CoCoRo: The self-aware swarm of underwater robots

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The EU-funded project CoCoRo ("Collective Cognitive Robots", ICT, EU-FP7) aims for generating a heterogeneous swarm of AUVs that is used for environmental monitoring (water pollution, effects of global warming) and search purposes (black-boxes, toxic waste dumps, polyp fields).

The CoCoRo system will consist of several subsystems: A 'floating base station', which feeds global information (e.g., GPS) into the system, a self-aware 'ground swarm' that performs the focal task and a 'relay swarm' that bridges the communication between the these two agents. Both, the ground swarm and the relay swarm consist of AUVs able to perform 3D underwater swimming, with many on-board sensors to interact with the environment. While the ground swarms exploits self-organization and mainly local-neighbour interactions, the relay swarm exhibits vertical directed communication.

The floating base station allows human interaction with the CoCoRo system and also lateral communication (to other base stations nearby) and global communication (GPS, UMTS, …). The system is planned to be scalable as several of these CoCoRo systems can be deployed in parallel to increase the size of the searchable area. The floating base station can support the self-organization of the AUVs by delivering important cues to them (sound, light, …). The objective is to develop new solutions in terms of collective AUVs control and mechanical system.

The hardware development in CoCoRo is based on novel engineering approaches and adopts ad-hoc technologies in order to fabricate several autonomous underwater vehicles (AUVs) able to swim in 3D by means of propellers and a buoyancy system, and to explore complex and unpredictable environments thanks to the flexibility, autonomy and reliability of the system.

In order to navigate the underwater environment and to recognize objects, several proprioceptive and exteroceptive sensors are equipped to the robot. Novel solution by using blue light, pressure wave and coupled electrostatic oscillators, both for underwater exteroceptive sensor and swarm communication, will also be investigated. The usage of modulated blue light as optical communication has advantages, since it is robust to the interferences and has high bandwidth for relaying the measured data from the 'ground swarm'.

The CoCoRo platform contains a fault tolerant hardware abstraction layer (HAL) and middleware that affords important levels of fault identification and recovery than seen on current platforms. In addition, a novel aspect will be a bio-inspired operating system that, as default behaviour, allows the underwater swarm to shoal and maintain coherence. Using inspiration from T-regulatory networks of the immune system, we work on developing self-regulating swarms which are capable of automatic recovery from certain types of failure, so as to allow the swarm to reconfigure to complete the task.

To allow the underwater swarm to exhibit a high level of self-awareness, several mechanisms form biological 'swarm systems' like fish-shoals, honeybees, immune-systems and brains are incorporated into the CoCoRo software. This way, information will be processed, filtered and/or augmented already at low levels on a local basis and swarm-level memory and swarm-level cognition will emerge.

It is of interest for engineers to design collective intelligence but some form of control has to be implemented in a non-centralized manner. Self-organized systems impose constraints on the type of control. In CoCoRo, we aim at studying these constraints and to develop mechanisms to modulate collective behaviour without global communication.

One of essential research challenges in design of collective systems consists in creating a certain level of macroscopic intelligence expressed in terms of collective sensing and reasoning, decision making, distributed and self-organized planning, cooperative and collaborative behaviour. The underwater environment imposes not only a very hard requirement for 3D navigation and actuation, but also essential limitations for individual communication and sensing. Thus, achieving advanced collective capabilities requires very specific usage of typical underwater interactions such as blue light, hydro acoustic and pressure waves, oscillators coupled by means of electrostatic fields and other approaches. One of the tasks consists on implementation and integration of these approaches on the experimental platform and development of local algorithms creating a desired level of collective intelligence, leading finally the phenomenon of collective self-recognition.

In CoCoRo, the issue of collective discrimination of environmental properties is addressed in a series of 'ethological' experiments using the CoCoRo system, as soon as hardware prototypes are available. Correlated simulation-based research is currently in progress: One research track will investigate whether information has to be processed at an individual or on a collective level given the cognitive capabilities of the agents. Self-awareness and collective self-recognition will be experimented with a developed methodology that allows the detection and quantification of various forms of collective cognition. Designing bio-inspired experiments and appropriate metrics to evaluate the level of cognition reached by the systems is a research issue in itself.

In conclusion, CoCoRo could be a novel underwater swarm that mixes bio-inspired motion principles with biology-derived mechanisms of group-level awareness in a blended manner. This way a novel robotic system will be generated that is highly scalable, very reliable and – in parallel – very flexible concerning its behavioural potential.

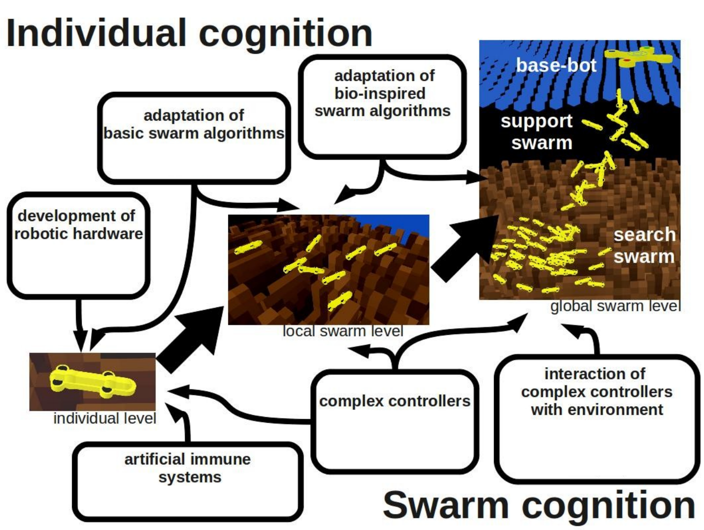

Fig. 1: The three levels of awareness and the levels of adaptation in the CoCoRo system.