Preface

Unconventional computing is a journey to uncover principles of information processing and computation in physical, chemical and biological systems and to apply these principles in developing novel computing paradigms, architectures and implementations. This emerging field of science and engineering is predominantly occupied by theoretical research, e.g. quantum computation, membrane computing and dynamical systems computing. For a hundred theoretical papers there may be just one experimental laboratory paper. Only a handful of experimental prototypes are reported so far, for example, gas-discharge analogue path finders; maze-solving microfluidic circuits; geometrically constrained universal chemical computers; specialised and universal chemical reaction–diffusion processors; universal extended analogue computers; maze-solving chemotactic droplets; enzyme-based logical circuits; spatially extended crystallisation computers for optimisation and computational geometry; and molecular logical gates and circuits. A weak representation of laboratory experiments in the field of unconventional computers could be explained by technical difficulties, costs of prototyping of novel computing substrates and also psychological barriers. Chemists and biologists do not usually aspire to experiment with unconventional computers because such activity diverts them from mainstream research in their fields. Computer scientists and mathematicians would like to experiment but are "scared" of laboratory equipment. If there was a simple to maintain substrate, which requires minimal equipment to experiment with and whose behaviour is understandable and appealing to researchers from all fields of science, then progress in designing novel computing devices would be much more visible. There is such a substrate. This is the slime mould *Physarum polycephalum*.

Physarum polycephalum belongs to the species of order *Physarales*, subclass *Myxogastromycetidae*, class *Myxomycetes*, division *Myxostelida*. It is commonly known as a true, acellular or multi-headed slime mould. Plasmodium is a "vegetative" phase, a single cell with a myriad of diploid nuclei. The plasmodium is visible to the naked eye. The plasmodium looks like an amorphous yellowish mass with networks of protoplasmic tubes. It feeds on bacteria, spores and other microbial creatures and microparticles.

In our European project "Physarum chip: growing computers from slime mould", we designed and fabricated a distributed computing device built and operated by the slime mould *P. polycephalum*. In Physarum chips, data are represented

by spatial configurations of attractants and repellents, or by geometrical constraints of the substrate, and the slime mould represents results of the computation with morphology of its protoplasmic networks or changes in electrical oscillator activity. Advantages of the Physarum chips are parallel inputs (optical-, chemo- and electrical-based) and outputs (electrical and optical) and their ability to solve a wide range of computational tasks, including optimisation on graphs, computational geometry, robot control, logic and arithmetical computing.

We fabricated a range of sophisticated machines made from the slime mould: sensors, image processors, logical gates, memristors, self-healing wires and memory devices. Most of these slime mould computers function in space and present results of their computation by changes in the morphological structure of their protoplasmic networks. This morphological computing behaviour is visually attractive and aesthetically appealing, and therefore we decided to share the best snapshots of slime mould computers with the World by preparing this atlas. In this unique set of photographs and micrographs, we illustrate in superb detail the nature of the slime mould computers and hybrid devices. Each entry includes a self-contained description of how the visualised phenomenon is used in the relevant slime mould computer, and has real scientific, theoretical or technological interest. This atlas is unique in providing the depth and breadth of knowledge in harnessing behaviour of the slime mould to perform computation. The atlas will help readers to understand how exploitation of biological processes has sparked new ideas and spurred progress in many fields of science and engineering.

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