PADERBORN UNIVERSITY

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Information Technology
Automatic Control Group
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Proposal for a Master's Thesis Project

Active SLAM for aerial robots in dense environments

Background

Simultaneous mapping and localization have relied on passive methods, which require the constant supervision and intervention of trained operators. This increases the complexity and cost of deploying robotic systems and limits their autonomy and operational efficiency. Additionally, passive SLAM methods may struggle in dynamically changing environments or under challenging conditions, leading to suboptimal mapping and localization accuracy. Active SLAM (A-SLAM) presents a solution that allows for the autonomous exploration of environments without the need for human supervision. The resultant mapping data can subsequently find utility across various applications, such as inspection tasks, evaluation of disaster-affected areas, and aiding assistant robots.

Thesis Goals

This thesis aims to develop a three-layer framework to optimize and influence every step of the exploration. Inspired by the work developed in [1], this thesis will seek to implement a 3D A-SLAM where the main information is the amount of entropy observable from a given point of view. While a ground robot that stands still uses little energy, a hovering drone depletes energy resources. Thus, a study on efficiently doing raytracing in a 3D world is necessary to compute the optimal heading in real-time. Considering the 3D world gives an additional degree of freedom, but also new challenges in planning and optimization.

Intermediate Goals

- Literature review on active SLAM algorithms [1, 2, 3].
- Integrate a 3D navigation system and adapt the pipeline to flying robots, see Fig. 1.
- Research and develop a method to perform real-time 3D heading computation for A-SLAM.
- Develop the control approach (e.g. LQR, MPC) to reach the desired waypoints.
- Simulation and real-time experiments of the proposed approach.

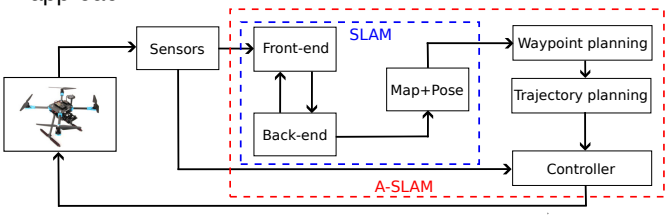

Figure 1: Architecure of SLAM and A-SLAM.

Knowledge

Required:

- Interest in SLAM, control, navigation
- Experience with ROS / Gazebo desired
- Experience with C++ / Python desired
- Good problem-solving capabilities
- Enthusiasm for learning

Not required, but a big +:

- Experience in real-time experiments with drones

References

[1] E. Bonetto, P. Goldschmid, M. Pabst, M. J. Black, and A. Ahmad, "irotate: Active visual slam for omnidirectional robots," *Robotics and Autonomous Systems*, vol. 154, p. 104102, 2022.

[2] C. Papachristos, F. Mascarich, S. Khattak, T. Dang, and K. Alexis, "Localization uncertainty-aware autonomous exploration and mapping with aerial robots using receding horizon path-planning," *Auton. Robots*, vol. 43, p. 2131–2161, dec 2019.

[3] J. A. Placed, J. Strader, H. Carrillo, N. Atanasov, V. Indelman, L. Carlone, and J. A. Castellanos, "A survey on active simultaneous localization and mapping: State of the art and new frontiers," 2023.

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