3D Radiation Mapping System Applied to Handheld and Mobile Robotic Platforms

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Conventional radiation survey methods utilizing handheld dosimeters typically rely on fixed-point or close-proximity measurements. This approach makes it difficult to identify the direction of the radiation source and can significantly increase the risk of radiation exposure. Similarly, general gamma-ray imaging equipment typically provides only 2D images, offering directional information about the source but lacking detailed spatial distribution data. Recently, active research has been conducted on visualizing contamination distributions on 3D maps to obtain detailed spatial contamination information [1]. Furthermore, to prevent human exposure, development is increasingly focusing on systems mounted on various Unmanned Ground Vehicles (UGVs) [2]. In this study, we developed a mapping technology that visualizes the location of radioactive contaminants and dose rate distribution in 3D space through a multi-sensor fusion process utilizing a gamma-ray imager and spatial information acquisition sensors.

The proposed system consists of a gamma-ray imager, a Light Detection and Ranging (LiDAR) sensor for acquiring 3D spatial information, and an RGB-D camera for capturing RGB color data. For multi-sensor fusion, the extrinsic matrix was obtained through a sensor calibration process using the intrinsic matrix of each sensor. Using this, the LiDAR point cloud, RGB images from the RGB-D camera, and gamma-ray data from the gamma-ray imager were registered. This process enables the generation of a 3D spatial map that combines the accuracy of LiDAR with the visibility of RGB images, upon which the distribution of gamma-ray sources is visualized.

The developed system was implemented on three platforms consisting of a hand-held type, a tracked robot, and a quadruped robot. To validate the platforms, experiments were conducted in indoor and outdoor environments using standard sources (^{137}Cs, ^{60}Co). All platforms successfully detected the locations of hotspots and visualized the contamination distribution in 3D space. The contamination distribution was obtained in the form of both dose rate-based maps and hotspot-based maps. Through this study, the hand-held platform was verified for rapid exploration of indoor spaces, the tracked robot for long-duration mapping of large indoor and outdoor areas, and the quadruped robot for operation in complex terrains such as forests. The developed 3D radiation contamination mapping technology is expected to contribute to the efficient identification of and response to contaminated areas while minimizing operator exposure.

Figure 1. Example of 3D radiation contamination mapping using multiple platforms

1. Vetter, Kai, et al. "Advances in nuclear radiation sensing: Enabling 3-D gamma-ray vision." *Sensors* 19.11 (2019).
2. Marques, Luís, Alberto Vale, and Pedro Vaz. "State-of-the-art mobile radiation detection systems for different scenarios." *Sensors* 21.4 (2021).

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. RS-2025-16071958 and No. RS-2025-02310831).