



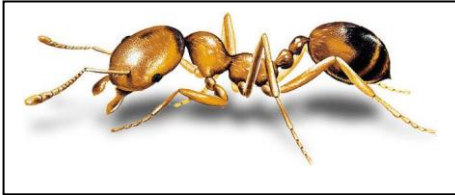
# THE WHITE ROSE GRID

## e-Science Centre

## Simulating Decentralized Behaviour of Ant Colonies

### Introduction

Ant colonies are complex biological systems which demonstrate robustness and efficiency in a manner which is desirable by emerging computational systems. Individual members of the colony are able to work collectively through self-organization. Further, individuals have the ability to make decisions in a decentralised fashion, based on locally available information. Despite the lack of direct communication, they employ chemical communication via pheromone deposition. Over time complex pheromone trails are observed to emerge, depicting optimal routes to food sources.



Simulating ant colonies is particularly a difficult task due to the necessity for large numbers of ant agents, as well as pheromone agents to be created dynamically by ant agents during the simulation. We produced agent-based models of Pharaoh's ants (*Monomorium pharaonis*) based on their foraging activities, aiming to deduce the emergence of the shortest possible routes to the food. The FLAME framework, developed by the University of Sheffield, was used as the platform, and the HPC server Iceberg, the Sheffield node of the White Rose Computing Grid, was used to run our models.

### Agent-based modelling

Agent-based modelling (ABM) involves the modelling of individual agents which are simulated together in a designed virtual world. An agent is used to represent an individual organism.

Agents can be encapsulated computer programs, which contain the local memory of the program and the functions it can perform in the environment as designed by its modeller. Therefore, the lowest-level components of a system are identified as agents, and the rules governing their real behaviour are applied. The agents communicate with each other via interactions through their surrounding environment.

### X-machines

X-machines are used to represent a formal architecture for agents. They are similar to Finite State Machines (FSM), which are autonomous machines, where the accepted inputs determine both the outputs and the transitions between a finite set of internal states. Similarly in X-machines, the agents are provided with a finite set of states (i.e. the ant agent is fed or unfed), also with a memory of such states and other possible variables (i.e. position in the environment). The machine, depending on the current state of control and the current values of the memory, consumes an input symbol from the input stream and determines the next state, the new memory state and the output symbol, which will be part of the output stream. These properties allow the X-machines to be more flexible and robust.

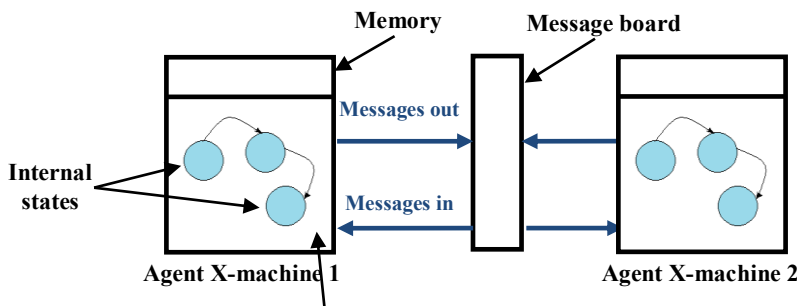


**“Agent-based modelling coupled with HPC, allows many individuals to be modelled, and solutions to be obtained over shorter simulation times.”**



## FLAME

FLexible Agent-Based Modelling Environment provides a platform for the creation of agent-based models. It is based on the theory of X-machines, where the communication between the agents is provided through a Message Passing Interface (MPI), called the message board. X-machine structures allow agents to carry an internal memory, which can be updated throughout the simulations. Agents operate according to rules, resulting in different states, while the communication is provided via message boards as shown below.



Transition functions are influenced by messages and memory

FLAME supports parallelism by incorporating the deployment of simulations on parallel computers via HPCx libraries. It is designed for use on large-scale supercomputers and is capable of efficient simulations of models involving many millions of agents, with only a minor communication overhead. It can be executed on a variety of parallel computational platforms. Various parallel platforms like SCARF, HAPU (within top 50 supercomputers in the world) have been used in the development process to test the efficiency of the FLAME framework.

### Exploiting HPC for Research

FLAME is the only ABM framework which enables models to be automatically parallelisable. Any model written in FLAME can be run in serial or parallel without any changes done to the model.

e-Science, i.e. running models in parallel, is really important for advancement in scientific research. If simulation of models takes more than 1 hour to run on a single machine, this is very time consuming and costly. Therefore it is necessary to attain results quickly. Further, in ABM, models can scale up exponentially depending on the number of agents and the functions to be performed. FLAME handles all these problems by accommodating large number of agents running in time defined by only an order of minutes. This is done automatically by FLAME which eliminates any manual effort for the modeller.

### Ant Models and HPC

Snapshot (left) from a model of 250 ant agents foraging in an environment of 500 by 500 mm (a realistic foraging space), shows the emergence of long-term pheromone trails towards food sources. Different colours reflect the effect of evaporation and deposition on the pheromone strength (blue strongest, green weaker, yellow weakest).

### Conclusive Remarks

Our models present the implications of using ABM approach, as well as the influence of HPC to simulate realistic ant colony sizes. Both technologies benefit the model simulations significantly, allowing large concentrations of agents to be modelled, as well as solutions to be obtained over shorter simulation times. Our work expresses the necessity for various computing, especially HPC, for the advancement of biological research.

### Further Information

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