HANCAD

Heterogeneous Ad-Hoc Network For The Coordination of Aquatic Drones

In this project, we studied heterogeneous ad-hoc networking for large-scale systems of aquatic surface drones. We assessed a number of different networking technologies for long- and short-range communication and developed novel ways of synthesising decentralised control for such large-scale systems. We built a prototype system of 10 aquatic surface drones and conducted several field experiments.

Main Project Team	
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Indicators	
Funding	40k €
Journal papers	6
Conference papers	21
Concluded PhD	1
Concluded MSc	7

Two Main Publications

A. Christensen, S. Oliveira, O. Postolache, J. Oliveira, S. Sargento, P. Santana, L. Nunes, F. J. Velez, P. Sebastião, V.C. Costa, M. Duarte, J. Gomes, T. R. Rodrigues, F. Silva, Design of Communication and Control for Swarms of Aquatic Surface Drones, "INSTICC International Conference on Agents and Artificial Intelligence ICAART", Lisbon, Portugal, Vol. 2, pp. 548 - 555, January, 2015

M. Duarte, J. Gomes, V.C. Costa, T. R. Rodrigues, F. Silva, V.L. Lobo, MM Marques, S. Oliveira, A. Christensen, Application of Swarm Robotics Systems to Marine Environmental Monitoring, "IEEE/MTS Oceans Conference", Shanghai, China, 2016, pp. 1 - 8, April, 2016

PROJECT WEBPAGE URL

http://biomachineslab.com/projects/control-of-aquatic-drones-for-maritime-tasks-coratam/

Fig. 1 Test scenario for link quality testing.

Fig. 2 Aquatic drone hardware developed.

GENERAL MOTIVATION AND OBJECTIVES

Finding novel ways of exploring and exploiting maritime opportunities is on the global agenda and of particular interest to Portugal given its history, territory and ambitions. Large-scale collectives of aquatic drones have the potential to take on essential tasks such as prospecting sites for aquaculture, environmental monitoring, sea life localization, sea-border patrolling and so on. All of these tasks require effective communication, distributed sensing, scalability, and robustness to faults, which can be facilitated by large collectives of autonomous drones equipped with the appropriate networking technology. The objectives of this project were to study and develop approaches to heterogeneous communication that enable decentralised coordination between autonomous drones and maintenance of communication links between a drone collective and human operators at a base station. We studied a heterogeneous network architecture comprised of (i) low-range and low-power communication technologies that enable drones to communicate and coordinate with their neighbours, and (ii) long-range technologies that enable a subset of the drones with extra large batteries to serve as gateways and relay messages to a base station located on land or on a vessel.

CHALLENGE

The main challenges addressed in this project was to design heterogeneous networking for swarms of aquatic surface drones, which included (i) characterising different communication technologies and their performance in aquatic environments, (ii) synthesising control for the individual drones that would lead to the desired global behaviour, and (iii) making the drones network-aware to avoid individual drones becoming disconnected and to allow for spatial reconfiguration to optimise communication performance.

WORK DESCRIPTION AND ACHIEVEMENTS

The project was divided into five work packages:

WP1 - Network Technologies for Aquatic Environments: The objective of this WP was to study and implement a heterogeneous network architecture for aquatic drones. We studied LoRa for long-range communication and 802.11g Wi-Fi for short-range communication. We furthermore studied how to include link quality estimates as input to the behavioural control to avoid drones becoming disconnected.

WP2 – Hardware Preparation: We developed a small and inexpensive aquatic drone platform and produced a total of ten units. Each drone had two motor for propulsion, onboard computation, communication, compass and GPS for localization, and a sensor to measure water temperature.

WP3 - Maintenance of Network Connectivity During Task Execution: We conducted studies of the synthesis of basic behaviours for collectives of aquatic drones. We then demonstrated for the first time a real swarm of aquatic drone outside of controlled laboratory conditions performing classic swarm tasks, such as dispersion, while remaining within communication range of neighbours.

WP4 - Demonstration Tasks: We experimented with a number of real-world proof-of-concept tasks for aquatic drones. We composed several primitive behaviours into controllers for complete missions, such as environmental monitoring and intruder detection. The synthesized control was extensively validated on the real system of aquatic drones.

WP5: Dissemination and Exploitation: Aside from publishing more than 27 scientific works, we presented the project and its results several fairs and business events, and our video "A Sea of Robots" received an award at the prestigious AAAI conference held in Phoenix, Arizona in 2016.

To the best of our knowledge, we are the first group in the world who has successfully taken a swarm robotics system with evolved control out of controlled laboratory conditions, and performed successful experiments in chaotic, real-world environments. We have furthermore built the key components to be able to create a large-scale network of drones.