Emergent Swarm Behaviours in Evolutionary Robotics

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ABSTRACT

We analyse emergent self-organising behaviours in swarms of robots through the use of evolutionary computation. We demonstrate the viability of evolutionary computation to generate emergent behaviours in robots with limited capabilities.

CCS CONCEPTS

•Computing methodologies → Evolutionary robotics; Mobile agents; Genetic algorithms;

KEYWORDS

Evolutionary swarm robotics, Genetic algorithms, Collective behaviours, Kilobots.

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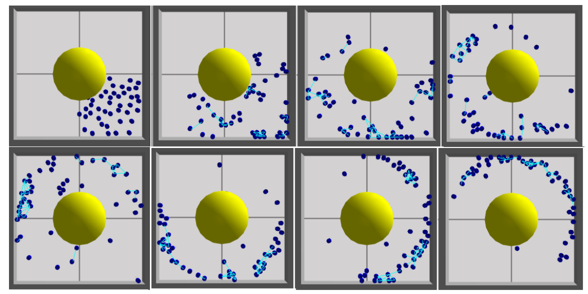

Figure 1: Evolution of negative phototaxis behaviour

1 INTRODUCTION

Evolutionary swarm robotics (ESR) is a field that uses evolutionary computation to evolve controllers for multi-robot systems. This field emphasises decentralised and self-organising behaviours that deal with limited individual abilities, local sensing and local communication. Typically, these multi-robot systems, whose behaviours are inspired by swarms in nature – ants, bees and termites – are physically quite simple. Similar to these insect societies, robotic systems need to be robust, scalable and flexible to change. These desired features can be achieved through different forms of self-organisation such as aggregation, coordination and exploration.

A common problem in evolutionary robotics is the idea of a reality-gap. This gap occurs when programs work well on simulated robots, but fail on real robots due to different actuation and sensing abilities. Thus, minuscule differences between simulation and reality can lead to largely disparate behaviours as it can be very difficult to simulate the actual dynamics of the real world [1]. We believe that by exploring the distinction between the reproducibility of behaviour and performance, we can measure the reality gap accurately and potentially minimise it. Our aim is to demonstrate the ability to scale in complexity and provide solutions for realistic applications, which has yet to be achieved in ESR [2].

2 METHODOLOGY

Evolutionary computation has never been carried out on robots with a high level of hardware and software constraints, such as Kilobots [3]. Much of the previous work on these robots use mathematical methods to demonstrate locomotion, communication and self-assembly [4]. In contrast, we use a genetic algorithm to evolve the Kilobots' behaviours; this determines how our robots react within the environment. We begin by initialising a population of genotypes, which are then evaluated based on a fitness function. Robots that perform above average are allowed to reproduce and their offspring are a result of crossover. This procedure is repeated until a controller meets the requirements of the evaluation. Our fitness evaluation is based on the distance between neighbouring robots and light intensity. When a Kilobot perceives a light source and a neighbouring robot, it sets its speed based on a look-up table, which in turn evolves the collective behaviour of negative phototaxis swarming (Figure 1).

3 CONCLUSION

Initial experiments have demonstrated the viability of using evolutionary computation on robots with limited capabilities; we have evolved a swarm of simulated robots that are simple, yet robust enough to carry out collective behaviours. In the future, we will continue to explore the use of evolutionary computation on Kilobots.

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