Comparative Analysis of Radioactive Contamination Mapping Between Unmanned Aerial Vehicle and Unmanned Ground Vehicle Equipped with Gamma-ray Imager

Joonhyuk Lee, Minseo Song, Dukwoo Kim, Changyu Ko, Seungho Lee, Hyeonseong Lyu and Manhee Jeong*
Nuclear Engineering, Jeju National University, Jeju-si, Republc of Korea
**Corresponding author: mhjeong@jejunu.ac.kr*

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1. Introduction

Radioactive Contamination mapping is essential for nuclear facility monitoring, decommissioning operations, and emergency response situations. For effective radiation detection and mapping, appropriate platforms and sensors must be selected according to environmental conditions to conduct surveys [1]. In recent years, with advancements in unmanned vehicle and gamma-ray imaging technologies, integrated radiation detection systems have been actively developed and studied [2,3]. These systems provide the benefit of reducing radiation exposure by being deployed in the field instead of humans [4,5].

Unmanned vehicles can be generally classified into unmanned aerial vehicles (UAV) and unmanned ground vehicles (UGV). When utilizing drone systems among UAV, their high mobility and wide field of view enable rapid assessment of radiation distribution over extensive areas, making them suitable for initial site evaluation and rapid detection. This enables the identification of comprehensive dose distribution in contaminated areas and the establishment of key regions of interest.

Unmanned ground vehicles have the advantage of being able to operate for extended periods compared to unmanned aerial vehicles. Additionally, they enable stable movement and precise position control on the ground. Because of higher payload capacity, they allow for the integration of additional sensors such as light detection and ranging (LiDAR), enabling simultaneous acquisition of three-dimensional spatial information and radiation data. Through this approach, accurate 3D spatial mapping and radiation distribution maps can be generated, enabling more detailed localization and characterization of radiation sources.

This study compared radiation maps obtained using drones with those acquired by UGV. Additionally, this study aims to identify the characteristics and advantages of each platform and propose an effective step-by-step radiation detection sequence for on-site operations.

2. Methods

2.1 Experimental Equipment

This study compared data by mounting identical gamma-ray imager on two unmanned vehicle platforms.

a) **EPSILON-G**: Energetic particle sensor for identification and localization of originating nuclei-gamma (EPSILON-G) is a coded aperture-based gamma-ray imager. This sensor system employs a 12×12 arrays of Silicon Photomultiplier (SiPM) and $Gd_3Al_2Ga_3O_{12}$:Ce (GAGG(Ce)) scintillator, utilizing a tungsten MURA mask. The energy resolution for ^{137}Cs is 7%, and the imaging sensitivity is less than 2 seconds in a 0.3 μSv/h environment. The field-of-view (FOV) is approximately 45° with an angular resolution of 6.8°.

b) **Drone System**: The drone used is an octocopter based on the Tarot X8 Octo model with improved transmission and propellers. The maximum payload capacity is approximately 14 kg, including the drone's own weight. With the gamma-ray imaging equipment mounted, flight time is approximately 10 minutes.

c) **UGV System**: An integrated sensor system was developed based on Unitree's mini-bunker tracked platform. The maximum speed is 1.5 m/s (no load), and it can operate continuously for up to 5 hours. The integrated sensor system consists of gamma-ray imager, Intel D435 depth camera, Microstrain CV7 inertial measurement unit (IMU), u-blox F9P global positioning system (GPS), Velodyne VLP-16 LiDAR, and an NVIDIA Jetson Orin Nano embedded computer.

Fig. 1. Equipment used in the experiment. EPSILON-G (left), drone (middle), mini-bunker (right)

2.2 Experimental Conditions and Data Collection

The experiments were conducted at the Second Athletic Field of Jeju National University, using a ^{137}Cs radiation source with an activity of 36.15 MBq. The drone operates in a boustrophedon pattern at an altitude of 5 m with a flight speed of 3.6 km/h. For the UGV, data were collected while moving at a speed of approximately 2.4 km/h on the ground following the same pattern. Additionally, the UGV was equipped with

LiDAR, enabling simultaneous acquisition of gamma-ray data and three-dimensional spatial information through LiDAR.

2.3 Data Processing and Analysis

The collected data are synchronized based on GPS information and time stamps from each platform. Subsequently, 2D radioactive contamination maps are generated for each platform. For the UGV system, point cloud data acquired through LiDAR and gamma-ray images were integrated to additionally generate a three-dimensional radioactive contamination map. Data analysis is performed using Python, and comparative evaluation between the two platforms will be conducted based on spatial resolution, source localization accuracy, and dose rate accuracy.

3. Results

Previous studies have confirmed that 2D radioactive contamination maps of the current experimental area can be successfully acquired using drones. Data measured at 5 m altitude identified the location of ^{137}Cs, and rapid data acquisition over the entire 50×80 m^2 area was achieved within 550 seconds.

The UGV performs direct measurements at ground level and is expected to simultaneously acquire 2D maps and 3D spatial information through LiDAR. Data from the two platforms will be comparatively analyzed in terms of spatial resolution, source localization accuracy, and measured dose rate accuracy. Detailed experimental results of this study will be presented at the conference.

4. Conclusions

In this study, radioactive contamination mapping of the same area was conducted using two different unmanned platforms. Through comparison of results from the two platforms, the advantages and disadvantages of each platform were identified, which is expected to enable effective planning for actual field deployment. By first analyzing field conditions through rapid drone mapping to determine general source distribution and intensity, and then deploying UGV for detailed analysis, efficient operator routes and operational plans can be established.

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