The Physarum Computer

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Physarum is a slime mold. It was observed over the past 10 years that the mold is able to solve shortest path problems and to construct good Steiner networks [2,4]. In a nutshell, the shortest path experiment is as follows: A maze is built and the mold is made to cover the entire maze. Food is then provided at two positions s and t and the evolution of the slime is observed. Over time, the slime retracts to the shortest s - t -path.

A mathematical model of the slime's dynamic behavior was proposed in [3]. The network is modelled as an undirected graph $G = (V, E)$ with two special vertices s and t . Each edge e has a diameter D_e and a length L_e . The length is fixed and the diameter changes over time. A flow of one is sent from s to t according to the following rule. The network is interpreted as an electrical network where the edge e has resistance L_e/D_e . Each vertex v has a potential p_v ; $p_t = 0$. For an edge $e = (u, v)$, we have a flow $Q_e = (p_u - p_v)D_e/L_e$. If $Q_e < 0$, the flow is in the direction from v to u . We have flow conservation in all vertices except for s and t . The net flow out of s is one and the net flow into t is one. The edge diameters develop according to the rule

$$\dot{D}_e = |Q_e| - D_e,$$

where $\dot{D}_e$ is the derivative of D_e with respect to time. If the current flow is larger (smaller) than the current diameter, the diameter increases (decreases).

Extensive computer simulations confirm the experimental findings. For the edges on the shortest s - t -path, the diameter converges to one, and for the edges off the shortest path, the diameter converges to zero.

For some simple graphs, convergence proofs are available. In particular, if G is a planar graph with s and t being on the boundary of the same face, convergence is shown in [1].

We review the work on the Physarum computer.

References

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