Enhancing cooperative transport using negotiation of goal direction

Alexandre Campo Shervin Nouyan Mauro Birattari
Roderich Groß Marco Dorigo

IRIDIA, CoDE, Université Libre de Bruxelles, Brussels, Belgium

Swarm robotics is a relatively new approach to the coordination of a system composed of a large number of autonomous robots. The coordination among the robots is achieved in a self-organised manner: the collective behaviour of the robots is the result of *local* interactions among robots, and between the robots and the environment. Each single robot typically has limited sensing, acting and computing abilities. The strength of swarm robotics lies in the properties of robustness, adaptivity and scalability of the group [1].

Foraging is a typical task considered in swarm robotics. It can be decomposed in an exploration subtask followed by a transport subtask. The robotic metaphor consists in the search and retrieval of an object. Therefore, the nest is the metaphorical term for the goal and the prey is synonymous of the object to transport. Examples of applications of foraging are toxic waste cleanup, search and rescue, demining and collection of terrain samples.

Central place foraging is a particular type of foraging problem in which robots must gather objects in a central place. Borrowing the terminology from biology, the central place is also called the *nest* and the objects are called *prey*. We focus on a specific case in which the transport of a prey requires the combined effort of several robots. This task is called cooperative transport. Several problems need to be solved to perform this task successfully. The coordination of the movement of the robots is one of them. This problem has been investigated by Groß *et al.* [2], in situations in which either all or some robots are able to perceive the nest.

In the present work, we study the cooperative transport of a heavy object by a group of robots towards a goal. We investigate the case in which robots have partial and noisy knowledge of the goal direction and can not perceive the goal itself. The robots have to coordinate their motion to apply enough force on the object to move it. Furthermore, the robots should share knowledge in order to collectively improve their estimate of the goal direction and transport the object as fast and as accurately as possible towards the goal.

We propose a bio-inspired mechanism of negotiation of direction that is fully distributed. The implementation of the negotiation mechanism is made on robots called *s-bots*, designed and implemented in the SWARM-BOTS project[1], and relies on visual communications with the camera and the LEDs of the robots. Four different transport strategies are implemented and their performances are compared on a group of four real robots, varying the goal direction and the level of noise. We identify a strategy in which robots negotiate and move at the same time that enables efficient coordination of motion of the robots. Moreover, this strategy lets the robots improve their estimate of the goal direction by sharing knowledge with their neighbours. Despite significant noise in the robots' communication, we achieve effective cooperative transport towards the goal and observe that the negotiation of direction entails interesting properties of robustness. This self-organised negotiation is likely to display properties of scalability besides the robustness shown in this paper. Our mechanism has several advantages, and particularly it is still efficient when the prey is not in motion. Additionally, visual communication opens the door to collective motion with or without transport or physical connections. The topology of the communication network is also likely to be very flexible, allowing the robots to school in very diverse patterns.

References

[1] M. Dorigo and E. Şahin. Swarm robotics – special issue editorial. *Autonomous Robots*, 17(2–3):111–113, 2004.

[2] R. Groß, F. Mondada, and M. Dorigo. Transport of an object by six pre-attached robots interacting via physical links. In *Proc. of the 2006 IEEE Int. Conf. on Robotics and Automation*, pages 1317–1323. IEEE Computer Society Press, Los Alamitos, CA, 2006.

[1] For more details, see the website of the project: http://www.swarm-bots.org/