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Disaster prevention system for accelerator tunnels utilizing ICT

The Great East Japan Earthquake in 2011 struck J-PARC when some researchers were in its Main Ring (MR) tunnel for regular maintenance. Fortunately, the tsunami at J-PARC was 4.5 m high, and everyone escaped safely from inside the tunnel. However, they escaped from the entrance, which was several hundred meters away, and not from the nearby escape exit. Although all the workers were aware of the existence of the escape exit, they could not use it. This suggests that the display, education, and training were insufficient. However, from the manager's viewpoint, it is difficult to guide and rescue the workers if they do not know where they are in real-time. Based on this experience, we decided to develop a system that can identify the real-time position of a worker in the accelerator tunnel. J-PARC, Tobishima Corporation, and Kansai University Tagashira Laboratory have been working on the research and development of this system since 2015.

Since the accelerator tunnel is underground, GPS is ineffective. In addition to identifying the location of workers, it is desirable to have a character-based record that can be distributed simultaneously for communication purposes instead of using the personal handy-phone systems (PHS). To build a robust system that operates reliably even in the event of a disaster, we installed a dedicated LAN, feeder, and access points (APs) and use a lithium-ion battery to protect the system from power outages. Moreover, an application was developed for commercial smartphones and PC servers, allowing workers to enter the tunnel carrying the dedicated smartphone. To achieve stable operation of the system, all the devices, except for the application to be developed, rely on commodity products. We have developed a system that makes the best use of existing information and communication technology (ICT) and made it a system that can be expanded in the future.

The radiation resistance of the AP equipment installed in the tunnel is the primary concern for the introduction of the developed system to J-PARC. The J-PARC is a proton accelerator, and the inside of the tunnel during beam operation is a high radiation environment. During beam operation, the radiation dose is enough to kill a person who stays inside the tunnel for a day. According to the simulation, gamma and neutron rays are irradiated at a ratio of about 1:1. Generally, devices with semiconductors are vulnerable to radiation, and the damage caused by neutron rays is particularly severe. In fact, in a test conducted in 2015, the APs placed inside the MR tunnel broke immediately after the beam operation started. Since human entry is not permitted during beam operation, the APs do not have to be turned on during beam operation either. The radiation resistance will improve when the power is off. Experiments were conducted from 2016 to 2018 to measure the radiation resistance of the APs. It was confirmed that the resistance improved to approximately 2000 Gy when the power was turned off, while it failed at 1 Gy or less with the power on. The maximum radiation level at the location of the APs in the MR tunnel is estimated to be 600 Gy, so the APs do not need to be replaced for about two years. Details of this disaster prevention system are described in reference [1].

In 2019, APs were installed all around the MR tunnel, the developed application was installed on the smartphones, and a disaster prevention system was introduced. In 2020, we expanded the system to include video calls, work support using 360° cameras, and automatic recording of position and radiation measurements. Figure 1 shows the inside of the tunnel of the disaster prevention system and screenshots of the developed application. Thirty APs were placed at approximately every 50 m in the tunnel. The location of the workers was the location of the nearest AP. APs were also placed in facilities on the ground, such as the central control building, where an administrator stays. Ten dedicated smartphones were available at each of the two entry points. Workers could easily use the application as it enabled character-based information exchange similar to LINE. Additionally, to avoid interference with the work, a wearable device was prepared and connected to a smartphone to display the text information on it.

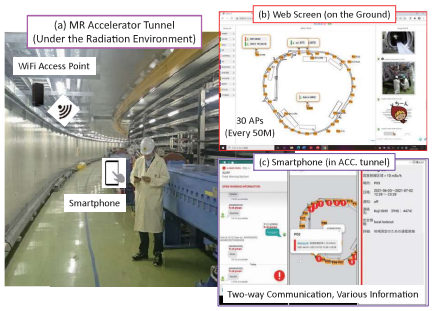

Fig. 1. a) Highlight of the Wi-Fi access point and the smartphone in the MR tunnel. b) Web screen of the developed application. c) Various images of the smartphone.

With the aim of future development of the system, we tried robots and drones in 2021. Although it is necessary to carry a dedicated smartphone to use the disaster prevention system, it is not obligatory to carry it to enter the tunnel. The system is being continuously improved for user-friendliness, but only half of the workers carry it. To overcome this situation, we are focusing on the use of robots that are capable of automatic tracking. If the robot that tracks the worker carries the information terminal, the worker does not have to carry it. Additionally, we have started an attempt to detect abnormalities different from the usual by having a robot patrol to acquire images inside the tunnel and automatically analyze them. The drone complements the action range of the robot and is intended to cover the range that the robot cannot reach owing to obstacles. Figure 2 shows the images of the drone and robot tests performed in the MR tunnel. The test was conducted with the cooperation of Sohgo Security Services (ALSOK) Co., Ltd. Many issues have been observed in these experiments. The reflection of light on the floor made the automatic analysis of the floor challenging. Moreover, it was observed that the drone had a problem with automatic flight. Further modifications are planned to continue development in the future. A press release was issued at the end of FY2021 to summarize the development so far. Seven members of different media companies participated in the press release. Figure 3 presents the images from the press release. We will continue to utilize the latest ICT to prevent disasters.

Fig. 2. a) Drone test in the MR tunnel. b) Video from the drone. c) Robot demo in the MR tunnel.

Fig. 3. a) Picture of the press release on March 30, 2022. b) The MR tunnel tour at the press release.

Reference

[1] K. Ishii *et al.*, Proc. 12th Int. Particle Acc. Conf. (IPAC2021), 2228 (2021), doi:10.18429/JACoW-IPAC2021-TUPAB315.