Modelling Information Flow In Bio-Inspired Swarm Networks

I propose to undertake a project that examines communication models in swarm robotics, investigating algorithms that promote movement analogous to information flow in biological networked systems.

In recent years, there has been increased interest in modelling biological systems as a basis for wireless sensor network (WSN) architectures (Bitam et al, 2016, Khan et al, 2014), particularly with regard to self-organising and self-healing properties. There have been numerous statistical investigations of communication (particularly Sasaki, 2013, Sumpter, 2012) in emergent biological systems, using Monte Carlo[1] methods to explain communication behaviour in a range of contexts. Concurrently, there has been long-running investigation into the possibilities of emergent behaviours in robotics, developed from investigations of subsumption architecture (Reynolds 1986, Braitenberg 1984) into multi-agent distributed systems (Shiell 2016). My work will seek to build on and combine these fields of research within the field of swarm robotics, developing patterns of complex swarm behaviour to inform a practical understanding of swarming networks.

I will model behaviours that allow swarm networks to self organise, using emergent natural systems such as slime moulds and ant colonies to provide structural examples (CITE). Viewing swarm systems as a basis for physical computation (Piccinini, 2016), I would examine patterns of information flow between swarming elements. This work is related to the subject of my current dissertation, which explores the information flow properties of slime mould *Physarum Polycephalum*, investigating cellular automata models for slime behaviour (Gunji 2008, Jones, J) as a means of modelling fault tolerant, self-organising networks (Houbraken 2012, Tero 2010).

My methodology for this research would follow two main streams of investigation. The initial phase of the project would involve the computer simulation and modelling of different biological systems, in a similar (though more developed) manner to my current dissertation research, informed by a review of statistical approaches. These would likely include Monte Carlo and Bayesian methods (Sasaki, 2013, Sumpter, 2012) and behaviour trees (Jones, S. 2016). These simulations would then be developed to include physical constraints imposed on real-world systems, closing the 'reality gap' (Koos et al 2012).

The second part of this research would seek to implement the more successful bio-inspired models in real-world scenarios on the Kilobit swarm. This would explore the practicality of implementing these protocols in real-world self-organising networks. A list of desired behaviours could be compiled from early simulations, and these patterns demonstrated on a large scale. A metric for information flow (likely morphological, potentially dependent on spatial frequency) will be established, and different swarming configurations measured for effectiveness. This project will build on computation and metric-free investigations of the Kilobit swarm (Gauci, 2014), which investigate self-organising and emergent properties. In building on these models, this project will combine mechanistic, algorithmic and information theoretical approaches to produce novel demonstrations self-distributing networked swarms.

[1] A form of statistical simulation that works with randomised values

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