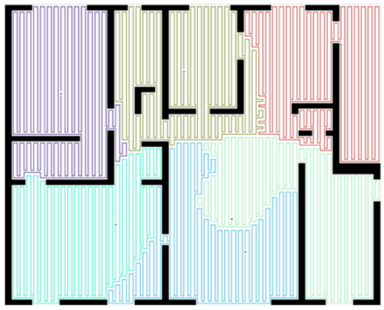
Robot Swarm Coverage in Aquatic Ecosystems

MSc Dissertation Theme for 2026/27



A robot coverage task can be defined as the robot covering completely a given area of interest to perform therein a given useful operation (Choset, 2001). Practical examples of coverage tasks include vacuum cleaning the floor of a residence, mowing the lawn, sampling of physical quantities in a large aquatic area (e.g., an estuary), plowing, spraying, weeding, grain harvesting, landmine detection, etc. In a coverage task, the mobile robot or unmanned vehicle navigates autonomously within the area to be covered, while avoiding obstacles and using motion patterns that allow covering completely the area (Galceran & Carreras, 2013). These motion patterns aim at visiting at least once, and preferably only once, every point within the area to be covered in each run of coverage, as well as maximizing the use of straight movements to minimize energy expenditure in turns. The use of multiple robots or a swarm to perform the task can significantly reduce the time required to cover completely the environment but requires some sort of coordination of the robots' actions. While coverage with a single robot has been extensively studied, multi-robot coverage (Gao et al., 2026) has been less studied. Many of the coverage methods proposed in literature abstracts the environment through a cellular decomposition, e.g., grid-based decomposition, exact cell decomposition, Boustrophedon decomposition, etc. The grid-based decomposition (Gabriely & Rimon, 2002) is the most popular due to its simplicity.

This MSc dissertation project aims to develop a coverage algorithm for swarms of small autonomous surface vehicles used in aquatic ecosystems for environmental monitoring. Besides adaptive data sampling, which can be simplistically seen as informed stochastic search, swarm coverage is another key swarm behavior for the use-case scenarios of the REMORA project being currently conducted at ISR – University of Coimbra. The use-case scenarios are a fish farm and a marina. Other two auxiliary swarm behaviors required in the marina scenario are connectivity-preserving swarm deployment with multi-hop communication to a base station and, in the end of the mission, swarm aggregation near the base station.

The objectives are: i) development of swarm coverage algorithm tailored to the REMORA project's use-case scenarios; ii) development of algorithms for the connectivity-preserving swarm deployment and swarm aggregation collective behaviors; iii) implementation of the algorithms in ROS 2 and their experimental validation.

Work plan for the 1st semester: analysis of the state of the art; familiarization with tools and key methodologies required by the dissertation project (ROS 2, robotic simulators integrated in ROS 2, classical swarm robotic algorithms); design of a preliminary version of the coverage algorithm.

Workplan for the 2nd semester: development of the coverage algorithm; development of the connectivity-preserving swarm deployment algorithm; development of the swarm aggregation algorithm; experimental validation, both in simulated and physical robot swarms.

Candidates to this MSc theme should have basic knowledge of swarm robotics and possess good programming skills (C++ and/or Python).

The work will be carried out at the Mobile Robotics lab of the Institute of Systems and Robotics - University of Coimbra.

References

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Gabriely, Y., & Rimon, E. D. (2002). Spiral-STC: An on-line coverage algorithm of grid environments by a mobile robot. In Proceedings of the 2002 IEEE International Conference on Robotics and Automation (pp. 954–960). https://doi.org/10.1109/ROBOT.2002.1013479

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