celle d'un savant cloué sur sa chaise, ne pouvant remuer qu'un doigt pour faire défiler sur un écran d'ordinateur des mots impossibles à prononcer, mais capable, par la seule force de son mental, de déchiffrer les mystères les plus ardus de la création.

Temps, éternité, naissance, mort sont des termes prégnants qui dépassent le cadre de la stricte rationalité. Hawking était mieux placé que quiconque pour juger de la précarité de la condition humaine face à l'écrasante immensité du cosmos. La prodigieuse force intellectuelle qui l'a toujours animé illustre puissamment qu'il y a dans la connaissance le signe d'une « revendication » de l'être humain face au cosmos. Au-delà de ses faiblesses, c'est ce qui en fait toute la grandeur et, selon moi, ce qu'il y a d'essentiel à retenir de la vie et l'œuvre de Stephen Hawking.

[1] Texte initialement écrit par l'auteur sur son blog. https://blogs.futura-sciences.com/luminet/2018/03/15/stephen-hawking-1942-2018-travaux/ Puis publié dans la revue *L'astronomie*. J-P. Luminet, « Stephen Hawking, un astronome hors normes », *L'Astronomie* 132, 2018, 42-45.
[2] Du moins dans le cadre de la théorie des cordes, à laquelle adhérait Hawking. Mais dans d'autres approches, comme celle de la gravité quantique à boucles, le paradoxe est parfaitement résolu. (La gravitation quantique à boucles, théorie quantique pour le champ gravitationnel, permet de décrire des phénomènes gravitationnels quand leurs effets quantiques doivent être pris en compte. Par là, on unifie la théorie de la relativité générale (notion d'espace-temps) et les concepts (énergie et matière) de la physique quantique, ndr).

Unconventional Computing. Personal choices

Andrew Adamatzky

Unconventional computing is a science in a flux, where norms are dynamics and truth is relative, or, less poetically and by Cambridge dictionary, this is different from what is usual or from the way most people do things. The field of unconventional computing is highly interdisciplinary and open to wild ideas. The unconventional computing can be split in two parts: 1) practical, experimental laboratory, computing, or implementation of computing devices with novel substrates (this part can also include computer models, which imitate novel computing substrates with near physical accuracy) and 2) theorizing about computing and nature-inspired algorithms and developing novel and original theories of computation and software implementation of algorithms inspired by nature, and computing-related philosophical theories. A comprehensive, tutorial style, guides to all aspects of unconventional computing can be found in recently published "bible" of unconventional computing[1] or more concise introductions in Springer's encyclopedia volume.[2] Let me briefly introduce most cool directions of unconventional computing, along the lines of my editorial for.[3]

Optical computing

Optical computers use photons to transfer information, and lasers, modulators, filters and detectors are used instead of conventional electronic elements of the information can be transformed via opto-electronics devices or interaction between streams of photons. There is a wide spectrum of optical computing devices, analog and digital optical computers, continuous state machines, photonic integrated circuits, including photonic neurons and photonic spiking processes, and photonic analogies with leaky-and-fire model.[4]

Reaction-diffusion computing

Waves propagating in unconstrained, or free-space, chemical systems are also proved to be capable for implementation of logical circuits, and robot control and computational geometry. In reaction-diffusion processors, both the data and the results of the computation are encoded as concentration profiles of the reagents. The computation *per se* is performed via the spreading and interaction of wave fronts. There are experimental prototypes of precipitating chemical processors for computing of Voronoi diagram and skeleton of a planar shape, and collision-free path calculation, control of robotic hand, and implementation of logical gates and arithmetic circuits in Belousov-Zhabotinsky excitable chemical medium.[5]

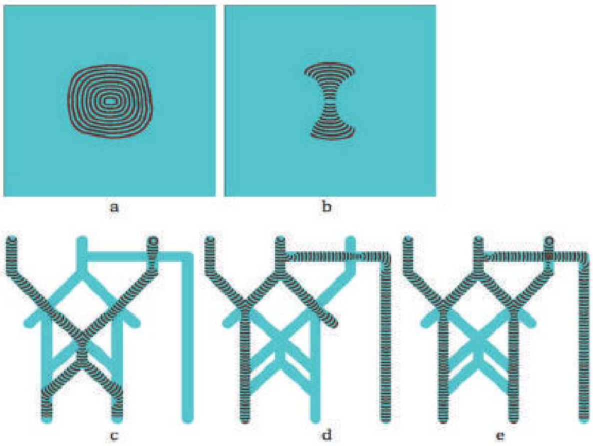

Fig. 1. Computing with waves in Belousov-Zhabotinsky (BZ) medium. Time lapse snapshots of the propagating and interaction wave-fronts.[6]

(a) A circular wave in Oregonator model of BZ medum.
(b) Two wave-fragments propagating North and South.
(c) Fredkin gate implemented in BZ for inputs x=1, y=1, z=0.
(d) Fredkin gate implemented in BZ for inputs x=1, y=0, z=1.
(e) Fredkin gate implemented in BZ for inputs x=1, y=1, z=1.

Enzyme-based computing

Concentrations of enzymes represent Boolean values; functionality of logical gates is encoded in the reactions between the enzymes. By cascading enzymatic reactions it is possible to implement enzyme-based logical gates and interface them with conventional electronics. Outputs of signals generated by enzymatic-circuits can be studied using optical and electrochemical methods, impedance spectroscopy and conductivity measurements. The enzymatic-based logical systems coupled with semiconductor devices make unique digital biosensors.[7]

Physarum computing

Slime mould *Physarum polycephalum* is a single cell visible by unaided eye. During its foraging behavior, the plasmodium spans scattered sources of nutrients with a network of protoplasmic tubes. The plasmodium optimizes its protoplasmic network to cover all sources of nutrients, stay away from repellents, and minimize transportation of metabolites inside its body. The plasmodium's ability to optimize its shaper attracted the attention of biologists and later computer scientists. Experimental laboratory prototypes of slime mould based computing devices include shortest path and maze solvers, approximation of spanning trees, evaluators of transport networks (Fig. 2), Voronoi diagram, concave hull; attraction-based, ballistic, opto-electronic, frequency-based and micro-fluidic logicals gates and implementation of Kolmogorov-Uspensky machine.[8]

Analog computing

In 1876 Lord Kelvin envisaged that a computation by directly exploiting law of Nature and invented differential analyzer. Ideas of analog computation emerged, flourished, almost deceased by 1980s and then were resurrected in 1990s in ever growing field of computing based on continuous representations by means of continuous processes. Currently we witness resurrection of the field, esp. analog large scale integration circuits, field programmable analog arrays,[9] and mechanical analog computers, mechanical and electro-optical devise for integer factorization and including self-assembling devices and molecular machines.[10]

Computing with conductive polymers

A concept of a wire, called mnemotrix, which decreases its resistance when traversed by an electrical current was proposed in 1980s, and experimentally implemented with organic conductive polymer polyaniline early 2000s. Polyaniline and other conductive polymers are proved to be an almost universal computing substrate capable for realization of oscillators, synapses, logical gates, perceptron and Pavlovian learning with the conductive polymers.[11]

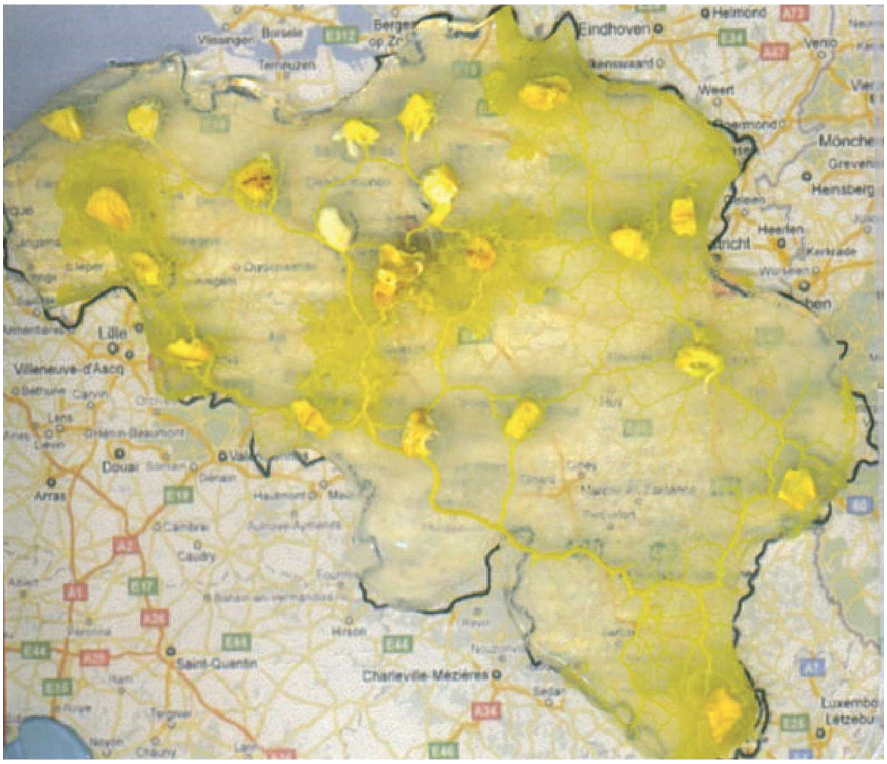

Fig. 2. Slime mould Physarum polycephalum evaluates transport networks in Belgium.

Plant computers

Plants are highly intelligent systems, they continuously make distributed sensorial fusion, concurrent decision making and parallel actuation. The plants are efficient green computers *per se*. However, the plants are programmed and hardwired to perform a narrow range of tasks aimed to maximize the plants' ecological distribution, survival and reproduction. Possible designs and prototypes of plant-based computing systems that could utilise morphological development of roots, interaction of roots, and analog electrical computation with plants, and plant-derived electronic components. In morphological plant processors data are represented by initial configuration of roots and configurations of sources of attractants and repellents; results of computation are represented by topology of the roots' network (Fig. 3). Computation is implemented by the roots following gradients of attractants and repellents and interacting with each other. Electrical properties of plants can be modified by loading the plants with functional nanoparticles or coating parts of plants of conductive polymers. Thus we could make living variable resistors, capacitors, operational amplifiers, multipliers, potentiometers and fixed-function generators. The electrically modified plants can implement summation, integration with respect to time, inversion, multiplication, exponentiation, logarithm, division.[12]

Molecular automata

The automata are built using phenomena of binding, dissociation and catalytic actions related to nucleic acids, and algorithmic DNA self-assembly. The molecular automata can act as language recognizers, transducers and controllers, logical gates, and cascaded in arithmetic circuits, therapeutic and diagnostic automata.[13]

Collision-based computing

In collision-based computers travelling localisations represent data – the presence of which in a specific location represents a logical "1" ("true") and vice versa – which are conditionally routed to represent an output state. When two objects collide, it can be said that computation has been achieved as signal routing is altered. The collision-based started with Fredkin-Toffoli billiard-ball,[14] in a context of conservative logic, where hypothetical billiard balls of equal mass and dimensions that travel along the grid lines of a Cartesian lattice at uniform speed may collide with each other, altering their final trajectories and hence the output of the billiard ball machine. Key feature of the collision-based computers is that they do not need wires – any part of space can be an instantaneous wire, and they can executer reversible-logical circuits. Collision-based computers have been implemented in experimental laboratory with wave-fragments in excitable chemical media,[15] liquid marbles,[16] soldier crabs,[17] slime mould,[18] intracellular vesicles,[19] and partly, plant roots.[20] The field of collision-based computing also includes design and implementation of logical circuits based on interaction of solitons.[21]

Evolution in materio

This is a unifying subfield of the unconventional computing aiming to demonstrate that any chemical, physical and living substrate can be used as a computing device, or evolving computing abilities of unconventional computing substrates by reconfiguring their physical structure. The evolutionary algorithms are used to find values of input variables that should be applied to a substrate so that the substrate carries out a useful computation. Examples include evolving liquid crystals, conductive and electro-activated polymers, voltage controlled colloids, Langmuir-Blodgett films and Kirchhoff-Lukasiewicz machines.[22]

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[2] A. ADAMATZKY (ed.), "Unconventional Computing", *Encyclopedia of Complexity and Systems Science Series*, Springer, 2018.

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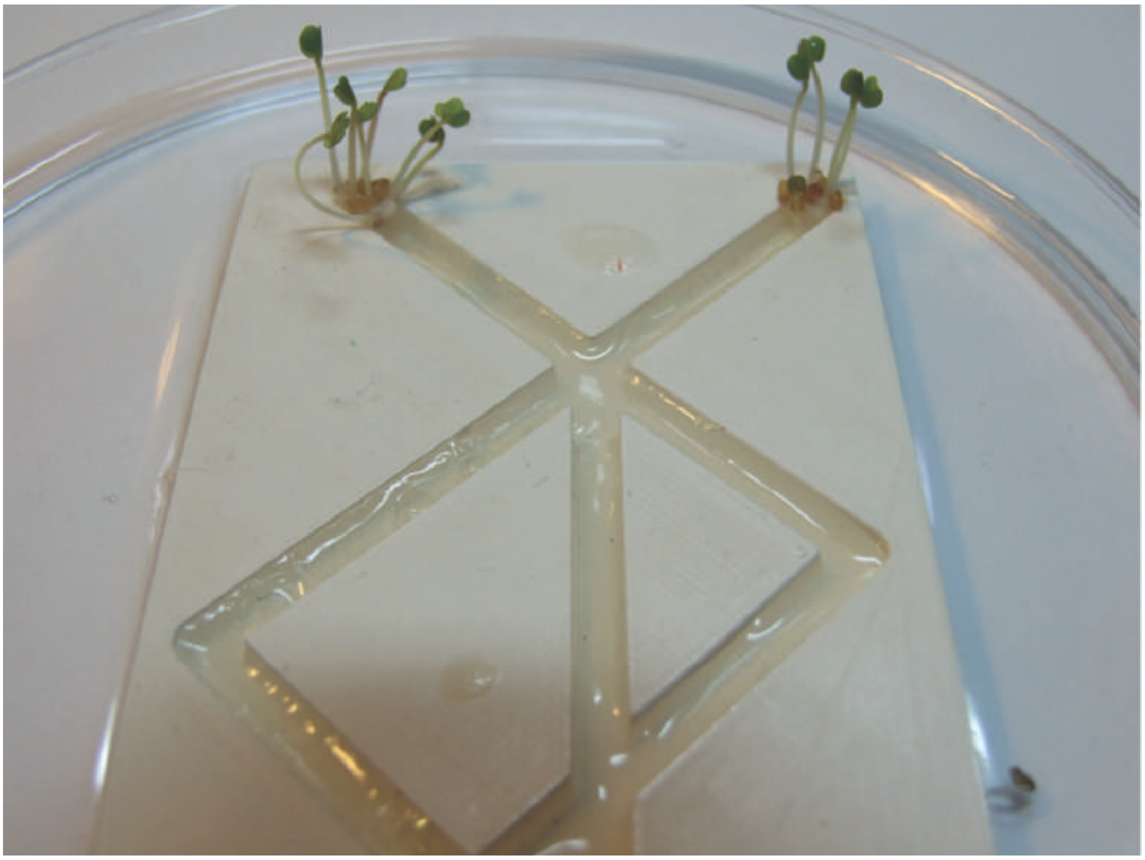

Fig. 3. Experimental setup of plant root collision-based gate. Details are in note 12.

Memory Evolutive Systems and their Applications

Andrée Ehresmann, Jean-Paul Vanbremeersch, Mathias Béjean

Biological, neuro-cognitive, or social systems are evolutionary multi-scale, multi-agent, multi-temporality systems, able to adapt to changing conditions through learning. The Memory Evolutive Systems (MES), introduced by A. C. Ehresmann and J.-P. Vanbremeersch,[1] give a methodology for studying such "living" systems and the problems of dynamical hierarchy, emergence and cognition they raise. MES interweave 2 domains of mathematics: 1) Category Theory[2] to introduce the structure of an evolutive hierarchical system developing a plastic Memory with emergent properties; 2) Dynamical systems to study the local dynamics of a network of "co-regulators", each with its own rhythm. For length limitation, we give MES' main characteristics in an intuitive way. More details are given in the book[3] and papers on the site.[4] For illustrating figures, see the slides of [5].

Hierarchical Evolutive Systems

The configuration of the system at time t.

Following Ludwig Bertalanffy, a system S consists of interacting components. In a living system both the components and the links through which they can interact vary in time, with addition or suppression of some of them. The *configuration of S* at a time t consists of