Towards Bio-hybrid Systems Made of Social Animals and Robots

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Abstract. For making artificial systems collaborate with group-living animals, the scientific challenge is to build artificial systems that can perceive, communicate to, interact with and adapt to animals. When such capabilities are available then it should be possible to built cooperative relationships between artificial systems and animals. Machines In this framework, machines do not replace the living agents but collaborate and bring new capabilities into the resulting mixed group. On the one hand, such artificial systems offer new types of sensors, actuators and communication opportunities for living systems; on the other hand the animals bring their cognitive and biological capabilities into the artificial systems. Novel bio-hybrid modeling frameworks should be developed to streamline the implementation issues and allow for major time saving in the design and building processes of artificial agents. We expect strong impacts on the design of new intelligent systems by merging the best of the living systems with the best of ICT systems.

Keywords: Mixed society, bio-hybrid systems, collective intelligence, social emergence, collective robotics, behavioral biology.

1 Introduction

The scientific field of animal-machine interaction at the collective level has been barely explored. We envision the design of intelligent artificial systems capable of closing the loop of interaction between animals and robots. Our envisioned methodology allows numerous social interactions among individuals of a mixed society composed of animals and robots, finally showing novel system properties [4]. Robots that interact with animals and can participate in their social activity can form a mixed robot-animal society, which is coherent at the collective level. Mixed societies are dynamical systems where animals and artificial agents interact and cooperate to

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produce shared collective intelligence. Artificial agents do not replace the animals but collaborate and bring new capabilities into the mixed society that are inaccessible to the pure groups of animals or artificial agents. Each category of agents, living or artificial, may react to signals or perform tasks that the other category does not detect or perform.

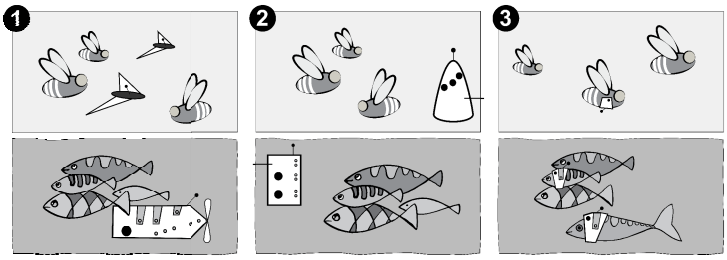

Fig. 1. Concepts of artificial (1) mobile, (2) static and (3) mounted nodes interacting with different types of animal societies

Artificial agents interacting with living animals may be designed in different forms (see Fig.1): (1) Mobile nodes: autonomous mobile robots that mix with living animals. (2) Static nodes: distributed immobile sensor-actuator units. (3) Mounted nodes: sensor-actuator units mounted on the animals themselves and conferring them new capabilities. The problems that have to be solved and a large part of the solution for these problems are unconventional compared to today's state of the art in ICT. The challenge for robotics and ICT is to design novel systems that are capable of handling natural collective intelligence in real-time heterogeneous environments [4].

2 Proposed Methodology

Mixed societies of animals and robots are at the crossroad of animal social behavior and collective robotics, as well as on the intersection of natural and artificial collective intelligence [3,4]. The development of such bio-hybrid systems requires parallel and coordinated research tracks between behavioral biology and robotics. The first technological challenge is to make the robots accepted by the animal societies by finding appropriate channels of communication corresponding to specific animal traits such as motion patterns, visual, olfactory, sound cues and cognitive processes They require the development of specific, novel and safe sensors and actuators. For example, good results with cockroaches were obtained by using olfactory cues [2]. These cues were calibrated olfactory signals that were simply deposited on the robot bodies. To establish interactions between chicken and autonomous mobile robots filial imprinting, an innate learning window can be used to create social attachments with robots [1]. Quantitative studies of animal social behavior have to be undertaken to build mathematical models, necessary to design the behavioral modules and programs used in robots [4]. The challenge is to put together interdisciplinary research teams involving behavioral biology and ICT engineering and sharing common scientific frameworks.

3 Expected Impact of Bio-hybrid Social Systems

One potential field of application is management of domestic animal stocks that all are social animals. This may lead to various agricultural applications such as low-stress management of livestock. Optimal management of such systems could be achieved by integrating artificial adaptive system elements into animal groups to coordinate their activities among each other and with animals. Thus, behavioral modulation of animals will be done in a more natural way without suppressing their instincts, living conditions or neglecting established hierarchies.

Another field of application is research in animal behavior [2,4]. By introducing artificial agents into animal societies one can test individual and group reactions to various stimuli; by combining robots with quantitative ethograms one can achieve an unparalleled automation of animal behavior experimentation. Such automated and robotized systems may significantly improve the field of biomedical research that is using model animals.

Social bio-hybrid systems could also be used to manage wildlife animal pests or resources in particular group living species. We envision artificial intelligent systems capable of interacting and modulating the behavior of wild species treated as pests or as valuable resources.

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