The Tool for Modeling of Evolution of the Artificial Life

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Abstract

Software simulator allowing experiments with the evolution of simple organisms.

Chapter 1

Introduction

Artificial Life, (commonly **Alife** or **alife**) is a field of study and art form that examines systems related to life, its processes and its evolution through simulations using computer models, robotics, and biochemistry (called "soft", "hard", and "wet" approaches respectively [1]).

Because of its predominance within the field, the term "Artificial Life" is often used to specifically refer to soft alife.

The term Artificial life was first coined by Christopher Langton in the late 1980s at the first "International Conference on the Synthesis and Simulation of Living Systems" (otherwise known as Artificial Life I) at the Los Alamos National Laboratory in 1987. He envisioned a study of life as it could be in any possible setting.

Artificial life studies "natural" life by attempting to recreate biological phenomena from scratch within non-living media like computers or RNA structures of molecules. Alife complements the traditional analytic approach of traditional biology with a synthetic approach in which, rather than studying biological phenomena by taking apart living organisms to see how they work, one attempts to put together systems that behave like living organisms.

The process of synthesis has been an extremely important tool in many disciplines. Synthetic chemistry - the ability to put together new chemical compounds not found in nature - has not only contributed enormously to our theoretical understanding of chemical phenomena, but has also allowed us to fabricate new materials and chemicals that are of great practical use for industry and technology.

Artificial life amounts to the practice of "synthetic biology" and, by analogy with synthetic chemistry, the attempt to recreate biological phenomena in alternative media will result in not only better theoretical understanding of the phenomena under study, but also in practical applications of biological principles in the technology of computer hardware and software.[2]

The seminal novelty of ALife lies in its synthetic approach. Whereas traditional research is essentially analytic, breaking down complex systems into basic components, Alife attempts to construct complex systems from elemental

units.[4]

For example, answering of questions like how the simple rules of Darwinian evolution lead to high-level structure, or the way in which the simple interactions between ants and their environment lead to complex trail-following behavior promises to provide novel solutions to complex real-world problems, such as disease prevention, stock-market prediction, and data-mining on the Internet.[3]

Artificial life can be split into various subfields according to chosen substrat of the system (digital, mechanical or test-tube) as well as according to aspect of natural life, that is in the focus of the research.

One of terms related to Artificial life is Evolutionary computation. It is a general term for several computational techniques which are based to some degree on the evolution of biological life in the natural world and simulated using computers. Evolutionary computation thus uses techniques of natural world and applies them using computers in other fields of interest. The most widely used form of evolutionary computation are Genetic Algorithms. Evolution techniques are often focused on evolution of motion, shape, visual art and music.

This thesis deals with digital substrate, so it is bounded within software approach to Artificial life. Because of the fact that Artificial life uses synthetic methods, the logical realization of software based Artificial life are software simulators that perform the construction of complex systems from elemental units.

Target of this thesis is to introduce a simulator named Abeetles, that mimics life of simple organisms and is concerned with evolution of deliberately chosen features and behavior. The system avails experiments with evolution of the organisms under different conditions. Furthemore, several experiments performed with the system are described and a few other proposed.

Chapter 2

Artificial life simulators and position of Abeetles among them

Software simulators of Artificial life can be ranked in many ways. This thesis will expand on three classification possibilities. First, cathegorisation according to the method of creature definition will be used. Second, simulators will be distinguished with respect to the feature or features of Artificial life, that they attempt to simulate. Third, the criterion of purpose of the simulator and target group of users will be used. Four section places Abeetles into thse classification systems and thereby specifies sphere of Artificial life that will be dealt in this thesis

2.1 Classification by creature definition

Individual agents are in existing systems modeled and constructed in many different ways. Most of them can be classified in the following way:

- **Program Based** - In program based simulators an individual is represented by a program, which substitutes biological DNA. Language of the program is usually Turing complete. Assembly derivatives are the most common languages used. Tom Ray's Tierra is the most famous example of a program based simulator.
- **Module Based** - An agent in a module based system is a composition of individual modules. These modules modify the creature's behaviors and characteristics either directly, by hard coding into the simulation (leg type A increases speed and metabolism), or indirectly, through the emergent interactions between a creature's modules (leg type A moves up and

down with a frequency of X, which interacts with other legs to create motion). Generally these are simulators which emphasize user creation and accessibility over mutation and evolution.

- **Parameter Based** - If an organism is generally constructed with defined and fixed behavior, that is controlled by various parameters that mutate, the system is referred as a parameter based. hat is, each organism contains a collection of numbers or other finite parameters. Each parameter controls one or several aspects of an organism in a well defined way.
- **Neural Network Based** - These simulations have creatures that learn and grow using neural networks or a close derivative. Emphasis is often, although not always, more on learning than on natural selection.

2.2 Classification by simulated phenomenon

Another grouping of simulators can be done according to phenomenon, that they try to simulate. `http://vlab.infotech.monash.edu.au/`

- **Networks** - Complex natural systems are simulated according to network theory (or diktyology) as networks or graphs and their statistical and topological properties are analyzed.
- **Nonlineal** - Nonlineal systems are systems that cannot be mathematically described as the sum of their components. While certain assumptions can be made for linear systems, that often make the mathematical modelling of such systems easy, mathematical modelling of nonlineal systems is often very difficult or impossible. As a result, nonlineal systems are often studies through use of simulations.
- **Swarms** - A swarm is a group of independent agents that gather together in order to collectively carry out a certain task. Typically, each agent exhibits a very simple behaviour pattern that is influenced by direct or indirect interactions with other swarm members. As a result, the swarm as a whole may exhibit complex and intelligent behaviour patterns. In nature, swarms can be observed in social insects, fish schools, but also in primitive single cell organisms.
- **Evolution** - Evolution is the process of development or grows by accumulation of small advantageous changes. The study of all forms of evolutionary processes is one of the primary goals of ALife. This includes the study of biological evolution of species as well as other evolutionary processes in natural, artificial and social systems.
- **Cellular Automata** - A cellular automaton (CA) is a discrete model that consists of a cell-grid, where each cell is in one of a number of well-defined states. The grid can be in any finite number of dimensions, though the mostly studied CAs have one or two dimensions. The time in the model

is discrete and the state of each cell C at time t depends only on the cell-states within some well-defined neighbourhood of C at time t-1. The update function (also called the update rule) is a table that defines the state for each cell at time t as a function of the state of the neighbourhood of C at time t-1.

2.3 Classification by purpose

Apparently, the main purpose of Artificial life simulators is to simulate artificial life. The target can be the complexity of simulation as well as the concentration on a small selection of its attributes. As the simulator is a software system, it is designed for a certain group of users and expected usage. And decision in this field influence interface, adjustability and output of the program. Also availability of the system is related to the purpose.

- **Games** Frequent purpose of simulators is entertainment, because game industry is constantly researching for new ideas to animate artificial characters. Simulators from this class are usually supplied with attractive user interface, but neither artificial life techniques and settings nor source corde are accessible to examination. The game Creatures is a well-known example of an artificial life computer program series, created in the mid-1990s by English computer scientist Steve Grand. The program is regarded as an important breakthrough in the advancement of artificial life research.

- **Scientific simulators** A simulator can be designed primarily for use as a platform in Artificial Life research. Such programs allow to perform experiments in certain subfields of Alife, e.g. evolutionary dynamics, theoretical biology etc. They are usually highly adjustable and configurable and afford opportunities to gather high-quality statistics. The grafical output is not expected to be the most important feature, in comparison with games. They are often open source. Tom Ray's system Tierra and Avida from Devolab are such simulations.

- **Simulators for teaching purposes** Efforts of creators of a simulator can be also concencentrated on an idea of demonstration of natural life processes using computer with the objective that through experimentation and interactive play users learn underlying patterns of life. Intriguing example is the simulator Mitozoos, where through mutation of spider-like agents can anybody explore relationship between genetic code and life.

- **Related systems** Many systems are closely related to Artificial life simulators, but they are not considered as Artificial life systems, because they only use techniques, that originate from Alife like genetic algorithms or ant colony optimization. Their purpose can be various. The primary difference lies in the fact that these simulators explicitly define the fitness of an agent by its ability to solve a problem, instead of its ability to find food, reproduce, or avoid death.

2.4 Classification of Abeetles

As far as definition of agents is concerned, target class of Abeetles are parameter based systems. Space of possibilities of Abeetles is bounded by finite number of parameters and Abeetles avails to explore what implies which setting of parameters in the world of this system.

In classification by simulated phenomenon Abeetles can be ranked among systems concerned with evolution. But the field of evolution is too wide and features that Abeetles examines will be described later.

The purpose of Abeetles is to be a prototype of scientific simulator. But not only for users from comunity of computer scientists, but also for those, who appreciate user friendly interface, even if it decreases performance of the system.