CoCoRo – A self-aware swarm of underwater vehicles

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The vast oceans that cover most of earth's surface are still mostly unexplored and their gigantic volume is impossible to monitor area-wide. Whenever something is lost (e.g., a black box of a crashed airplane; lost and sunken cargo) or something was illegally dumped into the ocean (e.g., toxic waste) either manned submarines or unmanned remotely operated underwater vehicles (ROVs) are used for recovery. In some cases it is also possible to use single autonomous underwater vehicles (AUVs), e.g. for periodical environmental surveys. However, to cover wider areas of the ocean these single-instance measures/explorations are not sufficient, thus autonomous wide-area seabed exploration is a future goal in this field.

In the last years, illegal dumping of toxic waste was reported in the Mediterranean sea (Wikinews 2009), which threatens ocean ecology, fishery economy and also the tourism industry in the European Union. As soon as one of these waste containers starts leaking and first traces of toxic substances can be detected in the water, the challenge is to find these source spots as soon as possible. Unfortunately, these substances do not form gradients of pollution in the water which can be simply followed “uphill” to the source by a singular gradient-ascent driven AUV. As one solution to this problem, the project CoCoRo aims for generating the enabling technologies for a whole swarm of AUVs. The swarm will act as an autonomous and self-aware distributed sensor network in the water that will be able to cover a large area to efficiently search for a target.

In addition to to specific search missions also frequent and autonomous environmental monitoring gets more and more important, because ocean ecology has a significant impact on certain human industries, e.g. fishing and tourism. Pollution or changes in water temperature can have a cascade-like effect on oceanic life, leading to explosive growth of non-native species or decreases of valuable fish stock: For example, in the last decade mass bloom of jellyfish caused severe damage to the fishery economy (Lynam et al. 2006). These blooms are assumed to be caused by ocean pollution, which affects the fields of polyps on the seabed, which are mostly still unexplored. Also the EU fishery is significantly affected by these threats, which are assumed to intensify in future. Also for these purposes, the CoCoRo project will investigate basic enabling technologies.

In CoCoRo we develop a swarm of small AUVs (length approx. 20-30cm, see figure 1) which exhibit several interesting features helping the swarm to survive in harsh oceanic habitats and also helping the swarm to achieve its objectives faster and/or more reliably. On the one hand, a CoCoRo swarm will consist of singular AUVs which are aware of their environment by exploiting multiple redundant sensor arrays (pressure, light, sound, …). On the other hand, the swarm members will interact in a “swarm-intelligent” way by simple interaction rules and by exchange of simple and redundant signals. See Bonabeau et al. (1999) and Kennedy and Eberhart (2001) for details on swarm intelligence. Exploiting these rules of interaction, the swarm can self-organize, generating swarm-level awareness or swarm-level cognition. Social organisms have shown that simple interaction rules were found to be able to generate group-level cognition, facilitating group-level decision making (see Camazine et al., 2001) and collective awareness (including swarm-level memory). In CoCoRo, we aim for generating similar systems by implementing bio-derived mechanisms like artificial immune systems, honeybee-derived algorithms or cockroach-derived behaviors.

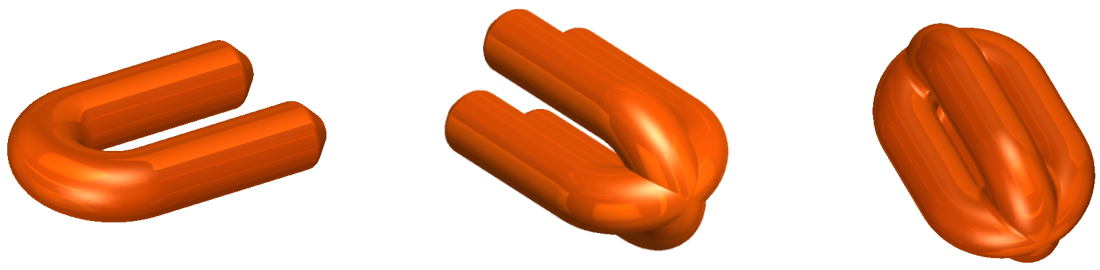

Figure 1: Concepts of CoCoRo AUV shapes with different abilities for the resulting AUV swarm. Each of these small AUVs will be equipped with multiple sensors to allow them to be aware of their environment and their swarm members. Images

contributed by Dr. Cesare Stefanini, Scuola Superiore Sant'Anna.

In ethology and physiology, a plethora of experimental setups have been designed to investigate (and to benchmark) the cognitive capabilities of organisms. As CoCoRo aims for swarm-level cognition which arises from self-organization, a similar set of benchmarks will be developed. We will start with simple experiments that analyze how well the CoCoRo swarm is aware of its own size and how well it is aware of environmental conditions. Later, we will investigate its capabilities in collective decision making and homeostatic balancing. Additionally, we will investigate how a swarm can be generated that is able to know that it does not know something. Finally, we plan to perform a mirror test to investigate if it is possible that a swarm – as a whole – can discriminate between its own mirror image and another swarm.

It is important to note that the scientific focus of the CoCoRo project is not hardware development. Instead, we concentrate on researching new algorithms, supported by appropriate sensor/actuator design, which allows to generate cognition and self-awareness in a decentralized, self-organizing way (see figure 2). Such mechanisms could significantly enhance the capabilities of autonomous technical devices, not only underwater, but also in everyday life, like in ad-hoc networks formed by smart-phones, cars or network-enabled household devices.

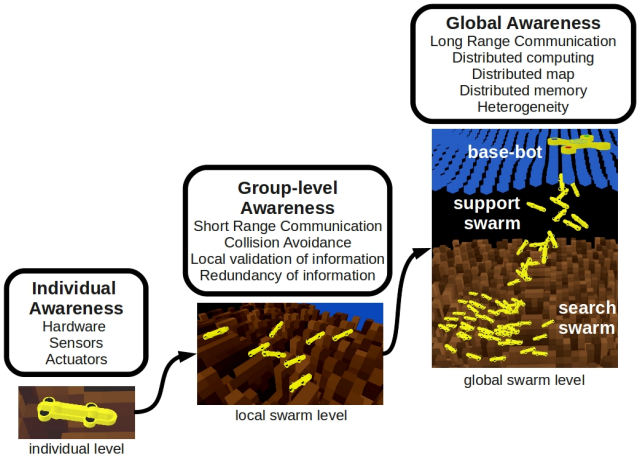

Figure 2: Different levels of awareness in the CoCoRo system. Individual AUVs are aware of their environment through their own sensors, groups of AUVs are aware of their swarm through short-range communication. Global awareness will be achieved by distributed swarm algorithms that lead to heterogeneous swarms. The base bot will serve as a connection to the water surface to allow for long-range communication to the researchers and to other CoCoRo systems.

References

Bonabeau E., Dorigo M. and G. Therualaz (1999) Swarm Intelligence: From Natural to Artificial Systems. New York, Oxford University Press, Santa Fe Institute Studies in the Sciences of Complexity, 1-307.

Camazine S., Deneubourg J.L., Franks N., Sneyd J., Theraulaz G. and Bonabeau E. (2001) Self-Organization in Biological Systems, Princeton University Press.

Kennedy J. and R.C. Eberhart (2001) Swarm Intelligence. Morgan Kaufmann (Publishers), San Francisco: 1-512.

Lynam C., Christopher P., Gibbons M., Bjørn E. and Axelsen B. (2006) Jellyfish overtake fish in a heavily fished ecosystem. Current Biology 16 (13) 492.

Wikinews (2009) Link: http://en.wikinews.org/wiki/Italian_mafia_accused_of_radioactive_waste_dumping.