World Academy of Science, Engineering and Technology
International Journal of Mechanical and Mechatronics Engineering
Vol:18, No:07, 2024

Remote Radiation Mapping Based on UAV Formation

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Abstract : High-fidelity radiation monitoring is an essential component in the enhancement of the situational awareness capabilities of the Department of Energy's Office of Environmental Management (DOE-EM) personnel. In this paper, multiple units of unmanned aerial vehicles (UAVs) each equipped with a cadmium zinc telluride (CZT) gamma-ray sensor are used for radiation source localization, which can provide vital real-time data for the EM tasks. To achieve this goal, a fully autonomous system of multicopter-based UAV swarm in 3D tetrahedron formation is used for surveying the area of interest and performing radiation source localization. The CZT sensor used in this study is suitable for small-size multicopter UAVs due to its small size and ease of interfacing with the UAV's onboard electronics for high-resolution gamma spectroscopy enabling the characterization of radiation hazards. The multicopter platform with a fully autonomous flight feature is suitable for low-altitude applications such as radiation contamination sites. The conventional approach uses a single UAV mapping in a predefined waypoint path to predict the relative location and strength of the source, which can be time-consuming for radiation localization tasks. The proposed UAV swarm-based approach can significantly improve its ability to search for and track radiation sources. In this paper, two approaches are developed using (a) 2D planar circular (3 UAVs) and (b) 3D tetrahedron formation (4 UAVs). In both approaches, accurate estimation of the gradient vector is crucial for heading angle calculation. Each UAV carries the CZT sensor; the real-time radiation data are used for the calculation of a bulk heading vector for the swarm to achieve a UAV swarm's source-seeking behavior. Also, a spinning formation is studied for both cases to improve gradient estimation near a radiation source. In the 3D tetrahedron formation, a UAV located closest to the source is designated as a lead unit to maintain the tetrahedron formation in space. Such a formation demonstrated a collective and coordinated movement for estimating a gradient vector for the radiation source and determining an optimal heading direction of the swarm. The proposed radiation localization technique is studied by computer simulation and validated experimentally in the indoor flight testbed using gamma sources. The technology presented in this paper provides the capability to readily add/replace radiation sensors to the UAV platforms in the field conditions enabling extensive condition measurement and greatly improving situational awareness and event management. Furthermore, the proposed radiation localization approach allows long-term measurements to be efficiently performed at wide areas of interest to prevent disasters and reduce dose risks to people and infrastructure.

Keywords : radiation, unmanned aerial system(UAV), source localization, UAV swarm, tetrahedron formation
Conference Title : ICARM 2024 : International Conference on Automation, Robotics and Mechatronics
Conference Location : Vienna, Austria
Conference Dates : July 29-30, 2024