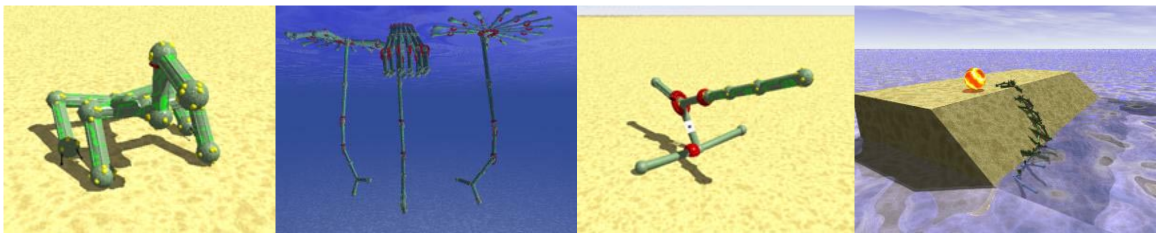


Introduction to

FRAMSTICKS

Simplified manual to start evolve your own creature

By Francesco Mondada,
with parts from the official FRAMSTICKS WEB site
made for the course “Bio-inspired adaptive machines” of Prof. Dario Floreano

LSA-EPFL, Switzerland (http://lsa.epfl.ch)

Homepage of framsticks: http://www.frams.poznan.pl/

Content:

1. About this manual

The goal of this manual is to give a **very short** introduction to framsticks, version 2.
To read this manual you should have an very basic idea about:

- Running a windows program
- How genetic algorithms work (very basic concept)
- How a neural network works (very basic concept)

2. Evolutionary process

The evolution procedure implemented in framsticks follows the scheme presented in figure 1.

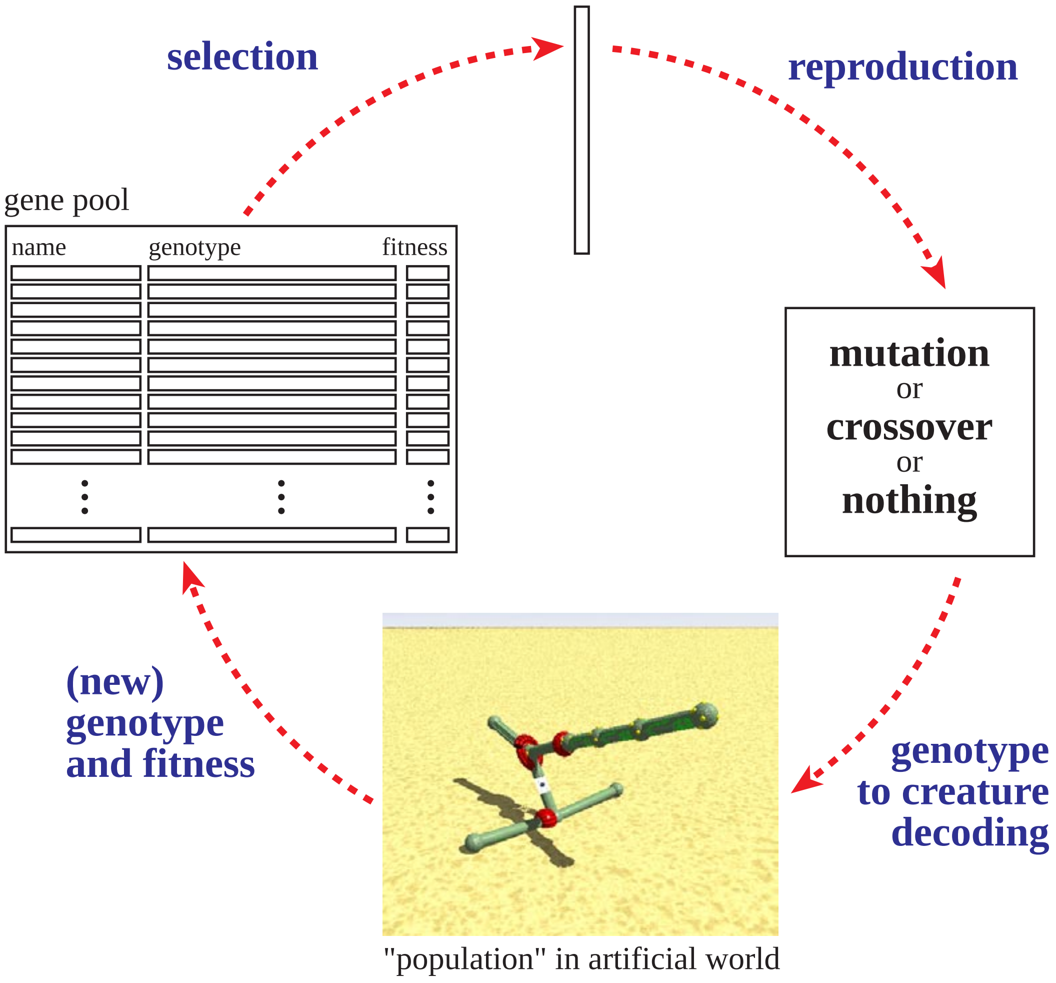

selection
reproduction
gene pool
name
genotype
fitness
mutation
or
crossover
or
nothing
(new) genotype and fitness
genotype to creature decoding
"population" in artificial world

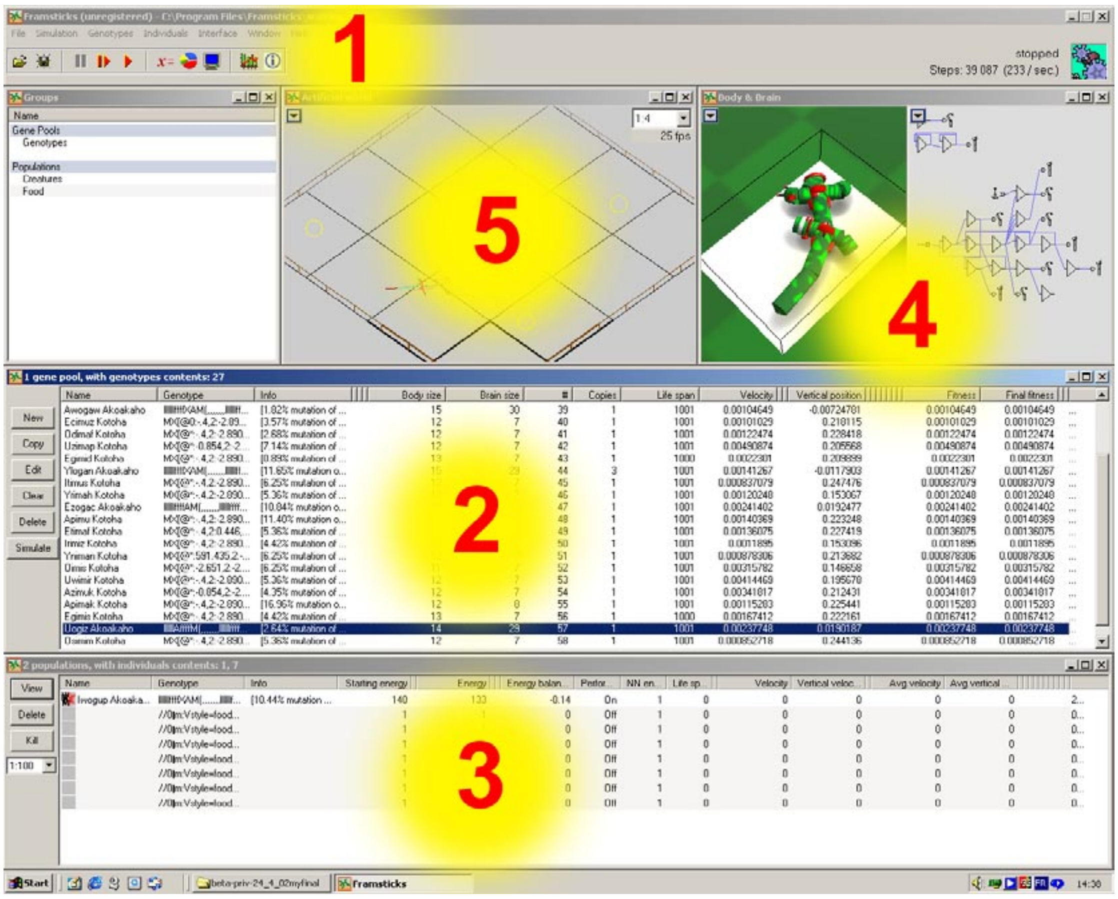
Figure 1: Implementation of the evolutionary process in framstick.

The evolutionary process of framstick has the following major elements:

- **Gene pool:** This is a large (typically >100) number of genotypes and their associated fitness. Each genotype has a name, generated automatically or manually.
- **Selection:** Genotypes are selected in the gene pool to be processed and tested. The selection mechanism can be defined by the user, choosing between random, fitness-proportional (roulette) or tournament (between 2,3,4 or 5 genotypes). All mechanisms (excepted random) are based on the fitness stored previously in the gene pool.
- **Genetic operators:** Framsticks applies randomly **one** genetic operator on the selected genotype(s). Probabilities can be set to define how many genotypes will be muted, crossed over or keeped unchanged.

- **Artificial world simulation:** The resulting genotype is then translated into a creature and placed in the artificial world. Several creatures can be tested at the same time (this group of creatures is called “population” in framsticks). During the life of the creature, several parameters are measured, such as velocity, vertical position, etc. The user can define the fitness by setting the weight of these parameters in the fitness function. As soon as the creature dies, the fitness is saved. If the genotype of the creature exist already in the gene pool, its fitness is updated using the new result of the simulation. If the creature is a new one, genotype and fitness are introduced in a new line of the gene pool. If the size limit of the gene pool is reached, a genotype is deleted using a mechanism defined by the user (randomly, inv-proportional to the fitness or only the worst). As soon as a creature dies, a new one is introduced in the artificial word.

3. User interface



Framsticks (unregistered) - C:\Program Files\Framsticks\...
File Simulation Genotypes Individuals Interface Window Help
stopped
Steps: 39 087 (233 / sec.)
1
Groups
Name
Gene Pools
Genotypes
Populations
Creatures
Food
Artificial world
1:4
25 fps
5
Body & Brain
4
2
3

1 gene pool, with genotypes contents: 27

Name	Genotype	Info	Body size	Brain size	#	Copies	Life span	Velocity	Vertical position	Fitness	Final fitness
Awogaw Akoakaho	IIIIffXAM[,,,,,,IIIIf...	[1.82% mutation of ...	15	30	39	1	1001	0.00104649	-0.00724781	0.00104649	0.00104649
Ecimuz Kotoha	MX[@0:-4,2:-2.89...	[3.57% mutation of ...	12	7	40	1	1001	0.00101029	0.210115	0.00101029	0.00101029
Odimaf Kotoha	MX[@*:-4,2:-2.890...	[2.68% mutation of ...	12	7	41	1	1001	0.00122474	0.228418	0.00122474	0.00122474
Uzimap Kotoha	MX[@*:-0.854,2:-2...	[7.14% mutation of ...	12	7	42	1	1001	0.00490874	0.205568	0.00490874	0.00490874
Egimid Kotoha	MX[@*:-4,2:-2.890...	[0.89% mutation of ...	13	7	43	1	1000	0.0022301	0.209899	0.0022301	0.0022301
Ylogan Akoakaho	IIIIffXAM[,,,,,,IIIII...	[11.65% mutation o...	15	29	44	3	1001	0.00141267	-0.0117903	0.00141267	0.00141267
Ilimus Kotoha	MX[@*:-4,2:-2.890...	[6.25% mutation of ...	[illegible]	7	45	1	1001	0.000837079	0.247476	0.000837079	0.000837079
Yrimah Kotoha	MX[@*:-4,2:-2.090...	[5.36% mutation of ...	[illegible]	[illegible]	46	1	1001	0.00120240	0.153067	0.00120240	0.00120240
Ezogac Akoakaho	IIIIffAM[,,,,,,IIIIfff...	[10.84% mutation o...	[illegible]	[illegible]	47	1	1001	0.00241402	0.0192477	0.00241402	0.00241402
Apimu Kotoha	MX[@*:-4,2:-2.890...	[11.40% mutation o...	[illegible]	[illegible]	48	1	1001	0.00140369	0.223248	0.00140369	0.00140369
Etimal Kotoha	MX[@*:-4,2:0.446,...	[5.36% mutation of ...	[illegible]	[illegible]	49	1	1001	0.00136075	0.227419	0.00136075	0.00136075
Irimiz Kotoha	MX[@*:-4,2:-2.890...	[4.42% mutation of ...	[illegible]	[illegible]	50	1	1001	0.0011895	0.153096	0.0011895	0.0011895
Yriman Kotoha	MX[@*:591.435,2:-...	[6.25% mutation of ...	[illegible]	[illegible]	51	1	1001	0.000878306	0.213682	0.000878306	0.000878306
Oimis Kotoha	MX[@*:-2.651,2:-2....	[6.25% mutation of ...	11	7	52	1	1001	0.00315782	0.146658	0.00315782	0.00315782
Uwimir Kotoha	MX[@*:-4,2:-2.090...	[5.36% mutation of ...	12	7	53	1	1001	0.00414469	0.195670	0.00414469	0.00414469
Azimuk Kotoha	MX[@*:-0.854,2:-2....	[4.35% mutation of ...	12	7	54	1	1001	0.00341017	0.212431	0.00341017	0.00341017
Apimak Kotoha	MX[@*:-4,2:-2.090...	[16.96% mutation o...	12	8	55	1	1001	0.00115283	0.225441	0.00115283	0.00115283
Egimis Kotoha	MX[@*:-4,2:-2.890...	[4.42% mutation of ...	13	7	56	1	1000	0.00167412	0.222161	0.00167412	0.00167412
Uogiz Akoakaho	IIAfffM[,,,,,,IIIIfff...	[2.64% mutation of ...	14	29	57	1	1001	0.00237748	0.0190187	0.00237748	0.00237748
Oamim Kotoha	MX[@*:-4,2:-2.890...	[5.36% mutation of ...	12	7	58	1	1001	0.000852718	0.244136	0.000852718	0.000852718

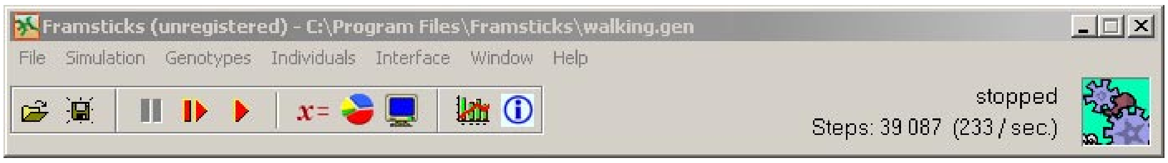
2 populations, with individuals contents: 1, 7

Name	Genotype	Info	Starting energy	Energy	Energy balan...	Perfor...	NN en...	Life sp...	Velocity	Vertical veloc...	Avg velocity	Avg vertical ...	
Ivogup Akoaka...	IIIIffXAM[,,,,,,IIIf...	[10.44% mutation ...	140	133	-0.14	On	1	0	0	0	0	0	2...
	//0|m:Vstyle=food...		1	1	0	Off	1	0	0	0	0	0	0...
	//0|m:Vstyle=food...		1	1	0	Off	1	0	0	0	0	0	0...
	//0|m:Vstyle=food...		1	1	0	Off	1	0	0	0	0	0	0...
	//0|m:Vstyle=food...		1	1	0	Off	1	0	0	0	0	0	0...
	//0|m:Vstyle=food...		1	1	0	Off	1	0	0	0	0	0	0...
	//0|m:Vstyle=food...		1	1	0	Off	1	0	0	0	0	0	0...
	//0|m:Vstyle=food...		1	1	0	Off	1	0	0	0	0	0	0...

Figure 2: The five main windows of the interface.

On the interface, five main windows allow the control of the evolution:

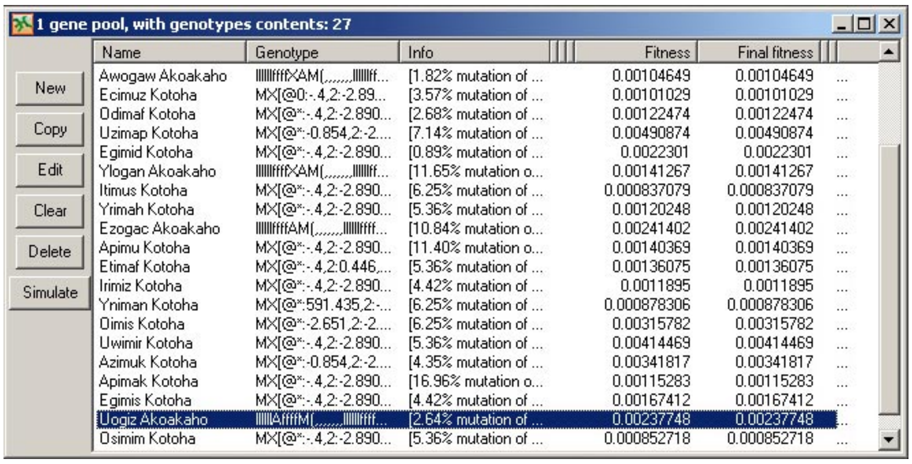
- The main control window, **number 1:**



Framsticks (unregistered) - C:\Program Files\Framsticks\walking.gen
File Simulation Genotypes Individuals Interface Window Help
x=
stopped
Steps: 39 087 (233 / sec.)

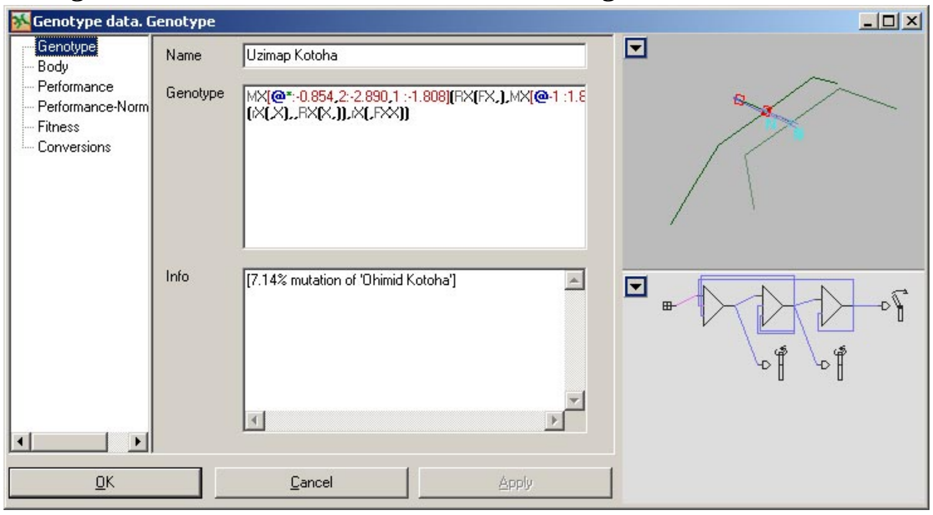
The red arrow allows to start/stop the simulation. The other icons give access to the parameters of the evolution, statistics and visualisation. Only the parameters of the evolution (“x=”) should be modified. On the right the number of simulation steps is displayed.

• The gene pool window, **number 2:**


1 gene pool, with genotypes contents: 27

Name	Genotype	Info	Fitness	Final fitness	
Awogaw Akoakaho	IIIIIIffffXAM(,,,,,,,,IIIIIIff...	[1.82% mutation of ...	0.00104649	0.00104649	...
Ecimuz Kotoha	MX[@0:-.4,2:-2.89...	[3.57% mutation of ...	0.00101029	0.00101029	...
Odimaf Kotoha	MX[@*:-.4,2:-2.890...	[2.68% mutation of ...	0.00122474	0.00122474	...
Uzimap Kotoha	MX[@*:-0.854,2:-2....	[7.14% mutation of ...	0.00490874	0.00490874	...
Egimid Kotoha	MX[@*:-.4,2:-2.890...	[0.89% mutation of ...	0.0022301	0.0022301	...
Ylogan Akoakaho	IIIIIIffffXAM(,,,,,,,,IIIIIIff...	[11.65% mutation o...	0.00141267	0.00141267	...
Itimus Kotoha	MX[@*:-.4,2:-2.890...	[6.25% mutation of ...	0.000837079	0.000837079	...
Yrimah Kotoha	MX[@*:-.4,2:-2.890...	[5.36% mutation of ...	0.00120248	0.00120248	...
Ezogac Akoakaho	IIIIIIffffAM(,,,,,,,,IIIIIIffff...	[10.84% mutation o...	0.00241402	0.00241402	...
Apimu Kotoha	MX[@*:-.4,2:-2.890...	[11.40% mutation o...	0.00140369	0.00140369	...
Etimaf Kotoha	MX[@*:-.4,2:0.446,...	[5.36% mutation of ...	0.00136075	0.00136075	...
Irimiz Kotoha	MX[@*:-.4,2:-2.890...	[4.42% mutation of ...	0.0011895	0.0011895	...
Yniman Kotoha	MX[@*:591.435,2:-...	[6.25% mutation of ...	0.000878306	0.000878306	...
Oimis Kotoha	MX[@*:-2.651,2:-2....	[6.25% mutation of ...	0.00315782	0.00315782	...
Uwimir Kotoha	MX[@*:-.4,2:-2.890...	[5.36% mutation of ...	0.00414469	0.00414469	...
Azimuk Kotoha	MX[@*:-0.854,2:-2....	[4.35% mutation of ...	0.00341817	0.00341817	...
Apimak Kotoha	MX[@*:-.4,2:-2.890...	[16.96% mutation o...	0.00115283	0.00115283	...
Egimis Kotoha	MX[@*:-.4,2:-2.890...	[4.42% mutation of ...	0.00167412	0.00167412	...
Uogiz Akoakaho	IIIIIAffffM(,,,,,,,,IIIIIIffff...	[2.64% mutation of ...	0.00237748	0.00237748	...
Osimim Kotoha	MX[@*:-.4,2:-2.890...	[5.36% mutation of ...	0.000852718	0.000852718	...

This window displays all genotypes and related information, including names and fitness. You can load examples of genotypes from “walking.gen” or other .gen files. You can select a genotype clicking on it. When a genotype is selected, body and brain of the creature are displayed in window 4. Double-clicking on a genotype, a window appear showing the detailed data of the genotype, allowing modification, comments etc, as following:


Genotype data. Genotype

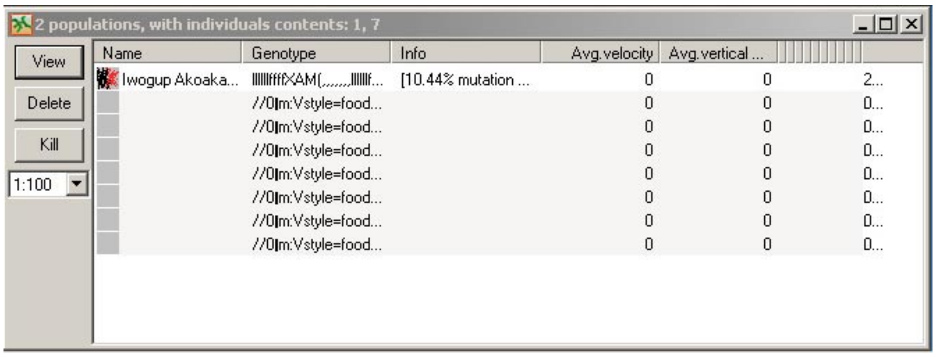
Name: Uzimap Kotoha

Genotype: MX[@*:-0.854,2:-2.890,1 :-1.808](RX(FX,),MX[@-1 :1.8
(rX(,X),,RX(X,)),rX(,FXX))

Info: [7.14% mutation of 'Ohimid Kotoha']

Six buttons on the left of window 2 allow to create/copy/edit/etc the genotype. The last button (simulate) allows the direct simulation of the selected creature in the artificial world.

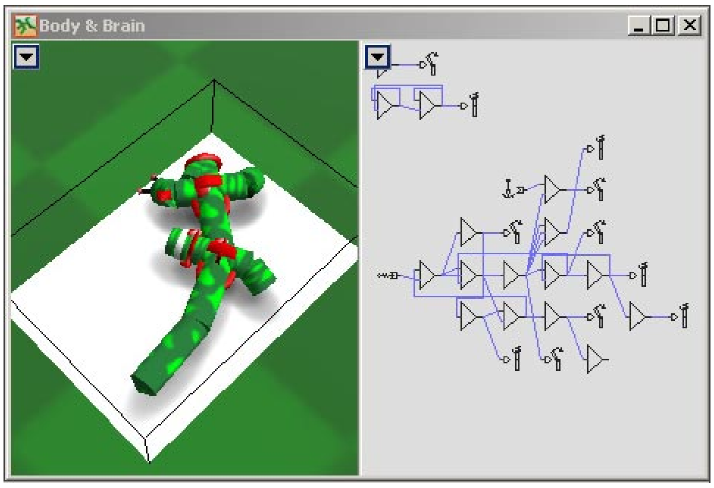
• The population window, **number 3:**


2 populations, with individuals contents: 1, 7

Name	Genotype	Info	Avg.velocity	Avg.vertical ...	
Iwogup Akoaka...	IIIIIIffffXAM(,,,,,,,,IIIIIIf...	[10.44% mutation ...	0	0	2...
	//0|m:Vstyle=food...		0	0	0...
	//0|m:Vstyle=food...		0	0	0...
	//0|m:Vstyle=food...		0	0	0...
	//0|m:Vstyle=food...		0	0	0...
	//0|m:Vstyle=food...		0	0	0...
	//0|m:Vstyle=food...		0	0	0...
	//0|m:Vstyle=food...		0	0	0...

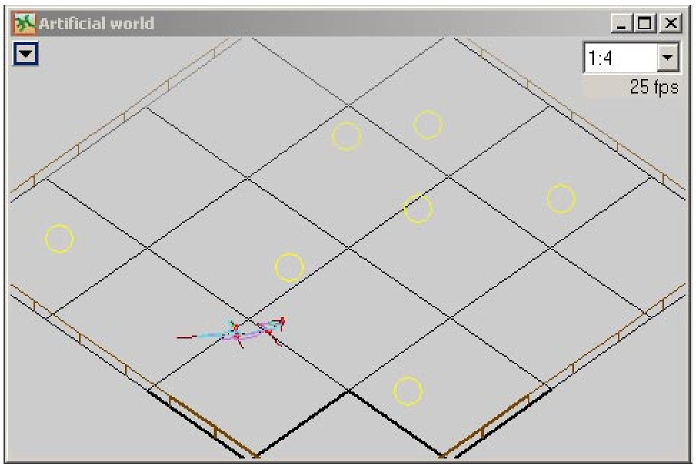
This windows displays the creatures under test in the artificial world. Selecting a creature you can observe in detail the creature in the artificial world (window 5) and its body and brain are displayed in window 4. The refresh rate of the window (1:100 in this example) can be reduced to speed up simulation.

- The body and brain window, **number 4:**



This window shows the body and brain of the selected creature. Small arrows (top left) allow the user to access to a local menu, useful for instance to set openGL (3D) visualisation.

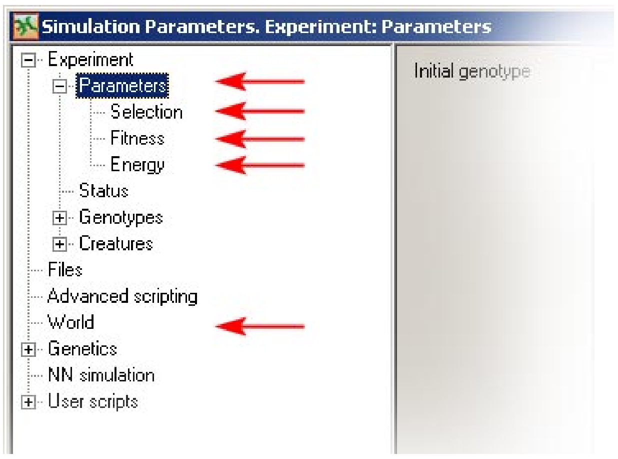
- The artificial world window, **number 5:**



This windows show the creatures moving around. A small menu on the top right permits to reduce the refresh rate of the window, for faster simulation.

4. Evolution and simulation parameters

Selecting the *x=* icon, you access to the evolution and simulation parameters. For a "standard" experiment definition, the most important parameters are in the following sub-menus :



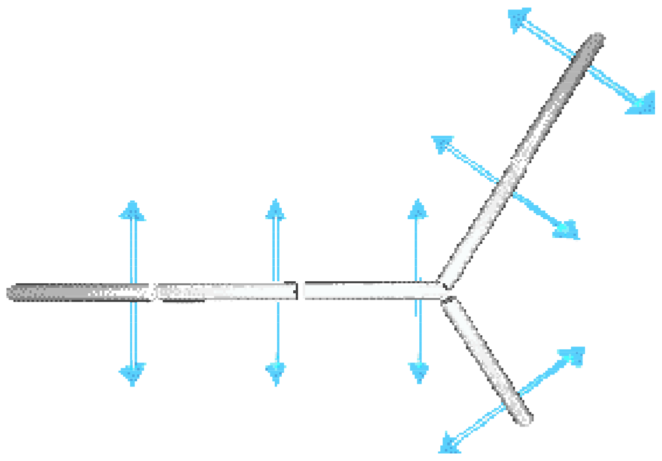
We will now describe shortly these five main parameter choices:

- **Parameters:**
  In this section you can mainly define the size of the gene pool, the method used to delete genotypes when the gene pool is full, and the number of creatures simulated in the artificial world. You can simulate more than one creature, other parameters should not be changed.
- **Selection**:
  In this section you define how many genotypes are mutated, crossed over or keeped unchanged during the evolutionary process. You can also define which is the selection rule. Default values are good for standard simulations.
- **Fitness:**
  Here you have the eight parameters that can be measured on a creature. For each parameter you can define how this parameter will influence the fitness function.
- **Energy:**
  Here you define how energy is managed: how much energy a creature has at the beginnig of its life, how much energy is spent by metabolism, how much energy units a food ball provides. “Automatic feeding” defines how many food ball will be automatically be placed in the environment. As soon as a food ball is eaten, a new food ball is created and placed randomly.
- **World:**
  Here you can define the type of world (for simple simulations always a flat surface), how big it is and how boundaries are managed. The boundary “teleport” bring always the creatures inside the arena, the “fence” is a wall all around the arena. All default parameters are good excepted boundaries, which should be set to “teleport”.

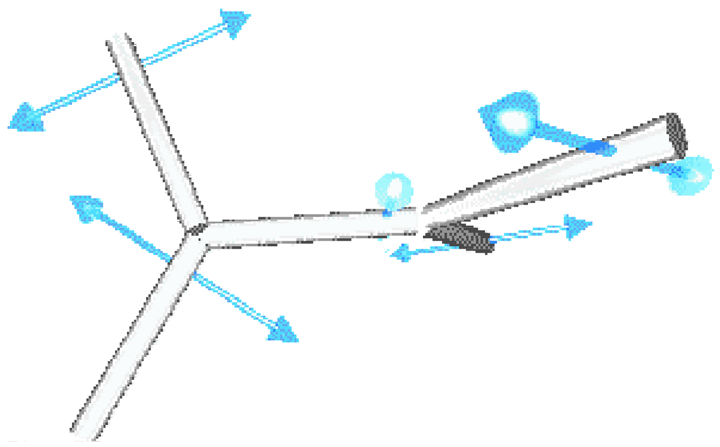
5. Genotype encoding

The genotype encodes the morphology, the placement of sensors and actuators and the neural network control. We will explain here the "f1" format of encoding, the best one for beginners.

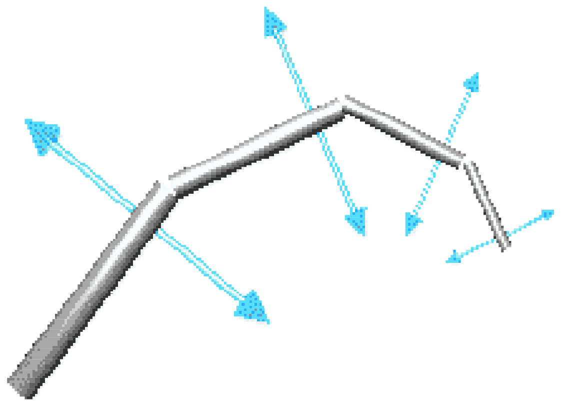
- **Morphology:**
  The morphology is based on sticks. A stick is represented in the genotype by a “X”. Branches are introduced by a “(“, separated by commas and ended by “)”. For instance “XXX(XX,X)” gives this:



  Modificators can be applied to the sticks, changing their properties. Modificators are represented by letters, placed before X's and ('s. They affect the following X and, usually less and less, further following Xs. Big and small letters can be used; big letters increase the given property while small ones decrease it. Existing modificators: R, r, Q, q, C, c, L, l, W, w, F, f, A, a, S, s, M, m, I, i, E and e. For instance the "R" modificator generates a rotation of 45 degrees of the stick. The genotype "X(X,RRX(X,X))" represents the following structure:



The modificator "C" controls the curvedness of the link. The modificator "L" makes the stick longer, the modificator "l" make it shorter. The genotype "XlCXlCXlCX" gives the following structure:



More examples and explanations on modificators are available under
http://www.frams.poznan.pl/a/al_genotype.html):

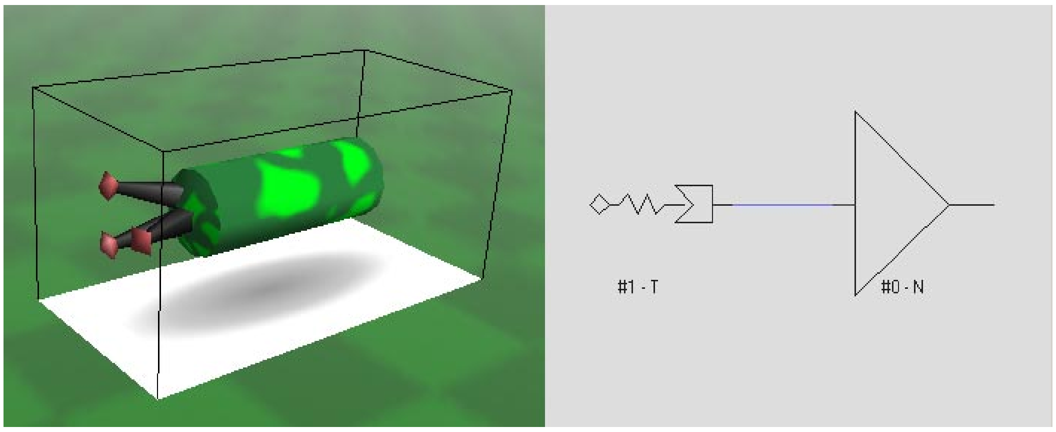
- **Sensors and actuators:**
  There are three possible sensors, each of them being represented by a letter:
  1. **G:** gyroscope
  2. **T:** touch sensor
  3. **S:** smell for food

  Actuators can be of two types:
  1. **@:** rotation of the stick
  2. **|:** bending of the stick

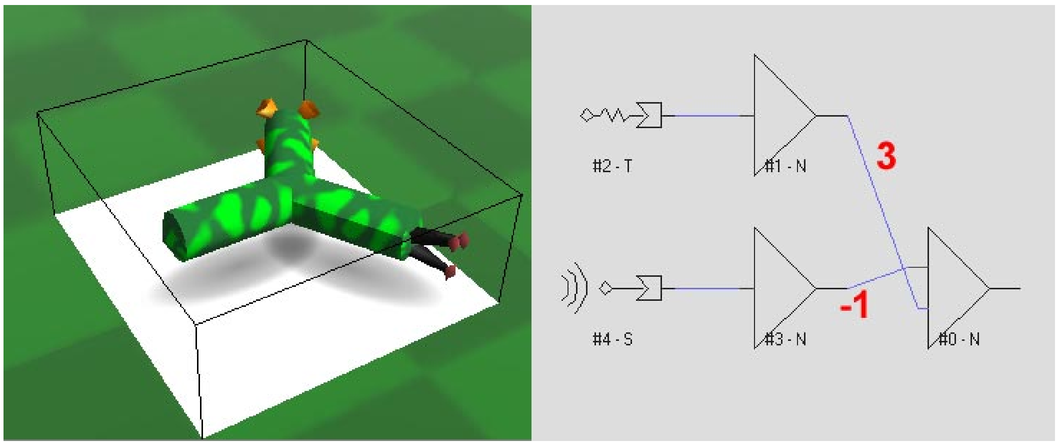
  Sensors and actuators are placed in [ ] after the corresponding X's. They are associated to neurons. See next section.

- **Neurons:**
  Neurons are units giving as output the sum of many weighted inputs. The syntax of this type of neuron is: [input:weight , input:weight , input...]. "weight" is a numeric value, positive or

negative. “input” can represent a sensors or another neuron. If a sensor is used as input, the letter of the corresponding sensor is placed as “input”. For instance “X[T:1]” represents a stick with a neuron having as input a touch sensor with weight 1, as following:



If the input is another neuron, the “input” field is a numeric value representing the relative position of the neuron in the genotype. In the genotype “X[2:-1,1:3](X[T:1],X[S:1])” , the first neuron has as input the last neuron (2nd neuron after its position) with weight -1 and the middle neuron (1st neuron after its position) with weight 3, as following:



To control an actuator, a neuron has to be associated with it. In this case the syntax of the neuron is: [actuator input:weight , input:weight , input...]. “actuator” is one of the letters presented above. For instance the genotype “X[| T:1]” represents a stick with a touch sensor as input of a neuron controlling the bending muscle, as following: