Distributed Control of Underwater Robots

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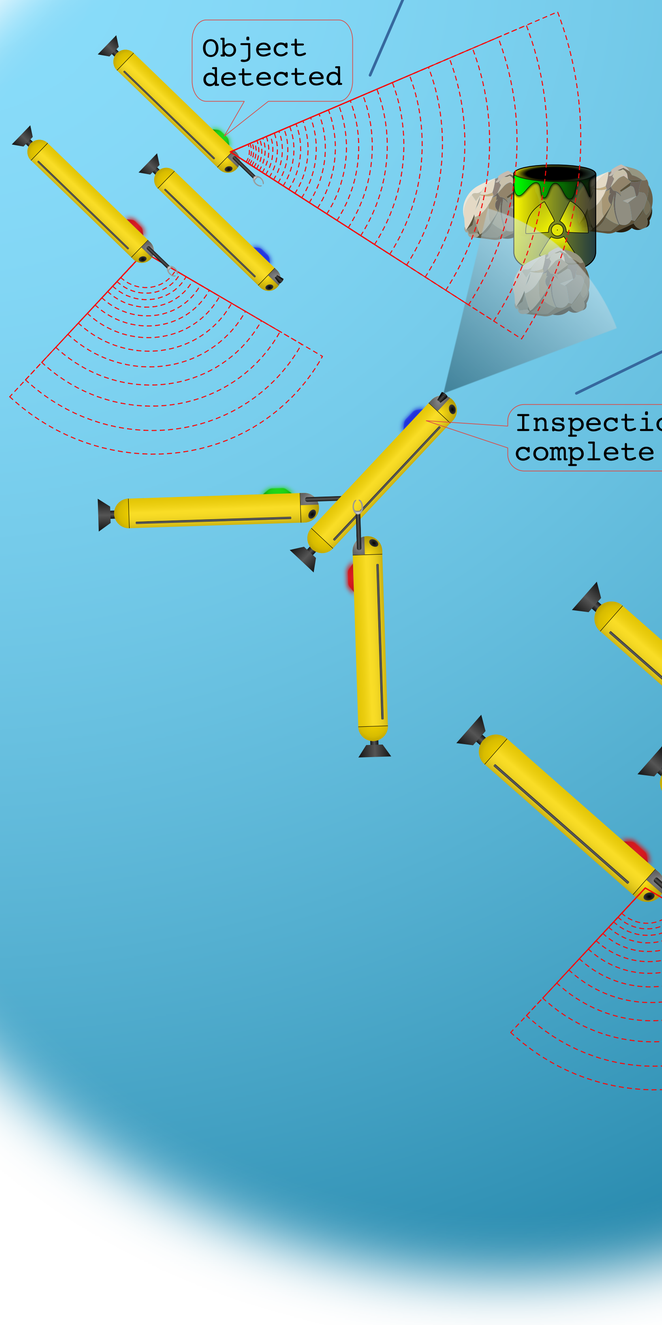
0. Introduction

The oceans play a crucial role economically and ecologically. Furthermore, 40% of the human population live next to coastal waters and are affected by the health of the oceans. However, only 20% are surveyed. Therefore, it's of paramount importance to increase our understanding of and monitoring the state of the oceans to mitigate negative effects.

We propose a distributed control scheme to enable cost-efficient surveying and inspection of the underwater domain.



1. Flight Formation

Team of agents surveying the ocean. Once they find something of interest, they decide to reconfigure into multi-thruster formation for the inspection task.

Challenges:
- Distributed coordination
- Formation control
- Limited communication

2. Multi-Thruster Formation

Agents reconfigure into multi-thruster formation. This enables more complex maneuvers to complete the inspection task. Establishing this formation requires autonomous decision-making, e.g. which sensor to use, which formation to get into.

Challenges:
- Distributed coordination
- Formation control
- Novel system dynamics
- Autonomous decision-making

3. Flight Formation

The agents complete the mission and return into flight formation. Now they continue their mission or return to base to upload data and receive new instructions.

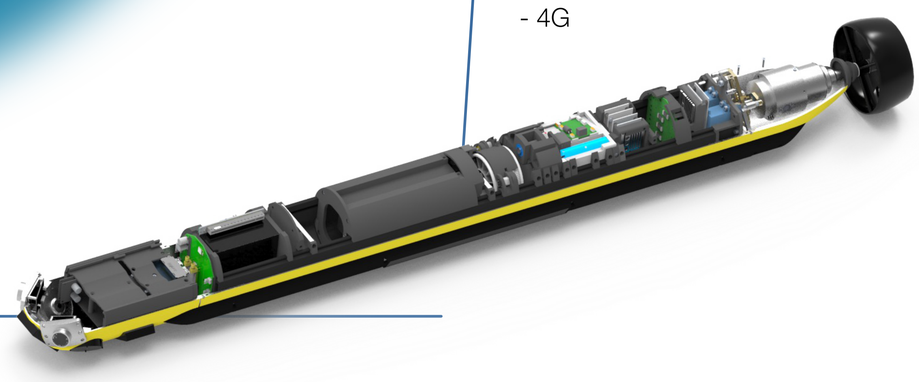
Challenges:
- Distributed coordination
- Formation control
- Autonomous decision-making
- Homing and docking

4. SAM

Actuators:
- Counter-rotating propellers
- LCG trim
- Variable buoyancy system
- Thrust vectoring
- TCG trim

Communication:
- Underwater acoustic coms
- Acoustic beacon
- Tether
- Wi-Fi
- 4G

Sensors:
- Sidescan sonars
- Forward and sideways facing cameras
- DVL
- Pressure sensor
- IMU
- CTD
- GPS
- Payload bay for mission dependent sensors

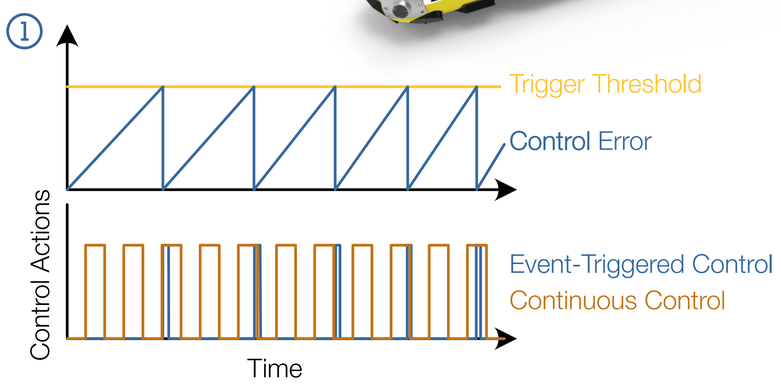


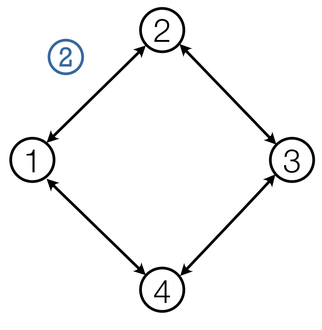
5. Methods

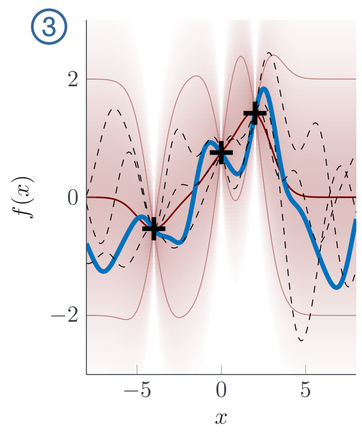
① **Event-based control:**
- Sending control signals based on trigger rules
- Advantage: less energy consumption;
  less requirements for communication;
  applicable to different layers of control, from high-level planning to low-level actuator control
- Disadvantage: more complex control structure

② **Distributed and decentralized control:**
- Agents consider other agents in their planning
- Advantage: no central planner;
  no need to communicate with central coordinator
- Disadvantage: computation can be harder

③ **Learning-based control:**
- Learn system dynamics during operation
- Advantage: can account for unforeseen configurations
- Disadvantage: potentially only sparse data; robustness







6. Conclusion

The oceans provide a living space for humans and animals alike. However, in order to safely and sustainably use these vast resources, we need the right tools. In our work, we leverage modern distributed control algorithms to enable AUVs such as SAM to autonomously assemble and solve complex tasks in an extreme environment. Thereby, we can collect crucial data about the state of the ocean to use and protect it sustainably.

DISCOVER

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WASP
WALLENBERG AI, AUTONOMOUS SYSTEMS AND SOFTWARE PROGRAM