

Implementation of Digital Twin-Based Metaverse Safety Service Technology for RTO Predictive Preservation

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Abstract – In this paper, a metaverse-based safety operation service platform is implemented for safe maintenance and operation of RTO devices. Most RTO systems operating 24 hours a day have limitations in responding immediately to a failure over a long distance, resulting in inefficient maintenance situations. In particular, the aging of field personnel, inexperience in equipment operation, and lack of transition due to the turnover of professional personnel cause many problems in equipment operation. Therefore, long-distance monitoring and safety training are required.

A virtual space is constructed based on the metaverse, and the equipment structure, circuit diagram, part characteristics, and detailed configuration are constructed in a 3D shape using digital twin technology. To this end, 3D modeling technology generates a mesh based on the design data of the RTO equipment and generates the texture of the equipment based on the actual picture. Low latency and high-quality data should be provided to multiple users in remote locations. It is delivered to XR devices, PCs, and smartphones to build a 3D virtual space on the site. At this time, the location of the remote user is shared with the site as location data using AR glasses (smartphones). Therefore, monitoring, which was operated as an existing 2D screen, is combined with 3D space to provide an environment and efficiency that can be intuitively and visually recognized.

Keywords - RTO, maintenance, edge-IoT, virtual space, monitoring

I. INTRODUCTION

Globally, environmental-related equipment is strengthening management of the sources of volatile organic compounds that cause high concentrations of fine dust and ozone. Chemical plants, metal surface treatment, automobile painting, and printing plants are often open 24 hours a day. Among the volatile organic compounds (VOCs) released into the atmosphere from factories, aromatic hydrocarbons such as benzene, toluene, and xylene are powerful carcinogens that cause leukemia, central nervous system disorders, and chromosomal abnormalities, and hydrochloride causes ozone layer destruction and global warming[1].

Heat storage combustion oxidation (RTO) and scrubber are used as devices to reduce volatile organic compounds (VOCs), and they are also used as follow-up measures depending on operating conditions and working conditions. Therefore, the efficiency of removing volatile organic compounds requires high conditions from 95 to 99%, but in order to have a higher removal efficiency, more installation area is required than the existing method[2].

Most volatile organic compound reduction devices such as RTO and scrubbers have monitoring functions within the

installation company, but maintenance is limited. In the event of a problem with the system operating the system, rapid maintenance and repair of the installed company are required.

Recently, strategies to reflect carbon reduction in corporate environmental, social, and governance (ESG) management are spreading to a global trend, and as the interest of all members of society, including consumers, investors, and the government, is increasing, it is emerging as a key factor in corporate survival and not a choice. Figure 1 shows the VOCs emission device and the site of the VOCs gas explosion[3].



Figure 1. The VOCs emission RTO and gas explosion

In this paper, we implement the metaverse-based safe operation service technology for the maintenance and safe operation of the Regulatory Thermal Oxidation (RTO), an air pollution reduction device. In particular, RTO devices that operate 24 hours a day have limitations in the immediate response when a failure occurs, and equipment installed overseas has inefficient maintenance situations due to problems such as physical distance. To overcome this, digital twin-based space and safety service technology are implemented by converting virtual space into a metaverse. The structure, design, configuration, and assembly manual of parts are implemented in 3D with digital twin parts. As a 3D modeling technology, a mesh is generated based on the design data of the RTO equipment and the texture of the equipment is generated based on the actual picture. Through a site reconstructed in 3D, fast high-quality data is transmitted from a remote location to an XR device, PC, and smartphone to track the user's parts.

II. METAVERSE-BASED SERVICE TECHNOLOGY

In the event of a failure due to 24-hour operation on weekdays, there are difficulties such as the exact location of the accident at the site, the treatment of VOC harmful substances, and immediate technical support services due to distance. In particular, if a complex equipment usage manual is immature, a lack of handover due to frequent turnover of field personnel, or a problem with factory operation occurs

when it is located at a wide and long distance, such as a chemical complex, it cannot be immediately dealt with [4].

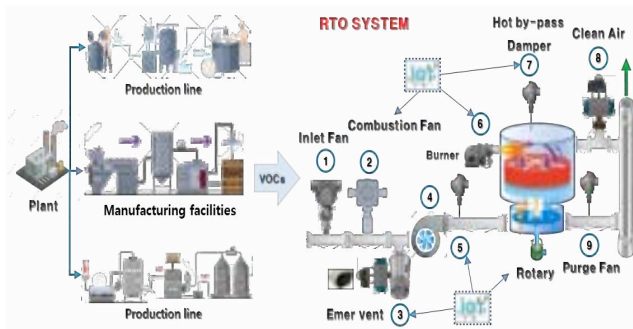


Figure 2. The connection between the production facility and the RTO.

Figure 2 shows the connection between the production facility and the RTO equipment, and the circle number in the RTO device is a picture of the sensor IoT attached to the location to be managed. Edge IoT can provide information to field managers, and the detected data can be connected to a server to be analyzed. For continuous monitoring, measurement data is transmitted remotely by connecting a sensor to the programmable logic controller (PLC) device of the RTO device[5].

Europe (EU) and the U.S. Environmental Protection Agency (EPA) are using IoT to build smart management systems for pollutants or managers. Figure 3 shows the digital twin-based remote service and metaverse visualization configuration with on-site interactive service support.

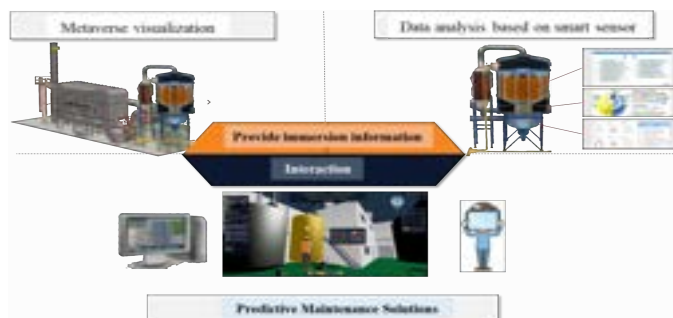


Figure 3. Digital twin-based remote services and metaverse visualization.

The data received by the PC or terminal server is analyzed through segmentation and data analysis. At this time, the rapid response to the failure is made through goggles in virtual enhancement, and through metaverse virtual space technology, it is possible to respond remotely without going directly to the site. It is possible to conduct safety education by creating the same environment and various scenarios as the site with a virtual space. Monitoring of major equipment currently operating with 2D screens is combined with 3D space to provide a monitoring environment that can be better recognized visually [6].

As tools for remote 3D meetings and collaborations, various digital virtual space service technologies are being developed, such as virtual offices (VRaum Meet), VRaum events that allow conferences or exhibitions, and the VRaum Factory that

can remotely collaborate with field staff in the same space. The VRaum Meet, where people can meet and meet in a virtual space for RTO devices, enables remote 3D virtual space meetings that provide screen sharing, data sharing, whiteboards, memos, as well as remote PCs and multiple virtual spaces for meetings. Figure 4 shows examples of VRaum Meet, VRaum events, and the VRaum Factory.



Figure 4. VRaum example of meet, event and factory.

3D Virtual Space Configuration technology reconstructs low-latency, high-quality data on-site through 3D virtual spaces in remote locations. It provides a multi-user-based XR device, PC and smartphone to identify user locations and movements and share remote user locations with sites based on AR glasses (smartphones). Figure 5 shows the service technology that constitutes the platform. Based on actual equipment design data, we model a 3D space that generates mesh and texture for the graphics of equipment. Building a platform for multiple users is based on a dedicated server, and one to four people can access the same virtual space at the same time. Location data and interaction between users are shared according to each user's movement.



Figure 5. Service platform configuration technology.

Figure 6 is a block diagram of a 3D voice conversation with an avatar that provides a service that includes interaction by implementing a 3D space-optimized communication method.



Figure 6. Diagram of an avatar and 3D voice conversation.

Applying avatars to virtual spaces, supporting multiple access to 3D voice chats using location-based voice functions, and making proximity sounds loud and far away sounds low for smooth and efficient communication within virtual spaces.

III. IMPLEMENTING THE RTO SAFETY SERVICES PLATFORM

3.1 Building element of RTO

In Figure 2, field rto can install edge IoT according to the lot of sensors connected to plc. At this time, it is converted to the server's database through the data log according to the PLC's trip information. Information is also transmitted to the field manager through the dashboard, and sensors connected to edge IoT use IEEE 485, LoRa, and WiFi modules for data according to wired and wireless conditions. The server program is implemented as a middleware-based system for smooth monitoring between field RTO operation status, control interface, and IoT device. At this time, location information using flash, installation date, equipment replacement date, sensor replacement date, number of malfunctions, and alarm function is added. Figure 7 shows the installation case for RTO facility training. It consists of system installation base ironing, PLC control panel, full foreground, internal construction, internal control panel and controller.



Figure 7. Installation case for RTO facility.

Figure 8 shows a detailed configuration example of an RTO device.

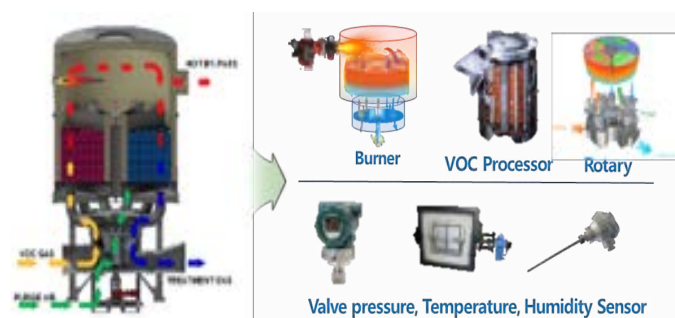


Figure 8. Configuration of an RTO device

Figure 9 shows the main RTO product installation and training items conducted offline. It occupies a very important educational program position for system installation and construction training in a virtual space.



Figure 9. Main RTO product installation and training items.

3.2 The safety service technology based on metaverse

In order to implement a metaverse-based safety education service platform, metaverse visualization and equipment manuals are provided by providing immersive information. It enables field situation sharing collaboration and simulation training for interaction. To know the RTO status information in Figure 10, field workers can check the status information of RTO equipment on AR devices (smartphones or tablets), and remote workers configure platform services to know RTO information of virtual spaces through PC monitors.



Figure 10. RTO status information.

Figure 11 provides intuitive information for workers through 3D visualization of digital twin-based RTO devices. Through Figure 10, an AR maker is attached to each part, which is expanded to the RTO entire device.

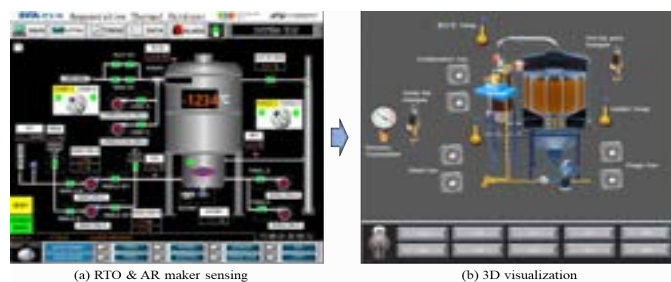


Figure 11. An AR maker & RTO expended entire device.

In order to share and collaborate with the field situation, remote user workers share it through AR device or PC (or VR device), which build real-time communication functions such as voice chat. At this time, the AR/VR (PC) device provides manuals and data for RTO equipment and major parts. Figure 12 shows the RTO equipment manual and monitoring information.

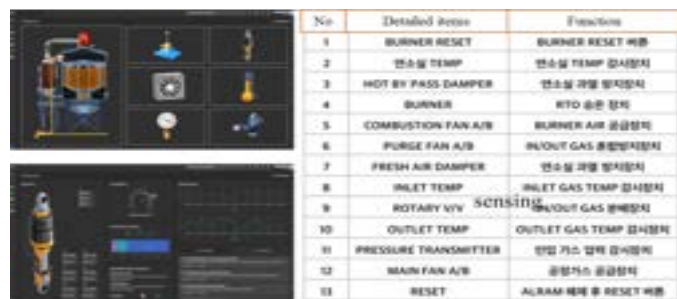


Figure 12. RTO equipment manual and monitoring information.

Figure 13 shows the travel route in case of an accident through 3D visualization of the site RTO facility and surrounding area.

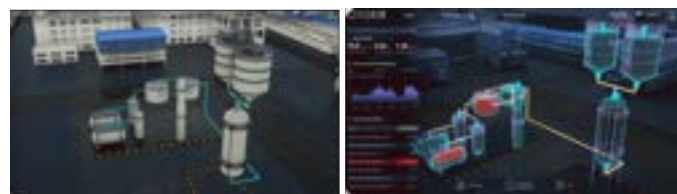


Figure 13. Travel route & 3D visualization of the site RTO

Figure 14 shows that sensor data from nine channels build a sensor database on a server. The right shows the database to be observed.



Figure 14. Sensor database on a server.

The data obtained from the sensor are data generated by physical sensors such as temperature, flow rate, and pressure of the RTO. By combining them, the concept of virtual sensors is applied to software calculate new indicator values such as the status of RTO emissions.

As real-time data collection of field operations becomes possible, various artificial intelligence machine learning techniques can be applied to preserve the system's prediction. A prediction algorithm may be applied using the acquired data. Table 1 shows the configuration diagram of the monitoring operation program.

TABLE 1. CONFIGURATION OF THE MONITORING SERVICE

Description	Observation Information management	Sensor measurement management
Status	Measure risk	Data analysis Tools
Analysis	Setting	Information management
Facility Management	Equipment management	Customization
Setting	Customizable	

Figure 15 is a visualization diagram showing the amount of decrease in VOC.



Figure 15. Showing the amount of decrease in VOC.

IV. CONCLUSIONS

A metaverse-based safety service platform was implemented to be used for RTO facility maintenance. In order to quickly cope with the failure of RTO devices, a safety response and education system is implemented so that it can respond remotely without going to the site through metaverse virtual space technology. Education and training are conducted by creating the same environment as the field with a virtual space and creating various situations. It provides a more intuitive and visually recognizable monitoring environment by combining the monitoring of major equipment currently operating with a 2D screen and the 3D space. As tools for remote 3D meetings and collaborations, various digital virtual space service technologies have been developed, including virtual offices (VRaum Meet), VRaum Event that can hold conferences or exhibitions, and VRaum Factory that can remotely collaborate with field staff in the same space. The VRaum Meet, where people can meet and meet in a virtual space about RTO devices, is a necessary tool for meetings, allowing for screen sharing, data sharing, whiteboards, memos, as well as remote 3D virtual space meetings that provide remote PCs and multiple virtual spaces.

ACKNOWLEDGMENT

This research is a research project (RS-2024-00446902) carried out with financial resources supported by the "2024 Smart Manufacturing Innovation Technology Development Project" by the Ministry of SMEs and Startups.

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