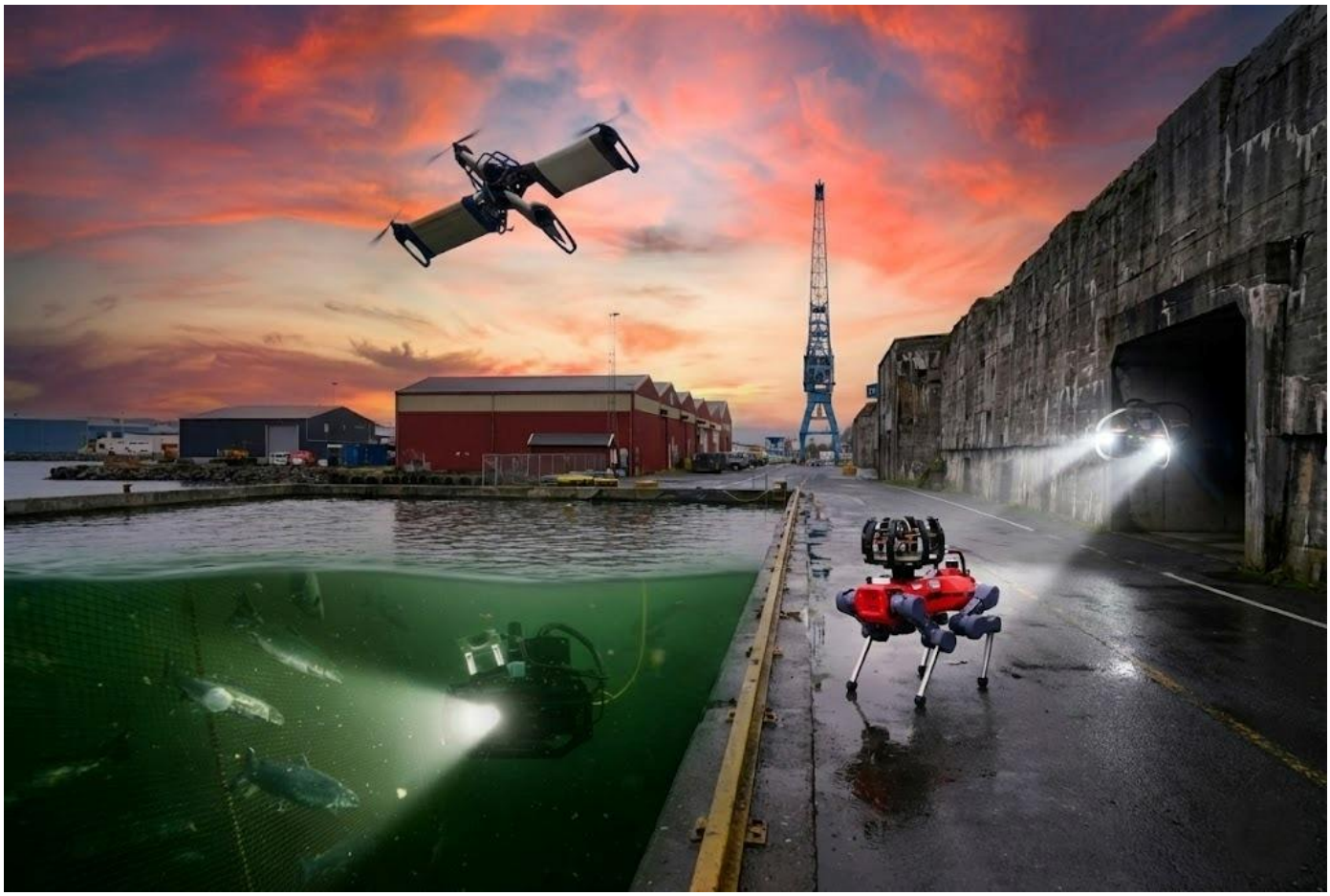
Exploration Path Planning for Nonholonomic Robots

Abstract: Exploration path planning has a long history in robotics. The Autonomous Robots Lab has developed one of the most widely utilized methods and software solutions (GBPlanner, also known as OmniPlanner), enabling efficient volumetric exploration across aerial, ground, and underwater robots.

While highly versatile, the current framework does not adequately support nonholonomic platforms such as fixed-wing UAVs and certain classes of underwater AUVs. These systems are subject to motion constraints (e.g., minimum turning radius, continuous forward motion) that fundamentally alter the feasible planning space.

This project aims to extend the existing framework (https://github.com/ntnu-arl/gbplanner_ros) by developing a sampling-based planning kernel tailored to nonholonomic systems. The focus will be on enabling dynamically feasible exploration trajectories for fixed-wing UAVs and underwater AUVs, while maintaining compatibility with the existing exploration gain formulation. The project also offers a strong opportunity to contribute to and impact the open-source robotics community.



Tasks:

- Review exploration planning methods with emphasis on nonholonomic motion constraints.
- Analyze limitations of the current GBPlanner/OmniPlanner framework for fixed-wing and AUV platforms.

- Design a sampling-based planning approach (e.g., kinodynamic RRT*, motion primitives) suitable for nonholonomic exploration.
- Incorporate vehicle-specific constraints such as minimum turning radius, velocity bounds, and dynamic feasibility.
- Integrate the new planning kernel within the existing **gbplanner_ros** framework.
- Validate the approach in simulation and real robots for fixed-wing UAVs and/or underwater AUVs.
- Contribute code and documentation back to the open-source repository.

Literature (indicative):

[1] LaValle, S.M., 2006. Planning algorithms. Cambridge university press.

[2] Karaman, S. and Frazzoli, E., 2011. Sampling-based algorithms for optimal motion planning. The international journal of robotics research, 30(7), pp.846-894.

[3] Pivtoraiko, M., Knepper, R.A. and Kelly, A., 2009. Differentially constrained mobile robot motion planning in state lattices. *Journal of Field Robotics*, 26(3), pp.308-333.

[4] Dang, T., Tranzatto, M., Khattak, S., Mascarich, F., Alexis, K. and Hutter, M., 2020. Graph-based subterranean exploration path planning using aerial and legged robots. Journal of Field Robotics, 37(8), pp.1363-1388.

[5] A Zacharia, A., Dharmadhikari, M., Singh, M. and Alexis, K., 2026. OmniPlanner: Universal Exploration and Inspection Path Planning across Robot Morphologies. arXiv preprint arXiv:2603.04284.

Main supervisor: Kostas Alexis, Professor, NTNU | **Co-supervisor:** Angelos Zacharia, PhD