Development of spatial radiation mapping framework using mobile robot with LiDAR and radiation sensor

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1. Introduction

Radiation monitoring in nuclear facilities is one of the most important tasks to determine whether the conditions of the facility is normal or abnormal. In addition, in abnormal situations, the radiation measurement results at a target site are necessary to design response actions made by human operators. Since a mobile robot with a radiation sensor can remotely measure radiation with respect to its position, it is widely investigated to secure the safety of human operators and increase efficiency of the facility management [1-3]. Groves *et al*. utilized simultaneous localization and mapping (SLAM) technology to merge terrain and radiation information for robotic exploration [2]. West *et al*. introduced Gaussian process regression technique to estimate spatial radiation distribution, and graphically merged the two dimensional (2D) spatial map and radiation distribution manually [3]. However, the conventional studies do not conduct the spatial mapping and radiation mapping in a single framework, which is necessary for future autonomous radiation monitoring operations. In this paper, we propose a spatial radiation mapping framework (SRMF) using mobile robot with LiDAR and radiation sensor for effective radiation monitoring of the nuclear facilities. The SRMF includes SLAM architecture, radiation mapping by regression methods, and visualization of spatial fusion map.

2. Spatial radiation mapping framework

The process of the SRMF is represented as Fig. 1. First, point cloud and radiation data are acquired by LiDAR and radiation sensor, respectively, which are equipped to a mobile robot. In SLAM architecture based on LiDAR, voxelization of the point cloud is conducted for down-sampling, and sample points are selected among the point cloud for the feature extraction. Then, the sample points are compared with the map data for localization, and the point cloud of the current frame is matched to the map data using scan matching algorithm such as iterative closest point (ICP). After the scan matching procedure, current pose of the robot is estimated, and the spatial map is updated by adding non-overlapped points of the current frame. These procedures can be implemented by various conventional SLAM architectures such as *hdl_graph_slam* [4] and *FAST-LIO* [5].

For data fusion of the spatial and radiation information, an integrated data matrix is required. Since the period to obtain each information is different, the frequency of data fusion should be designed considering the least common multiple of the periods for the spatial and radiation information. The estimated position information of the robot and measured radiation information which have the closest time stamp are updated to the integrated data matrix for each process of the data fusion. When the enough number of the fusion data is obtained, a data regression process is conducted to estimate the radiation distribution of the monitoring site. First, the whole positions within the spatial map is represented to a discrete matrix form like an 2D grid map, then the estimated radiation dose is calculated for each position using regression process such as Gaussian

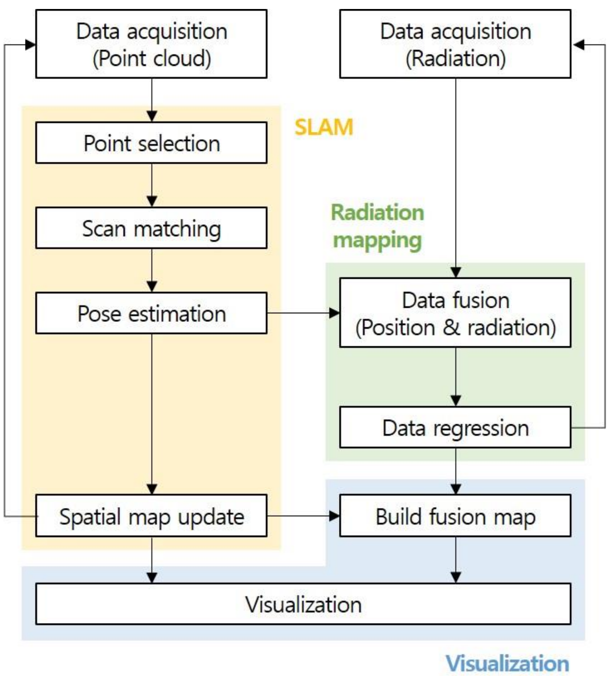

Fig. 1. Flow diagram of the proposed spatial radiation mapping framework.

process regression except the position where the robot was located.

Finally, a fusion map can be developed by converging the spatial map and the result matrix of the radiation data regression. For the intuitive visualization, the estimated radiation data is colorized and the occupied regions which were identified by the spatial map is represented as black or grey.

3. Conclusion

In this paper, we propose a spatial radiation mapping framework which includes SLAM architecture, radiation mapping, and visualization of spatial fusion map. This could contribute to future radiation monitoring operations which are expected to be conducted in remote, unmanned, and autonomous manner for safety and efficiency.

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