

Chapter 10

Cooperative Task Execution in Insect-Inspired Robot Swarms Using Reinforcement Learning

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ABSTRACT

This chapter proposes a novel framework for cooperative task execution in a swarm of insect-inspired robots by using Reinforcement Learning (RL) algorithms. Inspired by the collaborative behaviors observed in social insects, such as ants and bees, the proposed framework enables robots to autonomously coordinate their actions

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to accomplish complex tasks in dynamic environments. Each robot in the swarm acts as an autonomous agent capable of learning and adapting its behavior through interactions with the environment and feedback from other robots. By applying RL algorithms, such as Q-learning or Deep Q-Networks (DQN), robots learn optimal action policies to maximize task performance while considering the collective objectives of the swarm. We demonstrate the effectiveness and scalability of our approach in various cooperative tasks, including exploration, foraging, and object manipulation. This project showcases the potential of RL-based approaches to enhance the autonomy and adaptability of robotic swarms for collaborative task execution in real-world scenarios.

INTRODUCTION

Swarm robotics is the field of research that focuses on the behaviour of large groups of very uncomplicated robots. These robots work together and collaborate to complete problems that are beyond the capacity of each individual robot (Dorigo and Sahin, 2004). Task solving in this context is primarily dependent on self-organization and emergence. This means that the organisation of the swarm originates from inside the system itself, rather than being imposed externally. Furthermore, this organisation occurs in a decentralised manner through local interactions between individual robots (De Wolf & Holvoet, 2005). Swarm robotics algorithms mostly depend on cooperation and basic interactions among robots, rather than on intricate individual behaviours that necessitating advanced sensory skills. Specifically, in the context of navigation, this means that the emphasis is on collaborative navigation, where robots assist each other, rather than relying on maps (refer to Mirats Tur et al., 2009) or map-building techniques (such as simultaneous localization and mapping, as described by Durrant-Whyte and Bailey, 2006), or the use of an external infrastructure (such as a communication network or a localization system, as mentioned by O'Hara et al., 2008).

Several studies in the field of swarm robotics navigation focus on a specific scenario in which robots are required to travel repeatedly between two sites, such as transporting objects from one place to another. The majority of this work is founded upon indirect communication. The communication among robots is influenced by the foraging behaviour of specific ant species seen in nature (Werger and Matarić, 1996; Wodrich and Bilchev, 1997; Sharpe and Webb, 1999; Garnier et al., 2007; Fujisawa et al., 2008; Nouyan et al., 2009; Ducatelle et al., 2011a). This behaviour is dependent on stigmergic communication, which involves the indirect exchange of information through the local modification and perception of the surrounding environment. Ants deposit a chemical compound known as pheromone while travelling

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