Wil McCarthy

Materialien (englisch) zum SFGH-Vortrag vom 22.4.2017 von

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Contents

Chapter 1

Wil McCarthy

Wil McCarthy (born September 16, 1966 in Princeton, New Jersey) is a science fiction novelist, president and co-founder of RavenBrick (a solar technology company),[1] and the science columnist for Syfy. He currently resides in Colorado.[2]

Wil McCarthy popularized the concept of programmable matter, which he calls *wellstone*.

1.1 Books

1.1.1 Non-fiction

- *Hacking Matter* (2003) ISBN 0-465-04428-X

Novels

- *Flies from the Amber* (1995) ISBN 0-451-45406-5
- *Murder in the Solid State* (1996) ISBN 0-312-85938-4
- *Bloom* (1998) ISBN 0-345-40857-8

1.1.2 The Waisters

- *Aggressor Six* (1994) ISBN 0-451-45405-7
- *The Fall of Sirius* (1996) ISBN 0-451-45485-5

1.1.3 The Queendom of Sol

For more details on this topic, see The Queendom of Sol.

- *The Collapsium* (2000) ISBN 0-345-40856-X — Nebula Award nominee.
- *The Wellstone* (2003) ISBN 0-553-58446-4
- *Lost in Transmission* (2004) ISBN 0-553-58447-2
- *To Crush the Moon* (2005) ISBN 0-553-58717-X — Nebula Award nominee.

1.2 Short works

- "Amerikano Hiaika", *Aboriginal SF*, May/June 1991.
- "Dirtyside Down", Universe 3, 1994.
- "The Dream of Houses", *Analog*, November 1995. *Locus* recommended reading list.
- "The Dream of Castles", *Analog*, April 1997.
- "The Dream of Nations", *Analog*, October 1998. *Locus* recommended reading list.
- "Once Upon a Matter Crushed", *Science Fiction Age*, May 1999. Theodore Sturgeon Award Nominee. Locus recommended reading list. Became the first portion of *The Collapsium*.
- "No Job Too Small", *Aboriginal SF*, Spring 2001.
- "Pavement Birds", *Analog*, July/August 2002.
- "Garbage Day", *Analog*, December 2002. Became part of *The Wellstone*.

1.3 Radio plays

- *I Love Bees*, writer[3][4]

1.4 Non-fiction

1.4.1 Print

- "Programmable Matter, A Retrospective", *Nature*, October 6, 2000.
- "Ultimate Alchemy", *Wired Magazine* 9.10, October, 2001
- "This looks like a job for...Superatoms", *IEEE Spectrum*, August, 2005

1.4.2 Radio appearances

- *Coast to Coast AM*, “Programmable Matter”, April 18, 2003[5]
- *Coast to Coast AM*, “Quantum Dots”, April 26, 2004[6]

1.5 References

[1] *RavenBrick management team*, RavenBrick LLC, retrieved 2012-04-16

[2] "'Bloom' author biography”. Random House. Retrieved 2008-03-23.

[3] Sean Stewart, *I love bees information page*, retrieved 2012-04-18

[4] Wil McCarthy at the Internet Movie Database

[5] *Programmable Matter*, Coast to Coast AM, April 18, 2003

[6] *Quantum Dots*, Coast to Coast AM, April 26, 2004

1.6 External links

- WilMcCarthy.com
- Wil McCarthy at the Internet Speculative Fiction Database
- Wil McCarthy at the Internet Movie Database
- Wil McCarthy U.S. patents

Chapter 2

Programmable matter

Programmable matter is matter which has the ability to change its physical properties (shape, density, moduli, conductivity, optical properties, etc.) in a programmable fashion, based upon user input or autonomous sensing. Programmable matter is thus linked to the concept of a material which inherently has the ability to perform information processing.

2.1 History

Programmable matter is a term originally coined in 1991 by Toffoli and Margolus to refer to an ensemble of fine-grained computing elements arranged in space.[1] Their paper describes a computing substrate that is composed of fine-grained compute nodes distributed throughout space which communicate using only nearest neighbor interactions. In this context, programmable matter refers to compute models similar to cellular automata and lattice gas automata.[2] The CAM-8 architecture is an example hardware realization of this model.[3] This function is also known as "digital referenced areas" (DRA) in some forms of self-replicating machine science.[4]

In the early 1990s, there was a significant amount of work in reconfigurable modular robotics with a philosophy similar to programmable matter.[4]

As semiconductor technology, nanotechnology, and self-replicating machine technology have advanced, the use of the term programmable matter has changed to reflect the fact that it is possible to build an ensemble of elements which can be "programmed" to change their physical properties in reality, not just in simulation. Thus, programmable matter has come to mean "any bulk substance which can be programmed to change its physical properties."

In the summer of 1998, in a discussion on artificial atoms and programmable matter, Wil McCarthy and G. Snyder coined the term "quantum wellstone" (or simply "wellstone") to describe this hypothetical but plausible form of programmable matter. McCarthy has used the term in his fiction.

In 2002, Seth Goldstein and Todd Mowry started the claytronics project at Carnegie Mellon University to investigate the underlying hardware and software mechanisms necessary to realize programmable matter.

In 2004, the DARPA Information Science and Technology group (ISAT) examined the potential of programmable matter. This resulted in the 2005–2006 study "Realizing Programmable Matter", which laid out a multi-year program for the research and development of programmable matter.

In 2007, programmable matter was the subject of a DARPA research solicitation and subsequent program.[5][6]

2.2 Approaches

In one school of thought the programming could be external to the material and might be achieved by the "application of light, voltage, electric or magnetic fields, etc." (McCarthy 2006). For example, a liquid crystal display is a form of programmable matter. A second school of thought is that the individual units of the ensemble can compute and the result of their computation is a change in the ensemble's physical properties. An example of this more ambitious form of programmable matter is claytronics.

There are many proposed implementations of programmable matter. Scale is one key differentiator between different forms of programmable matter. At one end of the spectrum reconfigurable modular robotics pursues a form of programmable matter where the individual units are in the centimeter size range.[4][7][8] At the nanoscale end of the spectrum there are a tremendous number of different bases for programmable matter, ranging from shape changing molecules[9] to quantum dots. Quantum dots are in fact often referred to as artificial atoms. In the micrometer to sub-millimeter range examples include MEMS-based units, cells created using synthetic biology, and the utility fog concept.

An important sub-group of programmable matter are robotic materials, which combine the structural aspects of a composite with the affordances offered by tight integration of sensors, actuators, computation and communication,[10] while foregoing reconfiguration by particle motion.

2.3 Examples

There are many conceptions of programmable matter, and thus many discrete avenues of research using the name. Below are some specific examples of programmable matter.

2.3.1 "Simple"

These include materials that can change their properties based on some input, but do not have the ability to do complex computation by themselves.

Complex fluids

Main article: Complex fluids

The physical properties of several complex fluids can be modified by applying a current or voltage, as is the case with liquid crystals.

Metamaterials

Main article: Metamaterials

Metamaterials are artificial composites that can be controlled to react in ways that do not occur in nature. One example developed by David Smith and then by John Pendry and David Schuri is of a material that can have its index of refraction tuned so that it can have a different index of refraction at different points in the material. If tuned properly this could result in an "invisibility cloak."

A further example of programmable -mechanical- metamaterial is presented by Bergamini et al.[11] Here, a pass band within the phononic bandgap is introduced, by exploiting variable stiffness of piezoelectric elements linking aluminum stubs to the aluminum plate to create a phononic crystal as in the work of Wu et al.[12] The piezoelectric elements are shunted to ground over synthetic inductors. Around the resonance frequency of the LC circuit formed by the piezoelectric and the inductors, the piezoelectric elements exhibit near zero stiffness, thus effectively disconnecting the stubs from the plate. This is considered an example of programmable mechanical metamaterial.[11]

Shape-changing molecules

An active area of research is in molecules that can change their shape, as well as other properties, in response to external stimuli. These molecules can be used individually or en masse to form new kinds of materials. For example, J Fraser Stoddart's group at UCLA has been developing molecules that can change their electrical properties.[9]

Electropermanent magnets

Main article: Electropermanent magnet

An electropermanent magnet is a type of magnet which consists of both an electromagnet and a dual material permanent magnet, in which the magnetic field produced by the electromagnet is used to change the magnetization of the permanent magnet. The permanent magnet consists of magnetically hard and soft materials, of which only the soft material can have its magnetization changed. When the magnetically soft and hard materials have opposite magnetizations the magnet has no net field, and when they are aligned the magnet displays magnetic behaviour.[13]

They allow creating controllable permanent magnets where the magnetic effect can be maintained without requiring a continuous supply of electrical energy. For these reasons, electropermanent magnets are essential components of the research studies aiming to build programmable magnets that can give rise to self-building structures.[13][14]

2.3.2 Robotics-based approaches

Self-reconfiguring modular robotics

Main article: Self-reconfiguring modular robot

Self-reconfiguring modular robotics is a field of robotics in which a group of basic robot modules work together to dynamically form shapes and create behaviours suitable for many tasks. Like Programmable matter SR-CMR aims to offer significant improvement to any kind of objects or system by introducing many new possibilities for example: 1. Most important is the incredible flexibility that comes from the ability to change the physical structure and behavior of a solution by changing the software that controls modules. 2. The ability to self-repair by automatically replacing a broken module will make SRCMR solution incredibly resilient. 3. Reducing the environmental foot print by reusing the same modules in many different solutions. Self-Reconfiguring Modular Robotics enjoys a vibrant and active research community.[15]

Claytronics

Main article: Claytronics

Claytronics is an emerging field of engineering concerning reconfigurable nanoscale robots ('claytronic atoms', or *catoms*) designed to form much larger scale machines or mechanisms. The catoms will be sub-millimeter computers that will eventually have the ability to move around, communicate with other computers, change color, and electrostatically connect to other catoms to form different shapes.

Cellular automata

Main article: Cellular automata

Cellular automata are a useful concept to abstract some of the concepts of discrete units interacting to give a desired overall behavior.

2.3.3 Quantum wells

Main article: Quantum well

Quantum wells can hold one or more electrons. Those electrons behave like artificial atoms which, like real atoms, can form covalent bonds, but these are extremely weak. Because of their larger sizes, other properties are also widely different.

2.3.4 Synthetic biology

Main article: Synthetic biology

Synthetic biology is a field that aims to engineer cells with "novel biological functions." Such cells are usually used to create larger systems (e.g., biofilms) which can be "programmed" utilizing synthetic gene networks such as genetic toggle switches, to change their color, shape, etc. Such bioinspired approaches to materials production has been demonstrated, using self-assembling bacterial biofilm materials that can be programmed for specific functions, such as substrate adhesion, nanoparticle templating, and protein immobilization.[16]

2.4 See also

- Claytronics
- Computronium
- Nanotechnology
- Smart material
- Smartdust
- Ubiquitous computing
- Universal Turing machine
- Utility fog

2.5 References

[1] Toffoli, Tommaso; Margolus, Norman (1991). "Programmable matter: concepts and realization". *Physica D*. **47**: 263–272. doi:10.1016/0167-2789(91)90296-L.

[2] Rothman, D.H.; Zaleski, S. (2004) [1997]. *Lattice Gas Cellular Automata*. Cambridge University Press. ISBN 9780521607605.

[3] "CAM8: a Parallel, Uniform, Scalable Architecture for Cellular Automata Experimentation". Ai.mit.edu. Retrieved 2013-04-10.

[4] http://www.geocities.com/charles_c_22191/temporarypreviewfile.html?1205202563050

[5] "DARPA research solicitation". Archived from the original on July 15, 2009.

[6] DARPA Strategic Thrusts: Programmable Matter Archived December 12, 2010, at the Wayback Machine.

[7] Research

[8]

[9] "UCLA Chemistry and Biochemistry". Stoddart.chem.ucla.edu. Archived from the original on 2004-10-12. Retrieved 2013-04-10.

[10] M. A. McEvoy and N. Correll. Materials that couple sensing, actuation, computation, and communication. *Science* 347(6228), 2015.

[11] Bergamini, Andrea; Delpero, Tommaso; De Simoni, Luca; Di Lillo, Luigi; Ruzzene, Massimo; Ermanni, Paolo (2014). "Phononic Crystal with Adaptive Connectivity". *Advanced Materials*. **2** (9). pp. 1343–1347. doi:10.1002/adma.201305280. ISSN 0935-9648.

[12] Wu, Tsung-Tsong; Huang, Zi-Gui; Tsai, Tzu-Chin; Wu, Tzung-Chen (2008). "Evidence of complete band gap and resonances in a plate with periodic stubbed surface". *Applied Physics Letters*. **93** (11). p. 111902. doi:10.1063/1.2970992. ISSN 0003-6951.

[13] Deyle, Travis (2010). "Electropermanent Magnets: Programmable Magnets with Zero Static Power Consumption Enable Smallest Modular Robots Yet". HiZook. Retrieved 2012-04-06.

[14] Hardesty, Larry (2012). "Self-sculpting sand". MIT. Retrieved 2012-04-06.

[15] (Yim et al. 2007, pp. 43–52) An overview of recent work and challenges

[16] Nguyen, Peter (Sep 17, 2014). "Programmable biofilm-based materials from engineered curli nanofibres". *Nature Communications*. **5**: 4945. doi:10.1038/ncomms5945. PMID 25229329.

2.6 Further reading

- Goldstein, Seth Copen; Campbell, Jason; Mowry, Todd C. (June 2005). "Programmable Matter". *IEEE Computer*. **38** (6): 99–101. doi:10.1109/MC.2005.198.
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- McCarthy, Wil (2003). *Hacking Matter: Levitating Chairs, Quantum Mirages, and the Infinite Weirdness of Programmable Atoms*. New York: Basic Books. ISBN 0-465-04428-X.
- Yim, Mark; Shen, Wei-Min; Salemi, Behnam; Rus, Daniela; Moll, Mark; Lipson, Hod; Klavins, Eric; Chirikjian, Gregory (March 2007). "Modular Self-Reconfigurable Robot Systems". *IEEE Robotics & Automation Magazine*. **14** (1): 43. doi:10.1109/MRA.2007.339623.

2.7 External links

- "DARPA (US Military) Programmable Matter Thrust".

2.8 Text and image sources, contributors, and licenses

2.8.1 Text

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