CORATAM

Control of Aquatic Drones for Maritime Tasks

In this project, we built a fleet of autonomous aquatic surface drones and studied novel ways of synthesizing control for them. We applied approaches such as evolutionary computation that takes inspiration from Darwin's theory of biological evolution, and swarm intelligence, inspired by observations of social insects such as ants and bees to achieve collectively intelligent behaviors.

Main Project Team	
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Funding Agencies	
FCT	**50,000€**
Start Date	07/04/2014
Ending Date	31/07/2015
Indicators	
Journal Papers	6
Conference Papers	18
Concluded PhD	1
Concluded MSc	6
Two Main Publications	
M. Duarte, V.C. Costa, J. Gomes, T. R. Rodrigues, F. Silva, S. Oliveira, A. Christensen, **Evolution of Collective Behaviors for a Real Swarm of Aquatic Surface Drones,** PLOS One, Vol. 11, No. 3, pp. e0151834 - e0151834, March, 2016	
M. Duarte, J. Gomes, V.C. Costa, T. R. Rodrigues, F. Silva, VL Lobo, MM Marques, S. Oliveira, A. Christensen, **Application of Swarm Robotics Systems to Marine Environmental Monitoring**, IEEE/MTS Oceans Conference, Shanghai, China, 2016 (in press).	

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

Fig. 1 A total of ten aquatic drones were produced.

Fig. 2 Ten aquatic drones during an experiment at the naval base in Alfeite, Portugal.

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 the upcoming expansion of the Portuguese maritime territory. 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. Many of these tasks require distributed sensing, scalability, and robustness to faults, which can be facilitated by collectives of drones with decentralized control based on the principles of self-organization. In this project, we take a novel approach to the synthesis of behavioral control for multirobot systems in which we (i) evolve control hierarchically, and (ii) transfer control from simulation to real robotic hardware incrementally.

CHALLENGE

In the domain of largescale, decentralized robot collectives, the complexity stemming from the intricate dynamics required to produce self-organized behavior complicates the hand design of control systems. Artificial evolution, on the contrary, has been shown capable of exploiting the intricate dynamics and synthesize self-organized behaviors. Two main issues have prevented evolutionary computation from being applied to real-world robotics tasks, namely scaling to complex tasks and the transfer of control from simulation to real-robot systems. Finding solutions to complex tasks is challenging for evolutionary approaches due to the bootstrap problem and deception. When the task goal is too difficult, the evolutionary process will drift in regions of the search space with equally low levels of performance and therefore fail to bootstrap. Furthermore, the search space tends to get rugged (deceptive) as task complexity increases, which can lead to premature convergence. Another prominent issue in ER is the reality gap. Behavioral control is typically evolved in simulation and then only transferred to the real robotic hardware when a good solution has been found. Since simulation is an abstraction of the real world, the accuracy of the robot model and its interactions with the environment is limited. As a result, control evolved in a simulator tends to display a lower performance in reality than in simulation.

The hierarchical control synthesis approach adopted in the CORATAM project enables the use of evolutionary computation techniques for complex tasks in real robotic hardware by mitigating the bootstrap problem, deception, and the reality gap. The approach adopted allows up to recursively decompose tasks for the aquatic drones into sub-tasks, and synthesize control for each sub-task.

WORK DESCRIPTION AND ACHIEVEMENTS

The project was divided into three different work packages:

WP 1 Hardware Platform: We developed a small and inexpensive aquatic drone platform and produced a total of ten units. Each drone had two motors for propulsion, onboard computation, communication, compass and GPS for localization, and a sensor to measure water temperature.

WP 2 Basic Behaviors: We conducted simulation-based studies of the synthesis of basic behaviors for collectives of aquatic drones. The basic collective behaviors were those traditionally studied in the field of swarm robotics, such as aggregation, dispersion, area monitoring and homing. We demonstrated for the first time a real swarm robot system with evolved control operating outside controlled laboratory conditions.

WP 3 Complex Tasks: We then went on to study complex collective behaviors for real-world proof-of-concept tasks for aquatic drones We composed primitive behaviors into controllers for a complete missions, such as environmental monitoring and intruder detection. The synthesized control was extensively validated on the real system of aquatic drones.