Autonomic Pulse Communications for Adaptive Transmission Range in Decentralised Robot Swarms

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Liam McGuigan

- PhD at Ulster University
- Researching autonomic robotic swarms

- 14 years software engineering experience
- Interests include AI under real-time constraints

Swarm Robotics

- Large number of cooperating robots
- Need to be scalable and flexible
- Needs to be self-adaptive
  - Cannot rely on human input

Swarm-Level Self-Adaptation

- Most research focuses on agent behaviour adaptation
- Swarm can use aggregate information
- Can see the overall picture
- Swarm-level strategic changes can help with collaboration

Swarm Communication

- Required for swarm-level adaptation
- Problem of connectivity maintenance
- Different approaches with gradual relaxation of restrictions on robot behaviour:
  - All-time connectivity
  - Relaxed connectivity
  - Opportunistic connectivity

Fixed Transmission Range

- Transmission range of robots set at mission start
- Too high?
  - Potential waste of resources
  - Network interference
- Too low?
  - Reduction in swarm connectivity

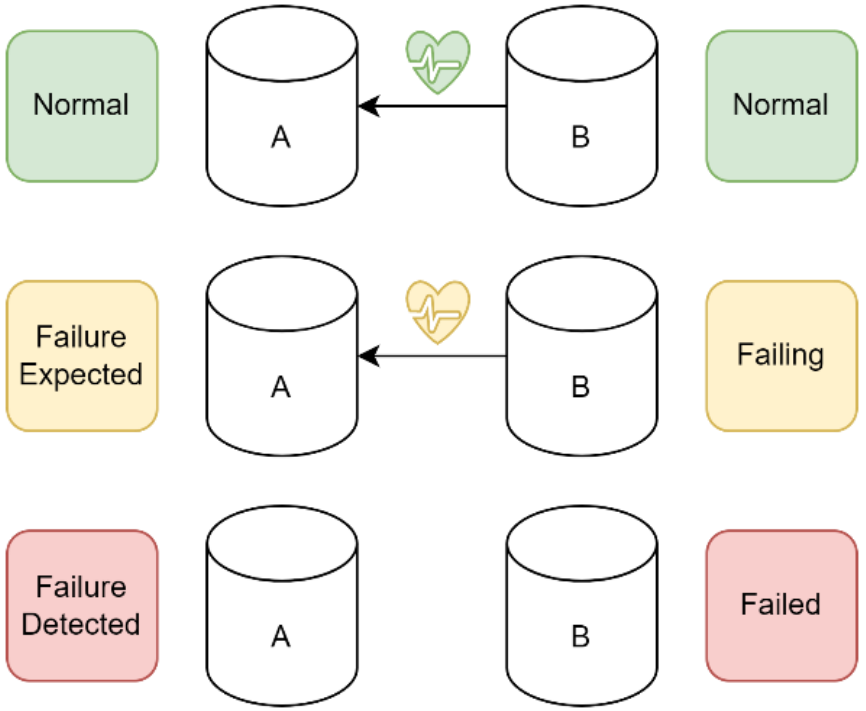
Objectives

- Devise a system for adaptively adjusting transmission range of individual robots

- Test performance of the system by sharing data throughout the swarm

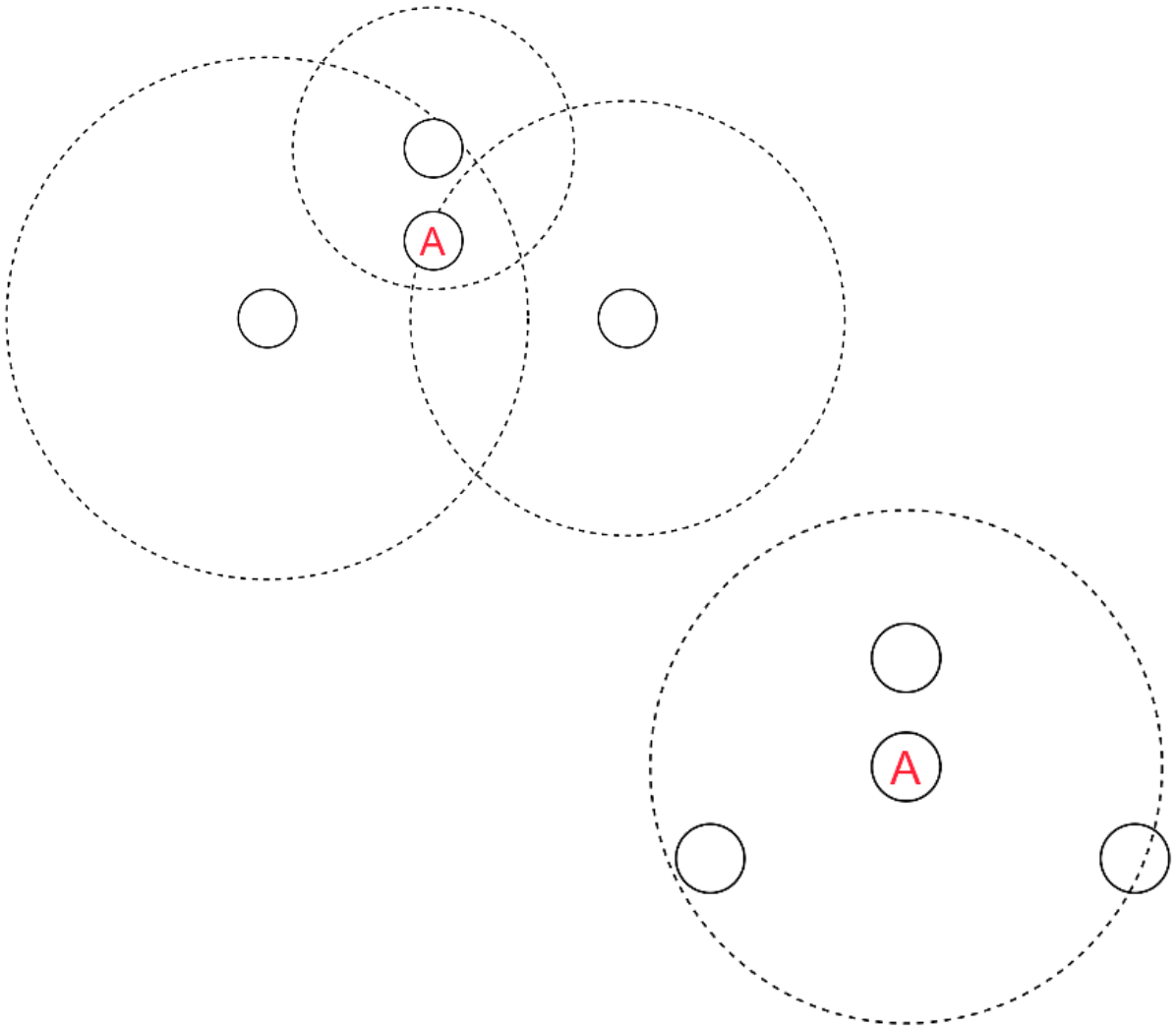
Pulse Monitoring

- Autonomic systems share their health status through periodic pulse
- Expands upon Heart Beat Monitoring
- “I am alive” becomes “I am healthy”



Autonomic Pulse Communications

- Robots send periodic pulse messages containing their position
- Average distance of received pulses in a fixed interval used to calculate local swarm density
- Mission-specific knowledge allows a suitable transmission range to be selected based on density
- No received pulses suggests an isolated robot, so transmission range increased to compensate
- “I am healthy” becomes “I am here”

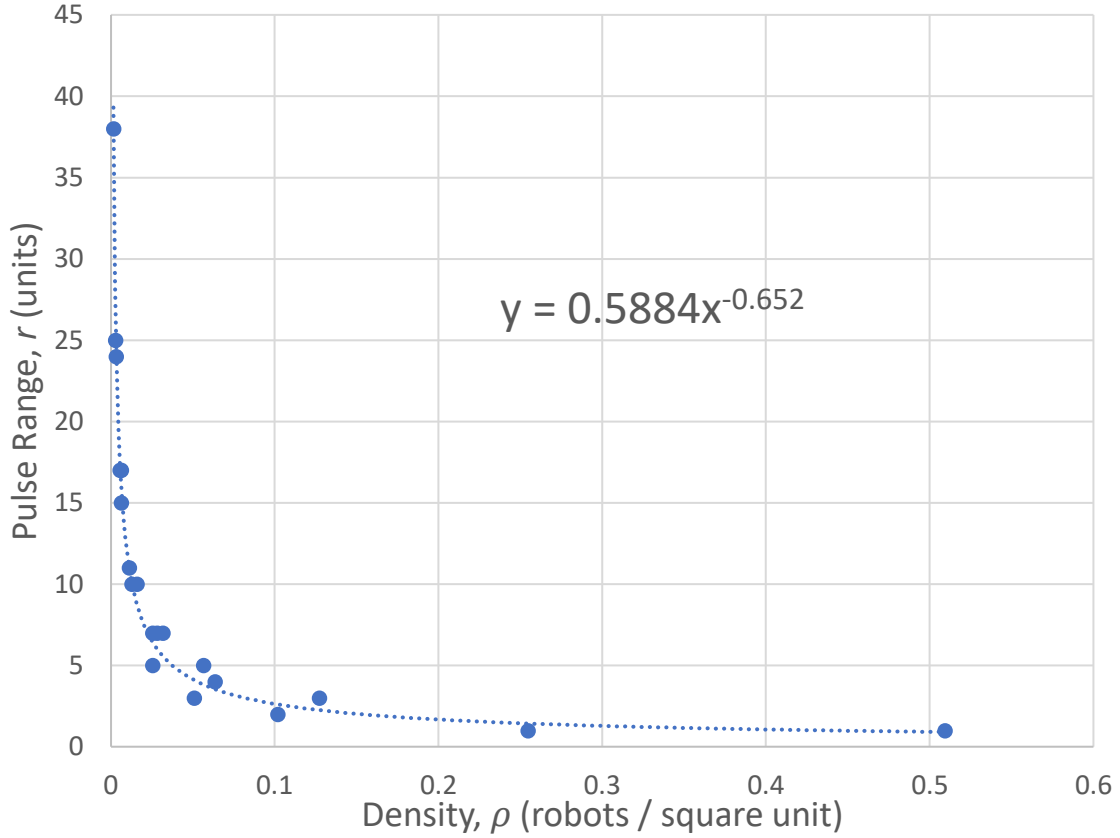


Simulation Task

- Swarm of robots must share a piece of data
- Data begins held by a single robot
- Data is shared via the periodic pulse messages if held
- Robots move randomly within a fixed circular area during the task
- Simulation ends after 250 ticks

Density-Pulse Range Relationship

- Required to allow transmission range to be decided based on swarm density
- Task simulated with fixed transmission ranges for a variety of swarm sizes and map sizes
- Ideal pulse range for determined by finding the lowest pulse range for which over 99.5% of swarm received data.



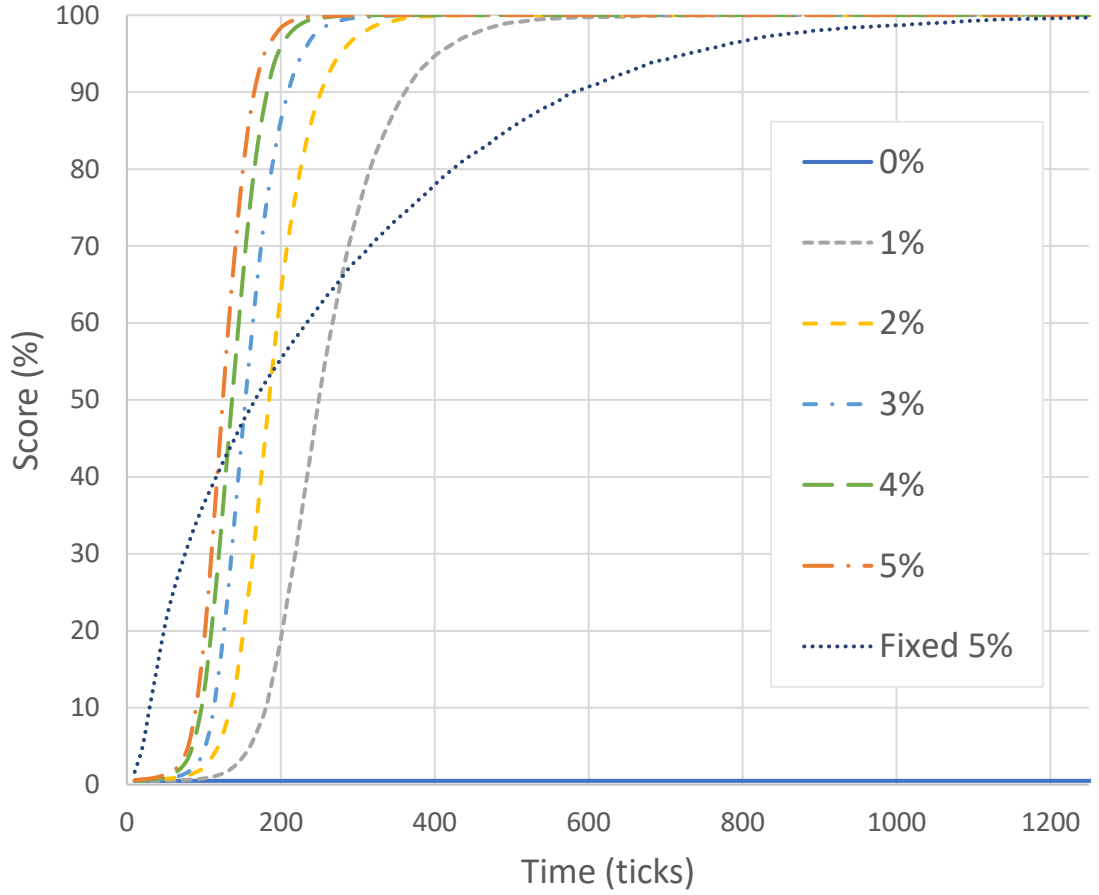
Adaptive Pulse Range

- Test repeated using the adaptive pulse range system.
- Density-Pulse Range relationship used as knowledge base
- Score of 100% achieved 17 out of the 20 scenarios.

Map Radius	Swarm Size	Fixed Range	Score	APC Range	Score
25	50	5	99.84%	7.28	100%
	100	3	99.82%	4.61	100%
	200	2	99.97%	3.04	100%
	500	1	99.96%	1.89	100%
	1000	1	100%	1.38	100%
100	50	38	99.88%	29.42	99.64%
	100	24	99.60%	21.63	99.98%
	200	17	99.53%	14.87	100%
	500	10	99.74%	8.98	100%
	1000	7	99.87%	5.82	100%

Communications Loss

- Implemented as a % chance of a successful message receipt
- 200 robots on a 100-unit radius
- Extremely robust, sharing data within 250 ticks when receipt chance as low as 5%



Conclusions

- A relationship can be established between the density of the swarm and the pulse range to use, to achieve successful communications.
- Autonomic Pulse Communication system uses this to achieve an adaptive transmission range by adapting the periodic pulses found in Pulse monitoring
- Robust even to low chance of communications success. Robots automatically adjust transmission range to compensate.

Future Work

- Application of APC system to more complex tasks
  - Foraging scenarios
  - Collective decision making
- Selective data transfer related to task needs, in more complex scenarios
- Accounting for situations in which the robots have no need to move through periodic boosts to the broadcast range

Thank You

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