Bee-inspired foraging in a real-life autonomous robot collective

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Abstract

In this demo[1], we show the emergence of Swarm Intelligence in physical robots. We transferred an optimization algorithm which is based on bee-foraging behavior to a robotic swarm with the advantage that this algorithm, and so the actual robots, do not require input of environmental parameters (e.g., pheromones).

1 Introduction

Many species have evolved over a long period of time to display behavior that is highly suitable for addressing complex tasks. In recent years, we see an increasing interest in taking inspiration from such behavior in order to create artificial systems that can also address complex tasks. Especially behavior within colonies of social insects, such as ants and bees, is receiving a great deal of attention, because this behavior is remarkably effective and robust given the highly limited capabilities of individual insects. The phenomenon of intelligent behavior that emerges from a collective of relatively simplistic interacting agents, is generally referred to with the term *Swarm Intelligence* (SI).

In this work, we aim to transfer social-insect behavior to embodied systems, i.e. to robots. For this purpose we investigate foraging behavior. Foraging is the task of locating and acquiring resources. Typically, the task has to be performed in an unknown and possibly dynamic environment [5]. We aim at developing a collective of robots that displays effective foraging behavior without any form of central control or simulation. The foraging task can be seen as an abstract representation of many other relevant tasks, such as patrolling and routing. Therefore, a successful embodied implementation of distributed foraging can result in promising applications such as security patrolling, monitoring of environments, exploration of hazardous environments, search and rescue in crisis management situations, etc.

Most research in SI is centered around and inspired by ant behavior [1]. Although ants have limited cognitive capabilities, they are able to effectively perform difficult tasks, e.g. distributed foraging. For this, ants deposit pheromone trails during their exploration of the environment.

Although pheromone is easy to implement in simulated SI systems, deploying it in embodied systems is not trivial. For instance, we would ideally have physical means of representing pheromone trails in the environment, which is only feasible in controlled environments such as factories (e.g. a grid of RFID tags being placed in the floor). In the absence of such physical means, the pheromone trails need to be simulated, either by a centralized component, or by the robots themselves. This places a high computational burden on the distributed system and limits scalability and applicability.

In our work, we focus on SI mechanisms that are not inspired by pheromone, namely the recruitment and navigation mechanisms employed by honeybees. Instead of using pheromones, honeybees make use of a mechanism called Path Integration (PI) for navigation, and a mechanism of direct communication for recruitment. Previous research in bee-inspired SI has led to the creation of a number of highly effective bee-inspired optimization algorithms [2, 4, 3] in simulation. The employed mechanisms are inherently fully decentralized, which makes bee-inspired algorithms also extremely suitable for implementation in embodied systems.

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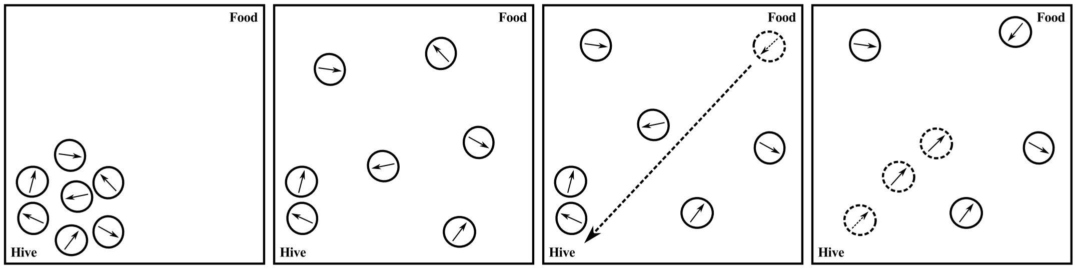

(a) E-pucks around the hive (b) E-pucks exploring (c) Food source found and return to hive (d) E-pucks exploiting

Figure 1: Biomimicry Foraging

2 Biomimicry foraging with e-pucks

In this demonstration, we present an implementation of the basic bee-inspired algorithm *Bee System* (BS) [2] on an embodied swarm. We investigate how capable the algorithm is in coordinating a large collective of robots in a situated foraging task. Our goal is to test for robustness, efficiency and scalability. In this demo, we show the first implementation of BS into a collective of autonomous robots, i.e. the e-puck robots[2].

In Figure 1, we present the stages that the experiment goes through. The goal of the experiment is to show that the BS foraging behavior actually works in an embodied swarm. Therefore, the experiment starts with a swarm of e-pucks surrounding the hive, see Figure 1(a). Figure 1(b) shows the stage in which a portion of the swarm starts foraging while others remain around the hive, waiting for information to exploit. Figure 1(c) presents the situation in which an exploring e-puck finds food and returns to the hive by using its constructed PI vector. Once returned to the nest, the e-puck communicates its PI findings by means of a virtual dance. The hive collects these experiences and offers these to recruits. Finally, Figure 1(d) gives the situation in which other e-pucks communicated with the hive and have attained the PI vector towards the food source and are traveling to the food source guided by this PI vector. With this we show the effectiveness of the embodied foraging behavior in a swarm of e-pucks.

3 The Demonstration

We demonstrate how the bee-inspired SI mechanism is used in a real-life autonomous robot collective which mimics the basic foraging behavior of bees. We show a small collective of robots executing a foraging task in a semi-dynamic environment with moving obstacles and variable food source locations. We also present a new extension board for the e-puck platform that enables the use of XBee communication for the robot swarm. More information about this demonstration can be found at our website[3].
As requirements for the demonstration we need an open space of about 1.5 x 1.5 meters with a flat and smooth surface. In general a 5 minute session would be sufficient to explain the system to the audience.

References

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[2]For more information about the robots visit: http://www.e-puck.org
[3]Online material about this demo: http://swarmlab.unimaas.nl/papers/bnaic2011demo