A multi-robot platform to study the collective adaptive mechanisms in mixed societies

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1 Introduction

Social animals are one of the most fascinating example of collective adaptive systems, for which complex collective behaviors can arise from social interaction that leads to self-organization of the group [1]. Indeed, by aggregating and taking collective decisions, animals can sometimes solve rather complex problems that an individual could not solve alone.

One of the way that researchers have used in the past decades to study the animal collective behavior is the setting up of mixed societies of animal and robots [2]. A mixed society is defined as *"dynamic systems, where animals and artificial agents interact and cooperate to produce shared collective intelligence"* [2]. Robots have been used, for instance, to influence the collective decisions using the Shepherd dogs effect in a mixed group composed of ducks and a robot as shown in [3], or were perceived by cockroaches as conspecifics and could take collective decisions together with the animals [4].

In the past few years, we designed a system to investigate the fish collective behavior, by having robotic agents inserted among the fish societies [5] [6]. We selected the zebrafish *Danio rerio* as a model to study the collective adaptive behaviors of social animals. The designed framework allows us to perform automated experiments of mixed groups of animals and robots. The controllers of the robots have parameters that can be adapted in order to have a closed-loop adaptation of the robots to the fish collective behaviors. Adding evolutionary algorithms into the loop will allow an automatized adaptation of these controllers, which offers perspectives for the study of collective animal behavior and adaptive mechanisms.

2 Robotic infrastructure

The robotic infrastructure that was designed to perform mixed societies of zebrafish and robots is described in Fig.1. Fish-lures are moving in direct contact with the fish inside an aquarium [6]. The lures are equipped with an actuated tail that can beat with different amplitudes and frequencies, so that they can send signals that are relevant for zebrafish social behaviors. Thanks to magnetic coupling, the lures are steered by wheeled mobile robots that are moving underneath the aquarium and that can achieve dynamic movements to mimic the two dimensional motion of zebrafish [5]. The robots are controlled in a closed-loop using visual tracking, that retrieves the individual position of the robots as well as the position of the fish in real-time. The wheeled mobile robots are continuously powered so that we can study the adaptive mechanisms of the agents during day-long experiments.

3 Closing the loop of interaction

In order to automatically control the robots so that they can reproduce the fish collective behaviors, and adapt to the fish, different levels of controllers have been implemented (Fig. 2). Inside a software running in a computer, the position of the agents is retrieved in real-time using visual tracking. Models of zebrafish shoaling based on the vision of zebrafish [7] are implemented to generate fish-like trajectories for the mobile robots. Control commands are then sent to the robots so that they reach these trajectories, using specific low-level controllers that mimics the locomotion of the fish. These controllers have several parameters that can be adapted depending on the zebrafish collective behavior observed.

4 Automated adaptation

Thanks to the framework set in place, the study of collective adaptive behavior can be investigated with a mixed group composed of several robots and animals. Evolutionary algorithms and optimization methods, such as the ones described in [8] will be used to produce appropriate decentralized controllers for the robotic agents, that will be adapted in real-time in experiments with mixed groups of animal and robots as shown in Fig. 3. This will allow the robots to better adapt to the animals and better integrate fish shoals.

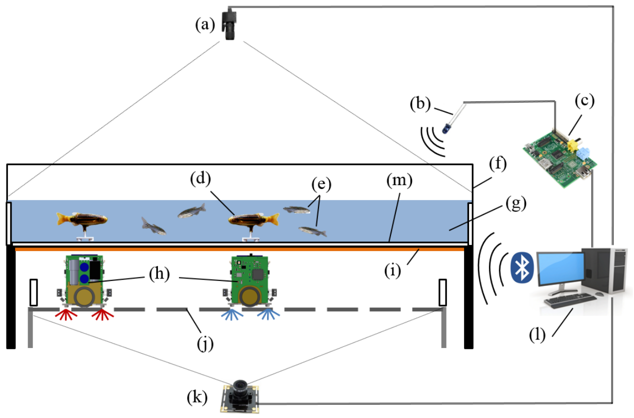

Figure 1: Schematic of the experimental setup. (a) Basler camera used to grab high-resolution frames to track the lures and the zebrafish. (b) IR emitter to emit the controlled commands for the lurs. (c) Raspberry PI to generate the required controlled commands to send to the lures. (d) Fish-lure inside the aquarium linked to the mobile robot through magnetic coupling. (e) Zebrafish. (f) Aquarium of 100 × 100 × 25 cm. (g) Water of 6 cm depth. (h) Wheeled mobile robots moving under the aquarium. (i) Copper conductive plates to power the mobile robots (VCC). (j) Perforated stainless steel plates to serve as ground contact for the mobile robots (GND) and to oberve the robots' LEDs from below. (k) 180 degrees fisheye camera to track the mobile robots from below. (l) The control station that runs the control and tracking software. (m) Teflon plate covering the bottom of the experimental tank.

5 Conclusion and further work

The system designed allows the collective adaptation of behaviors for two different societies, an artificial one composed of robotic agents, and a group of animals. Thanks to the adaptive mechanisms, some parameters of the robots' controllers can be automatically adapt to the animals, which offers perspectives for learning more on the adaptive mechanisms in social animals.

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7 Reference

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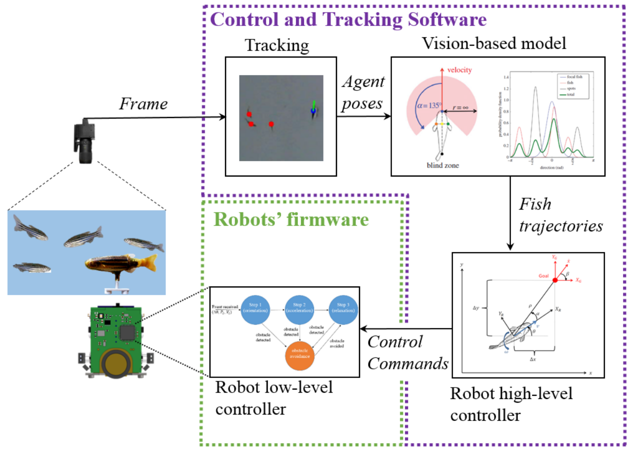

Figure 2: Control architecture to mimic the trajectories and locomotion of zebrafish. The poses of all the agents are retrieved by the visual tracking and used in the vision-based model of [7] implemented inside the control and tracking software. The estimated agent trajectories are sent to the high-level controllers of the mobile robots to compute the global command that needs to be sent to the robots to reach the desired targets. The commands are received by the robots that execute a finite-state machine to produce the zebrafish locomotion.

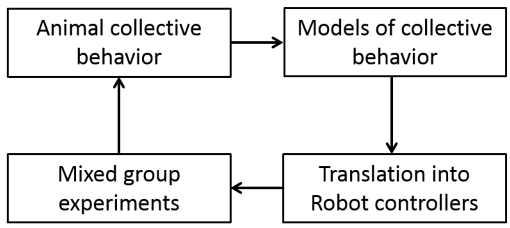

Figure 3: Closed-loop system of the adaptive mixed society of robots and animals.

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