# 論文 / 著書情報
# Article / Book Information

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| Title(English) | Energy-Aware Coordinated Image Sampling with Multi-drone Systems for 3D Model Reconstruction |
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（博士課程）
Doctoral Program

# 論 文 要 旨

THESIS SUMMARY

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| 系・コース：<br>Department of, Graduate major in | システム制御　系<br>システム制御　コース | | 申請学位（専攻分野）：<br>Academic Degree Requested | 博士<br>Doctor of　（ 工学 ） |
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要旨（英文800語程度）
Thesis Summary（approx.800 English Words ）


This thesis detailed a comprehensive algorithm for controlling the motion and camera rotation of a multi-drone system to ensure effective 3D model reconstruction. The algorithm is designed to provide rich angle coverage of a target field by controlling not only the drones' positions but also camera angles. The energy-aware controller is presented, and dynamic charging station assignment is shown to enhance the coverage efficiency.

In Chapter 1, we have discussed the motivation, related studies and contributions of this research. We introduced various application scenarios of drones and clarified the that this research considers the scenario of 3D reconstruction. We then introduced the existed studies related coverage control, QP-based control, CBF (Control Barrier Function)-based battery charging control and ADMM, which are basis of this paper. Finally, we clarified contributions of this research is the proposal of coordinated image sampling control that realizes camera rotation control and efficient energy management.

In Chapter 2, we have introduced the mathematical preliminaries that form the basis of our proposed algorithms. We began with the review of typical coverage control and then the persistent coverage control, which has a time-varying importance index. We also introduced CBF-based coverage control that uses control barrier functions combined with a QP(quadratic programming)-based controller to guarantee coverage performance. Additionally, we discussed angle-aware coverage control for monitoring the target field with rich view angles. Finally, we introduced a distributed optimization method, the Alternating Direction Method of Multipliers that is used in calculating the optimal charging station for drones.

In Chapter 3, we have proposed an algorithm for controlling multi-drone systems to do image sampling for 3D reconstruction. First, we defined the dynamics model that considering camera rotation control and a 5D virtual space that including both position and viewing angle. We defined a new performance function to evaluate the coverage quality of each point within the target field and established a spatial importance index update rule. We designed a QP-based controller that incorporates CBFs to ensure constraints. We employed JAX for JIT (just-in-time) compilation and GPU (Graphics Processing Unit)) acceleration, making the calculation meet real-time requirements. We validate the controller through ROS (Robot Operating System) 2 simulations, demonstrating its effectiveness compared to existing method.

In Chapter 4, we have addressed the problem of dynamically assigning charging stations to drones to enable long-duration operations. We defined the battery charging model and a battery charging CBF so that the drone will return to the charging station before battery run out. Then, we formulated the charging station assignment and a weighting coefficient setting method for the evaluation function based on the battery charging CBF value to avoid return failures that may occur due to assignment changes. We showed that the integer programming form assignment problem can be exactly relaxed into an equivalent linear programming problem. Applying ADMM, we showed two different types of distributed solutions to the charging station assignment problem that the optimization calculations are distributed to each drone controller. We conducted simulation on ROS 2 and verified the effectiveness of dynamically assigning charging stations in improving image sampling efficiency.

In Chapter 5, we future conducted experiments to verify the proposed control algorithm. We have shown the design of our control system architecture used in the experiment that uses RTK-GNSS

outdoors and a motion capture camera system indoors for positioning. We have presented the results of 3D reconstruction of an indoor scene and an outdoor farmland with images taken by DJI Mavic 3E. We reconstructed 3D models with images collected by the drone and show that the presented controller achieves superior 3D model quality compared to existing method.

In Chapter 6, we summarized the thesis and discussed the future direction of this research.