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Utilization of Drones for Monitoring and Estimating Ionizing Radiation Sources.

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1. Introduction

Technological advancement in recent decades has led to notable innovations in various fields, particularly in the development of unmanned aerial vehicles, commonly known as drones. These versatile and efficient tools have played significant roles in a wide range of applications, expanding monitoring and exploration possibilities in various contexts [1],[2]. One area where drones have excelled is in radiation monitoring, where their combination with specialized detectors offers an agile and safe approach to data acquisition in hard-to-reach locations and vast areas [3].

In this context, the need arises for integrated systems that can not only collect flight and radiation detection data but also ensure the reliability and accuracy of this information. This study aims to address this demand by presenting a system that integrates sensors for radiation monitoring on drones, with potential applications in Chemical, Biological, Radiological, and Nuclear Defense (CBRN) scenarios, in both radiological and nuclear aspects [4].

To ensure the accuracy of the collected data during flight, various calibrations and tests were conducted on the radiation detector, covering crucial parameters such as energy, angle, temperature, radiation dose, and speed of movement. These calibrations and tests are essential to correct any distortions and ensure the reliability of the measurements performed by the system.

In addition to increasing the reliability of the data, the practicality in analyzing the information was also considered in the development of the system. The visual representation of the data, through heatmaps and flight routes on a 2D map in HTML, provides a clear and intuitive view of areas with higher detected radiation dose rates, facilitating the identification of potential radiation sources and aiding decision-making.

Finally, the implementation of a search algorithm complements the proposed solution, allowing the creation of efficient routes to points of higher radiation intensity, providing a preliminary estimate of possible radiation sources near areas with high dose rates.

Thus, the developed system aims to offer an integrated and effective approach to radiation monitoring, combining the mobility and versatility of drones with the sensitivity and reliability of radiation detector data, contributing to safety and decision-making in different application contexts.

2. Methodology

Payload:
Using off-the-shelf materials and equipment, the integration of all sensors is carried out, ensuring that the payload is independent of the drone system. A suitable drone is selected to support the weight of the radiation detection system, ensuring stability and safety during flight.
The radiation monitoring system involves collecting data from the radiation detector, including header information, measurement identification, and spectroscopic counting data per channel. The raw detector data is stored on a Raspberry Pi 4b, along with GPS location information, thermocouple temperature, and inertial data. After the flight in the area of interest, the data is transmitted via Wi-Fi to a computer near the drone, allowing communication with the Raspberry Pi. After collection, the data is processed using Python to generate visualizations of the mapped area, a heatmap showing local radiation dose levels, and spectroscopy data collected every ten seconds.
Calibrations:
To ensure system accuracy, various calibrations were performed, including energy calibration, angular response, operating temperature, and dose calibration. Energy calibration aims to ensure precise energy values (in keV) in spectroscopic data, allowing for the identification of radionuclide types through their emission energies. This involves correctly associating detector channels with specific energy values through a calibration curve. Angular calibration determines the detector's efficiency in different directions relative to its orientation during flight, optimizing detection. Temperature calibration monitors the detector's response at different temperatures and applies corrections to ensure accuracy under variable conditions [5]. In dose calibration, the calculation of $\dot{H}^*(10)$ and the correlation between dose rate and detector net counting rate are essential for assessing exposure to ionizing radiation during flight.
Speed Test:
In this experiment, we investigated the relationship between movement speed and the measurement of radiation emitted from a Cobalt-60 source using the detection system (payload). The goal is to determine the most effective speed for radiation detection, especially in drone monitoring scenarios. Calibration involves fixing the detector to a vehicle and traveling a 120-meter path at different speeds (5, 10, 15, 20, 25, and 30 km/h), repeating the route to calculate an average of the measured values. The 60Co source is positioned 1 meter from the vehicle, aligned with movement, and all safety protocols are strictly followed.
Data Processing Software:
The Python software for data processing applies correction calculations directly to the raw data collected after monitoring the area. These calculations include corrections from the calibrations described in the methodology.
After data processing, it is used to generate an interactive HTML map through the Folium library in Python. This visual representation of the processed data facilitates interpretation and analysis of the results obtained in the monitored area. Additionally, a Dijkstra search algorithm is applied to the map, indicating the path from the initial position to the region with the highest radiation dose rate. This functionality aims to facilitate the identification of potential radiation sources and/or obtain the most efficient route for further exploration in the area with the highest dose rate.

3. Results and Discussion

The tests conducted proved to be efficient in characterizing the radiation detection system and enabling the acquisition of consistent data. The selected drone adequately supported the weight of the system, ensuring stability and safety during flight. Energy calibration using standard radioactive sources with different energies allowed for more reliable measurement of energy values in the processed spectrum after monitoring.

The angular calibration of the system ensured a detector efficiency response for frontal incidences of up to 120°. Temperature calibration demonstrated the system's ability to compensate for variations in detector sensitivity due to changes in ambient temperature.

Dose rate calibration established a relationship between radiation measurements made by the detector and the actual dose rate, thus providing coefficients to apply to collected data and obtain the $\dot{H}^*(10)$ dose rate value (μSv/h). Field tests demonstrated the system's performance at different speeds, with an average speed of up to 10 km/h recommended for detecting low-intensity sources, such as those used in the experiment. This speed may vary depending on the intensity of the source and the scanning distance but is recommended to maximize detection.

After correcting the raw data, they were mapped in an interactive HTML format, simplifying the analysis of the monitored areas. The use of the Dijkstra search algorithm proved to be efficient in identifying areas with high radiation levels, facilitating the determination of shorter paths for further exploration.

4. Conclusions

The aim of this study is to present an integrated methodology, which involves conceiving, developing, and integrating a radiation detector onto a drone to provide information about radioactive sources. Through this methodology, by integrating the radiation detector, we ensure greater accuracy in detection through corrections applied by calibration, thus obtaining more reliable measurements during drone flights. This technology has applications both in exploring specific regions and in monitoring scenarios related to Chemical, Biological, Radiological, and Nuclear Defense (CBRN).

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