Immunity in self-aware systems

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Immunity

Plants and animals have immune systems to help protect and repair

Images: Mark Coles
Swarming, Flocking

Apparent co-ordination of many individuals - no central control
Collective Behaviour

Collectives work together to solve problems that one (or a few) can not manage on their own

bbc.co.uk
Co-ordination

Fire flies appear to synchronise across a swarm
“Swarm” immunity?

immune cells acting together in an individual?

Survival as a collective?
An engineering perspective

Building systems that operate for long periods of time without human intervention is a challenge.

A swarm of robots

Big dog
So reality is different to sci-fi!
An immune system for a robot?

Sense and react to **events external** to the robot

Sense and react to **events internal** to the robot and swarm

Sense and react to **internal and external events** in an organism
An immune system sensing and reacting to the environment

We live in hazardous environments. T cells are one line of defence.

There are many hazardous environment we might like to monitor.

Sniffer dog robot with an immune system for sensing and reaction
The sniffing robot
An immune system for a “swarm” of robots?
Simple tasks ...

Simulation of foraging

State diagram for robot behaviour

- **grabObject**
  - ObjectInGripper

- **moveToObject**
  - **moveToBase**
    - Clear
    - ObstacleDetected
  - **avoidance**
    - Clear
    - ObstacleDetected
  - **scanArena**
    - ObjectInSight
    - ObjectLost

- **depositObject**
  - Done

- **leaveBase**
  - **randomWalk**

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**Fixed Parameters for Simulation.**
- Total object 4111 unit
- Initial object 211 unit
- arena width
- arena height
- Sample period 381s
- Fault injection time 8111s
- Simulation duration 24811s
- Component fault Motor
- Robot normal speed 1.28 m/s
- Fault magnitude partial 1.15 to 1.23 m/s
- Fault type complete

**Table I**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Obj</td>
<td>4111</td>
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<tr>
<td>Initial</td>
<td>211</td>
</tr>
<tr>
<td>Arena width</td>
<td></td>
</tr>
<tr>
<td>Arena height</td>
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<td>Sample period</td>
<td>381s</td>
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<td>Fault injection</td>
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<td>Motor fault</td>
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<td>complete</td>
</tr>
</tbody>
</table>

**Variable Parameters for Simulation.**
- We are interested in detecting anomalies caused by component faults in the robot.
- Variable parameters are set purely by arbitrary choice and can be changed if desired.
- The values for these parameters are set for other studies.

**Estimated time for a robot to collect and deposit one object by 28 normal robots in optimal conditions for other studies.**

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**Accuracy of detection is represented by:**
- Positive rate (TP / (TP + FN))
- Negative rate (TN / (TN + FP))

**Effect of time-varying presence of obstacles:**
- On the detection accuracy

**Effect of time-varying object placement rate:**
- On the detection accuracy

**Effect of time-varying object distribution:**
- On the detection accuracy

**Effect of time-varying environmental conditions:**
- The types and magnitudes of the component faults vary.

**Note:**
- The architecture for detecting anomalies under these conditions and analysing the results is described in detail.
A bit more complicated

Keeping a swarm of robots together

State diagram to control a robot
Things can go wrong

Maybe not as robust as we first thought?
Collective repair

The immune system has many responses which we can develop computer models of which we can exploit in swarm robots.
An individual immune system that monitors everyone else as well.
Swarm to Organism

SYMBRION
Organisms

Self-Assembling "Swarm" failure

Self-Assembling "Organism" failure

Recovery after assembly
What about underwater?
Creating healthy robots and swarms

Made some initial advances, but we are a long way from really reliable robots and swarms that can operate autonomously

Make use of insights from immunology to help drive our technology

Can a robot have an immune system? Yes, but not the same as you and I!!
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A bit of fun

Parrot AR-Drones

Synchronised Dancing