rule 110

{Alife Mutants Hackingsession on Systems and Organisms, Bielefeld 2004}

{Toy SMGT}

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An artificial world of Sperm Cells and Ova is described in the agent-based modeling StarLogo language. Genomes of these cells are color coded. If a Spermatozoon and Ovum meeting leads to the new Spermatozoon and new Ovum, which have a new genome, 'genome mutations' will have occurred. This system demonstrates different kinds of behavior depending on the 'mutation' parameter.

Minimal model for an idea of sperm-mediated gene transfer (SMGT):

The {Toy SMGT} StarLogo program generates an initial random population of artificial creatures: the Sperm Cells – turtles (T), and the Ova – patches (P). The user can also paint patches on StarLogo screen.

Each creature has a circular genome consisting of 1024 'genes', only one of them is active and coded by color with mod(1024).

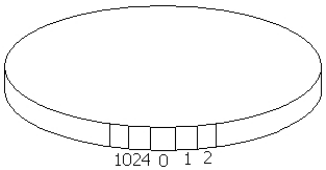


Fig. Genome organization
The cycle genome consists of 1024 genes, one of them is active and coded by color: color = {0, 1024}, mod(1024)

Spermatozoa jump in random direction (left, right <=90^{o}) and distance (<=5). If a Spermatozoon meets an Ovum, then they are said to be mating. The result of breeding is a new Spermatozoon and a new Ovum. The new genome appears after 'recombination', which is executed by the following iterative equation:

$$\mathbf{T(i+1) = |[T(i) + P(i)] / 2 * R|_{mod(1024)}} \qquad (1)$$
$$\mathbf{P(i+1) = T(i+1),}$$

where **T(i)** is the color code of individual Spermatozoon and **P(i)** is the color code of individual Ovum at the time **i** of breeding. **R** is mutation parameter on the interval]0, 4].

Different values of **R** were investigated during the computer simulation by parallel StarLogo execution of equation (1).
R = {0.5, 1, 1.001, 1.01, 1.5, 3, 4}

Listing of program {Toy SMGT} on StarLogo language

Observer Procedures:

```
to setup
  ca
  crt number  ; number of Sperm Cells
  ask-turtles [setc (random 1024)]
  ask-patches [if (random 1024) < 5 [setpc (random 1024)]]
  clearplots
end
```

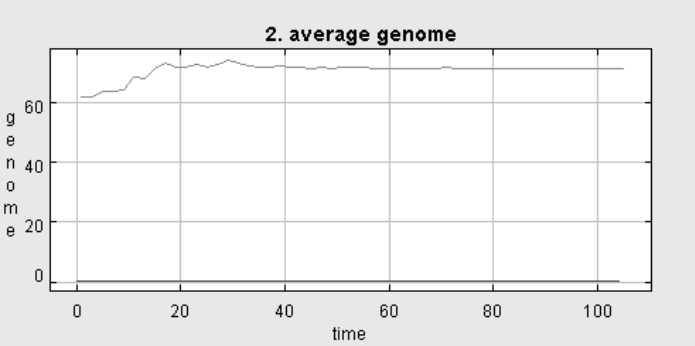
Turtle Procedures:

```
; {Toy SMGT} is a simple model of sperm-mediated gene transfer

turtles-own []
patches-own []

to setup
  setxy random screen-width random screen-height
end

to go
  fd random (5)
  rt random (90)
  lt random (90)
  find-ova
end

to find-ova
  if (pc != black) ; if find an Ovum, then average color * R
    [
    setc ((pc + color) / 2) * 1.01 ; coefficients: 0.5, 1,
                                   ; 1.001, 1.01, 1.5, 3, 4
    stamp color
    ]
end
```

Results

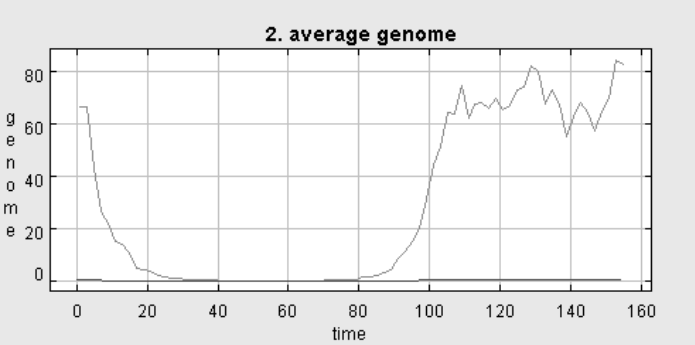
The behavior of the system was strongly dependent upon the value of the parameter **R**. The system demonstrated ordered (R<=1) and complex (R>1) regimes. In the case of high density Ova (close to 100%) and short step movement of Spermatozoa (<=2) the tracks and dynamic wave patterns of color on the screen are observed. Some examples are presented.

Movement of average ‘genome’ to stable focus at R=1 (average value of color/genome of all Sperm/turtles is green, patches – red).



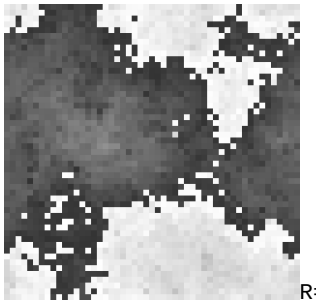
R=1

‘Collapse and emergence of life’. Moving of system downhill to black color at R=0.5, then uphill to different colors at R=1.5.



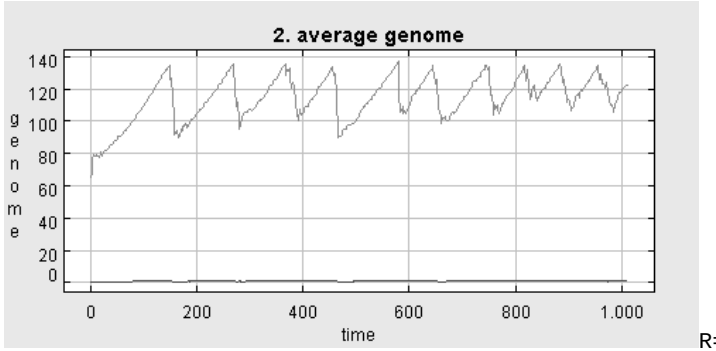
R=0.5→1.5

Waves of ‘genetic’ variations (R=1.001, Sperm step <=2, density of Ova/patches 100%)



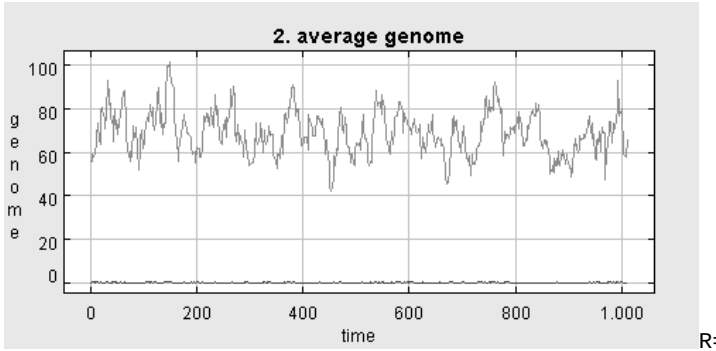
R=1.001, fd random (2), density 100%

Periodic behavior at R=1.01.



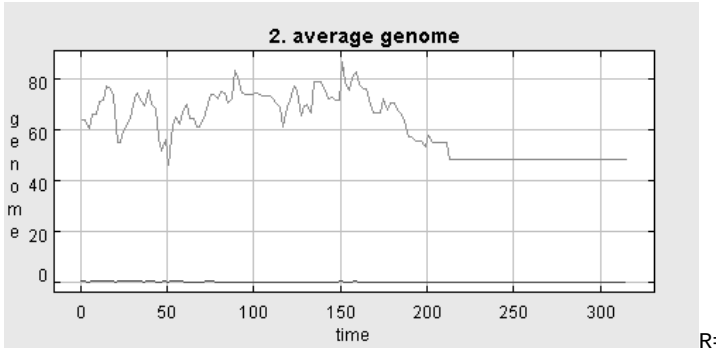
R=1.01

Chaotic behavior at R=3.



R=3

Strange attractor (R=4).



R=4

Resume

Complex and unexpected behavior of the artificial world of two agents - Sperm Cells and Ova – appears from the collective dynamic of the distributed creatures and parallel execution of iterative equation (1). The system demonstrates different regimes (stable, periodic, chaotic) and active wave patterns depending on the ‘mutation’ parameter **R** and the density of its inhabitants. ‘Collapse and emergence of life’, waves of ‘genetic’ variations, strange attractors, periodic and chaotic behavior were revealed. Equation (1) may be recommended for generation of ‘genome’ variations in the computer simulation. The {Toy SMGT} program could pose some philosophical questions about the definition and the origin of life from the cellular automata point of view.

Literature

Andrew Ilachinski, Zane Cellular Automata: A Discrete Universe. World Scientific Publishing Company. 2001

Vanessa Stevens Colella, Eric Klopfer, Mitchel Resnick Adventures in Modeling: Exploring Complex, Dynamic Systems with StarLogo Teachers College Press. 2001

Yaneer Bar-Yam Dynamics of Complex Systems (Studies in Nonlinearity). Westview Press. 1997

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