Framsticks: Towards a Simulation of a Nature-like World, Creatures and Evolution[1]

Maciej Komosinski and Szymon Ulatowski

Institute of Computing Science,
Poznan University of Technology
Piotrowo 3A, 60-965 Poznan, Poland

maciej.komosinski@cs.put.poznan.pl

http://www.frams.alife.pl/

Abstract. In this paper we describe our attempt to create a nature-like simulation model of artificial creatures. The model includes physical simulation of creatures, their interaction with the environment, their neural network control, and both directed and open-ended evolution. We describe a complex, three-dimensional simulation system, where various fitness criteria can be selected for evolving species, and a spontaneous evolution can be run. The work is still being developed, and we hope to make it a realistic model capable of producing real-life phenomena through an open-ended evolution in a life-like world of stick creatures.

1 Introduction

Artificial life research attempts to study real-life, biological organisms by creating and analyzing virtual creatures. Existing artificial life experiments seem to fall into two categories: the first is based on elegant, perfect, but often simple models. These are usually used for theoretical studies or to test some biological hypotheses – like those concerning coevolution in a pursuer-evader game [2], or evolution of spider nets and eyes [1]. Those in the second category use relatively sophisticated models, but the evolutionary mechanisms are not so much scientifically and biologically inspired. Instead, they focus on realistic simulation, graphics [7], or entertainment [6]. By encompassing the advantages of both approaches in **Framsticks,** we tried to fill the gap between advanced artificial life models with their consequences and advanced simulation tools with their realism. Here, the simulation model is reasonably biologically realistic, while the evolution model allows great possibilities for various experiments.

Our model encompasses a virtual, three-dimensional world and creatures (with their “bodies” and “brains”) that are capable of interacting with themselves (locating, pushing, hurting, killing, eating, etc.) and the environment (walking, swimming, etc.). The environment can be a composed of any combination of flat land, hills, and water. Evolution may be directed by the predefined criteria.

Although there have been many experiments so far, no attempt was made at spontaneous evolution using environments and creatures as complex as those in **Framsticks**. We hope that our model is complex enough to allow the emergence of

---

[1] Published in: Dario Floreano, Jean-Daniel Nicoud, Francesco Modada (Eds.), *Proceedings of 5th European Conference on Artificial Life*, 13-17 September 1999, Lausanne, Switzerland. Lecture Notes in Artificial Intelligence 1674, © Springer-Verlag. pp. 261-265.

sophisticated, life-like dependencies and phenomena, and simple enough to be simulated on existing computer systems.

The paper is organized as follows: section 2 describes the system architecture and models of evolution and simulation. In section 3 we focus on the evolutionary properties of our system, describing genotype representation, genetic operators like crossover and mutation, etc. In section 4 we briefly discuss the results of experiments performed so far, summarize the work and present our future goals.

2 Simulation model

2.1 System architecture

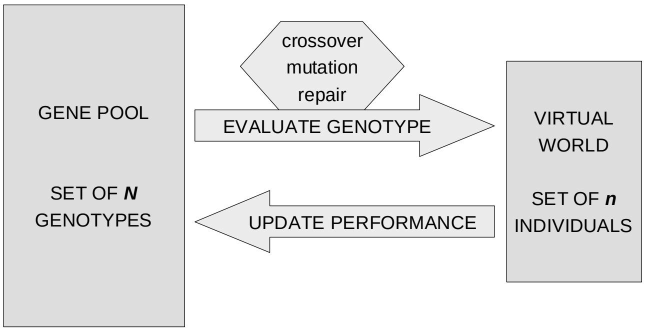
Our aim is to design the **Framsticks** model so that it allows for an open-ended evolution (including natural selection) of stick creatures, controlled by neural networks, in a three-dimensional world [4]. In the real world and some artificial life simulators (*Tierra*, *Avida*), the rules of selection and reproduction emerge from the simulated creatures' living conditions. In our simulator, these rules are already defined, as they are in other evolutionary models designed for optimization, such as genetic algorithms [3] and most of artificial life simulations [7]. Creatures in **Framsticks** are evolutionarily optimized according to some predefined criteria. However, it is possible to mimic an open-ended evolution with the "directed" model of evolution. This is the case when the chosen fitness criterion depends on the survival and reproduction abilities. Thus, an open-ended evolution can be simulated by using the life span selection criterion. The longer the creature lives, the better it reproduces in the environment, which is generally analogous to the real-world situation.

The main module of the simulator is the evolution simulator, which is responsible for maintaining the set of currently existing genotypes. This module must also obtain their multi-criteria evaluation in order to perform selection. All the individuals need not be simulated simultaneously: only a fraction of them are being evaluated in the virtual world at a time. The artificial world is thus a reduced model of the whole ecosystem. Such an approach is quite universal and has also the following advantages:

- a few individuals can be simulated much faster than a few thousand, so one can see the simulation in the real-time, study the behavior of creatures, and affect them,
- the only information needed to save/load the state of the evolutionary process is the performance of each genotype. The state of the virtual world is not saved.

In order to construct such an architecture (figure 1), two parameters are needed: a maximum number of genotypes, N, and a maximum number of individuals simultaneously simulated, n. Usually, n is significantly smaller than N. When the interaction between simulated creatures is not important, n may be set to 1. Larger values of n mean that a larger part of the whole set of individuals is simulated, and more interactions between creatures may happen.

Fig. 1.
The system architecture.

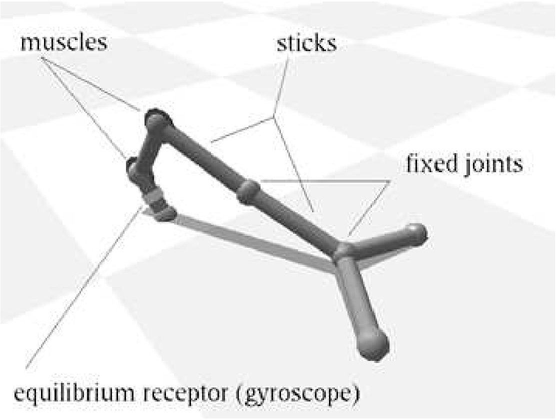


2.2 Physical simulation

The module used to evaluate individuals (genotypes) simulates the creatures and their environment. A three-dimensional simulator is used, in hope that a range of complex, various stimuli affecting organisms will be the origin of dynamic development. The first behaviors tested were the mechanisms of locomotion and orientation in an environment, so all the kinds of interaction between physical objects were considered: static and dynamic friction, damping, action and reaction forces, energy losses after deformations, gravitation, and uplift pressure – buoyancy (in water environment).

The basic element of the creatures is a stick (figure 2) made of two particles flexibly joined. Finite element method is used for simulation. Sticks can have various length, weight, strength, friction etc. Neurons (connected in any way) and receptors can also be placed on sticks.

Fig. 2.
A simple framstick creature.



Muscles (bending and rotating) are placed on stick junctions. The signal that controls a muscle changes the relative position of the adjacent sticks.

2.3 Neural network

Framsticks’ neurons are similar to those widely used in machine learning. Sophisticated and unnatural processing units (as in [7]) were not introduced; we proved that it is possible to construct complex modules (integrating, differentiating, summing, subtracting, and generators with different shapes) from simple neurons. Neuron properties can be additionally changed by three special parameters (all under control of evolution): *force*, *inertia* and *sigmoid*. These parameters modify the way neurons process signals. Details and sample neuronal runs can be found at [5].

An important aspect of the neural network is its interaction with the virtual world. Neurons can control muscles (*effectors*), and can obtain information from *receptors*. Currently, there are three kinds of *receptors*: those for orientation in space (equilibrium sense, gyroscope), detection of energy/food (smell) and detection of physical contact (touch).

3 Evolution

The genotypes used in **Framsticks** are described textually, so they can be easily read and modified by a human. Stick phenotypic properties are represented locally, but propagate through creature's structure with a decreasing power. The genotype describes precisely all the parts of the corresponding phenotype. Small changes in the genotype cause small changes in the resulting creature. Control elements (neurons, receptors) are associated with the element under their control (muscles, sticks). The current restriction is that only tree-like structures can be represented (no cyclical structures allowed).

Both physical structure (body) and neural network (brain) are described in the same genotype. The "body" is made of sticks, which have some properties: biological (muscle strength, stamina, assimilation, ingestion, initial energy level), physical (length, weight, friction) and concerning joints (rotation, twist, curvedness). The "brain" is made of neurons. The neural network can have any topology and complexity. An important property is that neural connections are described relatively. This lets sub-nets survive the crossover operation; the whole set of neurons can be moved to another place in the genotype (and in the creature), possibly with limbs, and can be still operational.

Two genetic operators were introduced: crossover and mutation. Mutation concerns many aspects of genotypic changes, each having adjustable relative probability. The crossover operator is a two-point one. A simple repair procedure is used, which can repair small errors and validate an invalid genotype.

In nature, groups of similar individuals share the same ecological niche and constitute species. In **Framsticks**, similarity to other coexisting species lowers the given species' fitness [3]. This introduces a pressure to diversify populations of species. The second mechanism which supports speciation is the specific crossover operation: the *corresponding parts* of genotypes of similar species are exchanged.

4 Conclusions and future work

The evolutionary experiments performed so far concerned mainly directed evolution, with fitness defined as speed (on the ground and in water). Many walking and swimming species evolved during these runs [5]. Usually, the first idea of "how to move" is a neuron connected recursively to itself, and controlling a bending muscle. Better methods of locomotion on the ground include chaotic pushing back, where the changing signals come from equilibrium sense or touch receptors. After further evolution the movement becomes more purposeful, and redundant parts are removed.

During the experiments, we had to modify simulation rules and fix bugs several times. Evolution turned out to be a very good method of searching the space of solutions (organisms), and was capable of finding fit individuals, regardless of their sensibility and validity. The faults in the simulator were sooner or later discovered by evolution, used in simulated organisms and exploited to the highest possible extent.

Currently, the genotypic representation seems to be the main limitation, because it does not allow for easy evolution of complex organism structures. Our future work will thus concern introducing a better representation: instead of coding the structure and neural network linearly, the genotype will describe a way of creating (growing) an organism. Such an approach will base more on the nature, and may make the search of the organism space even more effective.

Our future work will also concern defining a better similarity function, improvements of simulation rules and their parameters, and open-ended simulations. More receptors and more complex criteria for directed evolution may be introduced.

We hope that after further development of open-endedness in our three-dimensional simulation model, evolution will create organisms with more complex behaviors, and realistic, life-like phenomena will emerge.

Acknowledgements

This work has been supported from CRIT 2 – Esprit Project no. 20288.

References

1. Dawkins, R., *Climbing mount improbable,* W.W. Norton & Company, 1997.
2. Ficici, S. G., Pollack, J. B., Coevolving communicative behavior in a linear pursuer-evader game. In: *Proc. Fifth International Conference of the Society for Adaptive Behavior*, Pfeifer, Blumberg, Kobayashi (eds.), Cambridge: MIT Press, 1998.
3. Goldberg, D. E.: *Genetic Algorithms in Search, Optimization, and Machine Learning,* Addison-Wesley Publishing Co., 1989.
4. Komosinski, M., Ulatowski, Sz., Framsticks – Artificial Life. In: C. Nédellec, C. Rouveirol (eds.), *ECML '98 Demonstration and Poster Papers,* Chemnitzer Informatik-Berichte, Chemnitz, 1998, 7-9.
5. Komosinski, M., Ulatowski, Sz., **Framsticks** Internet site, http://www.frams.alife.pl/
6. Maes, P., Artificial Life meets Entertainment: Interacting with Lifelike Autonomous Agents. In: *Special Issue on New Horizons of Commercial and Industrial AI* **38**, 11 (1995) 108-114, Communications of the ACM, ACM Press.
7. Sims, K., Evolving 3D Morphology and Behavior by Competition. In: R. Brooks, P. Maes (eds.), *Artificial Life IV Proceedings,* MIT Press, 1994, 28-39.