Artificial Life Models in Software

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Preface

Artificial life is an interdisciplinary field of science, hosting experts from computer science, biology, physics, chemistry, and mathematics, as well as philosophers and artists. It focuses on studying the phenomena of life on all levels of complexity and organization — molecular, cellular, organismic, and population. These studies not only employ conventional computers (using both software and hardware), but also take place in wetware, using techniques of biochemical laboratory. Artificial life research is not limited to life forms existing on the Earth. It rather attempts to study the general principles of life which are common to all instances of life, both already recognized and yet unknown.

This book is dedicated to the software medium, the most popular and widely employed in the artificial life research. The software medium offers almost unlimited abilities for experiments, which are cheap, easily arranged, and modified. Additionally, such experiments can be repeated under the same conditions, and large amounts of data (unavailable in biological studies) can be collected for analysis. To begin experimentation, a model of life is required. Such models are built in software for all organizational levels of life. Most of the models described in this book are very general and therefore allow for a wide range of experiments.

Researchers, academicians and students in artificial life use specialized software to verify their ideas related to evolution dynamics, self-organization, origins of life, multicellular development, natural and artificial morphogenesis, intelligent autonomous robotics, evolutionary robotics, evolvable hardware, emergent collective behaviors, swarm intelligence, evolution of communication and evolution of social behaviors. Artificial life software systems are also essential tools in practical demonstrations in undergraduate and postgraduate courses in adaptive systems, evolutionary biology, collective robotics, and nature-inspired computing.

This monograph provides an introduction and guidance in modern, attractive software tools for modeling and simulation of life-like phenomena. Software projects covered here are still actively developed and supported by

the developers, who create their programs with both professional and amateur users in mind. In most cases, the simulators are employed in research, and results are published. Each chapter describes a single — usually free-to-use — software model, but references to other similar software packages and related scientific works are included as well. The origins of software packages, milestones in their development, and the most important or interesting experiments are also reported.

Every chapter is self-consistent and can be read independently. The compendium of chapters is split into four parts. The first part — Virtual Living Worlds, focuses on individual creatures and their populations. It includes discussions of *Avida*: a digital laboratory for studying populations of evolving programs; *Framsticks*: a model of three-dimensional creatures, their simulation, evolution, and experimentation with would-be animals and prototypes of bio-inspired robots; *Nerve Garden*: an Internet-based virtual terrarium reminiscent of a simple ecosystem; *GenePool*: an interactive software for experimenting with aesthetics-based sexual selection and evolution of swimming organisms; and *Sodarace*: an online-based interface, learning support and environment for construction, experimenting and competition between virtual two-dimensional mobile robots.

Dynamics of collectives of simple locally interacting entities is dealt with in the second part — Collective Artificial Life. There, we find discussion of several unique software (and also hardware) platforms — *Repast*: an advanced agent-based simulation toolkit for studying development of natural and artificial social structures; *EINSTein*: a multiagent-based simulator of land combat modeling individual behaviors and personalities of combatants; *StarLogo*: an educational programming language for simulation of life-like phenomena — from population dynamics to emergent behavior of complex systems; and *Eden*: an interactive artwork, including hardware implementation of cellular automata and agents, allowing observers to interact with the installation and influence the development of the artificial ecosystem.

Already mentioned in previous chapters, cellular automata — arrays of locally interacting finite automata, which update their states depending on the states of their neighbors, get a proper treatment in the third part — Magic of Discrete Worlds. Two remarkable software tools for studies of discrete universes are introduced here. *MCell* is a powerful explorer of cellular automata, which supports almost all known nontrivial cellular automaton rules and has a regularly updated database of old and newly discovered patterns. *Discrete Dynamics Lab* (*DDLab*) is an interactive tool for designing and investigating dynamics of discrete dynamical networks, including simulation of decision networks, generating attraction basins, and searching for mobile patterns.

The book completes — the fourth part — Artificial Life Arts, with two chapters raising aesthetical issues of would-be worlds. The first chapter of this part reveals ways to breed images and sounds using *SBEAT* (for graphics) and *SBART* (for music). These computer programs are designed to select and breed genotypes that represent graphical and musical pieces. The last

chapter of the book searches for a phenomenological understanding of what makes artificial life appealing to scientists, artists and laymen, and why people become attracted to certain forms of creative computer art.

The Appendix contains a table that summarizes software systems described in this book. For each program, the table includes a short description, information about availability on various platforms and operating systems, software requirements, license type, and the Internet web site address.

The book covers hot topics related to computer science, evolutionary and computational biology, simulation, robotics, cognitive science, cybernetics, artificial intelligence, multiagent societies, virtual worlds, computer graphics and animation, neuroscience, and philosophy. We hope that academics, researchers, graduate students, and amateurs interested in these fields will find this monograph a valuable guide to artificial life and an excellent supplementary reading.

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April 2005 *Maciej Komosinski*

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