AIS and Swarm Intelligence : Immune-inspired Swarm Robotics

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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

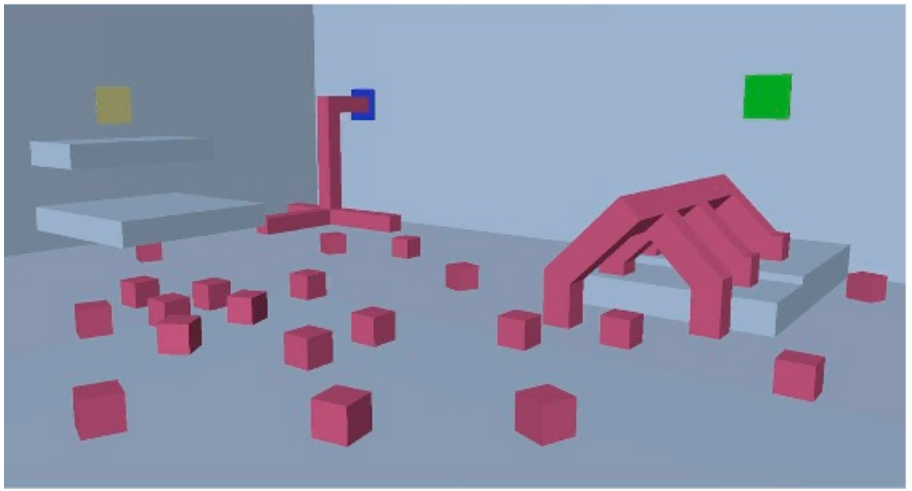
Complimentary not competitive ...

Recall :100 Robots, 100 Days

- A Grand Challenge for collective robotic systems in SYMBRION/REPLICATOR-Collective robotic system
  [Kernbach *et al*, 2010]

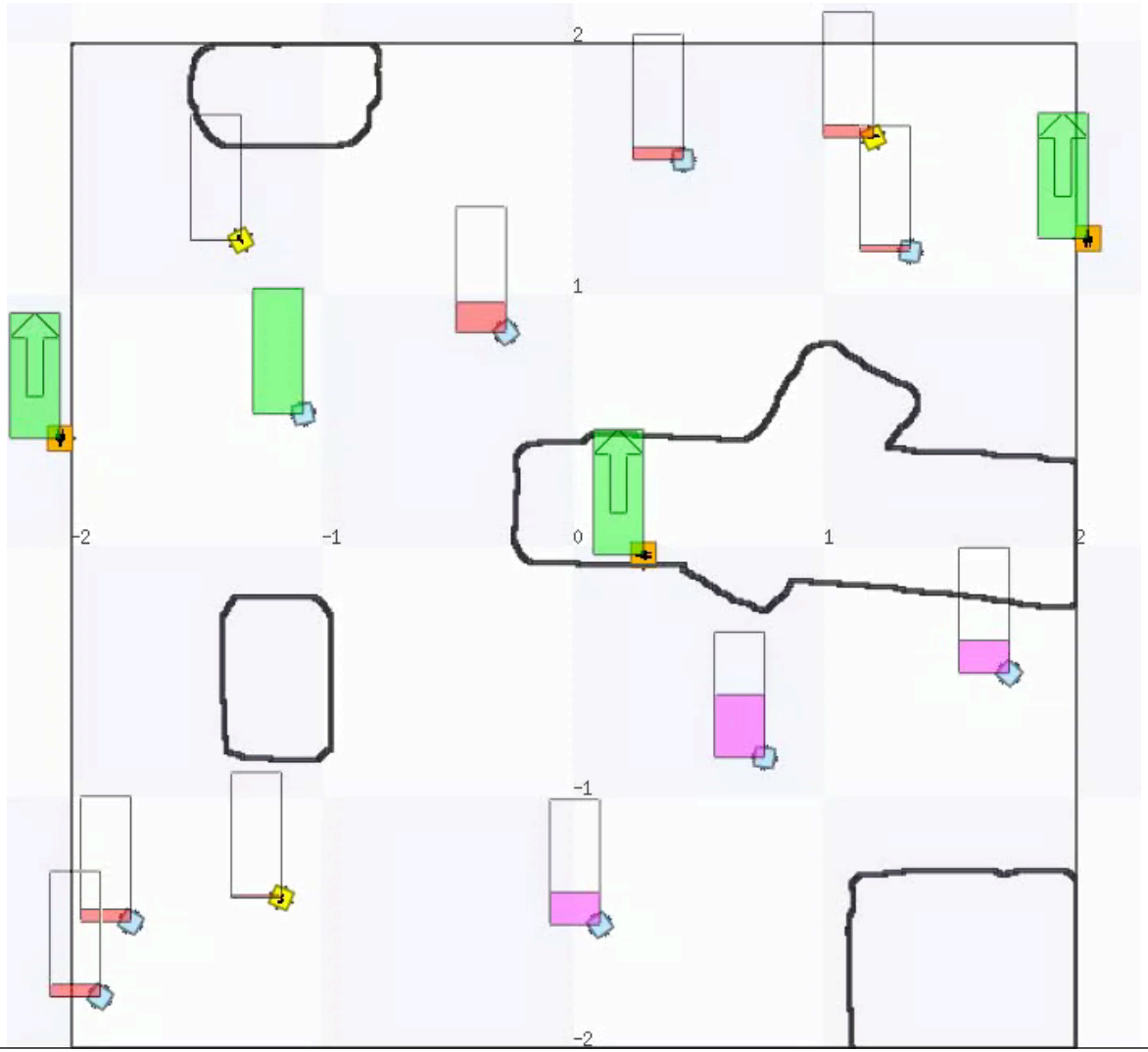
- Of interest here is the *survivability* of the organism/ collective

- Fault tolerance: failure of components, energy management at individual, swarm and collective

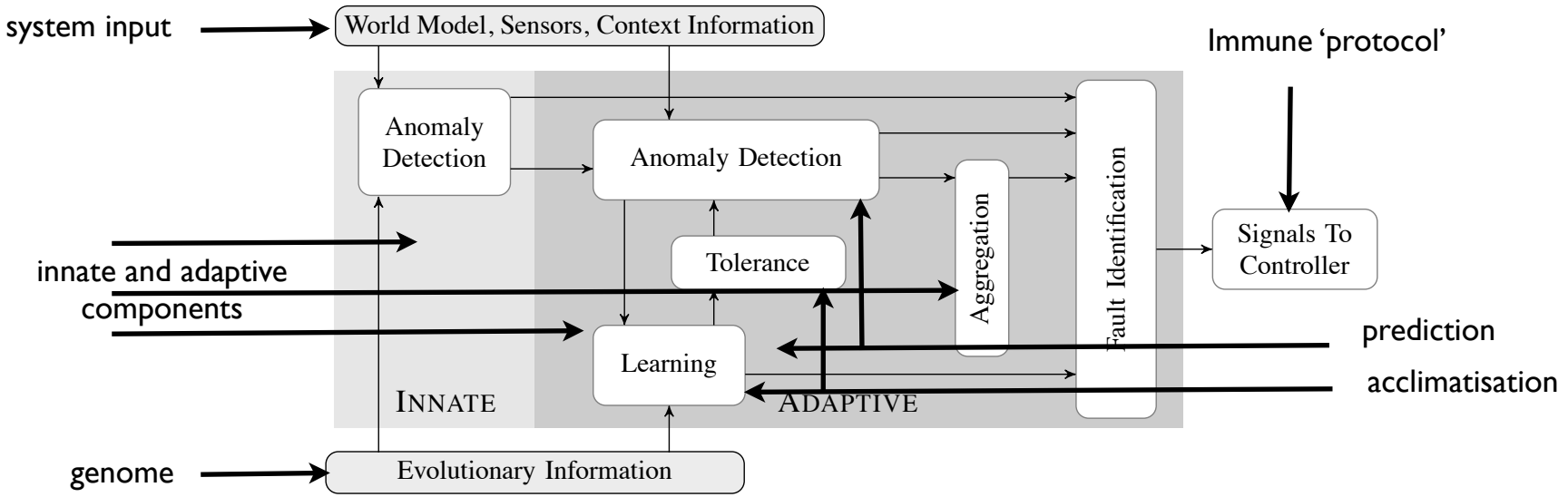


Robots have to self-organise to survive

Homeostatic operation



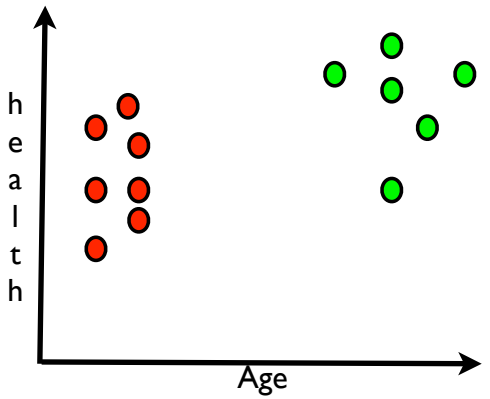
Potential Solution



AIS Lymph Node Framework [Timmis *et al*, 2010]

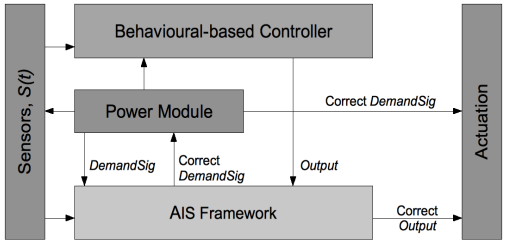
Measuring Performance of the System

- 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]

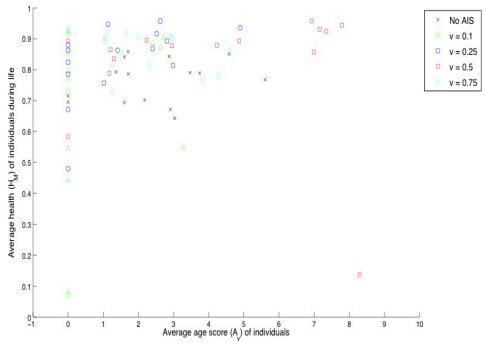


- Swarm level:
  - Exchange *health* information with neighbours to provide a *locality of health*
- Collective:
  - Lymph node architecture allows for exchange and *collective health*

AIS in the robots



Integrating AIS with other controllers

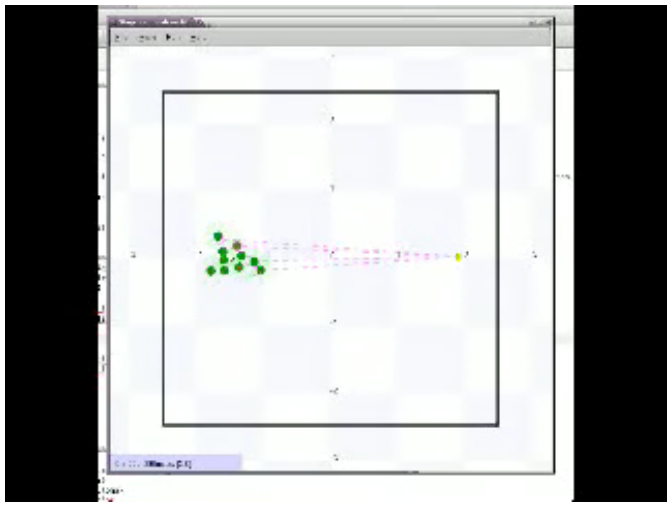


Improving the health of the robots

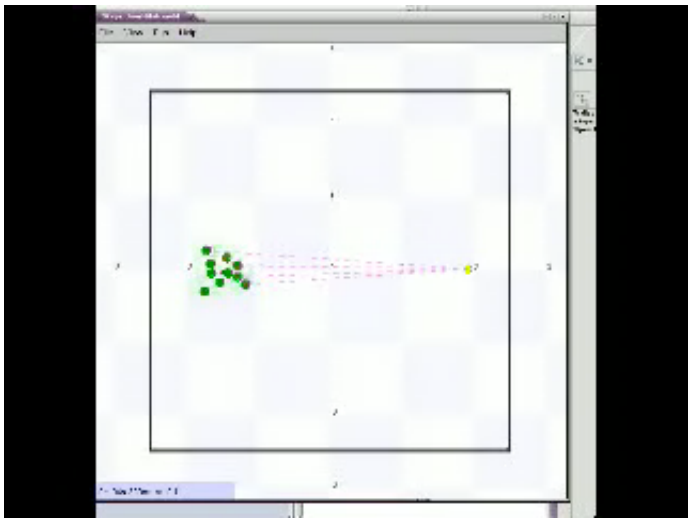
- Innate provides a health measure of the robot
- This is fed as one input to the adaptive (instance based) AIS
- The innate/adaptive AIS then detects presence of errors and then changes weights on a simple ANN to compensate
- Tested in the context of distressed robots, where they suffer large power 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

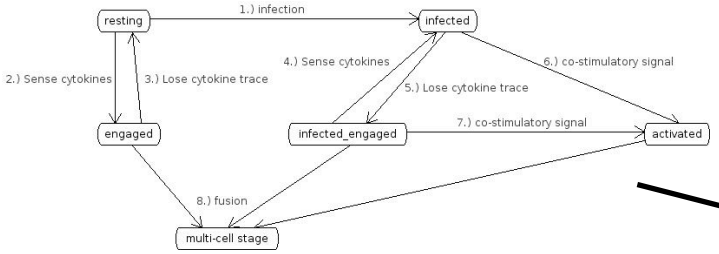


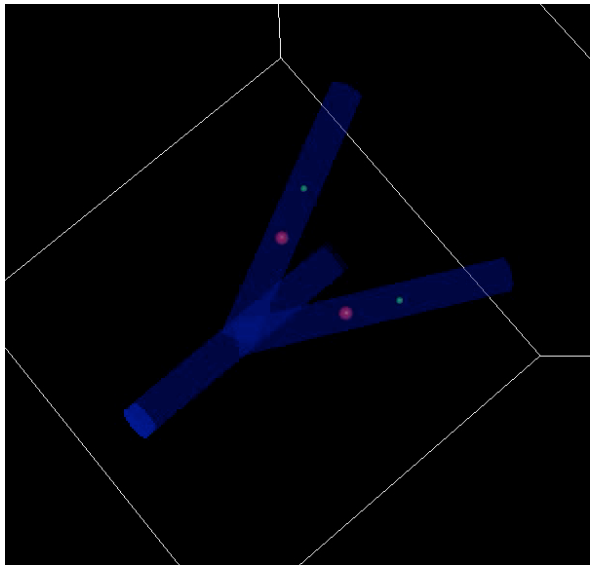
three failures

Towards self-healing swarms -

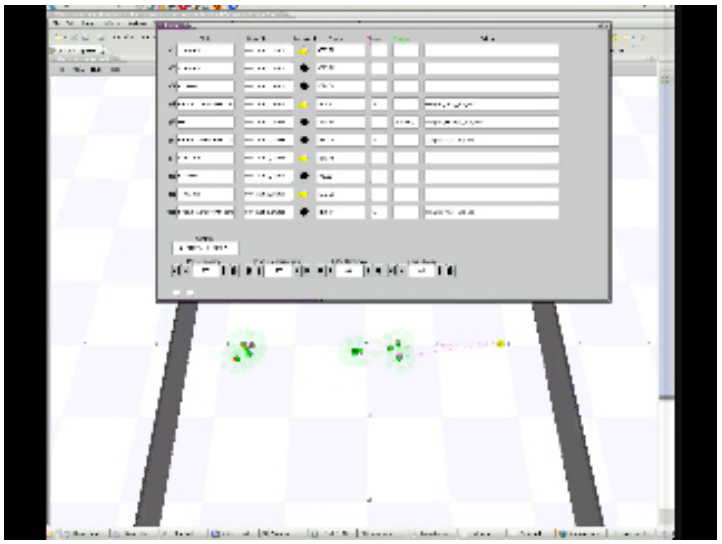
Granuloma Formation

domain model



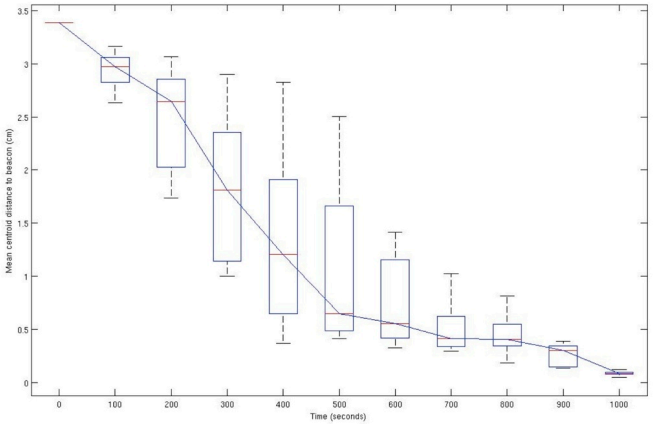


simulation

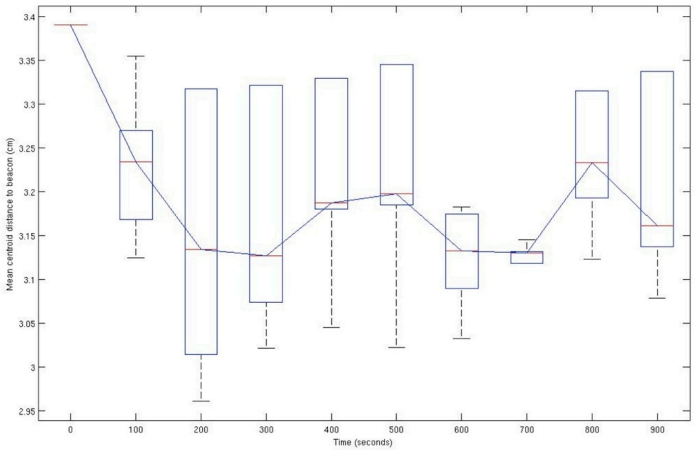


robots

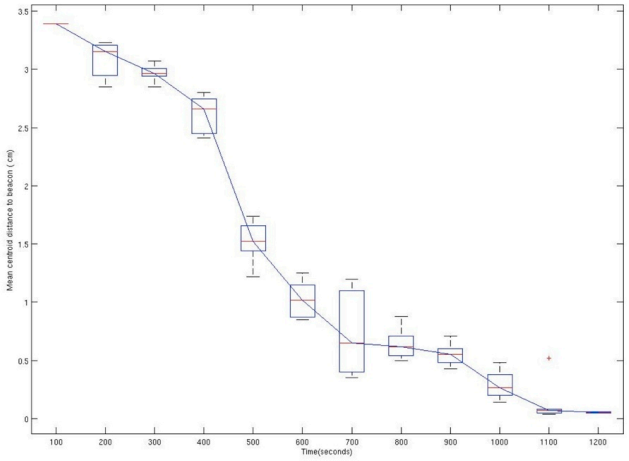
Measuring performance



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