A Study on Real-time Radiation Map Generation System that Combines LIDAR and Survey Meter

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1. Introduction

This study is about a system development for creating a map by scanning a 3D large-space in real time and simultaneously radiological measuring using survey meter along a moving path in the form of a single device. SLAM (simultaneous localization and mapping) algorithm is applied to the PCD (Point Cloud Data) generated through the lidar sensor scan to create a 3D map and movement coordinates in real time. And at the same time radioactivity levels by survey meter are also measured and displayed on the 3D physical configuration as a result of scanning. On the study it is found that the simultaneous measuring device developed, which functions 3D scan and radiological measuring, can be applicable in the stages of the construction, O&M, and decommissioning of nuclear power plants or other plants.

2. Related work

2.1 Background

The radiological survey meter can only measure the amount of radiation in a given space and cannot determine the amount of radiation based on time and location. In the case of fixed 3D scans, external experts must take measurements for an extended period of time at multiple fixed locations, and maps are generated after manually matching post-processed scan data. This process is costly and time-consuming. Moreover, if the shape inside the building changes, the modified shape must be recognized and manually reflected on the map after scanning, making it challenging to scan continuously.

The PCD, which is collected by measuring the site, can be converted into a 3D digital map for use in design, construction, and maintenance. However, the digital map generated from collected 3D point cloud data requires pre- and post-processing to ensure the quality of the data. Currently, pre-processing and post-processing of the digital map is done manually by workers. As a result, correcting the digital map can greatly impact the time and cost of the work, depending on the workers' skill level and the difficulty of the task. Therefore, in order to automate the analysis of digital maps, both pre-processing and post-processing must be automated. [1]

2.2 Related work

This study presents a system that generates a radiation map based on the SLAM algorithm, integrating a survey meter and a lidar sensor to measure radiation over time and space. It can be used to measure in narrow and complex buildings while moving freely, and automatically matches the collected data to form a 3-dimensional radiation map in real-time. This system can be operated by non-expert field workers, and any changes in spatial shape, movement path, and radioactivity measurements can be displayed to the operator in real-time through a user-friendly interface. Furthermore, documented information is immediately generated after the measurement is completed.

In previous studies related to SLAM, the focus was mainly on the accuracy of the SLAM matching algorithm and the generation of space maps for robot movement. For instance, some studies focused on the implementation of serving mobile robots [2], graph-based SLAM technology for BIM model generation [3], remote control and visual SLAM of autonomous mobile robots [4], and radiation mapping by drone [5]. However, in this study, the primary objective is to generate a radiation map using SLAM technology integrated with a radiation measuring instrument.

3. Real-time radiation map generation

The system developed in this study offers the operator a GUI-based visualization of the 3D map, the traveled route, and the radiation measurements of the movement coordinates. It also displays warning messages if necessary. Once the system is terminated, documents are generated containing the entire 3D movement coordinates (x, y, z) over time and radiation measurement values (in uSv/h) corresponding to each coordinate. Additionally, the 3D space map is created as a PCD file.

3.1 System configuration

Figure 1. shows the radiation map generation system developed in this study. To process high-speed real-time data such as scan data, radiation data, and SLAM matching algorithms, an embedded system configuration with a built-in CPU and GPU is necessary. The lidar is comprised of 128 laser channels that quickly scan the internal environment of the nuclear power plant in real-time. With a viewing angle of 90˚, it can scan the wide space both inside and outside of the nuclear power plant and buildings in a single movement.

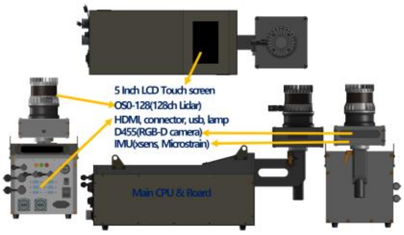

Fig. 1. Real-time mobile scan platform based on SLAM

3.2 Radiation map generation algorithm

Figure 2 shows the algorithm configuration diagram of the real-time radiation map generation system developed in this study. The lidar sensor scans spatial data which is used to create a 3D map and movement coordinates in real-time through the SLAM algorithm and IMU sensor. Simultaneously, the survey meter measures radiation levels and the data is received through wired communication, which is then fused with the movement coordinates to create time, x, y, z, and uSv/h data. The fused data is visualized and displayed on a 3D GUI-based map and is also saved as PCD and CSV files.

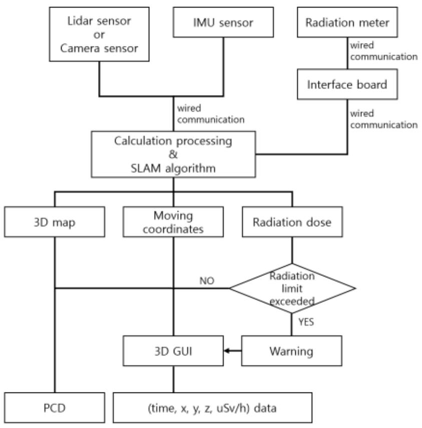

Fig. 2. Radiation map generation algorithm

3.3 Radiation map generation result

Indoor and outdoor areas were scanned using the mobile radiation scanning platform developed in this study. Radiation workers' effective radiation dose should not exceed 50mSv (5rem) per year, and the cumulative dose for 5 years should not exceed 100mSv (10rem). Hence, the system is programmed to display a warning state on the 3D map when the radiation measurement value exceeds 10uSv/h. Since no space in the experimental area exceeded the 10uSv/h limit, the system transmitted randomly generated radiation measurement data to the scan platform.

It was assumed that a specific area in the experimental site exceeded the radiation tolerance, and randomly generated 10uSv/h data was transmitted to the scan platform when moving into that area. Figure 3 presents the scanning results of the indoor area, showing the state in which the radiation limit was exceeded in a particular spot. Figure 4 displays the scanning results of the outdoor area, indicating that the radiation tolerance was surpassed in the space where the plant facilities are situated.

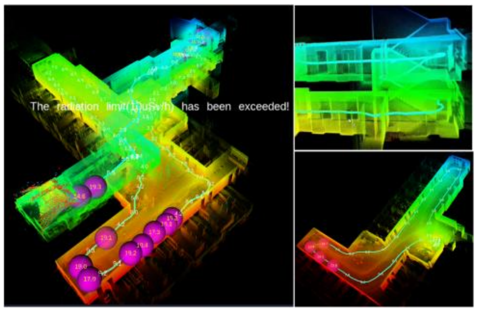

Fig. 3. Experimental result in indoor

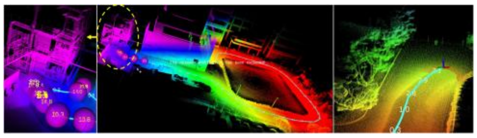

Fig. 4. Experimental result in outdoor

4. Conclusion

In this study, we proposed a real-time radiation map generation system that uses LiDAR and a survey meter to generate a 3D map and display the radiation dose on the moving path. In the future, we plan to perform actual internal/external scans of nuclear power plants using the developed mobile radiation scan platform to quantitatively evaluate its performance and conduct additional technical research.

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