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Performance Analysis of Collective Adaptive Behaviour in Time and Space

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Abstract

Many systems, both natural and engineered, exhibit collective adaptive behaviour. Natural examples are swarming animals and insects, and man-made examples include swarm robots and sensor networks. Indeed many systems have both human and ICT-based agents in play, distributed over some geographical region: an informatics environment as defined by Milner. Over recent years there has been increased interest in modelling these systems in order to understand their dynamic behaviour. Here we consider the subsequent issue of how to define useful performance measures for such systems, based on consideration of a simple, intuitive example.

Keywords: Spatio-temporal modelling, performance modelling, collective adaptive behaviour

1 Introduction

Systems which exhibit collective behaviour have many interesting properties. Examples from the natural world such as swarming animals and insects are often studied

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for their emergent behaviour, patterns which become apparent at the population-level but which were not readily apparent from the described behaviour of individuals. In engineered systems this emergent behaviour constitutes the *performance* of the system.

Increasingly large-scale, geographically distributed ICT systems are being developed to support human endeavour in a variety of ways. This can be considered to be the realisation of the *informatics environment* predicted by Milner and Weiser [10,13]. Such systems operate with human agents interacting almost transparently with computing elements. Examples include smart city applications such as smart transportation, smart grid and many modern automotive systems.

In such systems, their transparency and pervasiveness mean that it is perhaps more important than ever to investigate their behaviour from both a qualitative and quantitive point of view prior to deployment. Work is currently underway, for example in the QUANTICOL project [6] to develop modelling formalisms to capture the behaviour of these systems [5,9]. Here we start a complementary investigation into the types of measure that can be derived from spatio-temporal systems. Classic performance measures assume that there is a single locus of operation. When there is a (limited) spatial aspect to behaviour, state annotations are usually used to syntactically distinguish the different locations and regular performance measures are applied. We seek to take a more radical approach to support modelling in which space is modelled explicitly and exploited fully when characterising the behaviour of the system.

2 Leader and Follower Scenarios

We consider a simple scenario in which agents are moving in a two-dimensional grid, as shown in Figure 1. We assume that the grid is finite and that the boundaries are

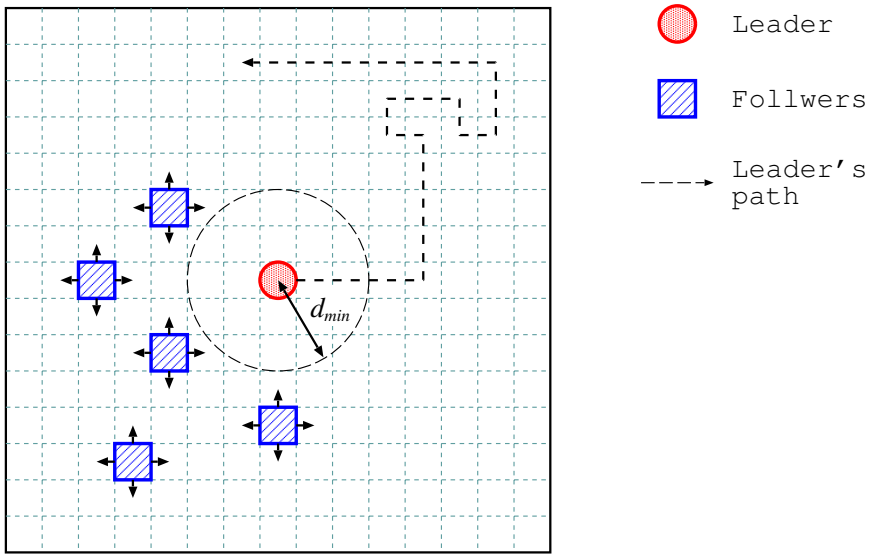

Fig. 1. The *Leader-Follower* scenario.

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