective, they were found to have a profound effect on reducing $CO_2$ emissions.

The use of the two technologies is currently being spread within the OKI Group and further development is in progress for commercialization outside the company. In addition to the technologies contribution to reducing $CO_2$ emissions within the company, OKI plans to actively promote the technologies effect of reducing environmental impact when they are commercialized. ◆◆

*1) Value calculated by OKI from the average g-$CO_2$/km value of passenger vehicles listed in Reference 5).
*2) Google is a registered trademark or trademark of Google LLC.

## ■ References


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## TIPS 【Glossary】

**XR (eXtended Reality)**
General term for virtual reality technologies such as AR (Augmented Reality) and VR (Virtual Reality).

**g-$CO_2$/km**
Index for evaluating $CO_2$ emissions associated with movement using a certain transportation mode. Index is expressed in grams of $CO_2$ emitted when traveling 1km using that transportation mode.