学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　博士(生命科学)　　　氏　名　SCHENZ Daniel Thorsten

学 位 論 文 題 名

Transportation Network Optimisation during Exploratory Migration in *Physarum polycephalum*

(モジホコリの探索移動中の輸送網効率化)

Transportation networks of biological systems are essential for enabling efficient mass flow where diffusion alone would be too slow. The aim of the present work is to study how a biological transportation network can be spatially efficient during extension concurrent with its domain.

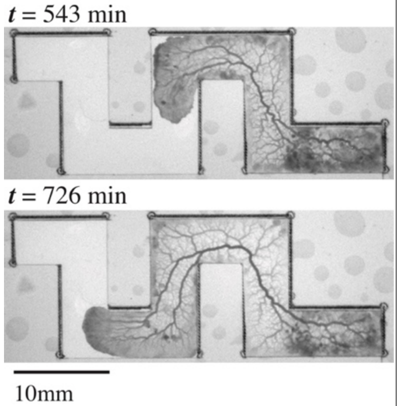

Figure 1: The extension behaviour of *Physarum polycephalum*. Note the trajectory of the main vein.

The true slime mould *Physarum polycephalum* is an apt model organism for this question, because it prominently features an adaptive tube network as it extends over surfaces and we have an understanding of the rules that shape this network, at least in a static situation. To understand the typical shape and development of the vein network of *Physarum* in the case of extension, too, we let the organism explore a spatially limited arena and observed the position of the main vein (figure 1). In this setting, the vein reproducibly traced a characteristic centre-in-centre trajectory at each corner while at the same time achieving almost ideal global efficiency.

In order to understand the development of the extending tube network of *Physarum* in its dynamic environment, we introduce a composite model considering the extension of the growth front, the development of the tube network, and the rhythmic contraction waves as a driving force for the cytosolic flux.

The resulting model (figure 2 top) robustly and accurately re-creates the key features of the organism’s extension. A variation of the model parameters and the observation of the results suggests that the centre-in-centre geometry is a product of the organism coupling the development of its vein net- work to the extension of the growth front such that current-reinforcement-based optimisation can work locally, while still allowing for the rapid construction of a tube network. As a corollary of this we introduce a simple graphical algorithm which is able to predict the vein position based solely on the growth front history with remarkable accuracy (figure 2 bottom).

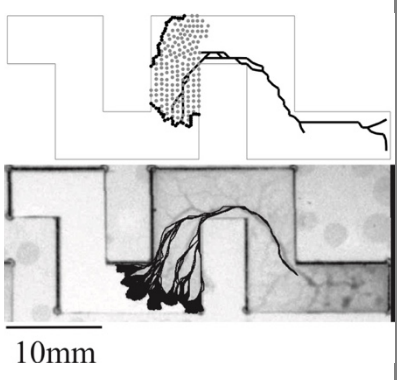

Figure 2: Snapshots of the model (top) and the model-derived algorithm (bottom), both closely resembling the behaviour of *Physarum*.

In summary, the construction of a mathematical model incorporating a number of physiological processes helped us understand how those different processes interact to produce an efficient behaviour in nature. Therefore, we claim that the advantage the current reinforcement mechanism confers to *Physarum* mainly lies in it affording the organism very efficient spatial exploration. In addition, the phenomenological algorithm is based on the general principles of local minimisation of connections and the pruning of globally disadvantageous connections, making it plausible that the algorithm may also capture the development of other flow-responsive networks that form within an expanding domain.