

# AIS and Swarm Intelligence : Immune-inspired Swarm Robotics

Jon Timmis

Department of Electronics

Department of Computer Science

York Center for Complex Systems Analysis

[jtimmis@cs.york.ac.uk](mailto:jtimmis@cs.york.ac.uk)

<http://www-users.cs.york.ac.uk/jtimmis>

# Are AIS just Swarm Systems?

- There are many similarities between some aspects of the systems
- Decentralised decision making (swarm, immune ..) require:
  - positive feedback, negative feedback, amplification and multiple interactions

# From a S.O. perspective

	Swarm system	Immune system
Positive feedback	laying pheromone	receptor recognition T-cell signalling
Negative feedback	pheromone evaporation	cell suppression
Amplification	locate new food source	clonal selection
Multiple direct or indirect signals	pheromone in ants visual communication in birds	lock & key recognition cytokine networks

Timmis *et al*, 2010

# Algorithms ...

1. **Create:** a population of novel individuals is created that represent candidate solutions to the problem being optimised by the algorithm.
2. **Evaluate:** each individual is evaluated based on pre-defined criteria that determine how well it solves the optimisation problem.
3. **Test:** a condition is tested to establish whether the algorithm terminates, returning an individual solution or set of solutions upon termination.
4. **Select:** a set of candidate solution individuals is selected to be used as the basis for the creation of the next generation of individuals.
5. **Spawn:** the new population of candidate solution individuals is generated for use in the next generation.
6. **Mutate:** variability is introduced to the algorithm either via altering a number of individuals of the new population or some other aspect of the algorithm.

Generic framework for population based algorithms (Newborough and Stepney, 2005)

# PSO

- 1. Create:** particles are either initially created with random positions and velocities in the search space. Neighbourhoods can be defined with various topologies such as ring, grid or star.
- 2. Evaluate:** usefulness of potential solutions are based on current position coordinate of a particle in solution space.
- 3. Test:** upon triggering the termination condition, the single best individual solution is returned as the output of the algorithm.
- 4. Select:** all particles are chosen to form the population for the next generation.
- 5. Spawn:** new individuals (position and velocity) created from parent and highest affinity neighbour so that particle moves towards best neighbour.
- 6. Mutate:** no mutation of an individual typically occurs, but the velocity of an individual undergoes an amount of random alteration which may be considered a type of mutation.

PSO using the generic framework for population based algorithms (Newborough and Stepney, 2005)

# Immune Networks

- 1. Create:** solutions (antibodies) are created with random shape-space receptors, or from those spawned in the previous generation.
- 2. Evaluate:** potential solutions are evaluated based on the problem-specific quality function.
- 3. Test:** upon triggering the termination condition, the entire population is returned as the output of the algorithm.
- 4. Select:** the N best solutions are selected from the total population of existing solutions + any cloned solutions.
- 5. Spawn:** clones of the selected individuals are spawned, where the number of clones produced by each individual is proportional to the quality of the individual.
- 6. Mutate:** clones are mutated with a probability inversely proportional to their solution quality. *Diversity in the population is increased by considering interactions between all clone pairs; pairwise distances between clone vectors are calculated; if the distance is less than a pre-defined threshold, the less fit clone is deleted.*

Timmis et al, 2010

# ACO

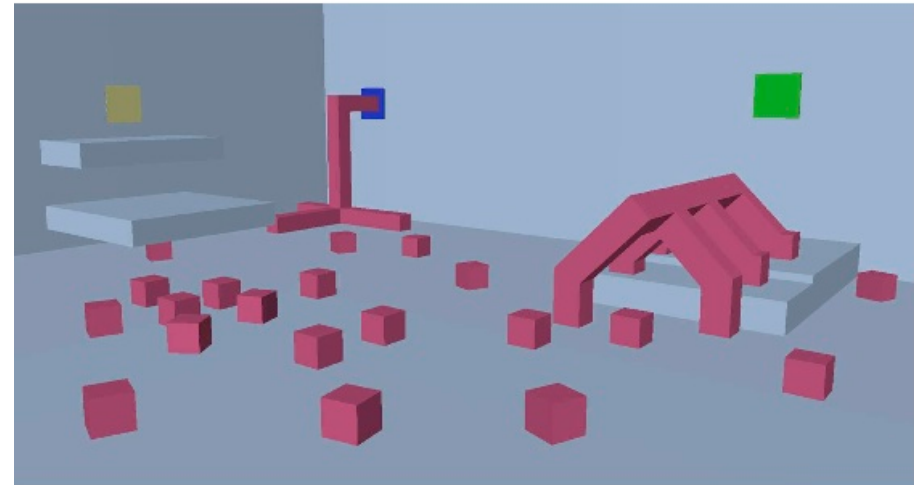
- 1. Create:** *a population of potential solution individuals is created each generation. A potential solution is constructed by an ant agent iteratively following a series of path steps based on pheromone levels until a complete potential solution is generated.*
- 2. Evaluate:** the best individual solution is the one with the shortest path.
- 3. Test:** upon triggering the termination condition, the single best individual solution is returned as the output of the algorithm.
- 4. Select:** no individuals from the current generation are selected for the next as each generation creates its own population from scratch.
- 5. Spawn:** no individuals spawned for next generation as none are selected.
- 6. Mutate:** *additional pheromone is laid at each path step of solution individual proportionally to how good the solution is, whilst pheromone is also reduced by a decay function.*

Timmis et al, 2010

**Complimentary not  
competitive ...**

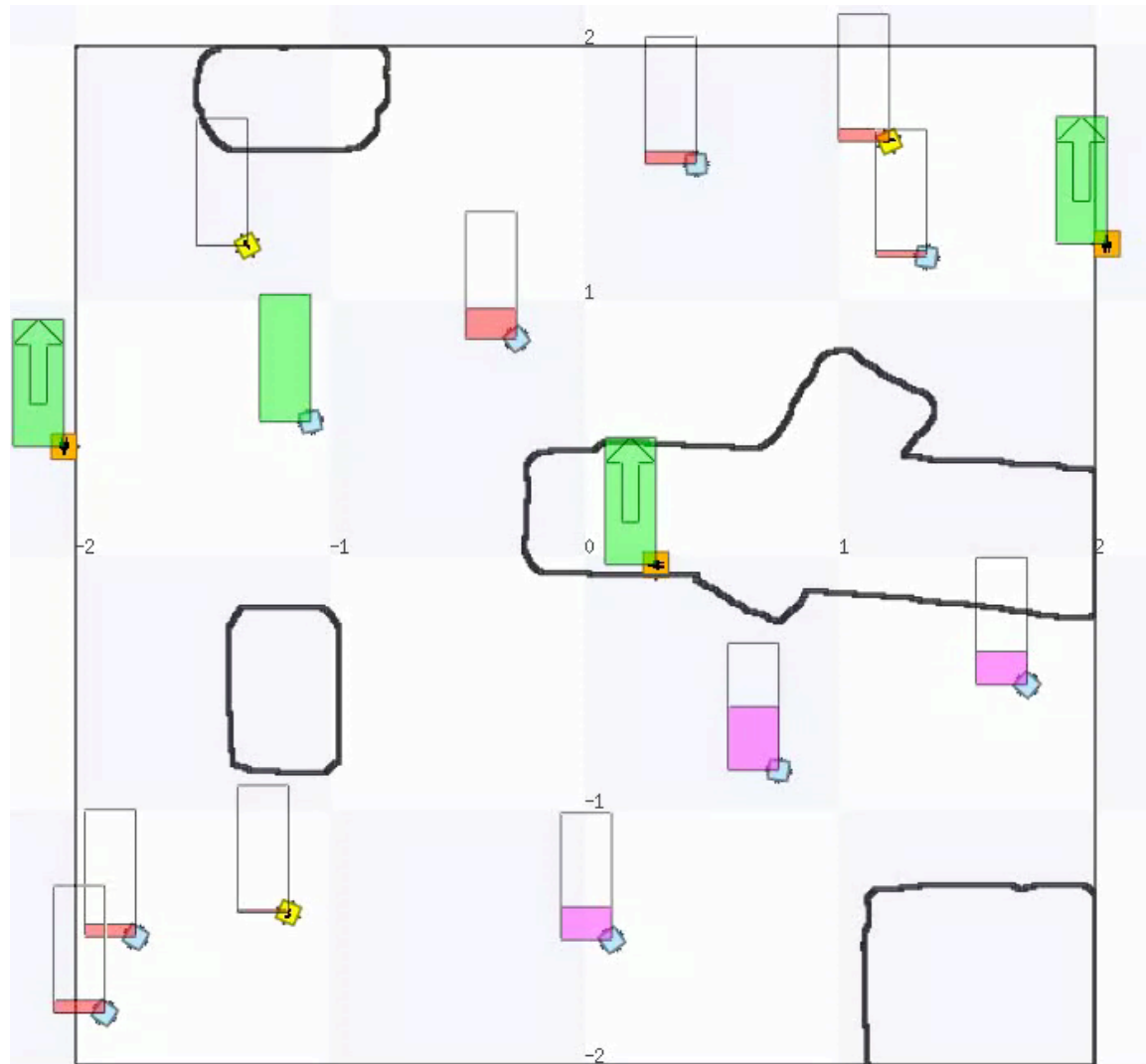
# Recall : 100 Robots, 100 Days

- A Grand Challenge for collective robotic systems in SYMBRION/REPLICATOR-Collective robotic system  
[Kernbach et al, 2010]
- Of interest here is the *survivability* of the organism/collective
- Fault tolerance: failure of components, energy management at individual, swarm and collective

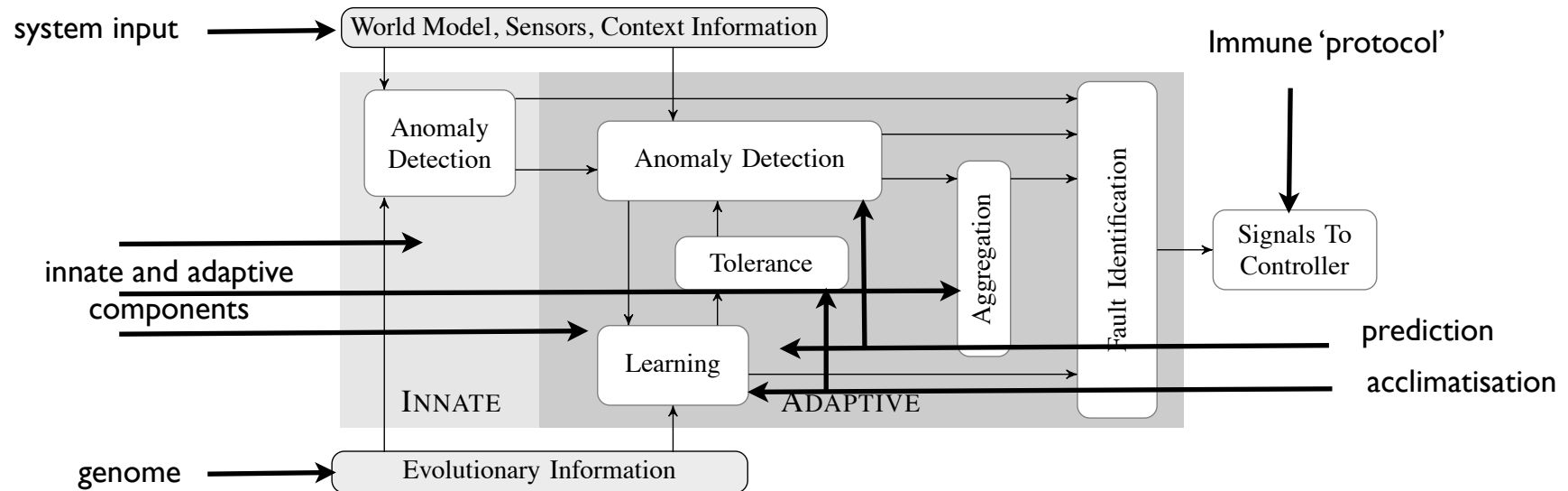


Robots have to self-organise to survive

# Homeostatic operation



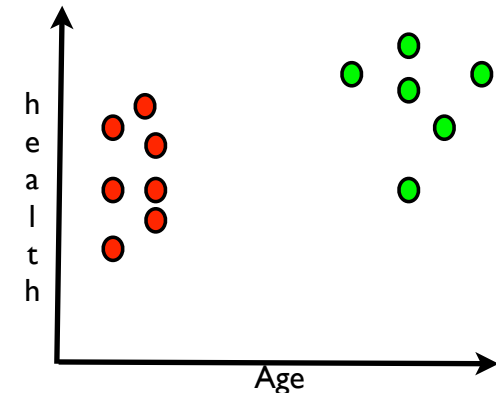
# Potential Solution



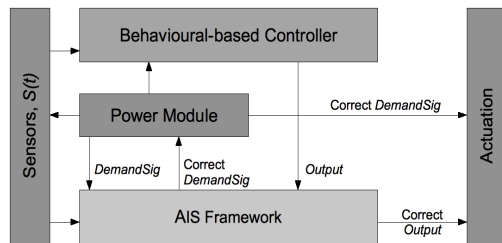
AIS Lymph Node Framework [Timmis et al, 2010]

# Measuring Performance of the System

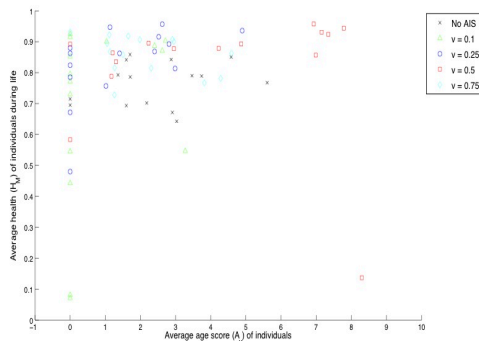
- Individual level:
  - Can define a *health measure* for each robot which takes into account state of robot, both internal and external information using a combination of innate and adaptive immunity [Symbrion SD2.6]
- Swarm level:
  - Exchange *health* information with neighbours to provide a *locality of health*
- Collective:
  - Lymph node architecture allows for exchange and *collective health*



# AIS in the robots



Integrating AIS with other controllers

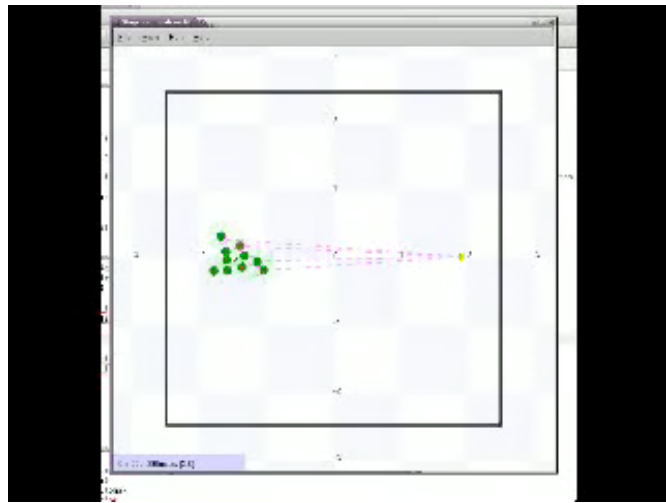


Improving the health of the robots

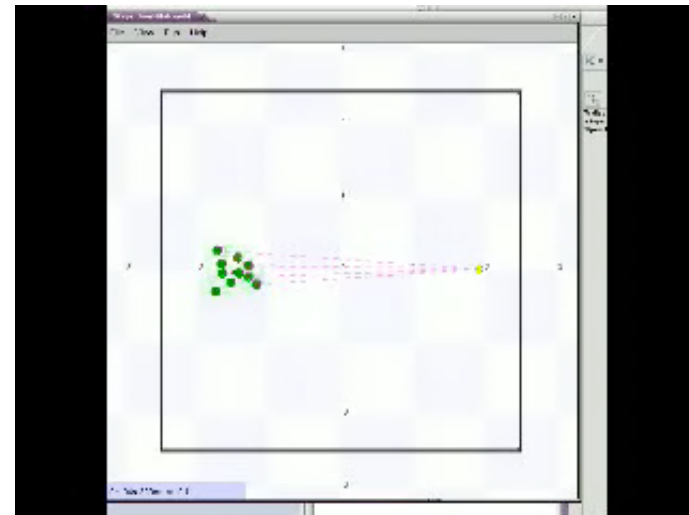
- Innate provides a health measure of the robot
- This is fed as one input to the adaptive (instance based) AIS
- The innate/adaptive AIS then detects presence of errors and then changes weights on a simple ANN to compensate
- Tested in the context of distressed robots, where they suffer large power loss in short spaces of time (not healthy), other healthy robots can help to recharge

# Swarm taxis

Swarm needs to be able to maintain coherence in a totally decentralised manner

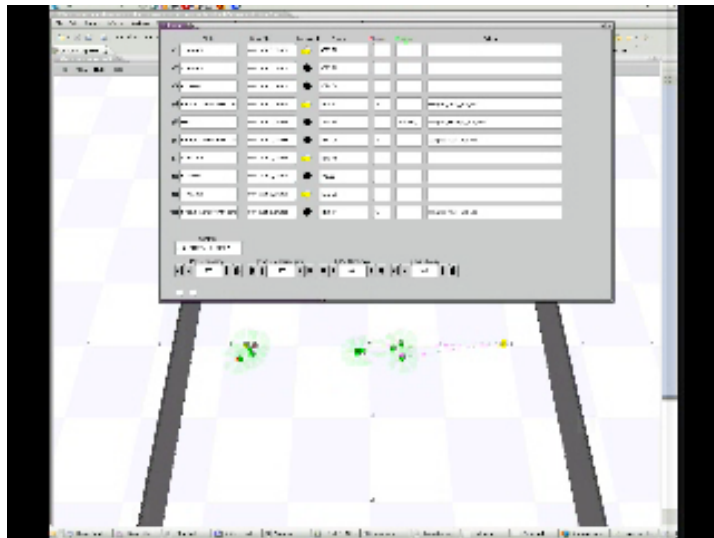
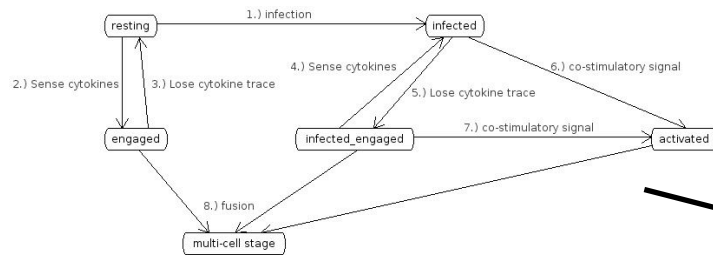


no failures

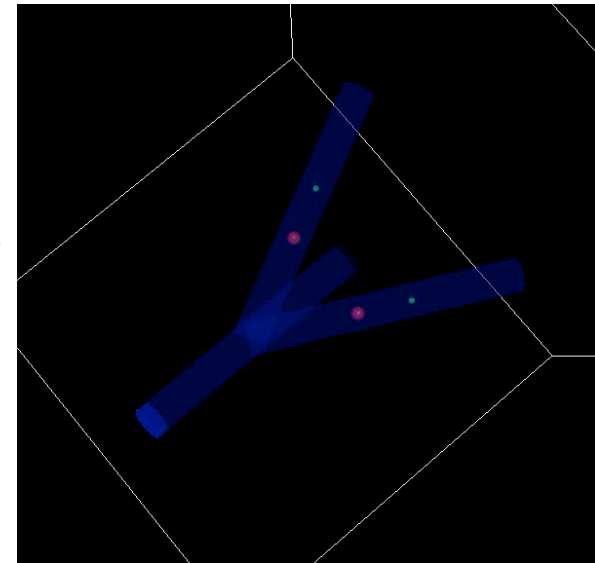


three failures

# Towards self-healing swarms - Granuloma Formation domain model

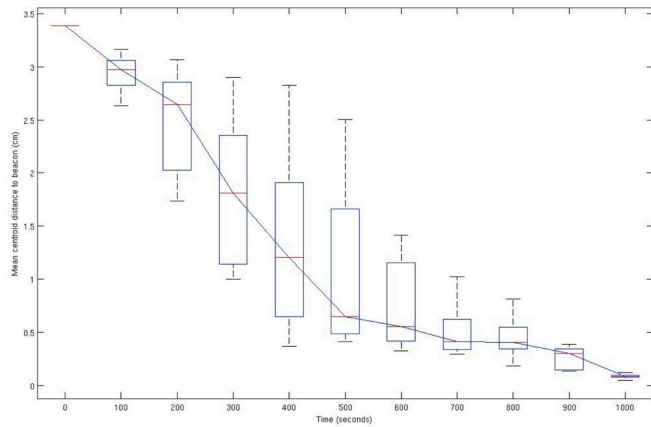


robots

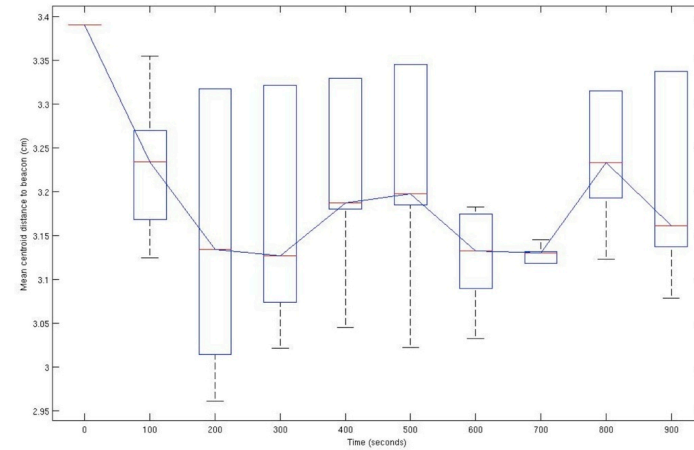


simulation

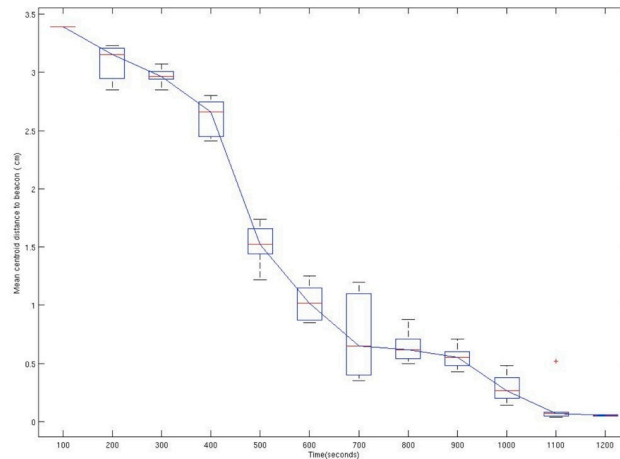
# Measuring performance



Single Failure



Three failures



four failures, but now with dynamic energy re-charging

# Summary

- Possible to combine approaches and take the best from each
- AIS and SI are very complimentary
- Many, many open issues in the research of each of these topics