



Comment

The case for close biological realism when attempting biomimicry  
Comment on “Does being multi-headed make you better at solving  
problems? A survey of Physarum-based models and computations”  
by C. Gao et al.

Chris R. Reid

*Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia*

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Biological transport networks, such as the interconnected tubular networks of fungal mycelia [1], the vasculature of plants and animals [2] and the vegetative state of protists such as slime moulds [3,4], are dynamic networks that continually adapt to their environment. As such, they make excellent candidates for biomimicry – the use of biological principles and mechanisms for improving the design of engineered systems. Biological networks are quick to exploit changing environmental parameters and robust to damage – loss of a single or small number of network edges or nodes will not lead to catastrophic disconnections or isolations within the network. Instilling robustness in networks comes at the cost of building additional redundant pathways, which has not been a priority for human network engineers with a mandate for short-term cost effectiveness. The resultant failure of key infrastructure in recent years (from railway networks to supply chains, power grids and financial systems), has seen a renewed interest in biomimetic methods for network design that balance efficiency with robustness. The target article [5] effectively reviews the contribution of slime mould-based models to this endeavour, and outlines the different modelling approaches that are driving our understanding of this fascinating system.

The authors rightly point out that many past attempts at biomimicry begin with a strong degree of biological realism, but over time become specialised and adapted until the resulting models and products bear no resemblance to their source of inspiration. This has been argued to be a fundamental mechanism that has prevented the large-scale success of biomimetic approaches to date [6]. One of the reasons outlined in [6] is the failure to understand or account for the complexity of natural systems, and to focus on a single attribute to attempt to emulate (usually the one that is easiest to understand, manufacture or copy). For instance, the authors of the target article, and the described models therein, focus on positive feedback in particular – where a behaviour or pattern is reinforced and amplified within the

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E-mail addresses: [chris.reid@mq.edu.au](mailto:chris.reid@mq.edu.au), [chrisreidresearch@gmail.com](mailto:chrisreidresearch@gmail.com).

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system. Including only positive feedback loops within a system is inefficient, providing “only a weak and imprecise thrust toward optimality” [7], whereas adding negative feedback loops to balance amplification forces (also commonly seen in nature) results in better performance [8,9].

In reality, arguing for closer adherence to biological realism is a hard sell when, in the majority of cases, better performance will be achieved by an adapted, loosely biomimetic system that is specialised for a given function. For this reason, and as pointed out in the target article, many of the new slime mould models already stray from biological realism, and are guilty of the same sins that the authors level against the more established field of ant-inspired algorithms. Even when a biological system has been thoroughly researched and understood, and a well-functioning model or algorithm developed as a consequence, there is usually a loss of efficiency or functionality when the algorithm is run in a physical system (be that a telephone network or a swarm of robots). This loss of performance can be due to unexpected interactions and behaviours of embodied agents or networks in the physical world. Schmickl [10] argues for two approaches for restoring performance; 1) adapt the algorithms themselves such that they perform better in the specific embodied format, using techniques such as artificial evolution. This technique is effective and efficient in the short-term, but takes the system further away from the biological processes that first provided inspiration, or; 2) adapt the physical embodiment of the engineered system to more closely mimic that found in nature. The second technique is the more costly and time-consuming, yet the authors of the target article (and biologists generally) argue that aiming for designs that more closely mimic nature could lead to long-term payoffs.

While the target article correctly highlights slime-mould biomimetics as an emerging and exciting field, the authors should not be so quick to rule out further inspiration from the field of social insects. As the authors highlight, the shift away from biological realism and the slow decline in popularity of the ant-based field was largely due to the assumption that natural ant colonies are incapable of solving dynamic problems, an assumption that has several times been proven wrong [11–13]. Computer scientists would do well to incorporate these new findings into their ant-based algorithms to update and potentially improve their product. Perhaps more importantly, modern networks themselves are becoming much more interconnected and parallel than their predecessors, and are beginning to spontaneously resemble the inner architecture of social insect colonies. Whereas once the challenge was how best to route an electrical signal through a telephone network of a few hundred thousand simple, identical nodes, modern problems include how best to route millions of datapackets through a global network of computers and data centres, each with its own capacity and processing speed. Information is now multimodal, coursing through these hyperdense networks in different formats and languages, all of which much be integrated to execute functions. Modern network systems often contain a high degree of parallelism, where the nodes themselves are not simple points to be connected, but each a powerful computer, running its own algorithms on a host of small independent processors. Modern networks thus bear a striking resemblance to a social insect colony [7] – each unit is capable of running behavioural algorithms and performing calculations in parallel, just as each individual ant in a colony has access to its own brain. As such, ant-based swarm intelligence approaches will see a revival as modern networks become further advanced.

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