

Chapter XI

Ant Colony Optimisation

Introduction

Ants are truly amazing creatures. Most species of ant are virtually blind; some of which have no vision at all, yet despite this, they are able to explore and find their way around their environment, discovering and ‘remembering’ routes between their nest and food sources. Ants exhibit complex social behaviours, with different roles assigned to different ants, and they are able to perform organised operations, even, for example, relocating their entire nest. Even a casual observer of an ant colony can see the efficiency and organisation with which they perform tasks such as foraging food. They are able to find and follow shortest paths between locations, negotiating obstacles between them, and this problem is an active area of interest in computer science, particularly in computer game AI.

What makes all of this possible is the acute sense of smell that ants have, and the secretion of *pheromones*, odorous chemicals that are deposited by the ants, and are subsequently smelt by other ants. For example, if an ant discovers a rich food

source, it will return to the nest, secreting some '*trail pheromone*' (a particular type of pheromone chemical) on the way. Other ants will detect the pheromone trail and follow it, and they too will be likely to find the food source and will return to the nest depositing more trail pheromone on the way, making the trail even more likely to be discovered by other ants. The more ants that discover the food by the pheromone trail, the more likely it is that other ants will also discover it. It is as a result of this positive reinforcement that many ant species are observed to move in narrow trails that follow shortest paths.

These behaviours have inspired artificial intelligence algorithms that have produced impressive results in various combinatorial optimisation problems. Artificial ant colonies can be simulated in a computer, and can be used to find shortest paths in a similar way to biological ants. This idea was originally proposed by Moyson and Manderick (1988) and their ideas have been developed by several researchers, but most notably Dorigo and Stutzle (2004). Various artificial ant colony algorithms have been developed and successfully applied to problems such as the travelling salesman problem (TSP), network routing, and resource scheduling. Much of this research is recent, within the past seven years or so, and it is a vibrant and growing area of academic activity. This chapter provides an overview of the topic of ant colony optimisation (ACO) and shows how it can be applied to path finding and other general problems relevant to computer games.

Foraging Behaviour of Ants

Before we look at artificial ACO algorithms, we will provide a brief account of the behaviour of real ants observed under laboratory conditions. This account is not intended to be an in-depth study of ant behaviours, since our objective is not to accurately describe ant behaviours, but to provide a background to implementing intelligent algorithms inspired by ant species. As stated before, ants exhibit many different complex social behaviours; this section will focus on one of these behaviours: *foraging*.

During foraging, ants will leave their nest and search for food. We shall assume for now that no prior pheromone trails exist, and that the ants have no prior knowledge of the location of the food. With no scents to guide their paths, the ants will explore the area in random directions. A small number of ants may discover food sources by chance. They will take some of the food and carry it back to the nest, leaving a pheromone trail behind. As explained before, the trails will be positively reinforced by more ants, and the trails will be established with strong pheromone scents, guiding ants to the food. With some ant species, it has been observed that

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