Autonomous Underwater Swarms: Docking problem and control strategies

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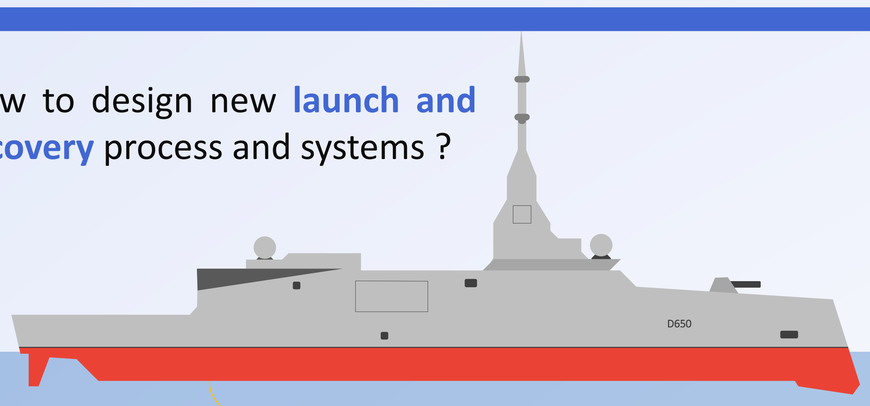
Context and Objectives

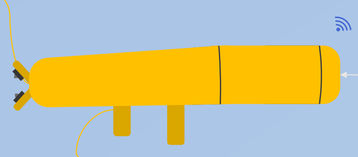
Experimental Context

How to design new **launch and recovery** process and systems ?



Can an USV manage its position **to cover an entire** area and **communicate** its location to AUVs?

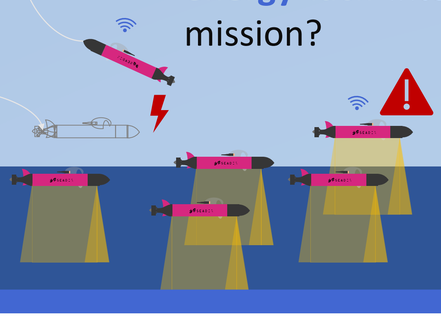
How can a robot **replace another** and **accurately reposition itself** within the swarm to maintain formation?



Application Domains:

- Underwater **archeology**
- Accident data recorder (**ADR**) **recovery**
- **Mines detection**

How to manage **object detection** and **energy lack** interruptions during the mission?



How can **rendezvous** strategies be integrated into autonomous **docking** frameworks?

The Challenge of Docking

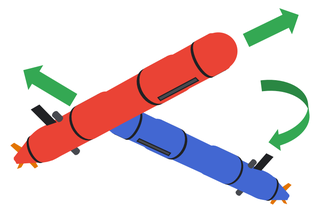
Control Laws for Inter-AUV Docking

Docking enables a robot to connect to another, allowing them to perform **coordinated movements, transfer energy** and **data**.

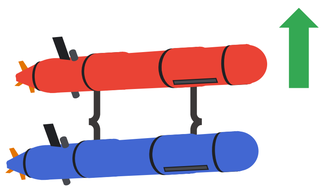
Inter-AUV docking requires **precise coordination** between autonomous vehicles in complex underwater environments. To ease docking procedures, control laws must allow:

- relative **positioning**,
- **heading** alignment,
- synchronization of **velocities**.

Strategies such as **relative pose estimation** and **leader-follower control** enable AUVs to dynamically adjust their trajectories to achieve robust docking, even in the presence of ocean currents and sensor noise.



Docked modular AUV can achieve new collaborative underwater motions



AUV can **transport others** to overcome **challenging conditions** and **transmit data**

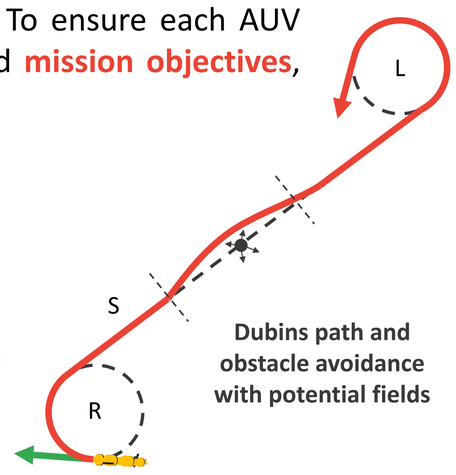
Towards a Solution

Dynamic Path Planning

Underwater swarms must constantly **adapt their desired paths** to avoid collisions, obstacles, and environmental disturbances. To ensure each AUV reaches its goal while **preserving swarm cohesion** and **mission objectives**, several techniques can be used, including:

- Artificial Potential Fields,
- Vehicle Routing Problem (VRP) Approaches
- Dubins path planner.

Dubins paths allow any vehicle with a bounded turning radius to **reach any target** position and orientation from any starting configuration, using only **straight lines** (**S**) and **left** (**L**) or **right** (**R**) **turns**

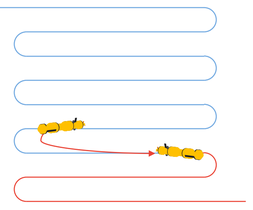


Dubins path and obstacle avoidance with potential fields

Seamless Replanning

When **switching** from a planned trajectory to a new objective — such as assisting a disabled teammate — the robot must smoothly transition between paths to maintain **stability** and ensure **reliable control**.

This requires **dedicated path transition strategies** that avoid abrupt maneuvers and guarantee safe reorientation.



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