# The Emergent Properties of Multi-Agent Systems


***A Project Presentation by Paul Tinsley regarding a Real-time Animated Multi-Agent Simulation System called "Animate"***

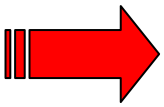
# Introduction

**Our project involved simulating emergent phenomena within a Multi-Agent System (MAS)**

**In this presentation we shall . . .**

- **Identify what emergence means**
- **Briefly examine the characteristics of the agents**
- **Illustrate examples of three classes of emergent phenomena**
- **Discuss how the phenomena arose and whether any were useful**
- **Highlight the significance of emergence**
- **Interactively demonstrate Animate's features**

# Emergence?



**It is essential to define what is meant by the word "Emergent." There are many viewpoints on emergence, but for our purposes, we define it to mean:**

***A sum of parts, that exist in a system, due to the interactions of its constituent members***

# Categories for Emergence

**Emergent phenomena tend to fall into three fundamental categories:**

- **Emergent Behaviour**

  ***Do non-explicit agent behaviours manifest themselves?***

- **Emergent Functionality**

  ***Does a phenomenon have some sort of purpose or effect?***

- **Emergent Structure**

  ***Is there a pattern to a phenomenon?***

***We shall demonstrate examples of all three***

# Animate's Agents

- **Reflex agents with internal state**

  ***They react rather than plan***

- **Production Systems**

  ***If / then rules fire from working memory***

- **Self-interested**

  ***No social concepts or social goals***

- **No inter-agent communication**

  ***No communication whatsoever***

- **Domain: 2D turn-based world**

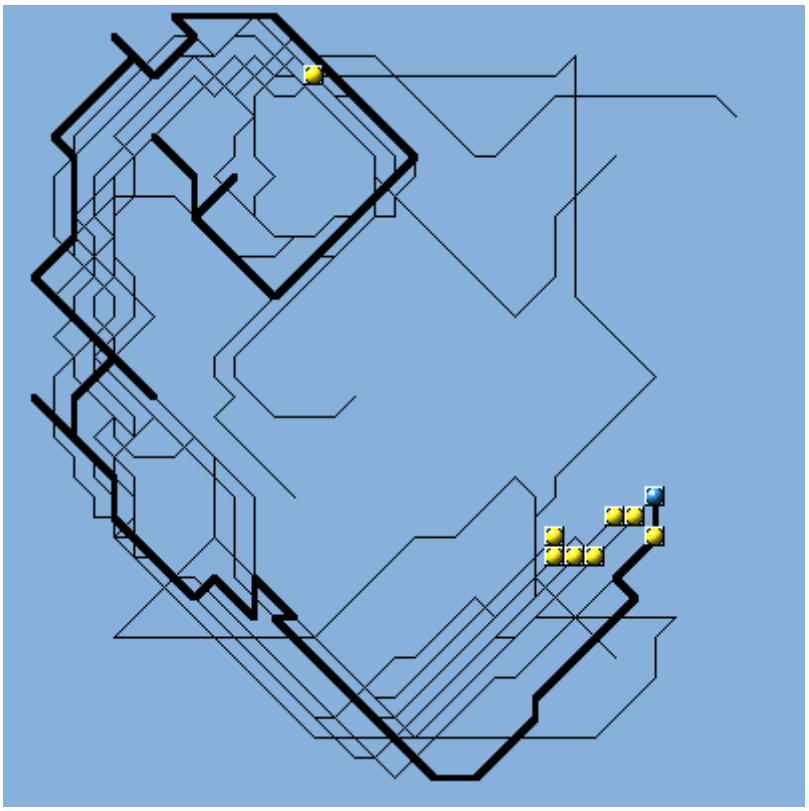
  ***40 by 40 squares – one object per square***

- **Arbitrated**

  ***Agent conflict resolution***

# Emergent Behaviour

**Using a Predators and Prey scenario, emergent flocking behaviours often developed. A pack of predators formed that chased the prey:**



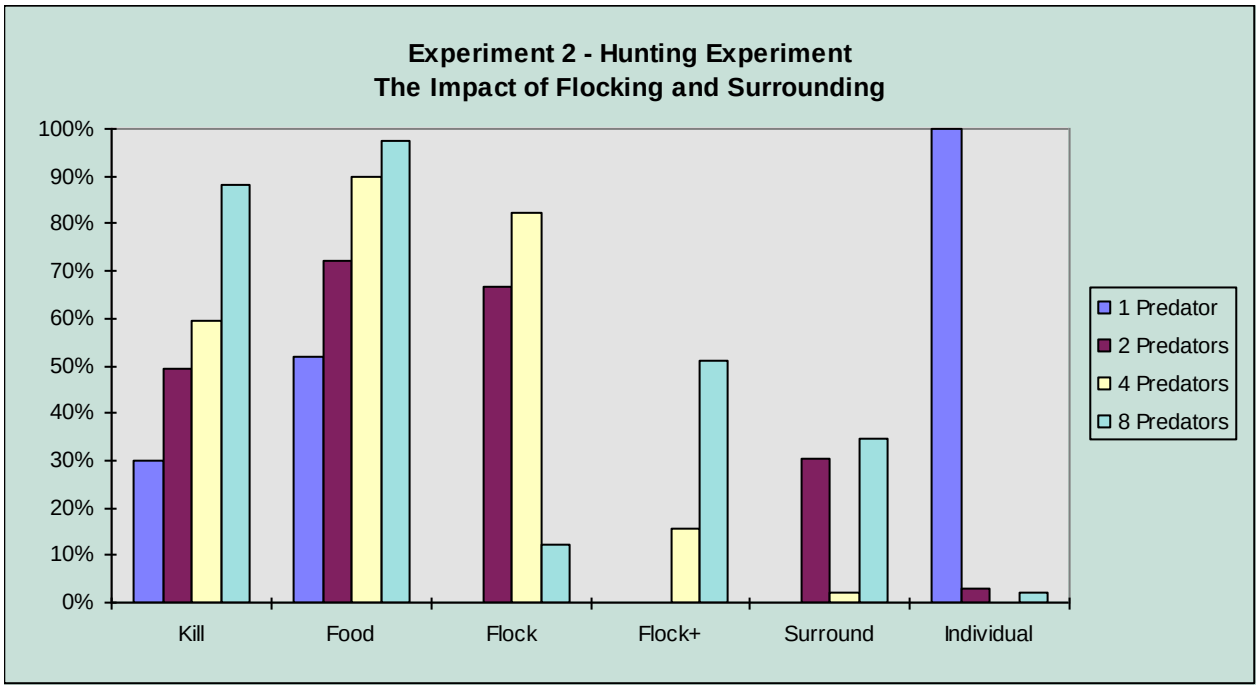
***Paths of all agents were tracked and plotted to reveal their movements***

***The prey steers the flock of predators***

**During simulation, the predator agents displayed an emergent flocking behaviour. They appeared to co-operate with one another by forming a hunting pack that pursued the prey agent. Yet, there are no co-operative plans, communication or social concepts / social goals!**

# Emergent Functionality

**We also discovered that there were benefits associated with the flocking phenomenon:**

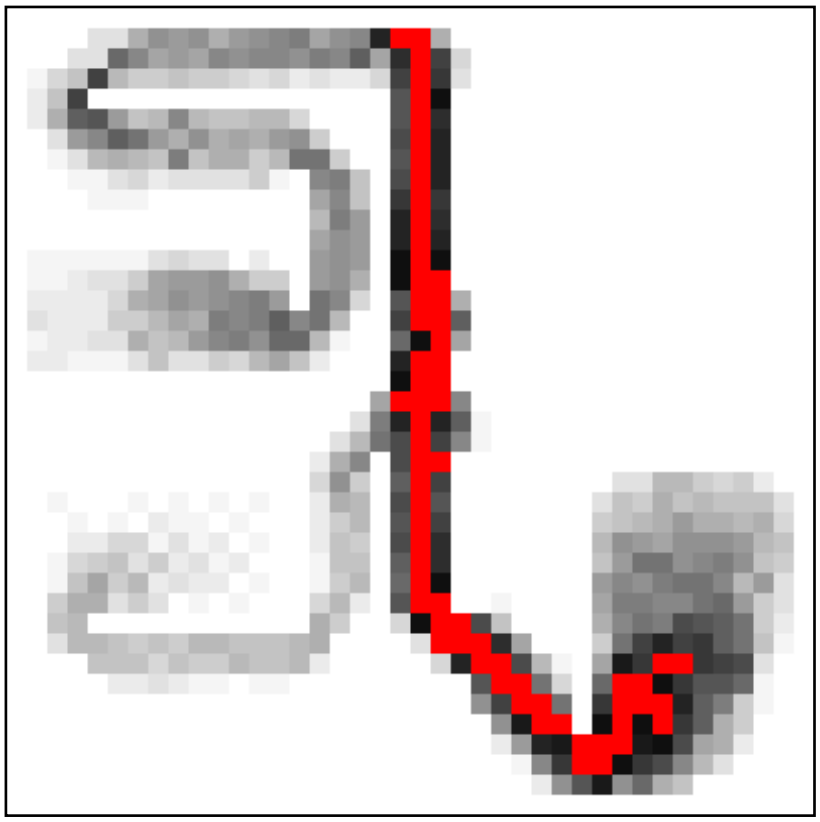



**There is an emergent functionality of flocking with improvements in the total amount of food gained by the "community" of predator agents**

**Flocks are beneficial as they put the prey under greater "pressure". Large predator communities lead to overcrowding. Hence, prey are more often surrounded and pure flocking plays a smaller role**

# Emergent Structure

**Using a building design scenario with "Crowd" agents, we plotted the paths that agents had taken during an escape simulation using a form of colour temperature:**



***The path densities left by Crowd agents escaping a building to a single exit (North)***

***A threshold may be set to indicate the strongest paths (red)***

**The emergent path structures were useful in determining where alterations to the building should be made in order to reduce the traffic density of agents and thus improve "safety"**

# Conclusion

## The Results

**We successfully demonstrated simple examples of the emergent properties of a Multi-Agent System, identified some causes and illustrated a possible utility of emergent path structures. We have found that our definition for emergence is strong.**

## The Alife Connection (Inspiration)

**Emergence is a consequence of independent objects interacting with each other within a domain. Evolution orders and manages complexity through emergent processes, yielding sophisticated and impressive life-forms. All life on Earth comes from the same ancient factory and was built over billions of years (Natural Selection).**

**Some final thought provoking musings – can we learn something from this? Have we already made a start – Object-Oriented Programming?**