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UNIVERSITÉ DE TOULON NTNU

MIR MARINE & MARITIME INTELLIGENT ROBOTICS

Reconfigurable Robotics for Subsea Operations

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1. Introduction

One of the major problems of underwater robotics for mass adaptation is cost. A large costly AUV/ROV needs ships, launch and recovery systems, robotic operators, and crew members onboard. Moreover, due to the associated high cost of every underwater vehicle, it's enormously risky to operate in harsh sub-sea situations. Just like in space for building infrastructure and long-term residence situations require modularity, flexibility and adaptive systems underwater. Reconfigurable robotics allows for adapting and restructuring the robot's physical configuration to our needs.

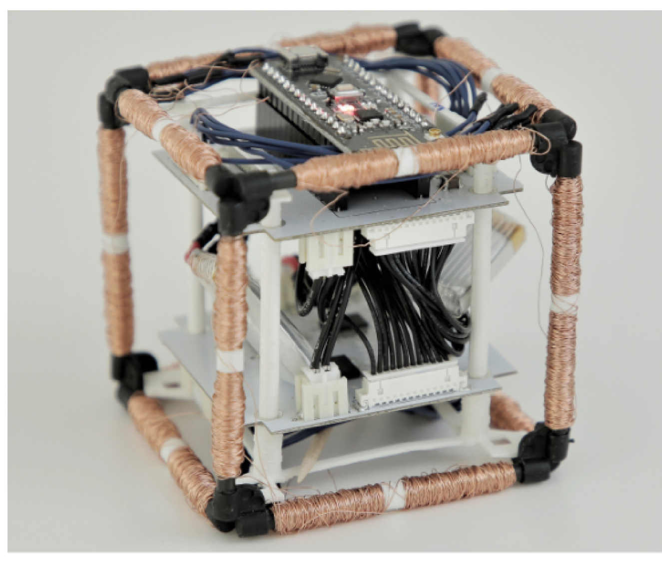

Figure 1: ElectroVoxel (MIT)

- **Modularity:** Often composed of modules or units that can be rearranged or replaced.
- **Adaptability:** Can be restructured to optimize for specific tasks or environments.
- **Cost-Effectiveness:** Each module of the robotic system should be low-cost and replaceable.
- **Dynamic Morphing:** Ability to shift between different shapes or configurations.
- **Multi-functional:** Can perform a variety of tasks by transforming their structure.

2. Motivation

Inspired from aerial and space robotics industry, underwater robotics can be benefited with modular self-reconfigurable robots. Modular robotics for terrestrial and underwater scenarios are being built for decades, however there were not enough compute power and efficient onboard artificial intelligence for practical applications.

1. In under ice exploration, researchers keep loosing their expensive AUVs.
2. In complex underwater terrain, maneuvering huge rigid and large AUVs is difficult.
3. There is a room for flexible underwater robotics which can be configured according to the operation needs.
4. We have enough computational power to fit complex processing in simple smaller nodes.

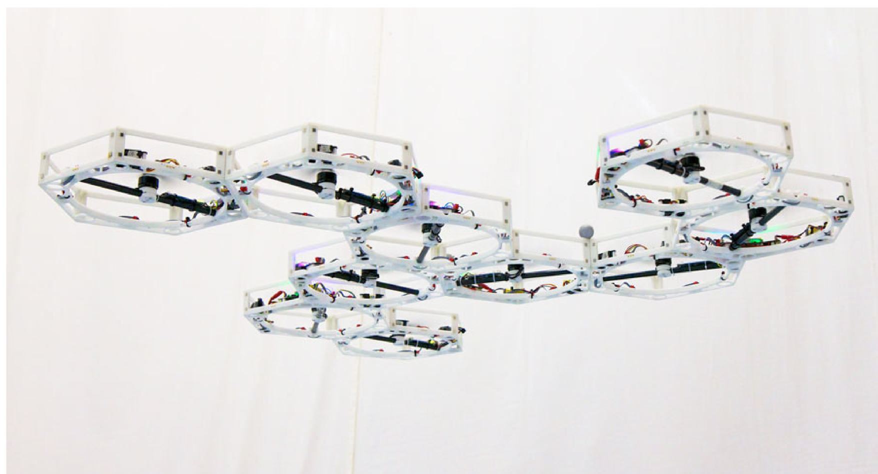

Figure 2: Distributed Flight Array (ETH Zurich)

3. State-of-the-Art

Figure 3: EEYL 500 [2]

- The ACM-R5 [1] and Perambulator series robots utilize a universal joint structure enabling three-dimensional motion.
- The Eelume 2 [2] marine snake-like robot, particularly the latest EELY500 version, is equipped with end effectors to enhance tasks like marine environment observation and pipeline exploration.
- Yang et al. [4] designed two generations of underwater self-reconfigurable robots, USS-G1 and USS-G2, in 2013. The USS-G2, an upgraded version, can reconfigure into various shapes like serial, circular, limb swimming, and quadruped walking based on environmental needs and tasks.
- Angel, developed by Mintchev et al.[3] in 2012, can swim using active rotatable joints connecting eel-like units. Each unit has three propellers and a docking system with a small permanent magnet and mechanical structure.
- Zhejiang University developed modular gelatinous cubes that can be assembled into various types of robots based on functional requirements.

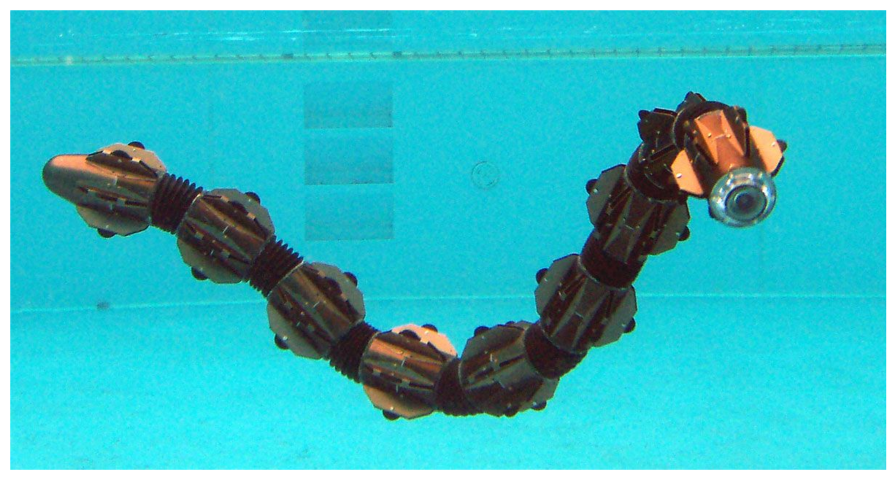

Figure 4: ACM-R5 [1]

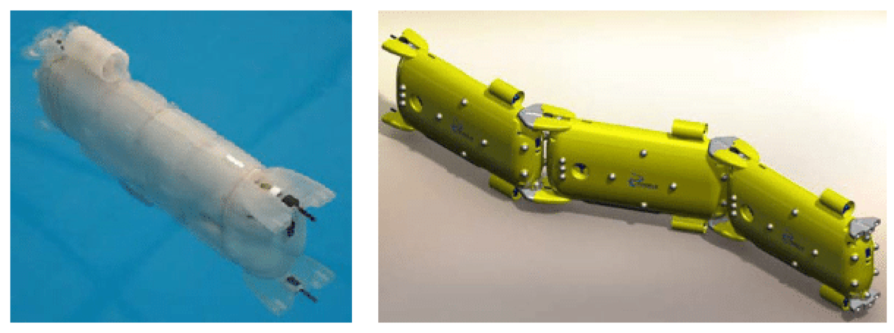

Figure 5: Angle [3]

4. Thesis Contribution

The goal of the master thesis will be to design and build modular units that are self-reconfigurable in multiple ways. Each modular unit will have its own propeller, a basic set of sensors and onboard processors.

- Research and design a cost-effective modular unit.
- Designing a control system that allows self-reconfigurations of the modules.
- Simulate and test the proposed system in underwater scenario to ensure its performance.
- Conduct field trials to test the system in real-world underwater environments.

References

[1] Shigeo Hirose and Hiroya Yamada. Snake-like robots [tutorial]. *IEEE Robotics Automation Magazine*, 16(1):88–98, 2009.

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[3] Stefano Mintchev, Cesare Stefanini, Alexis Girin, Stefano Marrazza, Stefano Orofino, Vincent Lebastard, Luigi Manfredi, Paolo Dario, and Frederic Boyer. An underwater reconfigurable robot with bioinspired electric sense. In *2012 IEEE international conference on robotics and automation*, pages 1149–1154. IEEE, 2012.

[4] Ke Yang. Dynamic model and cpg network generation of the underwater self-reconfigurable robot. *Advanced Robotics*, 30(14):925–937, 2016.