Artificial Life Models in Hardware

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Editors

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Preface

Artificial Life is the science of life-like artifacts. The Artificial Life scientists are a tasty blend of computists, engineers, biologists, physicists, chemists, and mathematicians, all straying away from their mainstreams. They implement living creatures in computer programs, hardware, and robots to better understand what Life is and what other Lifes could be. Advances in virtual models of life are discussed in the sister book, *Artificial Life Models in Software*.[1] The book you are reading now is about real-world implementations of life-like artifacts, the intriguing and exciting domain of the Artificial Life research. Browsing the chapters of the book, you will see that experiments with man-made objects offer unique opportunities in studying living phenomena in physical environment and provide workable proofs of theoretical concepts based on invaluable knowledge of direct experimentation with the practical world.

In no way can the ten chapters of the book cover the whole field of real-world implementations of life-like artifacts: there are hundreds of prototypes and thousands of papers in the field. Rather, the selected pieces of work provide a representative snapshot of the state-of-art in artificial life hardware to encourage readers to enter this kingdom of curiosities and to find their way in the labyrinths of amusement.

Jim M. Conrad and Jonathan W. Mills, *The History and Future of Stiquito, a Hexapod Insectoid Robot*, put up a laymen introduction to artificial life robotics. They invite us to the “kitchen” of robot design and share their success in developing Stiquito, an insect-like hardware creature, historically first ever unconventional robot made available to and actively used by general public.

“If things walk they are living!”, this thesis seems to be a key principle of hardware artificial life. There are four chapters on walking. Fumiya Iida and Simon Bovet’s robots learnt to hop and then run on four legs. Hopping and walking pattern generations, adaptable walking strategies, reward-based learning, and object following are discussed in the chapter *Learning Legged Locomotion*.

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[1] A. Adamatzky and M. Komosinski (eds). *Artificial Life Models in Software*, 1st edn. Springer, 2005; M. Komosinski and A. Adamatzky, 2nd edn. 2009.

Hardware designs of swimming and walking robots are presented by Alessandro Crespi and Auke Jan Ijspeer, *Salamandra Robotica: a Biologically Inspired Amphibious Robot that Swims and Walks*. The robot is controlled by onboard artificial neural network, which is crafted to be adaptable to conditions of locomotion.

Toshio Fukuda, Tadayoshi Aoyama, Yasuhisa Hasegawa, and Kosuke Sekiyama uncover designs of gorilla-like robots in *Multi-Locomotion Robot: Novel Concept, Mechanism and Control of Bio-Inspired Robot*. Transitions between different patterns of locomotion, including wall climbing, are amongst many intriguing features of the chapter.

Chapter *Self-Regulatory Hardware: Evolutionary Design for Mechanical Passivity on a Pseudo Passive Dynamic Walker* by Hiroshi Yokoi and Kojiro Matsushita is the only chapter that does not present any physical implementations. However, the models and blue-prints of passive walkers are based on extensive real-world experiments undertaken by Hiroshi Yokoi, his colleagues, and students. Their remarkable plastic-bottle walkers made a history in simplistic robotics. Yokoi and Matsushita's chapter perfectly complements Conrad and Mills designs in encouraging people to enter the field of life-like robotics.

Perceiving the environment via sensorial inputs by robots traveling without destination, that is, doing random foraging tasks, is studied by Paolo Arena, Sebastiano De Fiore, and Luca Patané in *Perception for Action in Roving Robots: A Dynamical System Approach*. Field programable gate arrays are used as the robot "brains," which learn to control chaotic information of sensorial stimuli. The ideas presented in the chapter are justified in experiments with wheeled robots and on-board learning hardware controllers.

Works on hardware implementations of life-like forms are dominated by robotic applications. Chapter *Nature-Inspired Single-Electron Computers* by Tetsuya Asai and Takahide Oya brings some diversity: Asai and Oya tell us how to build brains from networks of single-electron oscillators. Their architectures are scalable and thus offer novel ways of developing controllers for micromodel of life-like creatures. Computational power of neuromorphic processors, based on single-electron circuits, is demonstrated on the tasks of computational geometry and image processing.

All pieces of work in this book are about unconventional, novel, and emerging robotic and hardware designs. The last three chapters push boundaries of "unconventional" even further. These chapters present results of experimentations with novel substrates and interfaces between hardware and wetware.

Shuhei Miyashita, Max Lungarella, and Rolf Pfeifer, chapter *Tribolon: Water Based Self-Assembly Robots*, take on meaning of "wetware" literally. They design robots self-assembling on the water surface. Miyashita, Lungarella, and Pfeifer built a modular autonomous system of self-propelling plastic tiles capable of aggregation. The experiments shed light onto hierarchical mechanism of self-assembly and morphology as a guiding factor of assembly.

Most designers of robots and hardware take power as granted and focus on motor activities, sensors, information transducers, and control functions. When a battery dies and when main power supply is cut off, even the most sophisticated gadgets become worthless than a box of matches. Ioannis A. Ieropoulos, John Greenman, Chris

Melhuish, and Ian Horsfield take care for this not happen in future. They made energetically autonomous robots which are powered directly by bacterial metabolism. Detailed know-hows are presented in their chapter *Artificial Symbiosis in EcoBots*: the robots have on board fuel cells, where electricity is produced by live microorganisms.

In less than 10 years, the plasmodium of *Physarum polycephalum* raised from a humble slime mould to the amorphous intelligent creature proficient in computational geometry and optimization on graphs, and capable of learning. This would be a crime not to employ the plasmodium as a controller for robots. This was done by Soichiro Tsuda, Stefan Artmann, and Klaus-Peter Zauner who placed the plasmodium on board of a hexapod robot and interfaced the mould with motor controllers. Their experiments are described in chapter *The Phi-Bot: A Robot Controlled by a Slime Mould*.

The book concludes with *Chemical Controllers for Robots* by Andy Adamatzky, Ben De Lacy Costello, and Hiroshi Yokoi. The chapter overviews results of laboratory experiments on wheeled robot navigation with on-board excitable chemical medium, Belousov-Zhabotinsky reaction, and interaction between the chemical medium and robotic hand. Also discussed are possible implementations of distributed manipulators made of reaction-diffusion chemical media and plasmodium of true slime mould.

The volume is not exhaustive but striking in variety and interest selection of works. The distribution of topics reflects current dynamics of pursuits at the edge of artificial life, robotics and computer sciences: interests are oscillating, focus is shifting, new sub-fields are emerging. The main goal of the book is not to feed readers with frozen knowledge of dead facts but, to tease them with new discoveries. The book is a good reading indeed at all level of technical expertise: students, scientists, engineers, academicians, laymen – everyone will find something appealing for themselves.

We have read all chapters with great pleasure, and hope you will do the same.

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Andrew Adamatzky
Maciej Komosinski

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