Learning Goals

- understand some basic goals and concepts in artificial life (AL)
- become familiar with a simple example for an AL system: Langton’s ant
- get acquainted with the concept of emergent behaviour
- encounter the idea of a universal models of computation

What is Artificial Life?

Fundamental goal of biology: understand life!

What is life?
- growth through metabolism
- ability to reproduce
- internal regulation in response to the environment

Can we build artificial systems that have these properties?
*Note: This is different from building artificial intelligence!*

Artificial Life: Research area that is concerned with
- the simulation of life
- the realisation of life

in some artificial environment, usually the computer.

Goals in artificial life research:
- build machines (or computer programs) that exhibit life-like behaviour, such as growth, replication, communication, . . .
- identify (simple) formal principles underlying all life-like behaviour

Fundamental assumption:
“Life [is] a property of the organisation of matter, rather than a property of the matter which is so organised.” (Chris Langton)

A Simple Example: Langton’s Ant

- The ‘ant’ lives on an infinitely large, 2-dimensional grid.
- Each square in the grid can be black or white; you can think of these cells as pixels on a black-and-white display.
- At the beginning, all squares are white and the ant sits on one of them, e.g., in the middle, and faces in one of the four main directions, e.g., right.
- In each step, the ant follows these rules:
  1. If the ant is on a black square, it paints the square white, turns right 90 degrees and moves forward one square.
  2. If the ant is on a white square, it paints the square black, turns left 90 degrees and moves forward one square.
Langton’s ant . . .

- was invented by computer scientist Christopher Langton, one of the founders of the field of artificial life, in the 1980s.
- is one of the simplest and most widely known artificial life systems.
- despite its simplicity, shows surprisingly complex behaviour.

Emergent behaviour of Langton’s ant:

- For a long time, the pattern generated by the ant is complex and apparently random.
- After about 10 000 steps, the ant starts building an extremely regular structure: a diagonal ‘road’ consisting of a modules of 104 steps that are repeated indefinitely!
- The road building behaviour results from the interaction of the ants localised actions (defined by the rules) with its environment (the squares on the grid).

Some generalisations:

- Looking at the simple rules governing the ant’s behaviour, the road building behaviour is unexpected.
- Such unexpected, complex behaviour of a simple system is also called emergent behaviour.
- We have seen other examples of emergent behaviour when we looked at the simple rules we used for creating self-similar images of plants.

Related systems:

- Langton’s ant is closely related to a simple and well-known formal model of computation called a Turing machine.
  - Turing machines are universal models of computation, i.e., they can simulate any real computer and run any given algorithm.
  - Because Turing machines are much simpler to analyse than real computers, they are often used in theoretical computing science, e.g., in the analysis of the hardness of computational problems.
- Langton’s ant can also be seen as a special case of a type of formal system called a cellular automaton.
  - Like Turing machines, cellular automata are a universal model of computation.
  - As seen in the case of Langton’s ant, cellular automata often achieve surprisingly complex behaviour on the basis of very simple rules.
  - Cellular automata like Langton’s ant play an important role in the study of complex systems, emergent behaviour and artificial life.
Food for Thought:

- Can you think of other examples of systems that show emergent behaviour?
- What would we learn if we could build AL systems that accurately simulate interesting behaviour of biological systems?
- Could the universe be based on simple rules, not unlike Langton's ant?
- What is the difference between real life and a simulation?
- Could it be that we live inside a simulation and simply don’t know it?
- What is the Matrix? Would you take the red pill or the blue pill?

Resources

- Generation5 JDK Demonstrations (including Langton’s ant and slime mold simulation): http://generation5.org/jdk/demos.asp
- Luis Rocha’s course on Evolutionary Systems and Artificial Life: http://informatics.indiana.edu/rocha/alife.html
- Frequently asked questions from comp.ai.alife: http://www.faqs.org/faqs/ai-faq/alife/
- A nice collection of AL links: http://felix.unife.it/++/ma-bio-alife