NOVA IMS
Information Management School

AI

Artificial Intelligence

5 - Evolutionary computing - Alife

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Syllabus

1 – Overview and brief history of AI

- AI and Philosophy
- Historical Overview of AI and applications
- Paradigms and approaches

2 - Knowledge Representation and Reasoning

- Software Agents (Cognitive Agents v. Reactive Agents, BDI model,…)
- Propositional Logic
- First Order Logic
- Logic Programming
- An Introduction to Prolog

3 - Problem Solving

- Agents and search problems
- Blind search (*breadth-first, uniform cost, depth-first, bidirectional, …)*
- Heuristic search (informed) (A*, iterative deepening A* (IDA*), Tabu, SMA*, …)
- Local search and optimization problems (*(hill climbing, simulated annealing)*
- Problems of Constraint Satisfaction
- Search with opponents (Games)

4 - Machine Learning

- Apprentice agents. Approaches to the problem of learning
- Conceptual and inductive learning
- Case Based Reasoning

Syllabus

- Artificial Neural Networks
  - Neurobiology fundamentals
  - McCulloch & Pitts' Neuron
  - Hebb's Law
  - Simple Pattern Recognition Networks: Perceptron, Adaline (hints to non-linearly separable problems and multi-layer neural nets);
  - Pattern Associations (Hetero-Associative, Self-associative, Bidirectional (BAM))
  - Unsupervised Competition-based networks (Maxnet, Mexican Hat, Hamming Net, SOM)
  - Unsupervised Competition-based networks part 2 (ART1 and ART2)
  - Supervised Competition-based networks (LVQ, Counterpropagation)
  - Multilayered artificial neural network (Backpropagation, Neocognitron)
  - Deep Learning Introduction (CNN, GAN, …)

Fundamental Bibliography

5 - Evolutionary computing

- An introduction to Genetic Algorithms
- Artificial Life
- Artificial Immune Systems - AIS

6. Distributed AI

- Software Agent Societies
- Social Reasoning / Social Laws
- Strategies and approaches

7. Future of Artificial Intelligence and social/philosophical impacts

Artificial Life - What is ?

The study of artificial life (a-life) deals with the creation and evolution of organisms and systems similar to living systems.

The matter of which artificial life is produced is inorganic and its essence is information.

⇨Computers are test tubes in which new organisms are produced..

Artificial Life - Types

- Weak - Consists of simulating behaviors and types of life that exist in nature or different from everything we know (level of resemblance to real life variable)

- Strong - Consists of the long-term development of living organisms whose essence is information. (eg, live artificial robots or creatures that live inside computers)

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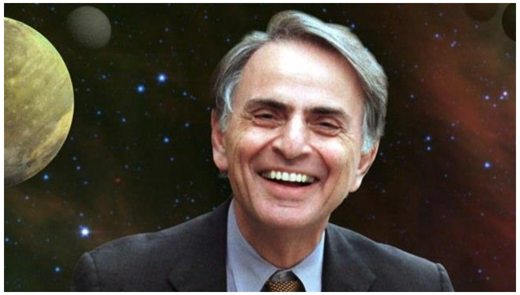
What means to be alive?

" … life is necessarily based on the chemistry of the carbon compounds and should work in an aqueous medium … " Gerald Feinberg (physicist) e Robert Shapiro (biologist)

"… there is no definition of life accepted by most people …" Carl Sagan (physicist)

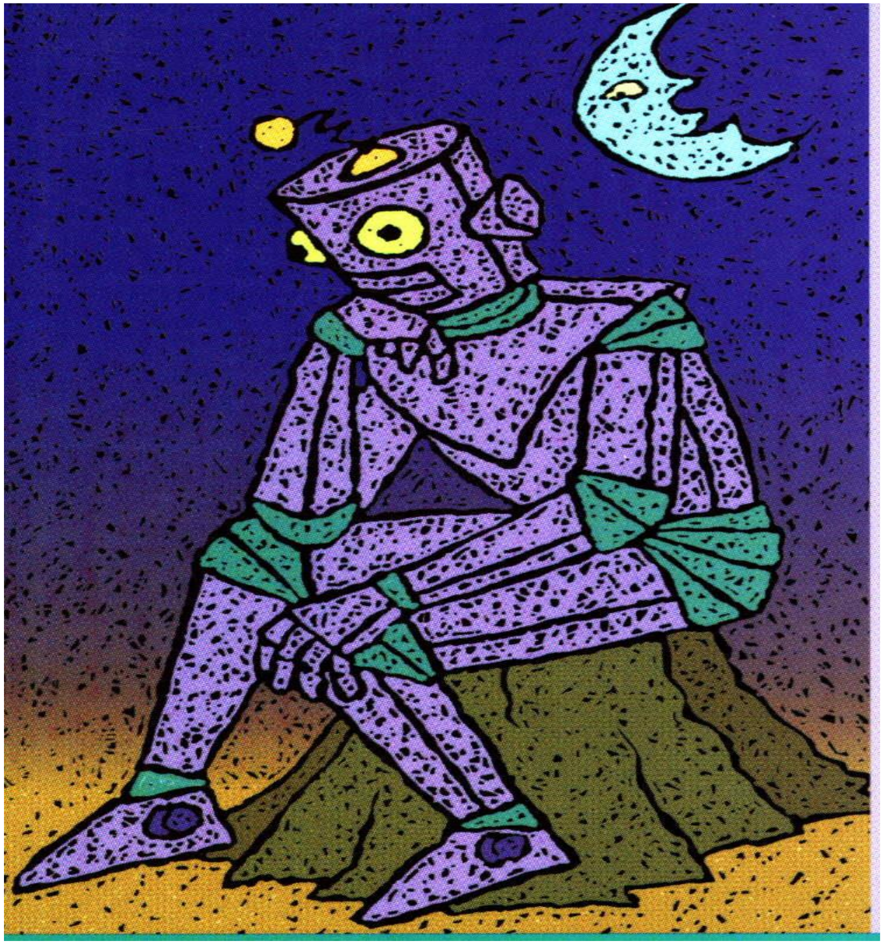


What means to be alive?

"… I doubt that it is possible to answer such questions in the philosophical field ... "Elliott Sober (philosopher)

"… If scientists intend to develop a broad theory of life, it will require them to accept radically inorganic things as being alive ... "Christopher Langton (organizer of the first conference on artificial life)

What means to be alive?

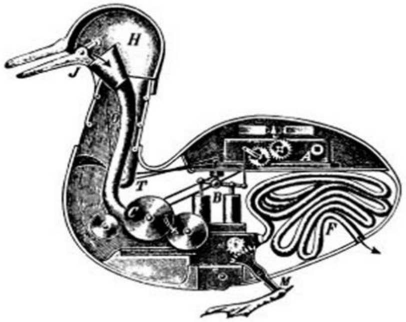


What it means to be alive?

The things we now consider to be alive are probably a subset of a broader class of organisms.

Artificial Life - Premonitions

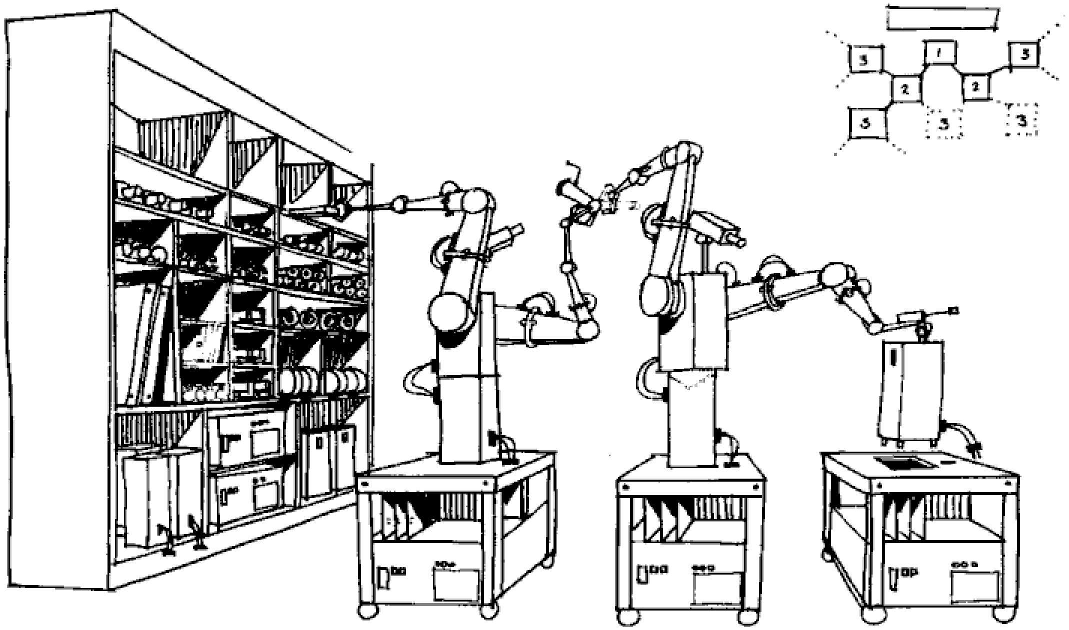
- Decartes - “.. animals are a class of automatons …”

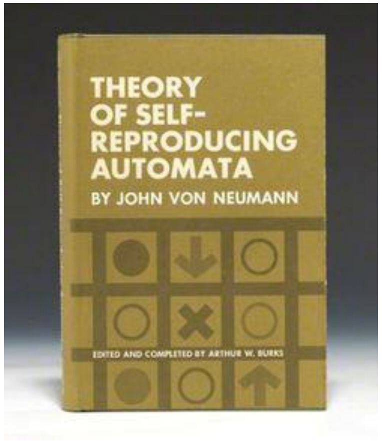


- Mary Shelley - monster invented in her famous novel “Frankenstein”

Artificial Life - Premonitions

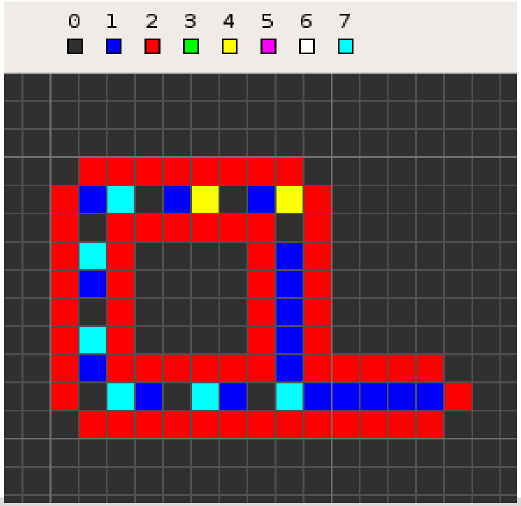
- John Von Neuman - self-reproducing machines (father of the concept of Artificial Life)



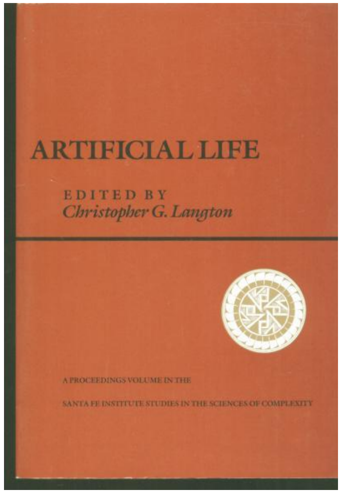


Artificial Life - Premonitions

- Christopher Langton - self-reproducing rings (if Von Neumann is considered to be the father of Artificial Life then Langton is at least the midwife !! - established Artificial Life as a new scientific domain)



Artificial Life - Birth



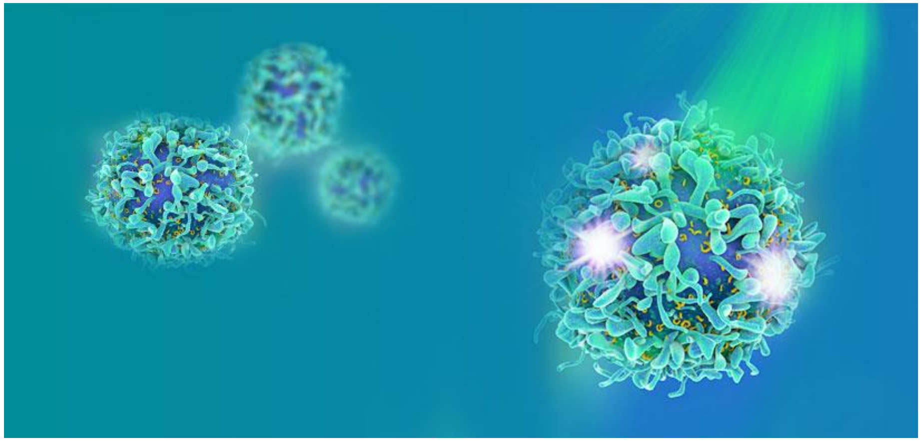
"Inter-disciplinary Workshop on the Synthesis and Simulation of Living Systems"

- September 1987 - Los Alamos - 1st Conference on Artificial Life of History
- It was organized by Christopher Langton
- It became known to history by Alife I
- "Magical" event where the scientific area of the Artificial Life was for the first time assumed

Artificial Life - What's the use?

- To build fully autonomous intelligent agents

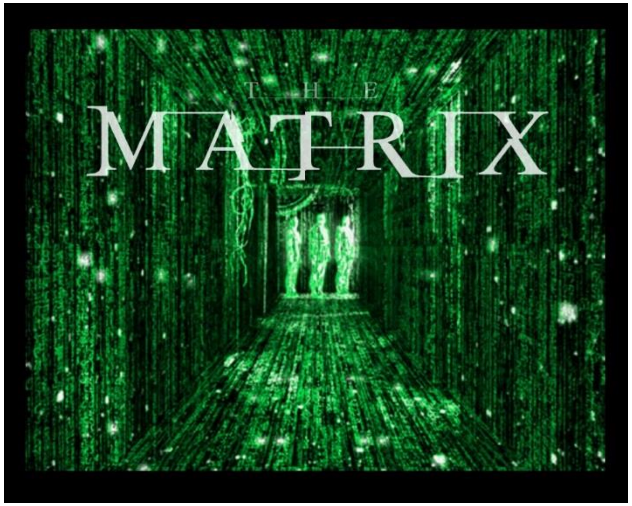
- To help understand the biology of living beings (simulating nature) - Only the simplest genetic systems can be solved analytically, and the evolutionary experiences in the laboratory are limited to a few generations being difficult to control and repeat !!!



Artificial Life - What's the use?

- To create new life forms: Artificial Faunas, Artificial Floras => Artificial Ecologies
- To better understand nature "the heart of God" ?????
- **THE GREAT PROGRAMMER ?????**





Example: AntFarm (Robert J. Collins, David R. Jefferson)

Objectives:

- To simulate the behavior of ants in the research of food and its loading to the nest, observing the emergence of coordination and cooperation among the ants.

Artificial Life - How to Build?

- To investigate the complex behaviors in complex environments, the evolution of the cooperation between different individuals and the evolution of the chemical communication (pheromone).

Key features of the example model:

- Several colonies of ants
  - Each colony consists of a small number of genetically identical individuals
- Each individual has the possibility to live and reproduce in the environment, to use sensors (external and internal) and to execute different Actions in each moment.

Artificial Life - How to Build?

- The behavior of each individual is determined by an ANN (artificial neural network)

- Each ant has the ability to detect and carry food as well as detect and drop pheromone (the chemical used by ants for communication)

- Each genotype represents the synaptic connections and ANN weights of the individual

Artificial Life - How to Build?

- Reproduction is done through the use of a genetic algorithm
- Cost associated with food demand
- Reward associated with bringing food to the nest

AntFarm - Operation

- The evolution in AntFarm is done in terms colony (super-organism) and not by individual ants.
- All ants in a colony contribute to the score.
- Each colony has a single genotype that encodes the Actions of all its ants

Artificial Life - How to Build?

- Although all elements of a colony are genetically the same, each ant receives different information on the sensors and therefore behaves differently.
- The score/suitability (fitness) function is based on the number of pieces of food loaded into the nest.
- The initial population is generated randomly
- Number of colonies: 16 384

Artificial Life - How to Build?

- Number of ants per colony: 128
- Distance between colonies: 16
- The pheromone that is left by the ants slowly decreases in quantity and may even disappear
- The nest is always placed in the center of the colony area (16 X 16)

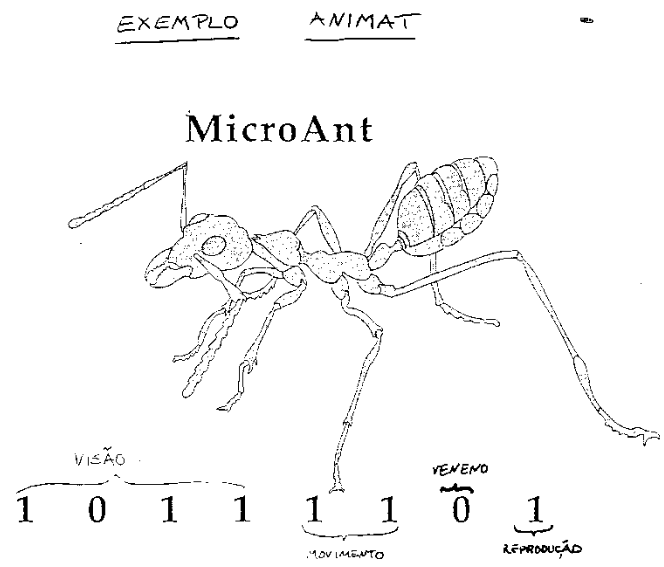
Artificial Life - How to Build?

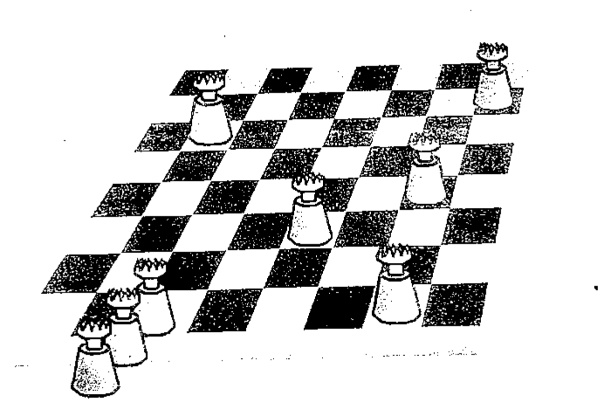
- The genetic information of each colony is represented by a chromosome of 25 590 bits
- All ants live to the end of their generation
- Each unit of food lost costs 1000 points
- Each pheromone unit droped costs 0.1 points

Artificial Life - How to Build?

- All other actions (move, grab, drop) cost 0.1 points

- In every 100 units of time the input sensors and the 21 bits of internal memory are processed by the behavior function (ANN) and actions are produced.





Other features:

- The global network consists of 64 neurons and 1709 connections

- Because the weights of each connection are encoded in 3 bits and the source / destination of each connection is encoded with 6 bits, then the network is specified with a 25 590 bit genome.

Objective (example):

Investigate complex behaviors in complex environments - the evolution of cooperation between different individuals.

To outline the main contours to construct an artificial life simulation environment from which we can get some conjectures about the ecosystem and about the desirable characteristics for the survival of species X

Artificial Life - How to Build?

Example (Artificial Ecosystem):

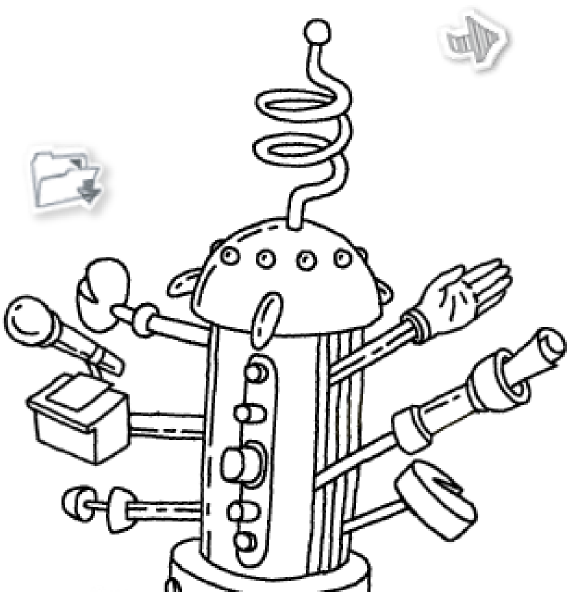
To design a system capable of helping to investigate the importance of the size of the wings and the intelligence of a given type of species of birds (type X) to escape to their predators (another species of birds - type Y).

Consider that in this environment there are 4 nests where the birds (type X) are protected from their predators but where they can not find food (the food is always outside the nests randomly distributed.

Artificial Life - How to Build?

- 2D ecosystem (200x200)
- Y moves randomly and "swallows" X if he is at its "reach"
- X has Myopic Vision
- X has the following moves (FE, F, FD, Back, Stop)
- The initial population X, number n, is randomly generated
- Energy cost associated with food demand and reproduction
- Reward associated with food intake

Construction of Artificial Ecosystems”



Artificial Life - How to Build? - 1st sketch

Environment (200 x 200)

	N					N	
	N					N	

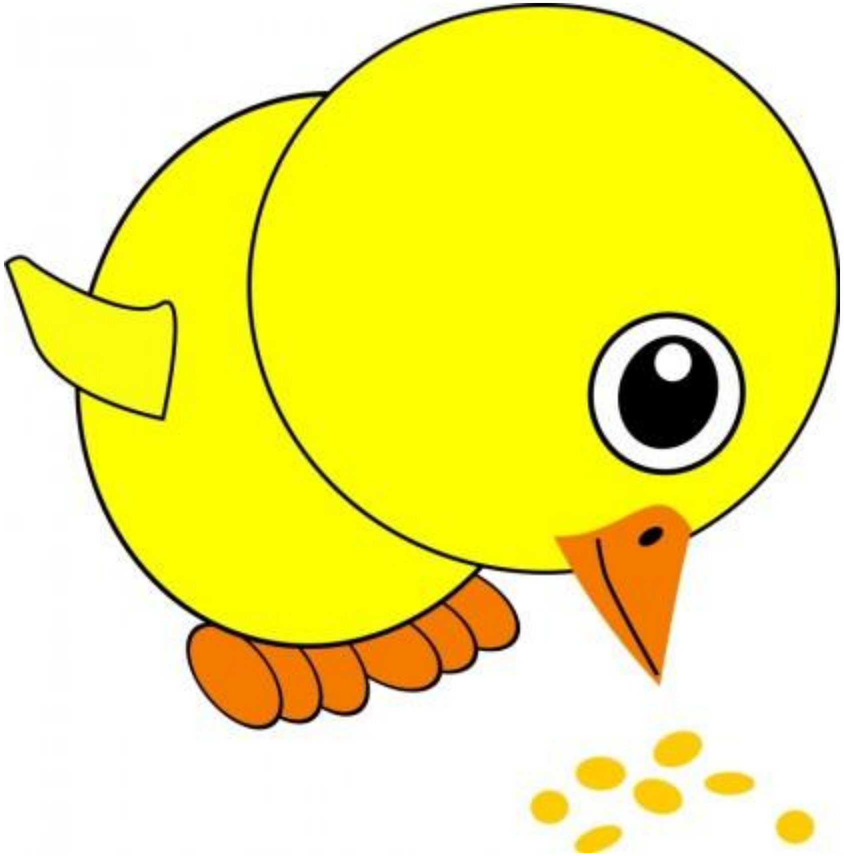
Myopic Vision

	x1
P	x2
	x3

Actions

FL, F, FR, B, Stop

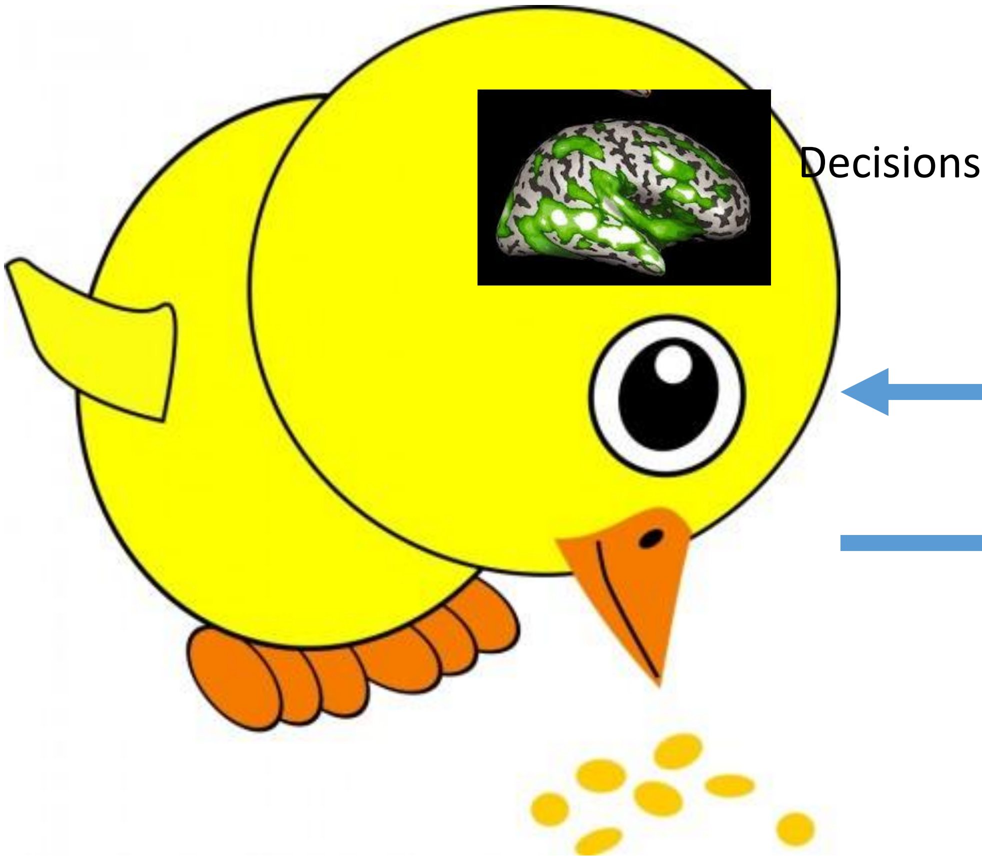
Artificial Life - How to Build? - 1st sketch

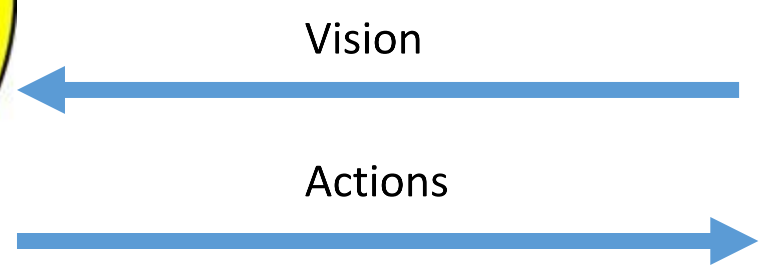


Each individual (X) has the possibility to live and reproduce in the environment, to use sensors and to take different actions in each moment.

Artificial Life - How to Build? - 1st sketch

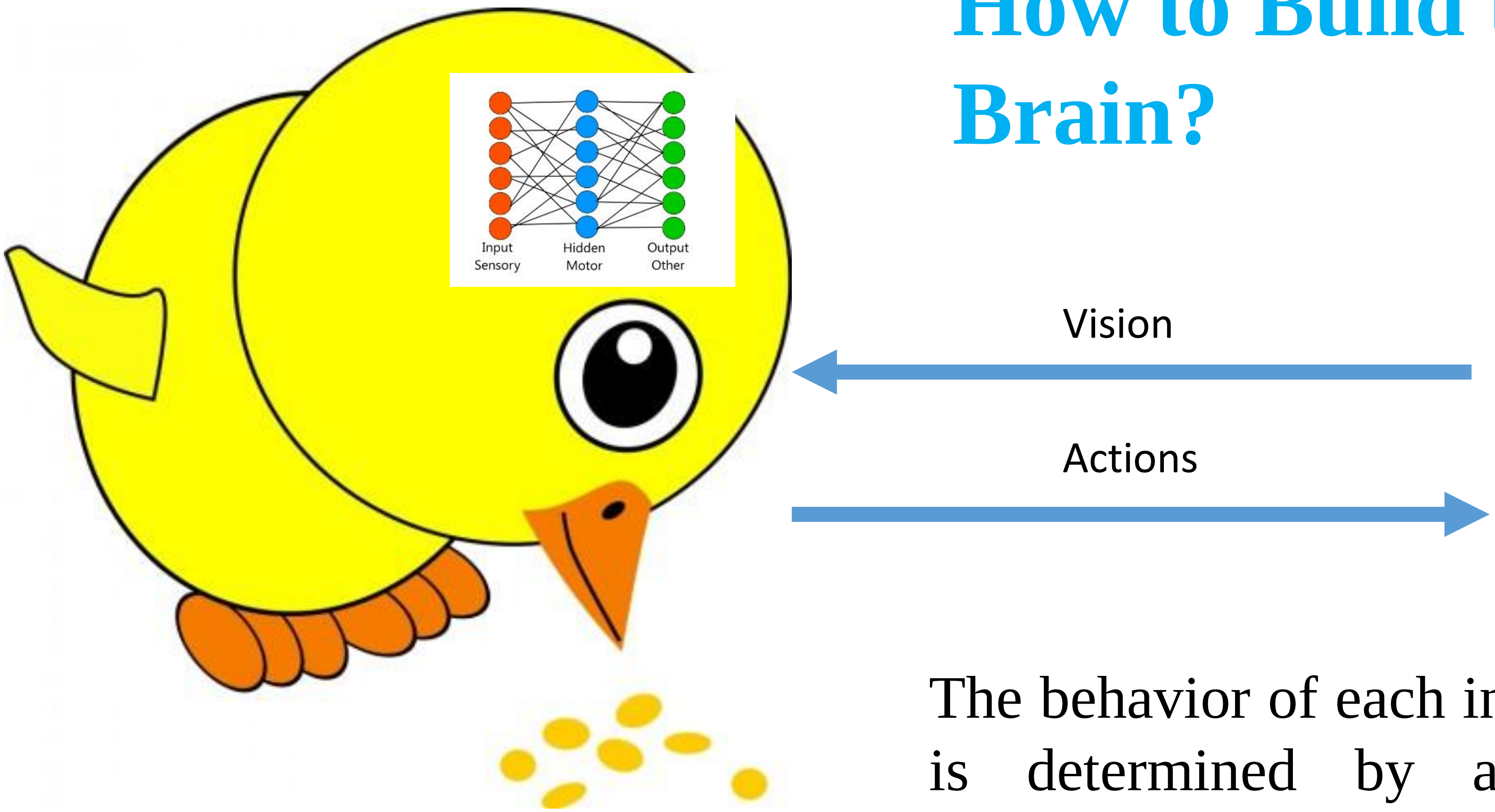
I need a brain to make decisions!





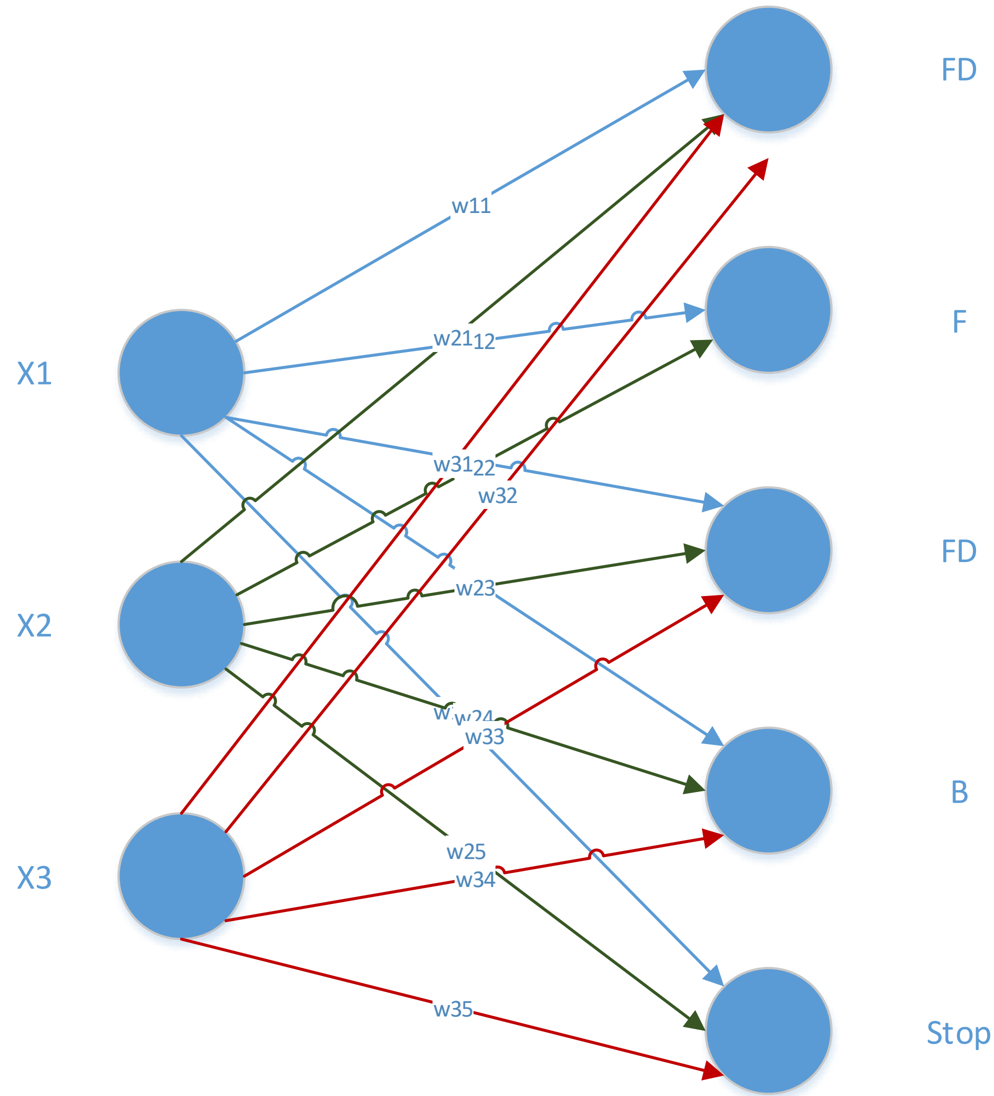
Artificial Life - How to Build? - 1st sketch

How to Build the Brain?



The behavior of each individual is determined by a neural network (ANN) or alternatively by a state machine (ASM)

a brain...

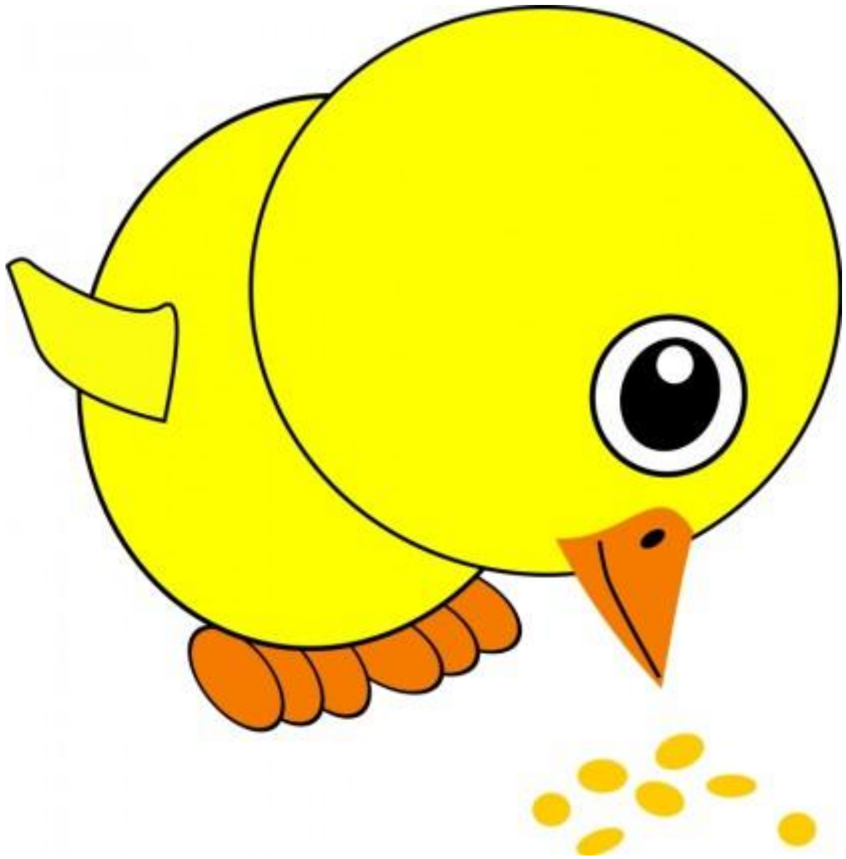


	x1
P	x2
	x3

Actions

FL, F, FR, B, Stop

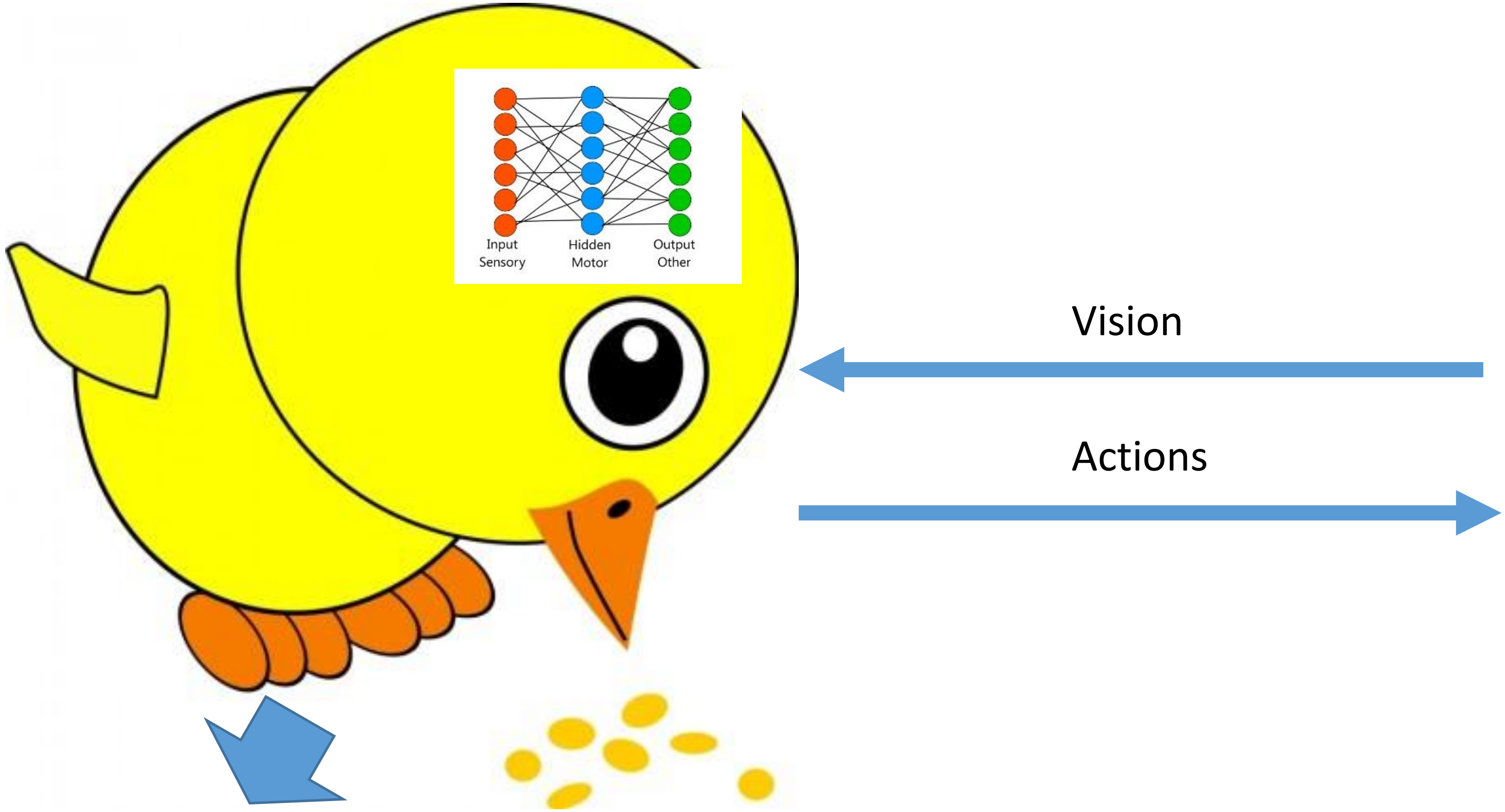
How to make the species reproduce and evolve?



Key features of the example:

Each individual (X) has the possibility to live and reproduce in the environment, to use sensors and to take different actions in each moment.

How to make the species reproduce and evolve?

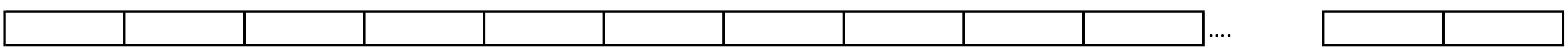


Reproduction is done through the use of genetic algorithms

Artificial Life - How to Build? - 2^{nd} sketch

Each genotype represents synaptic connections and ANN weights

It is necessary to code the origin, end and weight of each neuronal connection



Reproduction of the brains of individuals is performed using a **Genetic Algorithm**.

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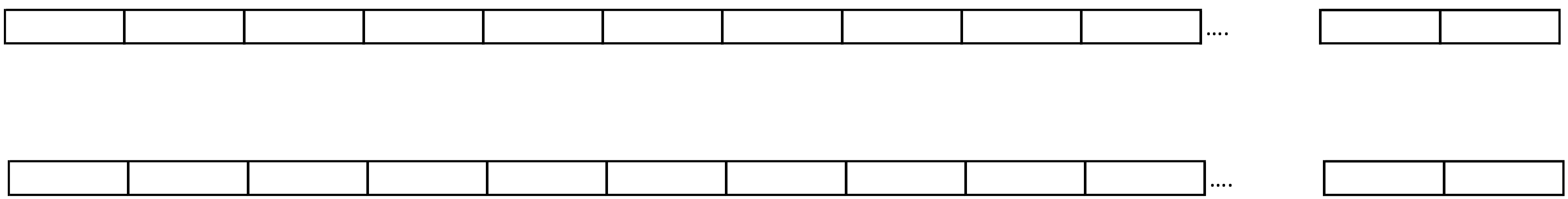
Artificial Life - How to Build? - 2nd sketch



ANN – The crossover reproduction process is complex - it depends on the type of neural network

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Exercise 1 -> **The chicken run**

- Design a system that can help investigate the importance of beak size and intelligence of a given type of chickens (type G) to feed on maize grains peck at their fox predators (type R).
- Outline the main contours to build an artificial life simulation environment from which to draw some conjecture about the ecosystem and the desirable survival characteristics of species G.
- Each time a type G chicken moves it loses energy and each time it eats it gains. When the energy reaches a zero value the chicken dies. The bigger is the beak, more food G can eats at a time (more energy). Unfortunately, type G chickens have a stomach problem and if they eat more than a certain limit they die of excess energy.
- Type R Foxes moves randomly.

Outline the main contours to build an artificial life simulation environment from which to draw some conjecture about the ecosystem and the desirable survival characteristics of species G by describing:

1. the main contours of this world (in 2 D)
2. the chicken brain (type G) using a neuronal network.
3. a Darwinian mechanism of evolution of chicken species (type G)

Exercise 2 -> **Rambix**

- Rambix is a reactive being who lives in an infinite 2D world. It shares the world with other beings of the same kind. Each Rambix has a force that translates its energy at any given time. Its field of perception is formed by the 8 immediately adjacent cells. It can detect free cells, with food or with other Rambixs. Its actions are of four types: move, eat, attack and escape. The movements are for North, East, South and West only.
- The behavior of an intelligent Rambix could be: It eats when it finds isolated food; attacks when he finds another weaker agent alone; flees when in his vicinity detects more than one Rambix. Eating increases his energy by **x** units. Attacking increases energy by **n / 2 units**, with **n** being Rambix's energy attacked. The victim always dies. All movements cost one unit of energy. If energy falls below a given threshold **y**, he dies!(and is replaced with a new that results for gene recombination of the two existent stronger Rambixs.

Outline the main contours to build an artificial life simulation environment from which to draw some conjecture about the ecosystem and the desirable survival characteristics of species Rambix by describing:

1. the main contours of this world (in 2 D)
2. the Rambix brain using a neuronal network.
3. a Darwinian mechanism of evolution of Rambix

Practical work - ALife

- Practical work 9 ALife ->
- Please check the published document in Moodle.

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