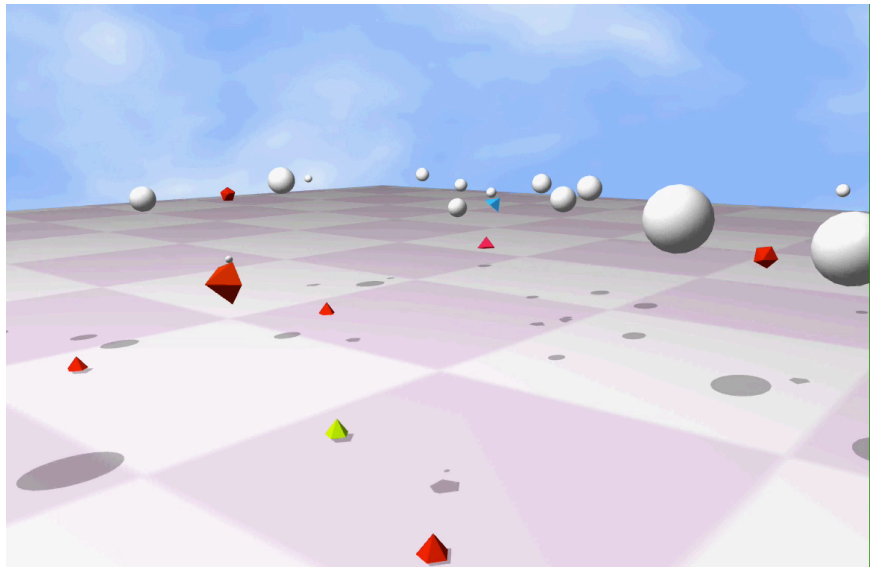
Life in Virtual (Fictional) Worlds



Lee Spector
Hampshire College, Amherst College, UMass Amherst
http://hampshire.edu/lspector

Artificial Life

Christopher Langton: Artificial life is the study of man-made systems that exhibit behaviors characteristic of natural living systems. It complements the traditional biological sciences concerned with the *analysis* of living organisms by attempting to *synthesize* life-like behaviors within computers and other artificial media. By extending the empirical foundation upon which biology is based *beyond* the carbon-chain that has evolved on Earth, Artificial Life can contribute to theoretical biology by locating *life-as-we-know-it* within the larger picture of *life-as-it-could-be*.

Life = evolution of programs

Death

- Life is program evolution
- Evolution is enabled by program death

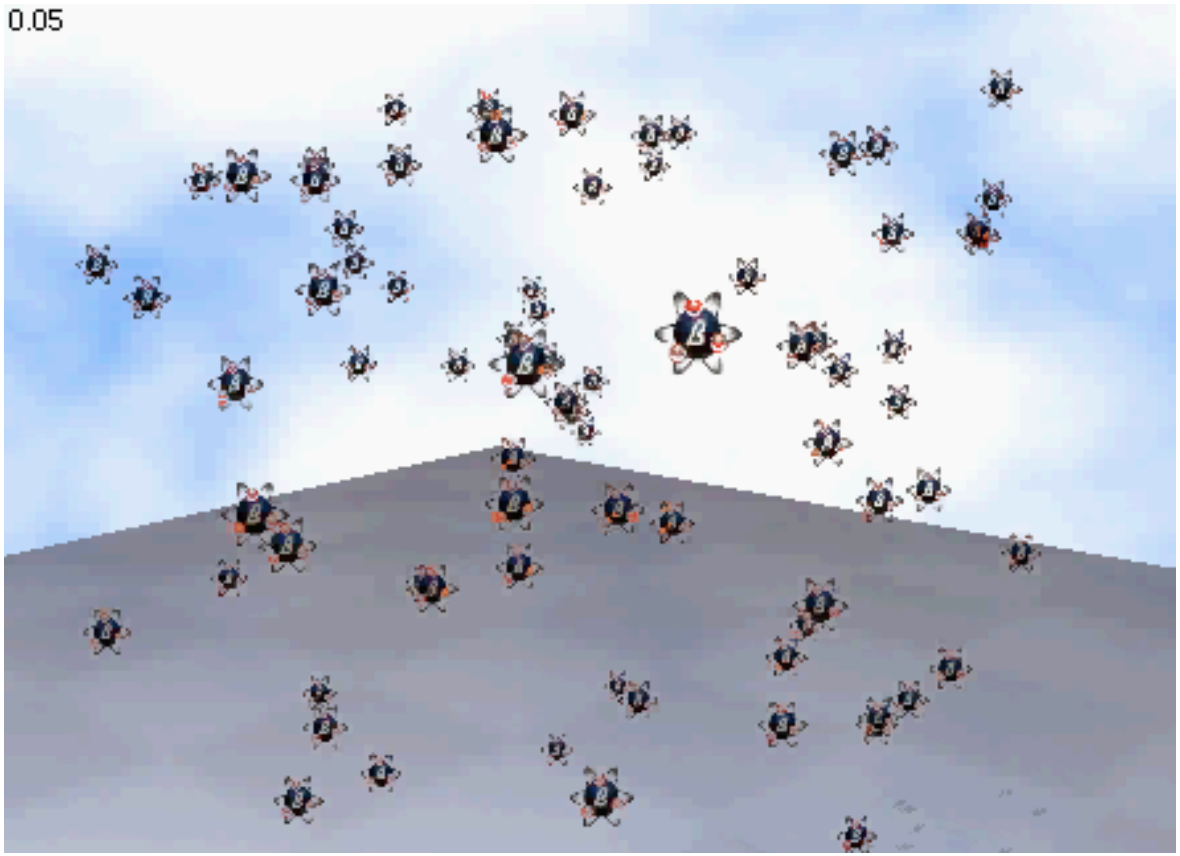
Digital Organisms

- For the study of general principles of living systems
- Populations of individuals that act locally in environments
- Explore, in silico, key aspects of evolutionary processes

BREVE Swarm

- By Jon Klein, after Craig Reynolds.
- Acceleration ≈ p1*[away from crowding others vector]
  + p2*[to world center vector]
  + p3*[average neighbor velocity vector]
  + p4*[to neighbor center vector]
  + p5*[random vector]
- Appears "life-like", but **no death**, so **no evolution**!

BREVE Swarm

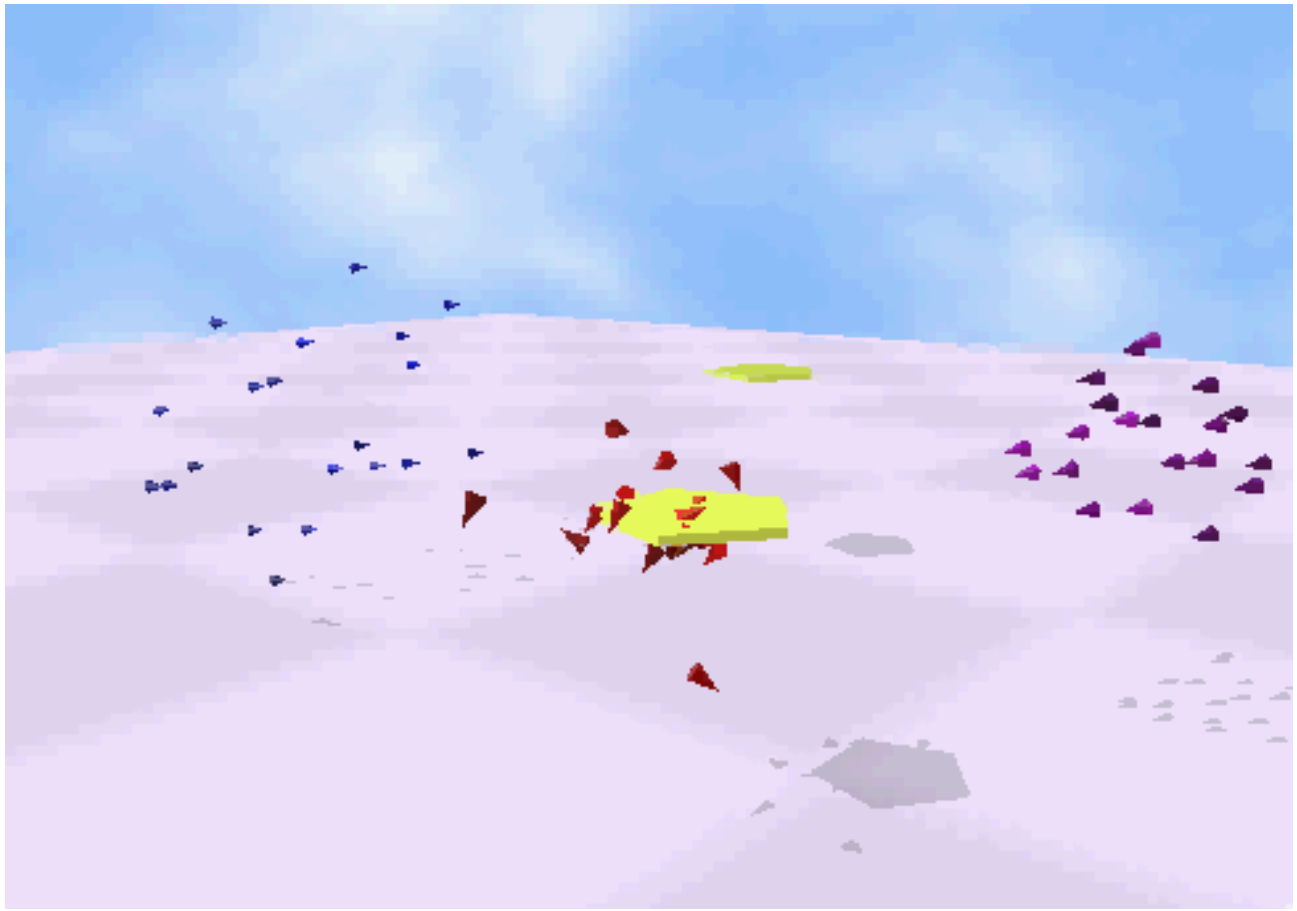


Variations

SwarmEvolve 1

- **Add death**, for evolution of goal-directed swarms
- ... + p6*[away from other species vector]
  + p7*[to closest energy source vector]
- Genotype = [p1, p2, p3, p4, p5, p6, p7]
- Energy costs (collisions, species outnumbered, etc.)
- Upon **death** (energy = 0), parameters replaced with mutated fittest (max age * energy) of species

SwarmEvolve 1



Multicellularity

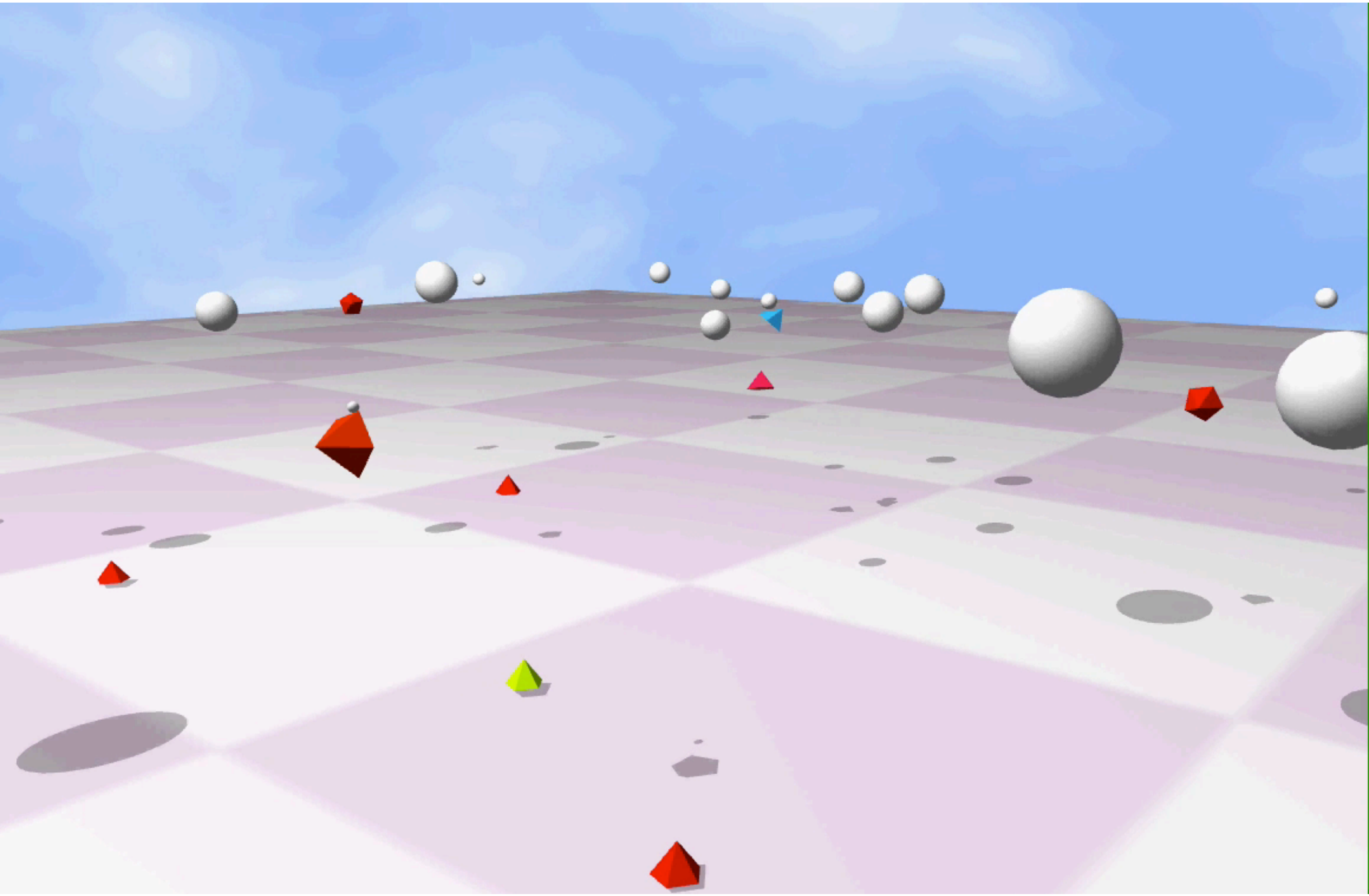
- Observed behavior: a cloud of agents hovers around an energy source. Only the central agents feed, while the others are continually dying and being reborn
- Emergent collective organization or multicellularity
- Peripheral agents: defensive organs; Central agents: digestive/reproductive organs.
- Emerges only because of **death**

Autoconstructive Evolution

- Individual programs make their own children, with endogenous variation
- Hence they control their own mutation rates and methods, sexuality, reproductive timing, etc.
- The machinery of reproduction and diversification (i.e., the machinery of evolution) evolves

SwarmEvolve 2

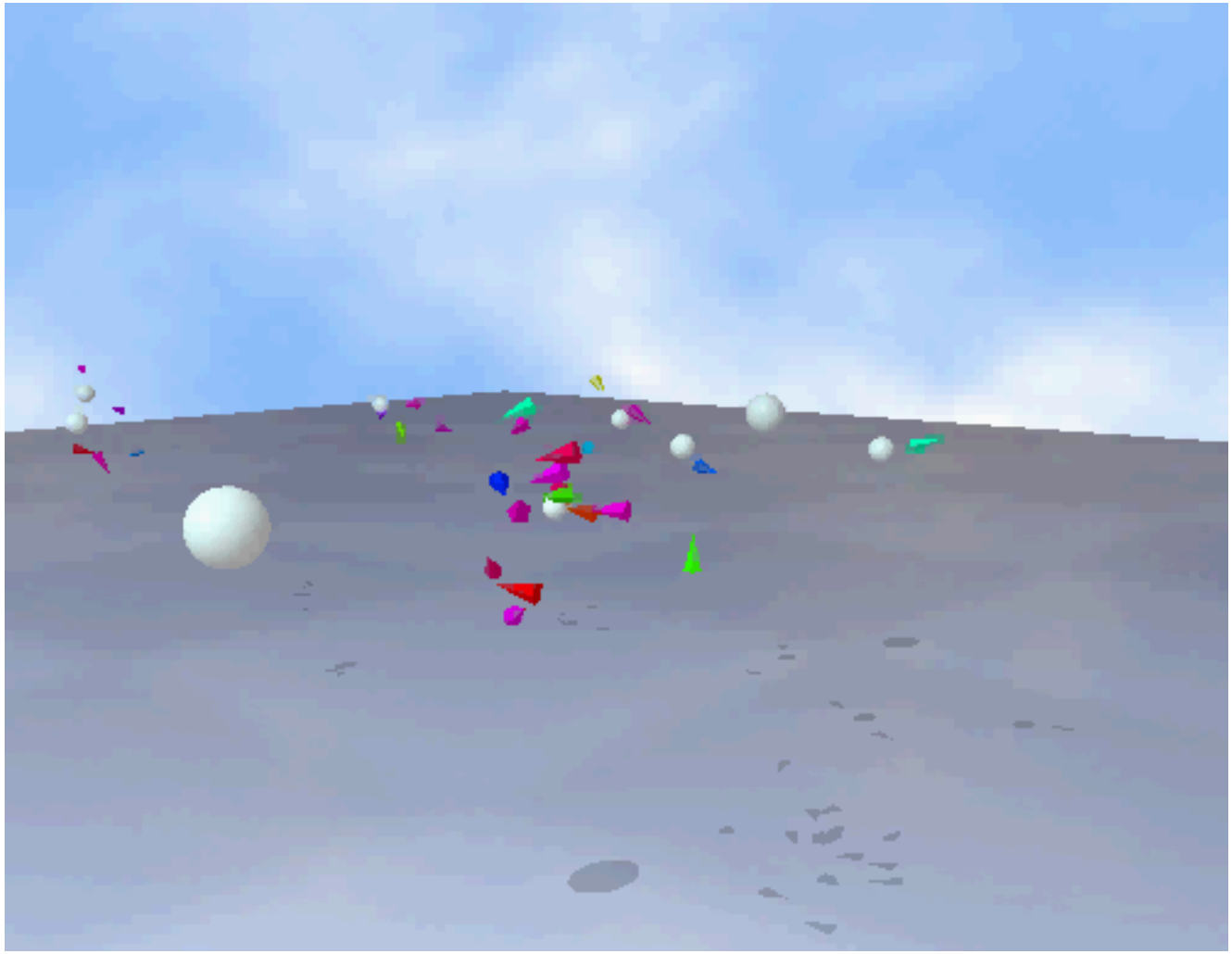
- A "swarm-like" agent environment with energy dynamics and conservation
- Behavior (including action, communication, energy sharing, and reproduction) controlled by evolved programs
- Supports exploration of relations between adaptation and various kinds of resource sharing, under a range of environmental settings



Evolved Strategy

- Reckless goal-seeking + sharing
- Functional instructions of evolved code:

  (toFood feedOther myAge spawn randF)
- Accelerates directly toward nearest goal, feeds others, and turns random colors
- Evolved mutation regime: rate $\propto$ 1/age
- High goal coverage, low lifetimes (rapid **death**)



Sharing and Adaptation

- Sharing is with closest agent of similar/dissimilar color
- Recipient must have less energy than provider
- **Mutual**: Share only if recipient tried to share
- **Charity**: Share regardless of recipient's behavior
- **Waste**: All energy lost (a control)
- **No-op**: No energy changes (another control)
- Various settings of environmental stability parameter

Results (1,625 Runs)

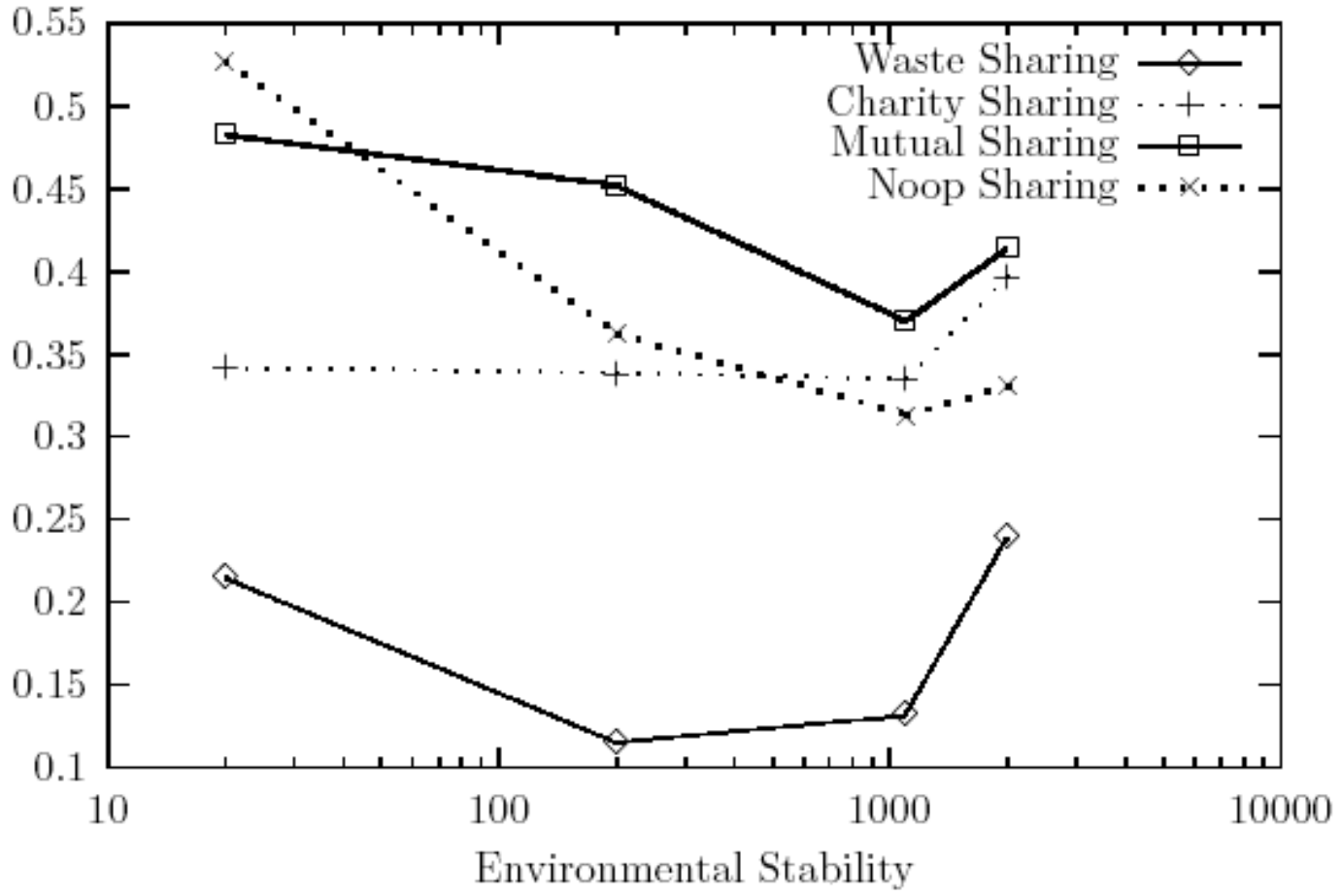
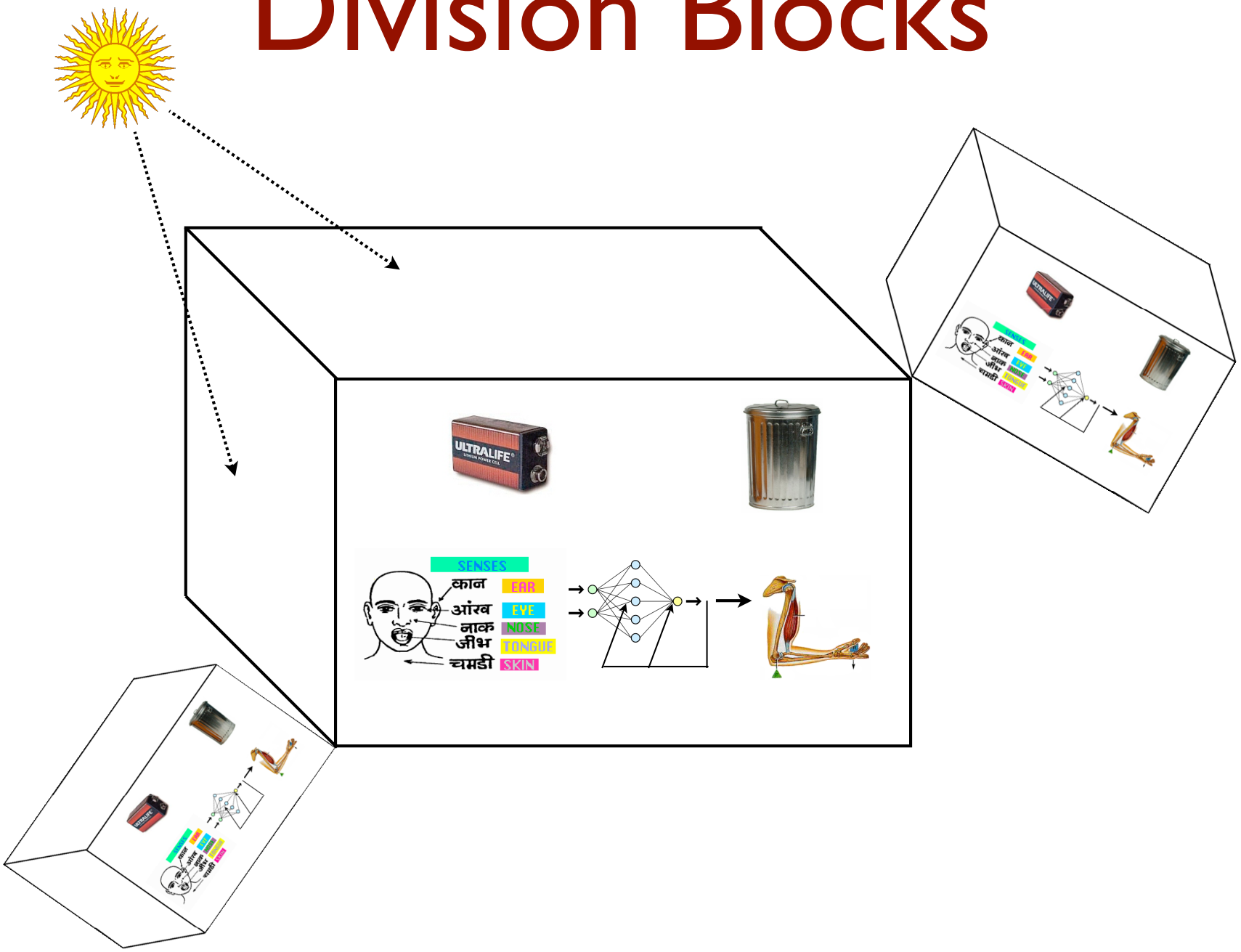


Fig. 4. Proportion of agents that share food (on the y axis) graphed vs. environmental (energy source) stability (on the x axis) for four sharing conditions (see text).

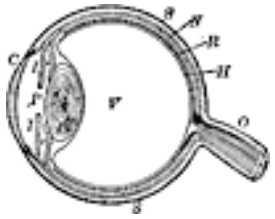
Code Cells

- Evolution of form, development and behavior (including problem solving and diversification).
- Push programs in links & joints; instructions include **`bud`**, **`break`**, **`scale`**, **`flow`**, etc.

Division Blocks

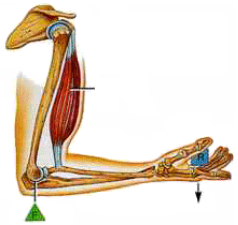


Sensors



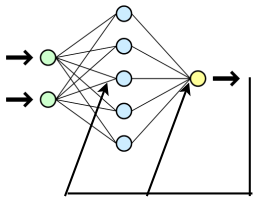
zero, plus, minus, energy, waste, exposure, pulse, rotx, roty, rotz, localtag, localenergy, localwaste, connectedtag, connectedenergy, connectedwaste, stemtag, stemenergy, stemwaste

Effectors



sizex, sizey, sizez, jointx, jointy, jointz, stemx, stemy, stemz, tag, donationsize, donationtolerance, stemdonationsize, stemdonationtolerance, collectionsize, collectiontolerance, stemcollectionsize, stemcollectiontolerance, copyfidelity, mutationlimit, matecontribution, matetag, adhesion, pulserate, sigmoidcompression

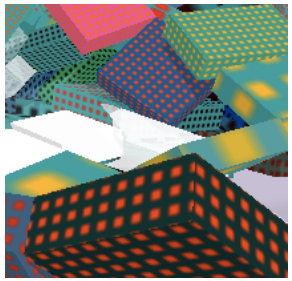
Neural Network



- Arbitrary recurrent architecture, genetically controlled.
- Division (via growth) and genetics (mutation and crossover) controlled by network outputs.
- Sigmoid activation function; steepness controlled by an effector:

$$\sigma(s) = \frac{2}{1 + e^{-cs}} - 1$$

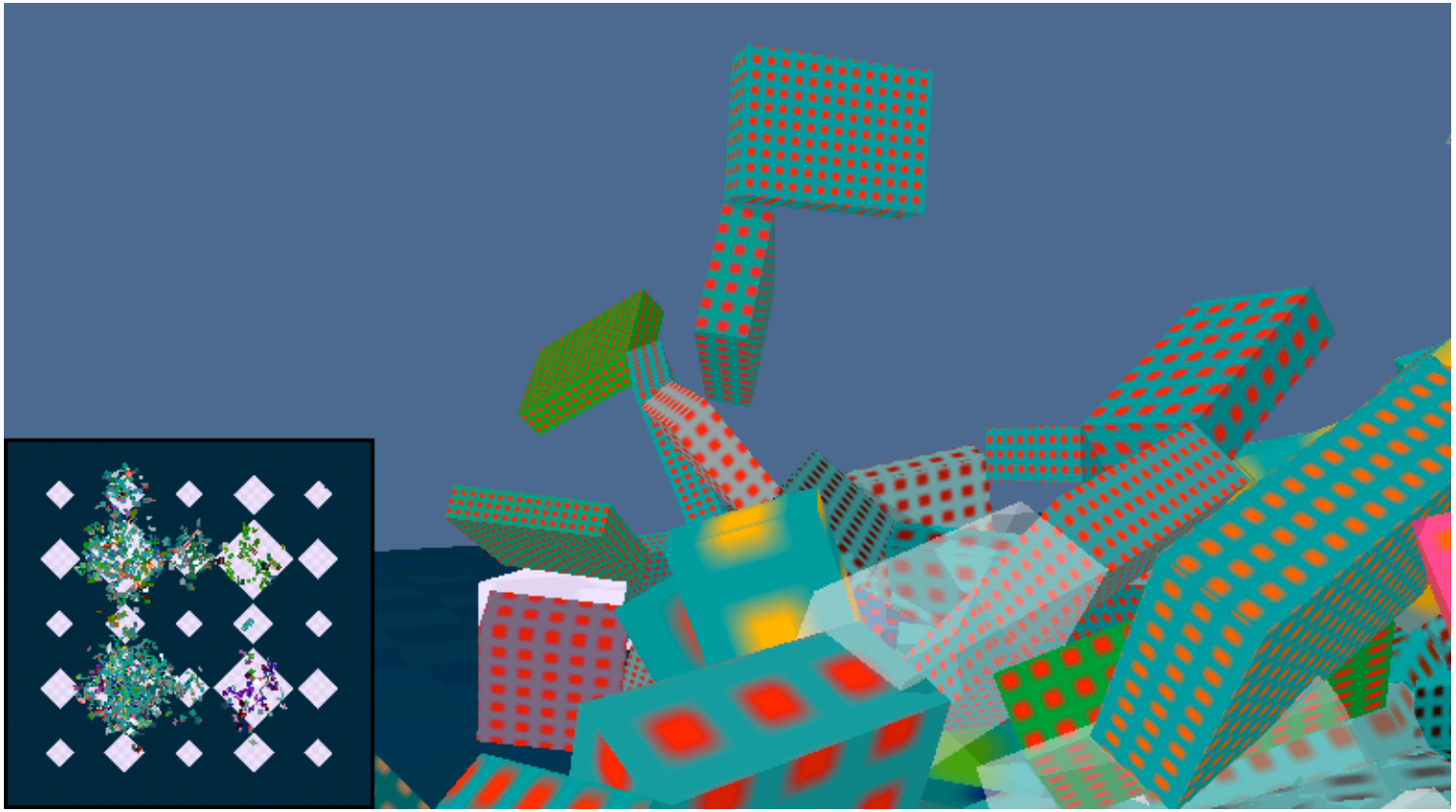
Skin



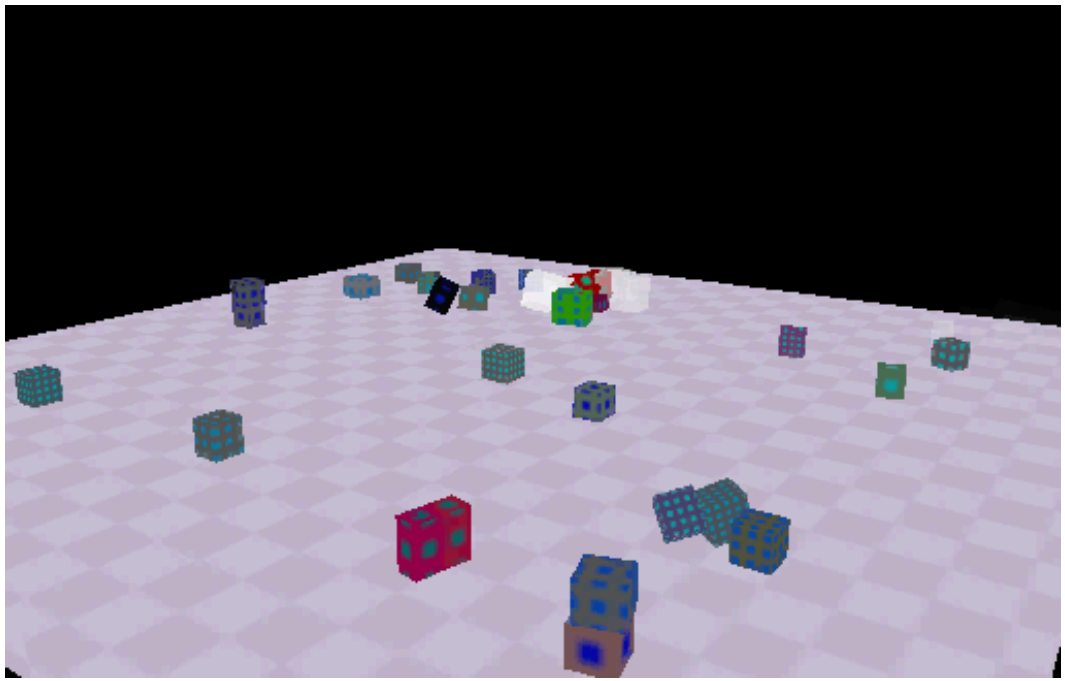
Patterns/colors show state. For results in paper:

- Dot density = energy
- Frame red = waste
- Frame green = energy donation tolerance
- Frame blue = energy donation size
- Dot red = sun exposure
- Dot green = waste collection tolerance
- Dot blue = waste collection size

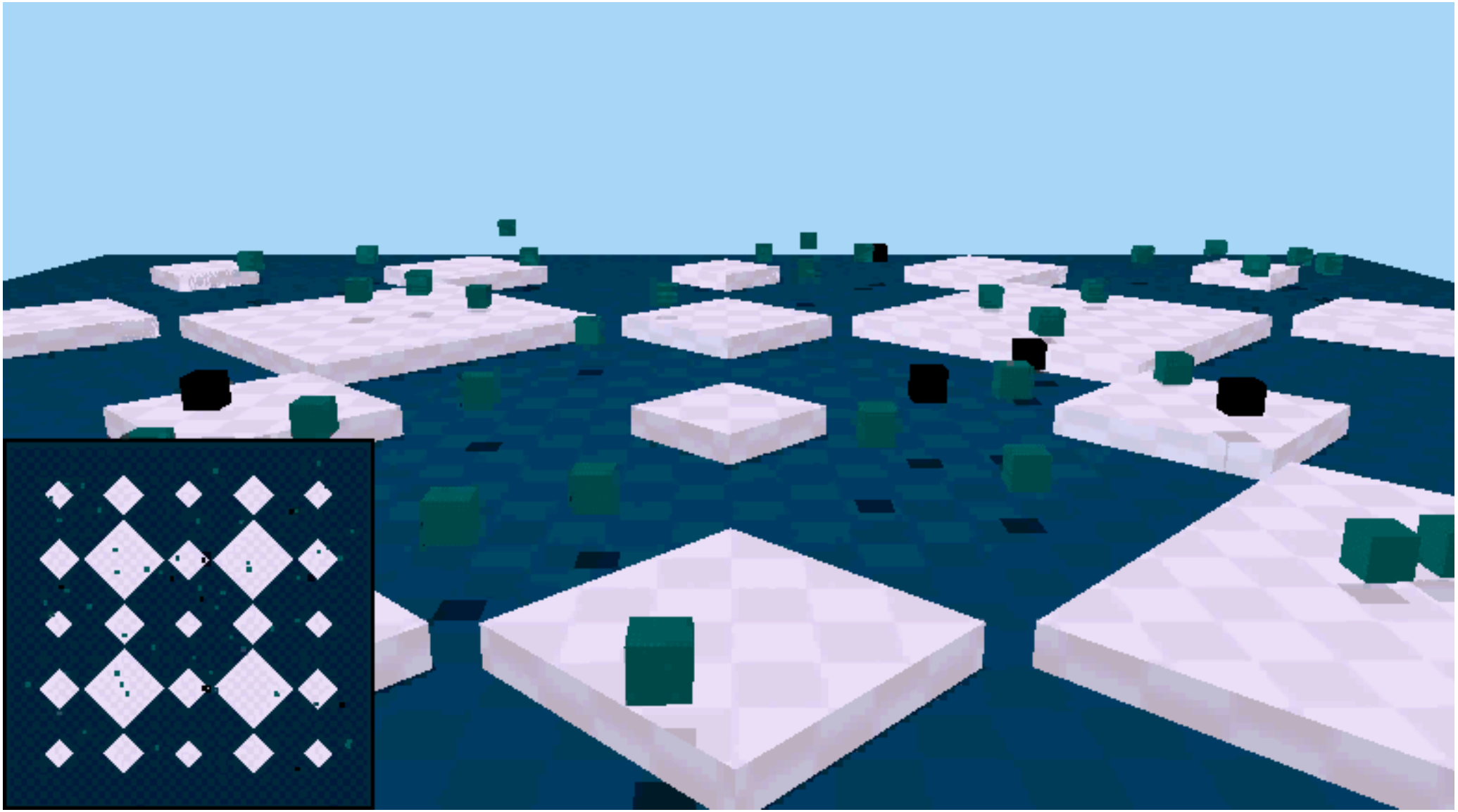
Waste

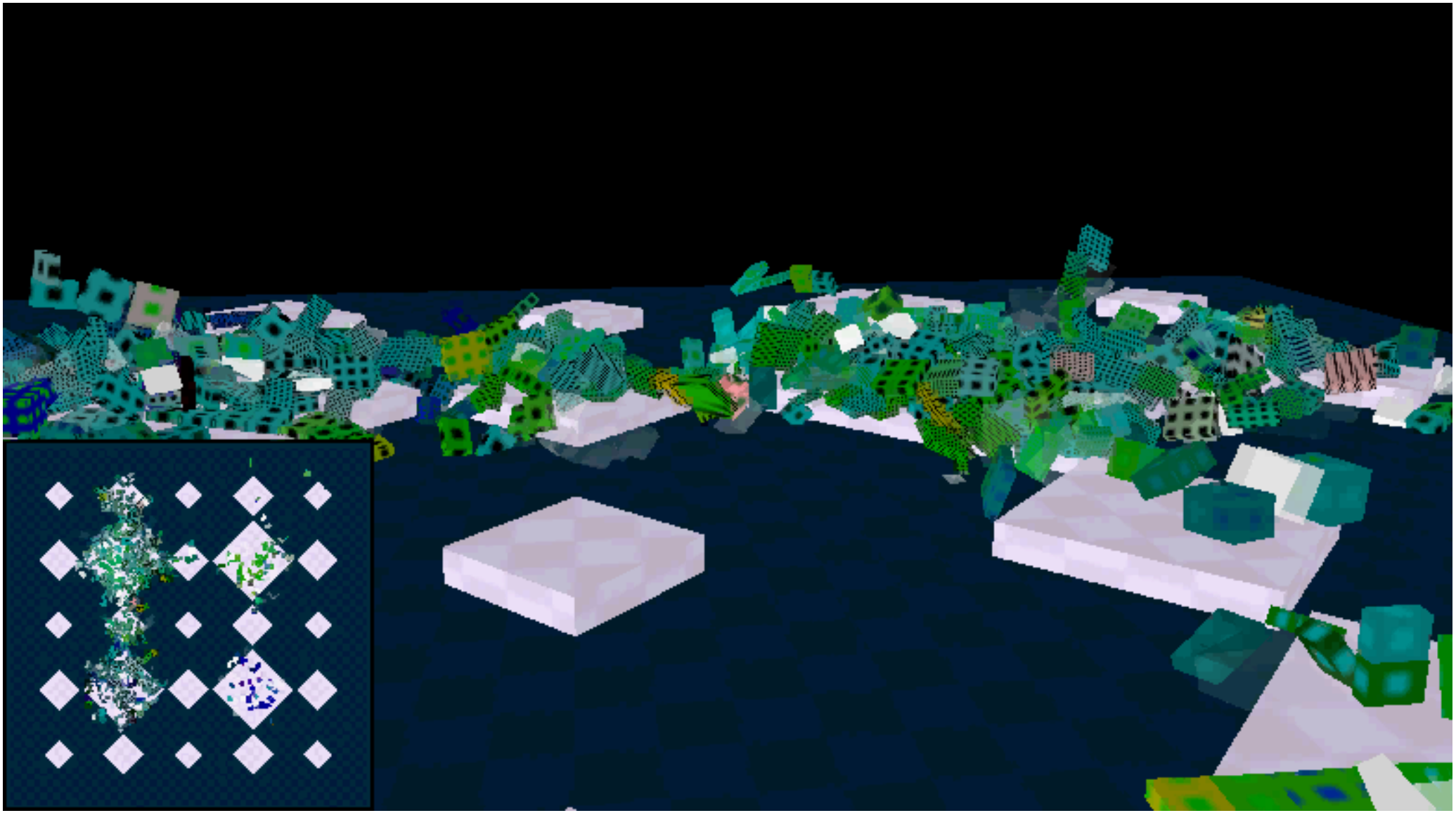


Reproductive Competence

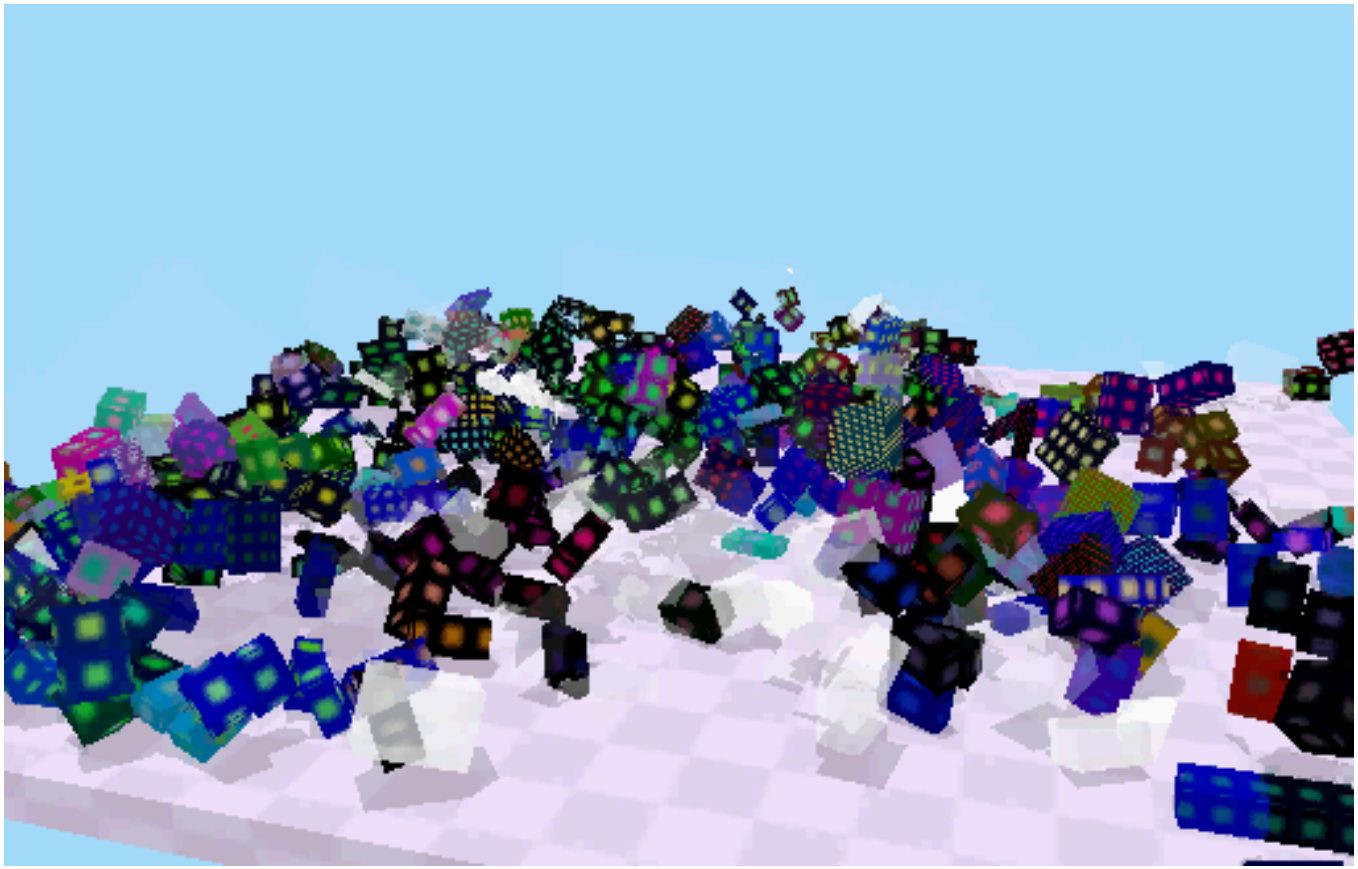


Reproductive Competence



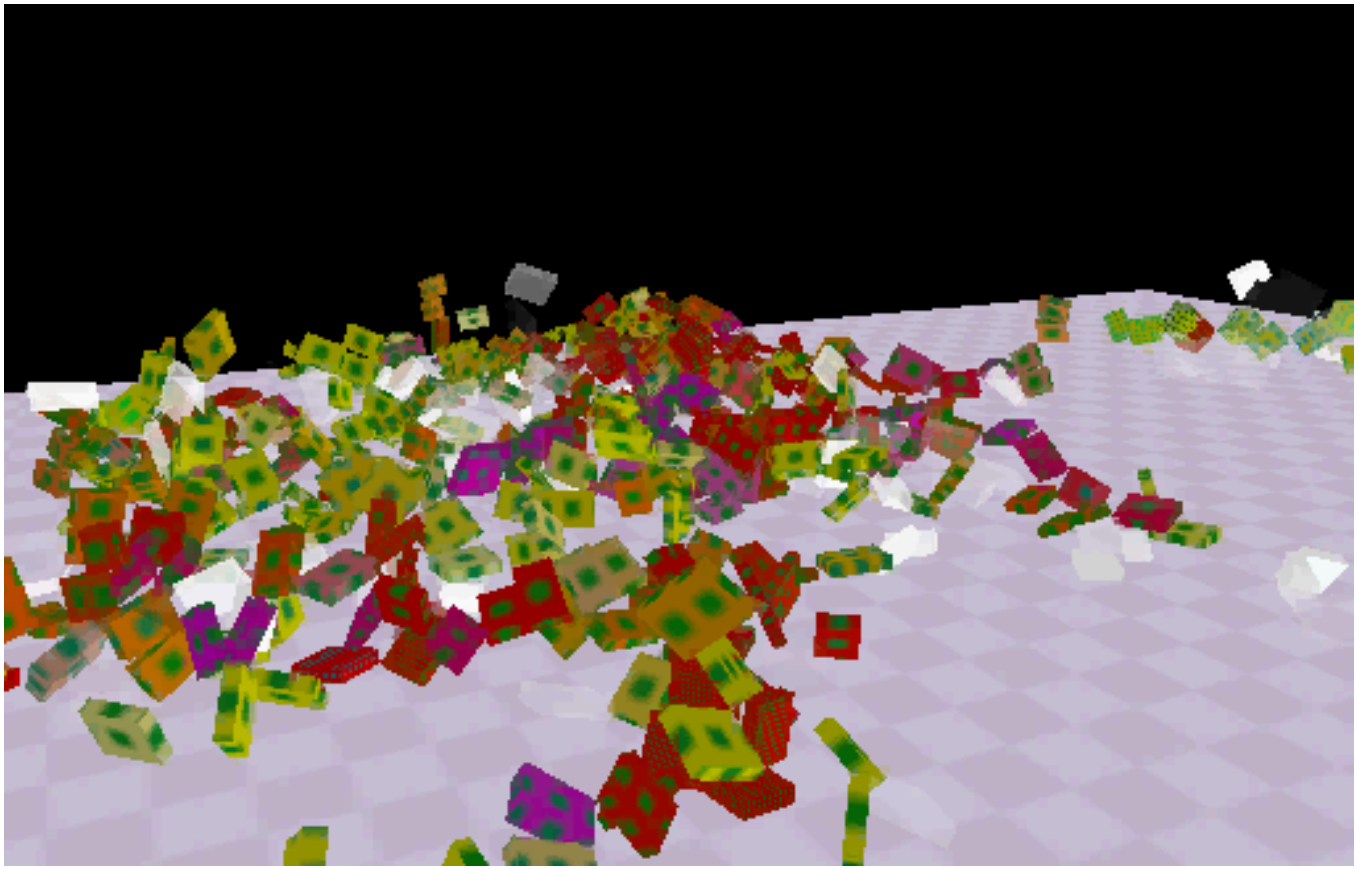


Seething



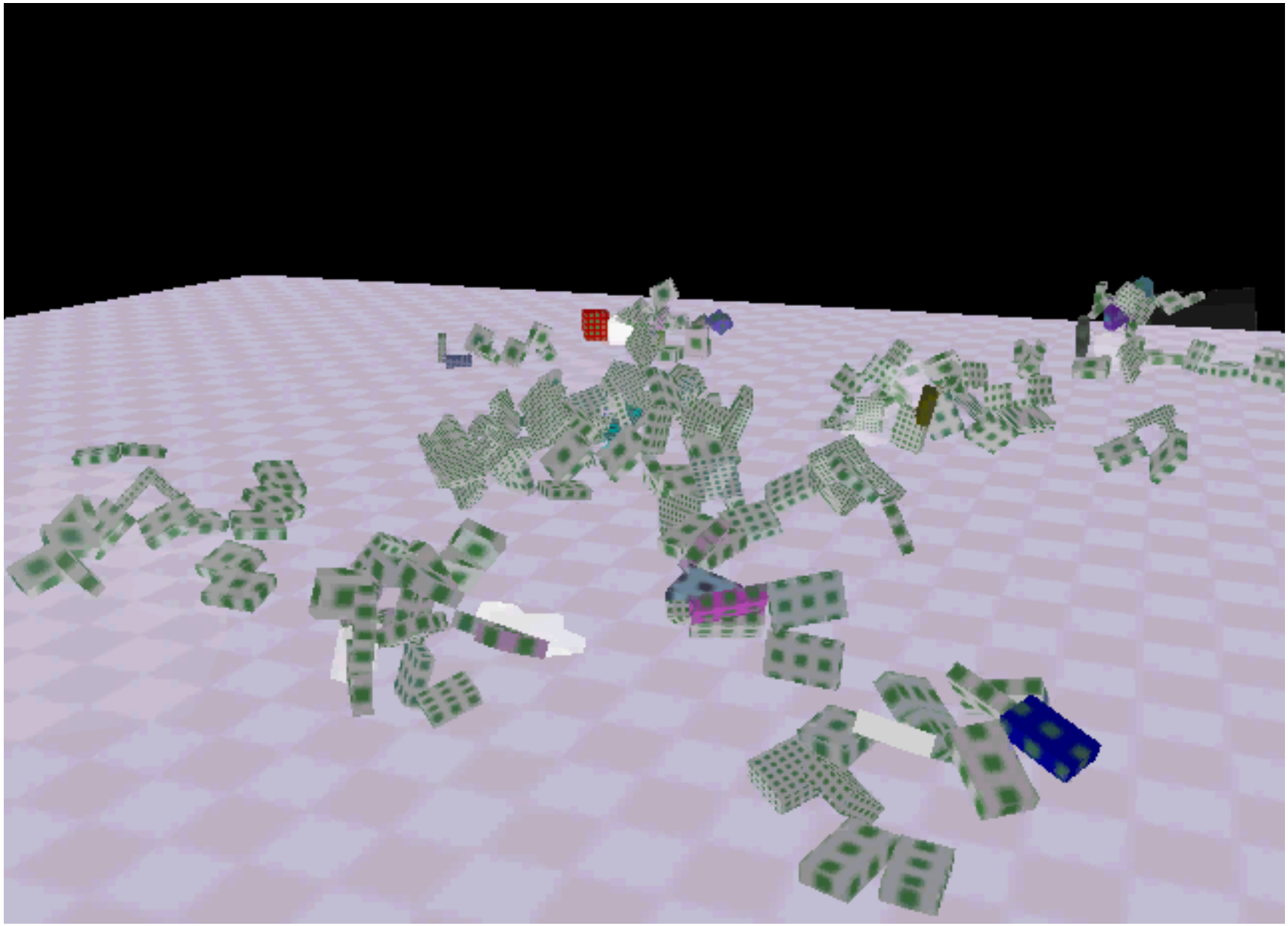
db20060602c

More Seething



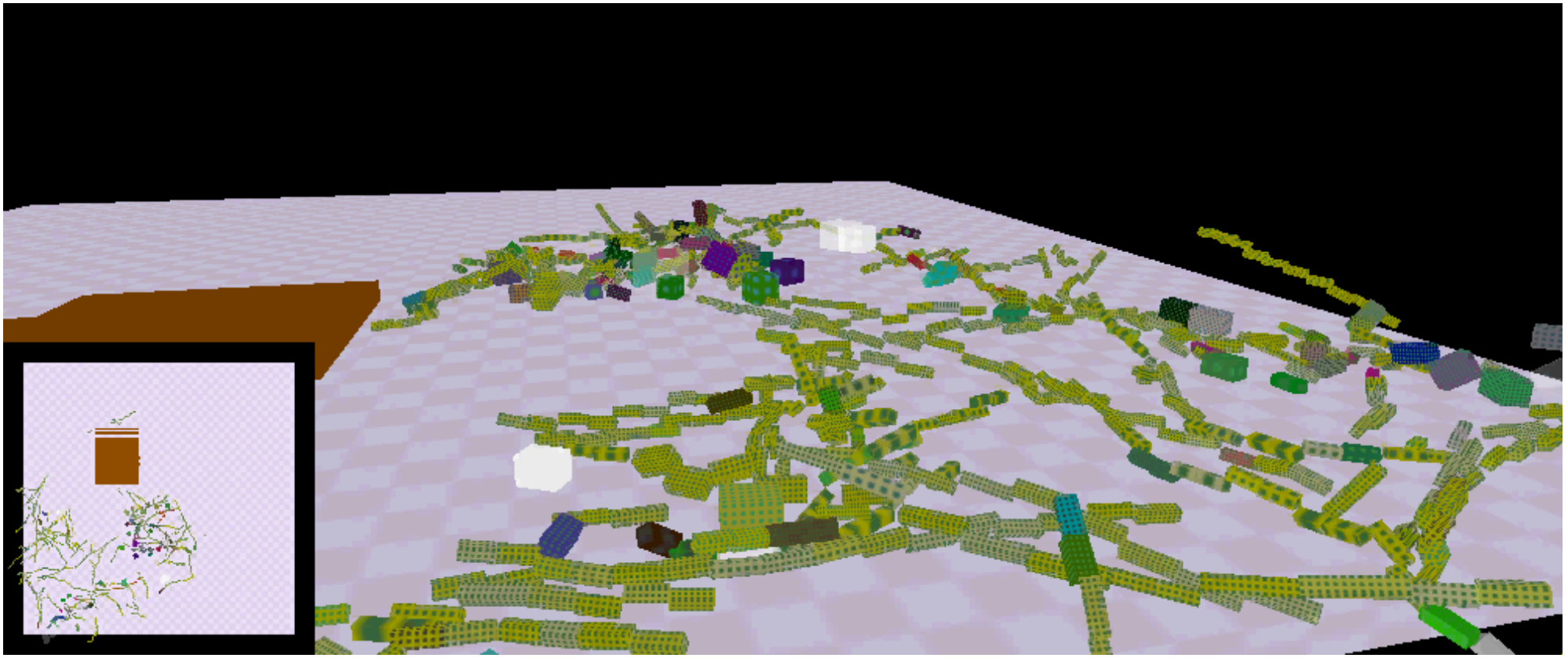
20060623

Death by Plagues

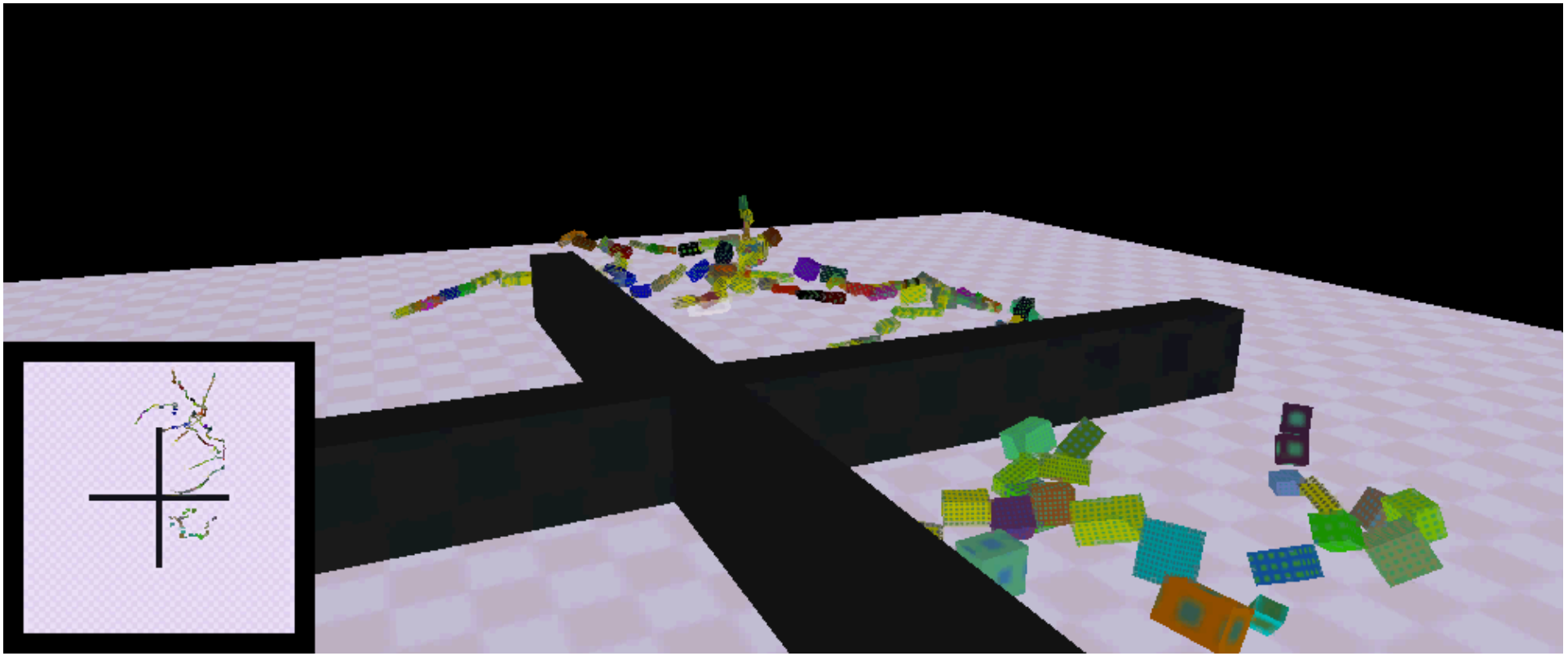


db20060811MBPa

Death by Comets



Mountains



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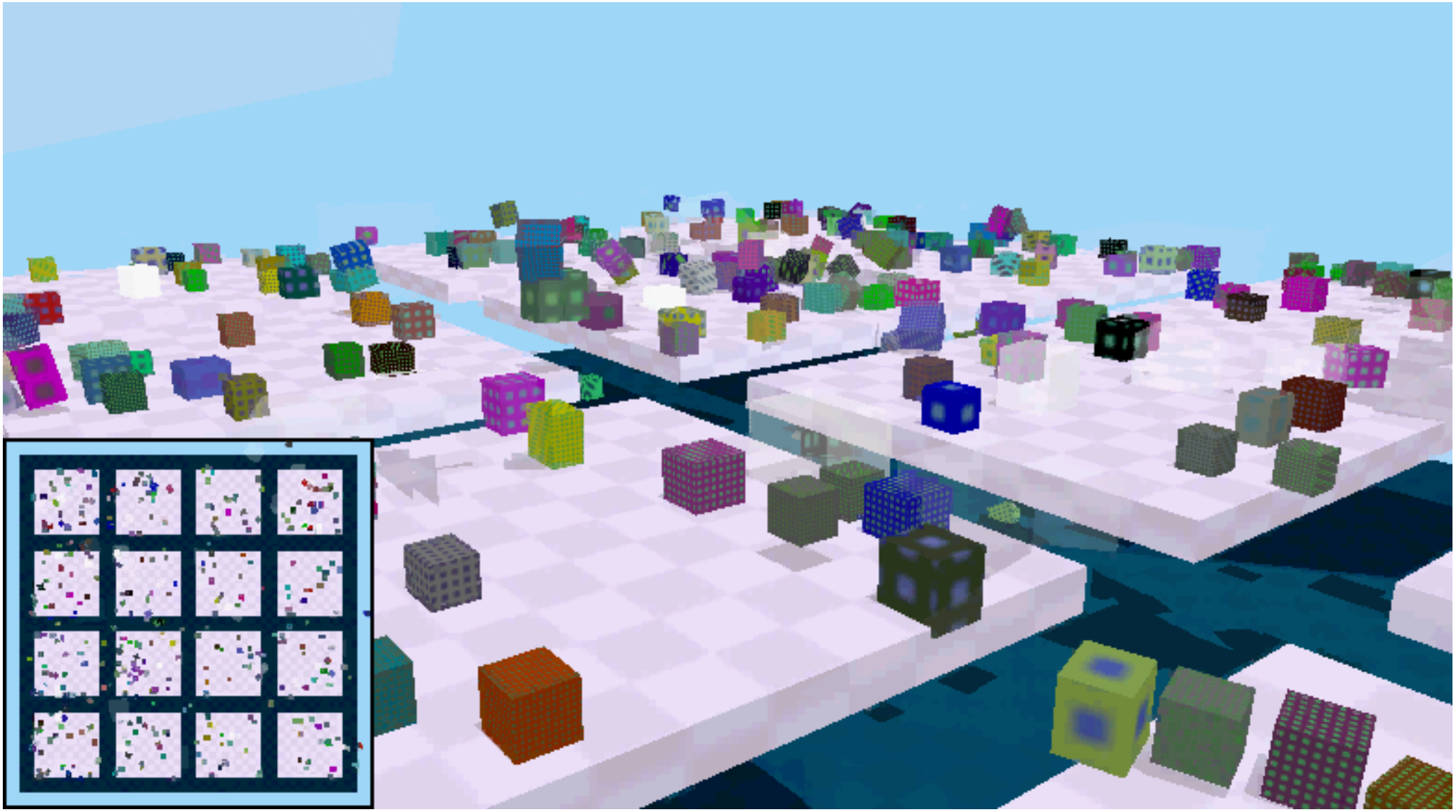
Islands



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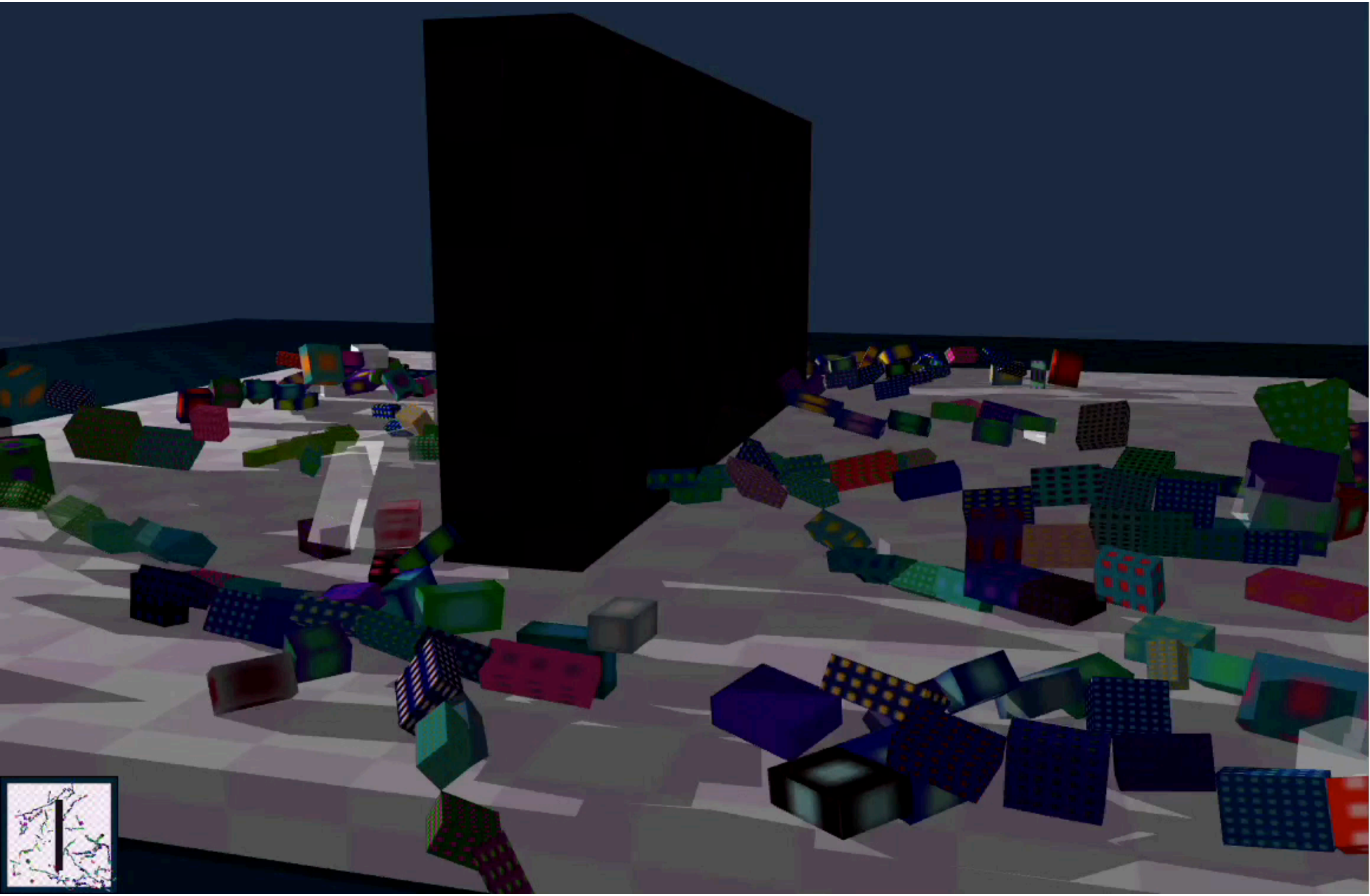
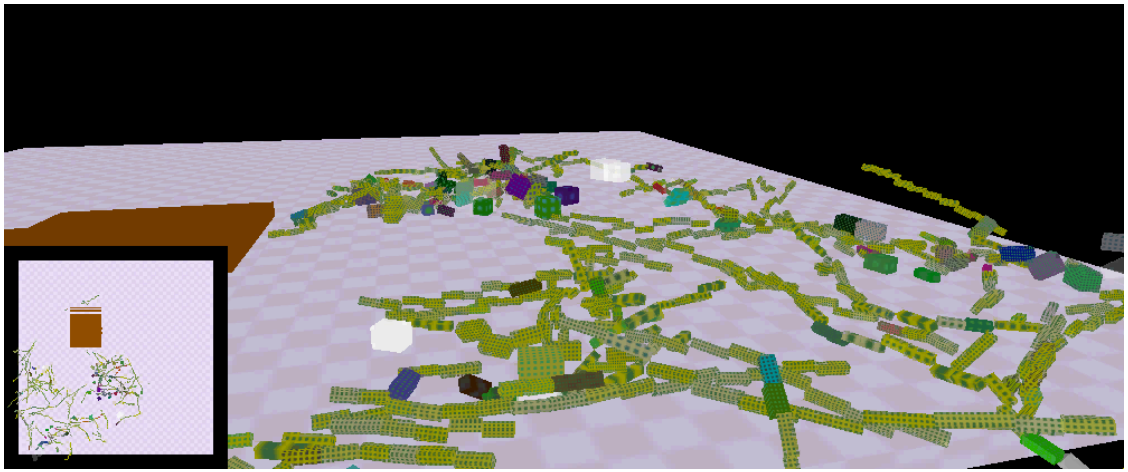
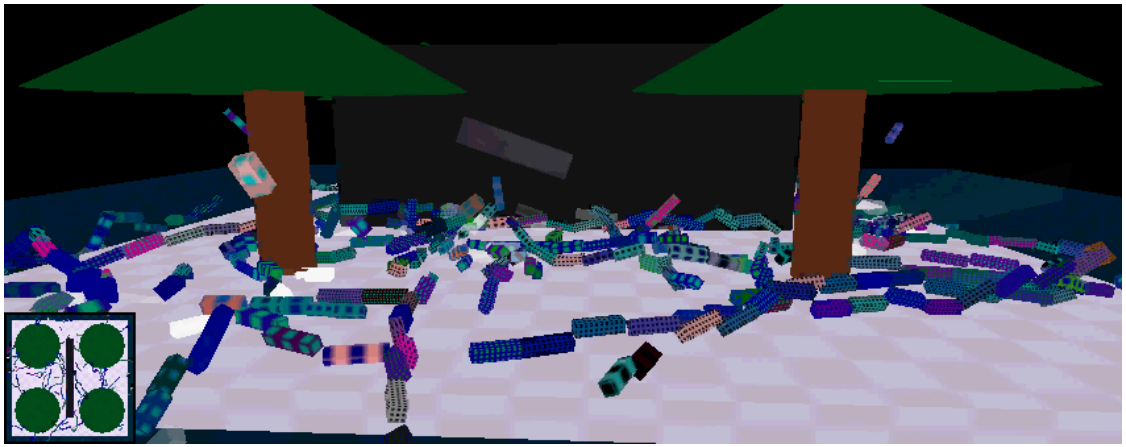
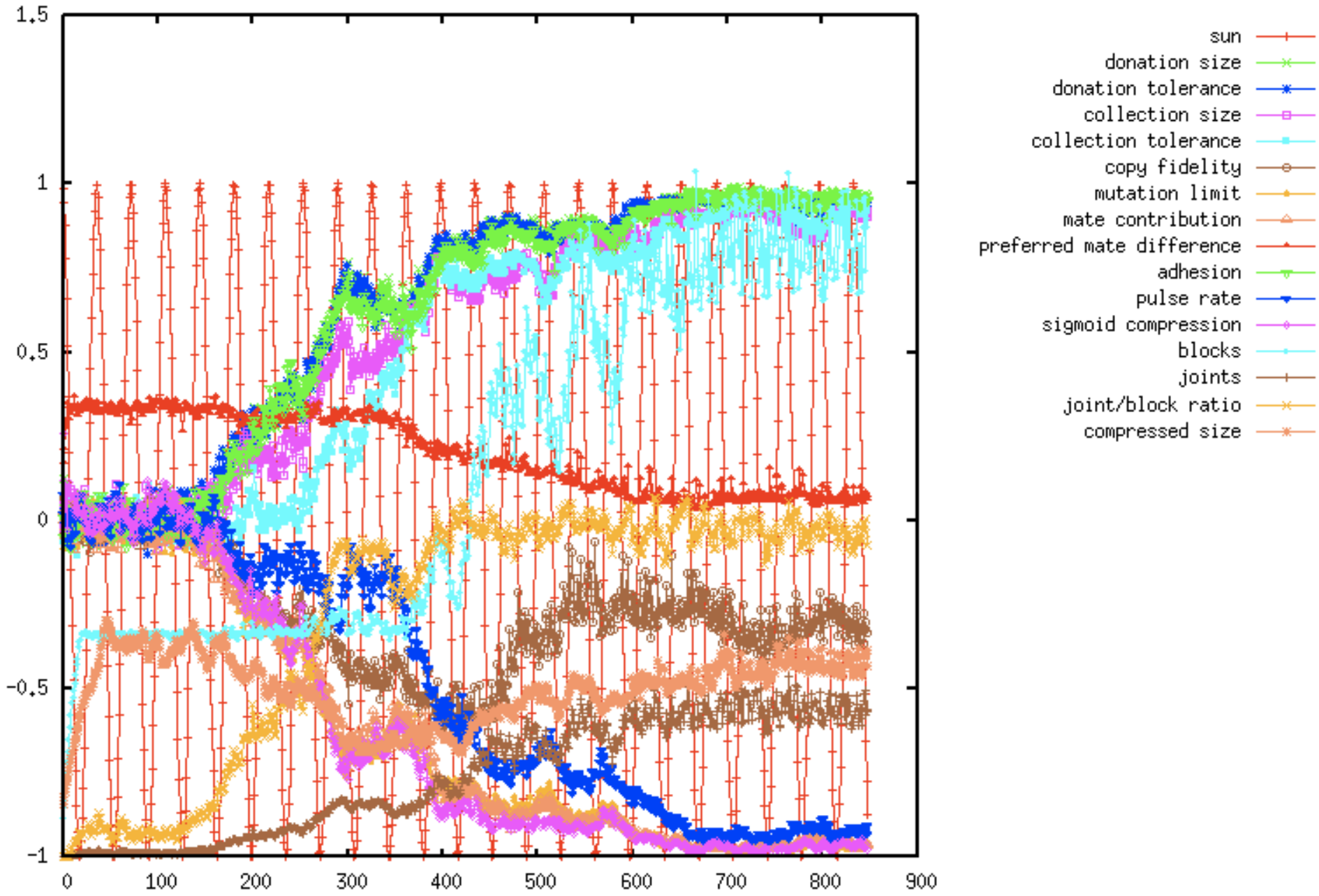


Variations



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300
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700
800
900
sun
donation size
donation tolerance
collection size
collection tolerance
copy fidelity
mutation limit
mate contribution
preferred mate difference
adhesion
pulse rate
sigmoid compression
blocks
joints
joint/block ratio
compressed size

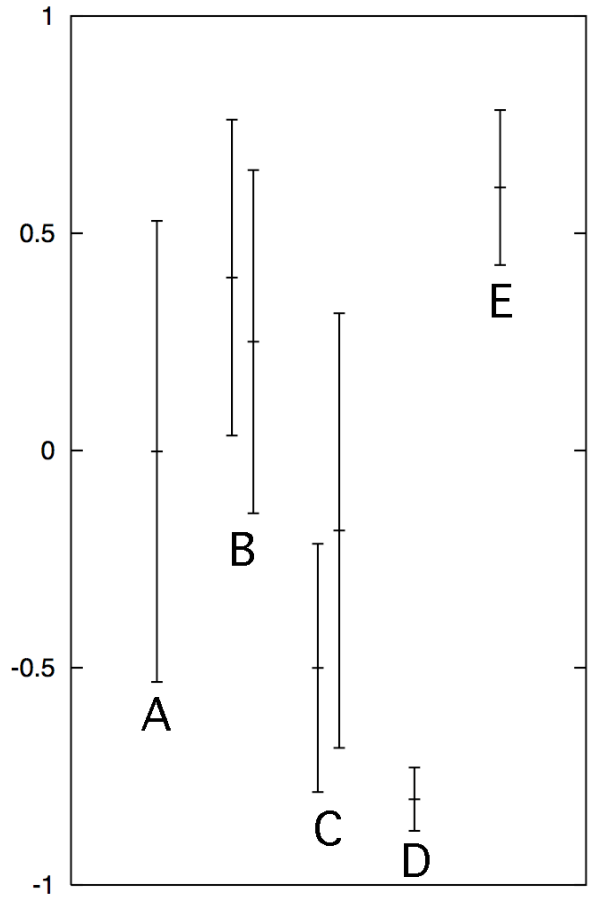
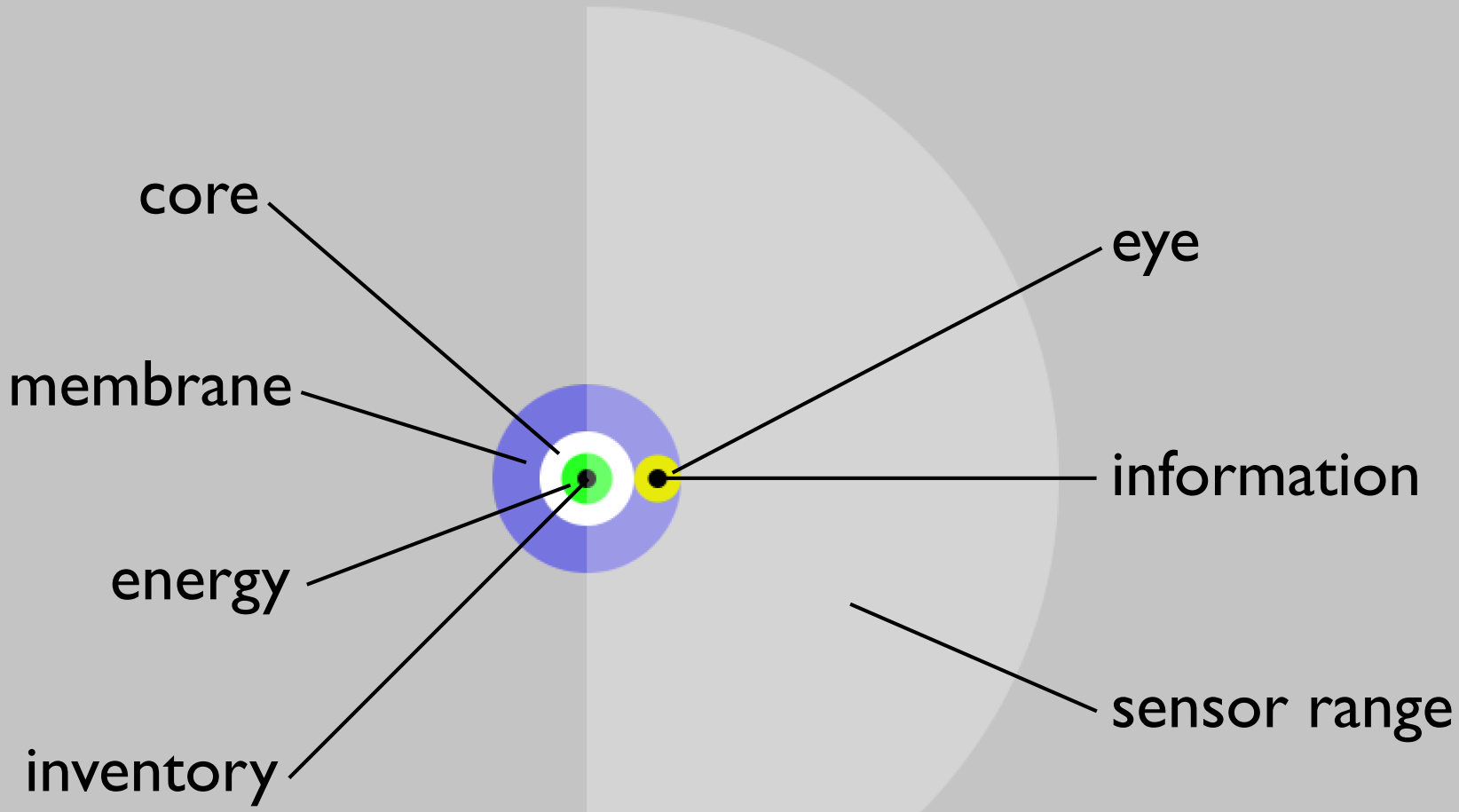
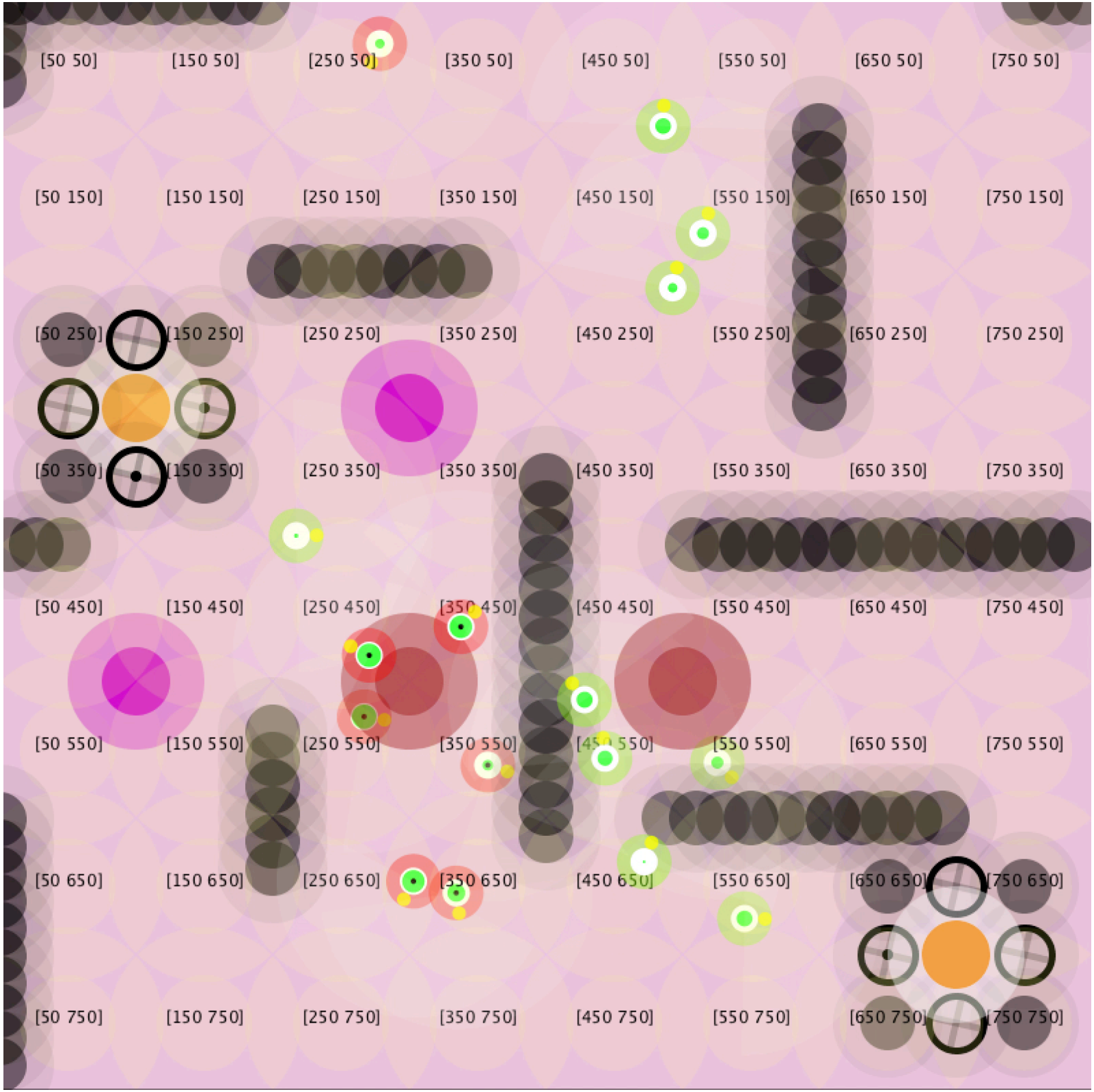


Figure 4: Averaged data from 40 runs of the Division Blocks system, collected after 1000 time steps of reproductive competence. Error bars indicate ±1 standard deviation. A: average tag values; B: average `donationsize` (left) and `donationtolerance` (right); C: average `stemdonationsize` (left) and `stemdonationtolerance` (right); D: average `matecontribution`; E: average `adhesion`.

Pucks


core
membrane
energy
inventory
eye
information
sensor range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[250 50]
[350 50]
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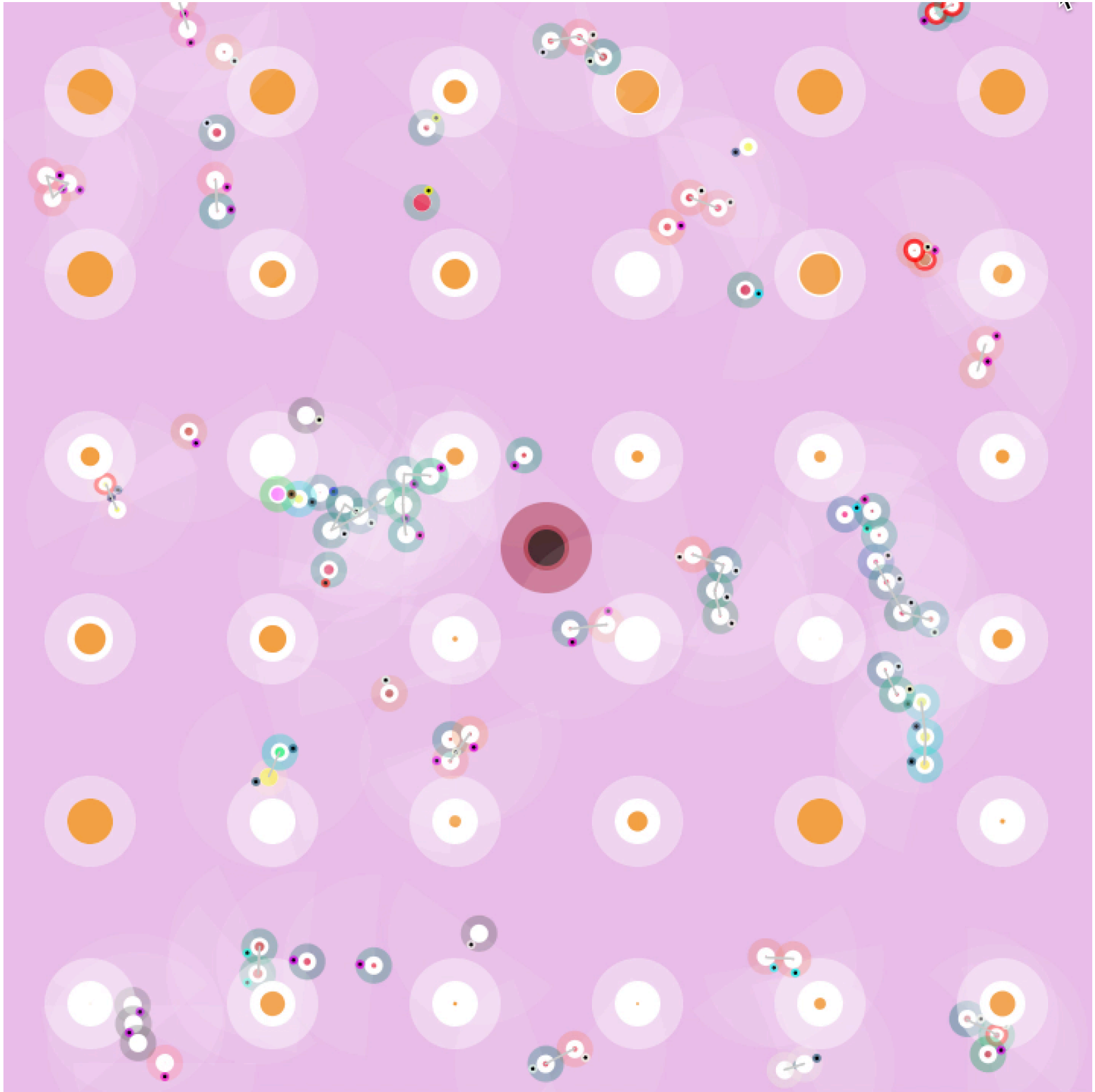
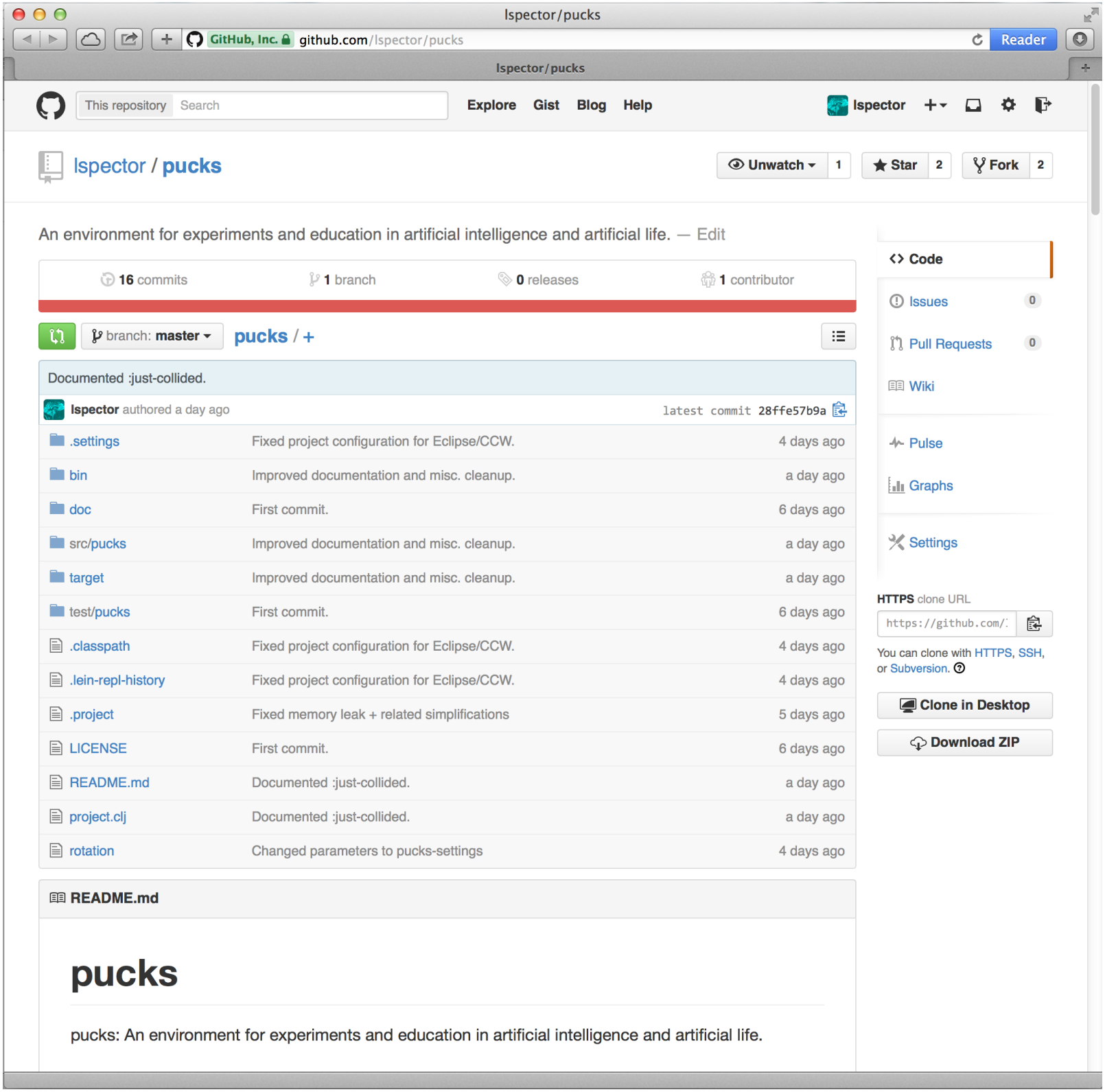



lspector/pucks
GitHub, Inc. github.com/lspector/pucks
Reader
lspector/pucks
This repository Search
Explore Gist Blog Help
lspector
lspector / pucks
Unwatch 1
Star 2
Fork 2
An environment for experiments and education in artificial intelligence and artificial life. — Edit
16 commits
1 branch
0 releases
1 contributor
branch: master
pucks / +
Documented :just-collided.
lspector authored a day ago
latest commit 28ffe57b9a
.settings Fixed project configuration for Eclipse/CCW. 4 days ago
bin Improved documentation and misc. cleanup. a day ago
doc First commit. 6 days ago
src/pucks Improved documentation and misc. cleanup. a day ago
target Improved documentation and misc. cleanup. a day ago
test/pucks First commit. 6 days ago
.classpath Fixed project configuration for Eclipse/CCW. 4 days ago
.lein-repl-history Fixed project configuration for Eclipse/CCW. 4 days ago
.project Fixed memory leak + related simplifications 5 days ago
LICENSE First commit. 6 days ago
README.md Documented :just-collided. a day ago
project.clj Documented :just-collided. a day ago
rotation Changed parameters to pucks-settings 4 days ago
README.md
pucks
pucks: An environment for experiments and education in artificial intelligence and artificial life.
Code
Issues 0
Pull Requests 0
Wiki
Pulse
Graphs
Settings
HTTPS clone URL
https://github.com/
You can clone with HTTPS, SSH, or Subversion.
Clone in Desktop
Download ZIP

Proposals

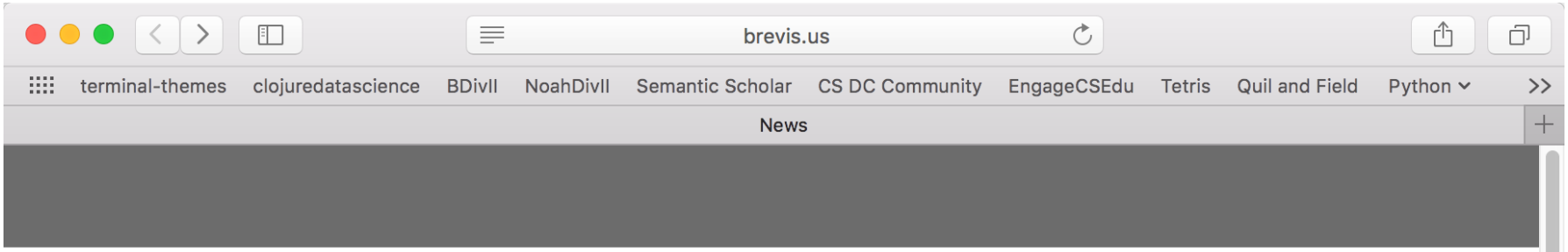
Proposal functions should take a puck and return a collection of proposals in the form of a map. Among the key/value pairs that can be included in proposals are:

Key	Value
:acceleration	a floating-point number indicating the target acceleration, which may be limited by settings for :max-acceleration and :max-velocity
:rotation	a floating-point number indicating the target rotation, which may be limited by the setting of :max-rotational-velocity
:spawn	a sequence of pucks that are potential offspring *(not yet fully implemented)*
:transfer	a sequence of transactions; a transaction is a map with four key/value pairs: :self (the value of which should be a puck ID), :other (the value of which should be a puck ID), :ask (the value of which should be a map with resources such as :energy as keys, and requested amounts as values), and :bid (the value of which should be a map with resources such as :energy as keys, and offered amounts as values); *the transaction specification is still under development*
:memory	a map of any keys to any values

Proposal functions may refer to any elements of the pucks that they received, although the :neighbors of those pucks will have been stripped and replaced with empty sequences, and the :positions of those pucks will have been stripped and replaced with [0 0]. Positions of offspring pucks specified in :spawn proposals will be interpreted relative to the positions of the parent pucks.

Open-Ended Evolution

?



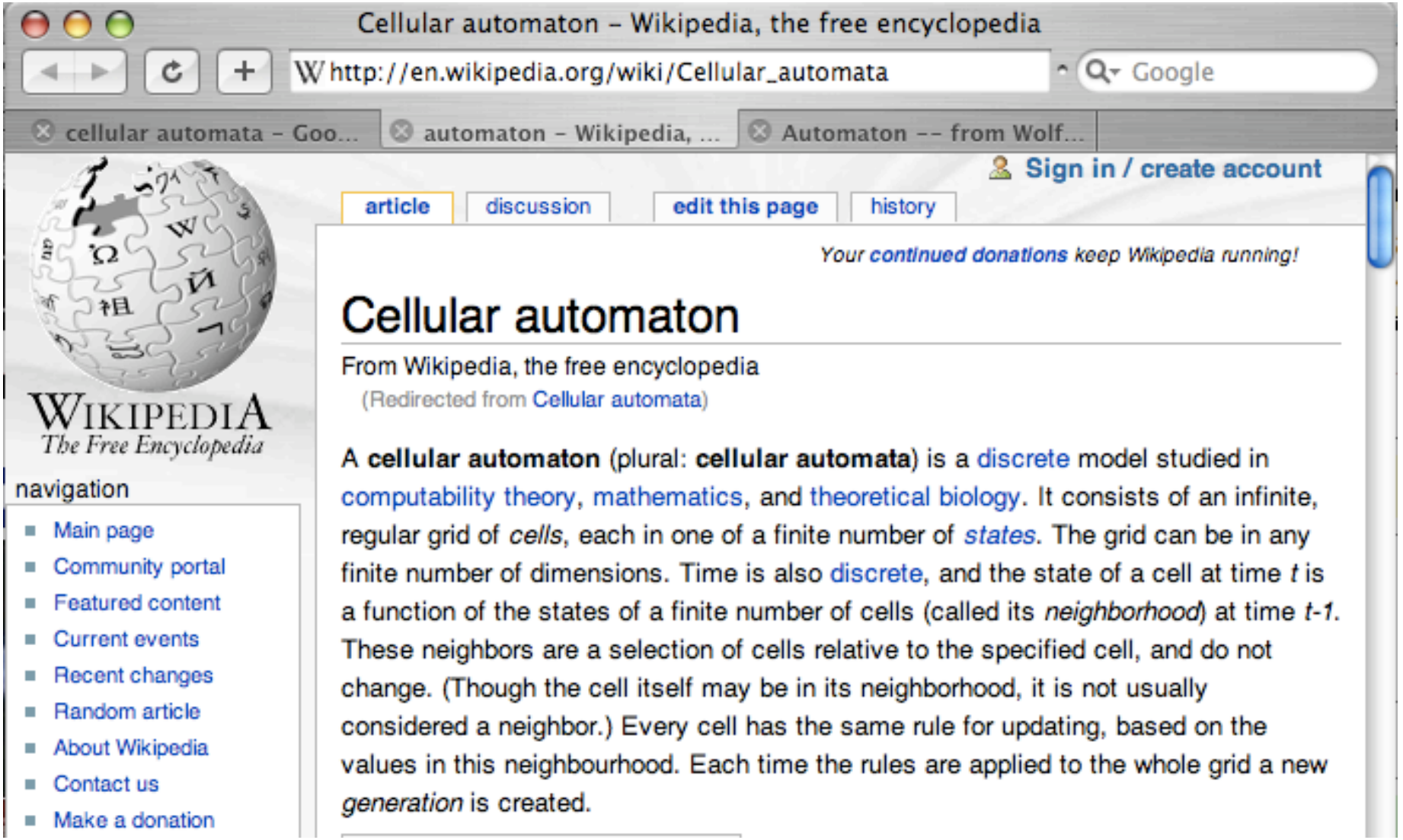
Brevis: A Functional Tool for Science and Artificial Life

Home About Docs Source Simula

Brevis is an open-source scientific and artificial life simulator that uses the functional language, Clojure, for writing simulations.

News

July 14, 2015 - Brevis has teamed up with the Waltham High School-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Google
cellular automata – Goo...
automaton – Wikipedia, ...
Automaton -- from Wolf...
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article
discussion
edit this page
history
Your continued donations keep Wikipedia running!
Cellular automaton
From Wikipedia, the free encyclopedia
(Redirected from Cellular automata)
A cellular automaton (plural: cellular automata) is a discrete model studied in computability theory, mathematics, and theoretical biology. It consists of an infinite, regular grid of cells, each in one of a finite number of states. The grid can be in any finite number of dimensions. Time is also discrete, and the state of a cell at time t is a function of the states of a finite number of cells (called its neighborhood) at time t-1. These neighbors are a selection of cells relative to the specified cell, and do not change. (Though the cell itself may be in its neighborhood, it is not usually considered a neighbor.) Every cell has the same rule for updating, based on the values in this neighbourhood. Each time the rules are applied to the whole grid a new generation is created.
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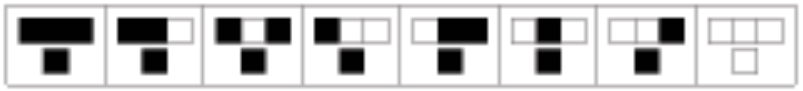
1-Dimensional CAs

from www.worlframscience.com

Rule 254

Rule specification (EPS: 20k)



Sequence of steps (EPS: 13k)

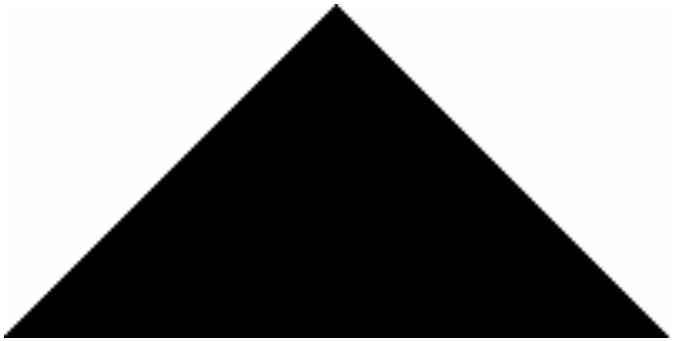
---

25 steps (TIF: 4k) (GIF: 1k)

25 steps with grid (EPS: 9k)

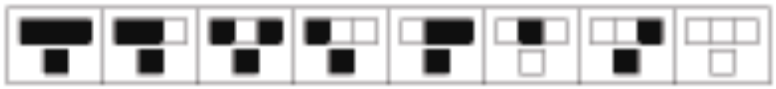
100 steps (TIF: 4k) (GIF: 1k) (as shown)

250 steps (TIF: 5k) (GIF: 3k)



Rule 250

Rule specification (EPS: 11k)



Sequence of steps (EPS: 13k)

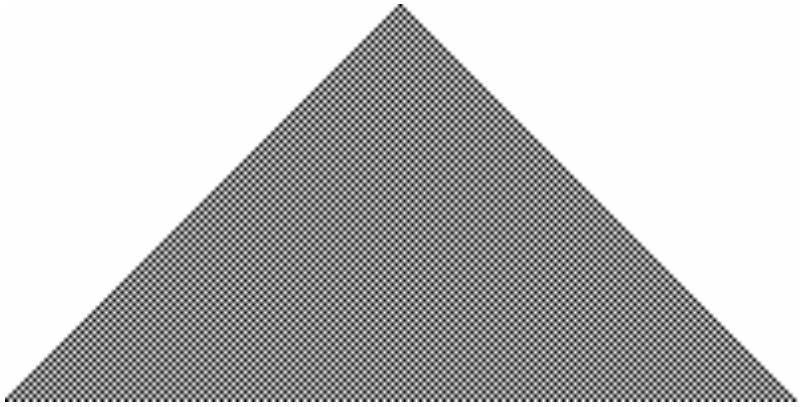
---

25 steps (TIF: 4k) (GIF: 1k)

25 steps with grid (EPS: 9k)

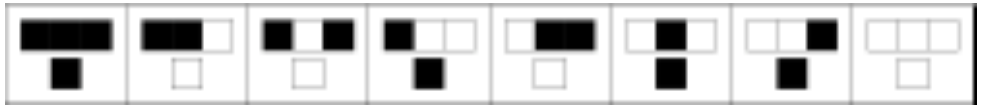
100 steps (TIF: 4k) (GIF: 1k) (as shown)

250 steps (TIF: 5k) (GIF: 3k)



Rule 150

Rule specification (EPS: 29k)



Sequence of steps (EPS: 11k)

---

25 steps (TIF: 4k) (GIF: 1k)

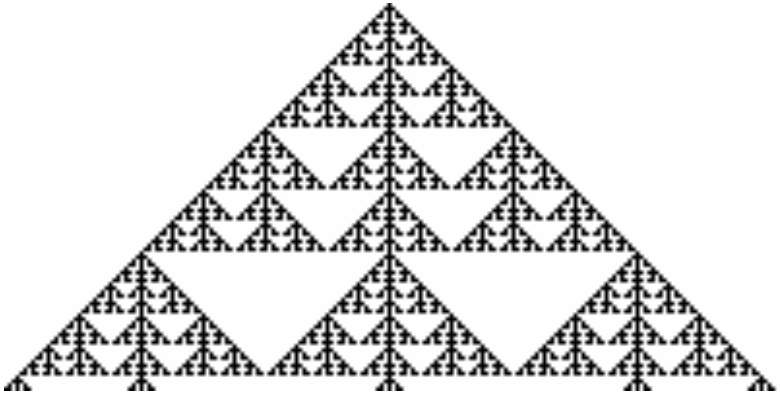
25 steps with grid (EPS: 31k)

100 steps (TIF: 4k) (GIF: 2k) (as shown)

250 steps (TIF: 5k) (GIF: 5k)

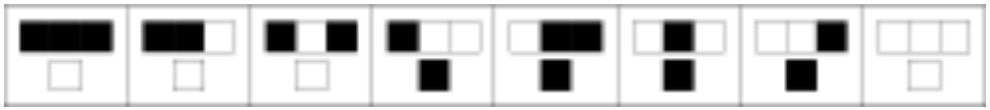
1000 steps (TIF: 14k) (GIF: 51k)

2500 steps (TIF: 37k) (GIF: 225k)



Rule 30

Rule specification (EPS: 29k)



Sequence of steps (EPS: 32k)

25 steps (TIF: 4k) (GIF: 1k)

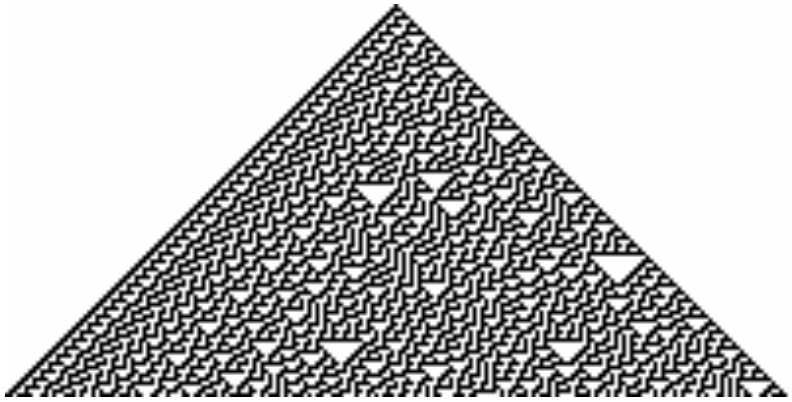
25 steps with grid (EPS: 31k)

100 steps (TIF: 5k) (GIF: 2k) (as shown)

250 steps (TIF: 10k) (GIF: 10k)

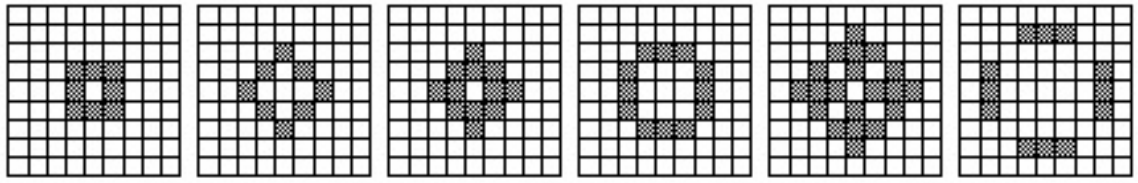
1000 steps (TIF: 86k) (GIF: 156k)

2500 steps (TIF: 500k) (GIF: 967k)



Conway's *Life*

- 2D cellular automaton.
- Stay alive with 2 or 3 living neighbors.
- Birth with exactly 3 living neighbors.
- Complex dynamics; Turing complete.



We'll return to this shortly for the assignment!

Secure https://en.wikipedia.org/wiki/Reaction–diffusion_system

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Reaction–diffusion system

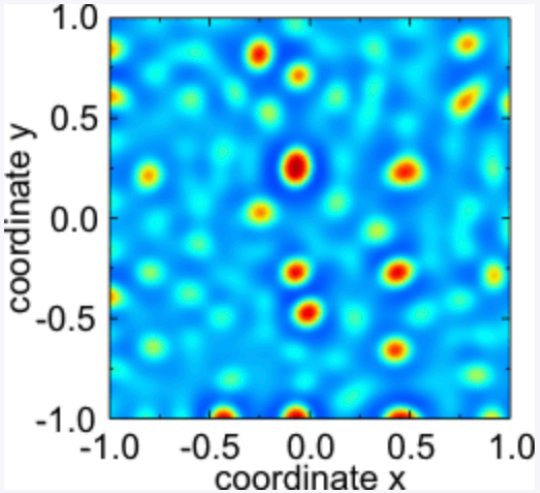
From Wikipedia, the free encyclopedia

Reaction–diffusion systems are mathematical models which correspond to several physical phenomena: the most common is the change in space and time of the concentration of one or more chemical substances: local chemical reactions in which the substances are transformed into each other, and diffusion which causes the substances to spread out over a surface in space.

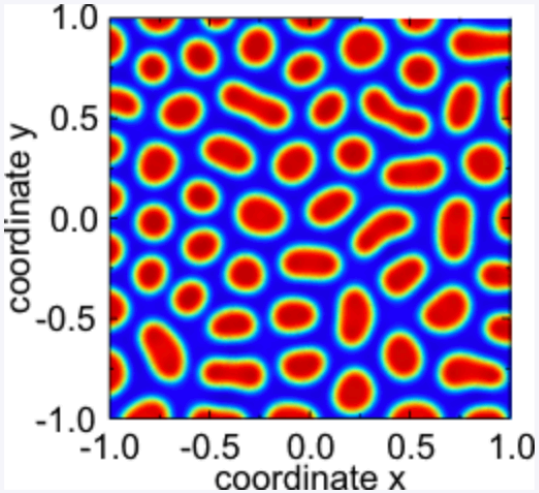
Reaction–diffusion systems are naturally applied in chemistry. However, the system can also describe dynamical processes of non-chemical nature. Examples are found in biology, geology and physics (neutron diffusion theory) and ecology. Mathematically, reaction–diffusi d in the general form

∂_t

where accounts for all local reacti nation of travelling waves and wave- re like dissipative solitons. Each iable.



State of the system at $t = 10$.



Almost converged state at $t = 100$.

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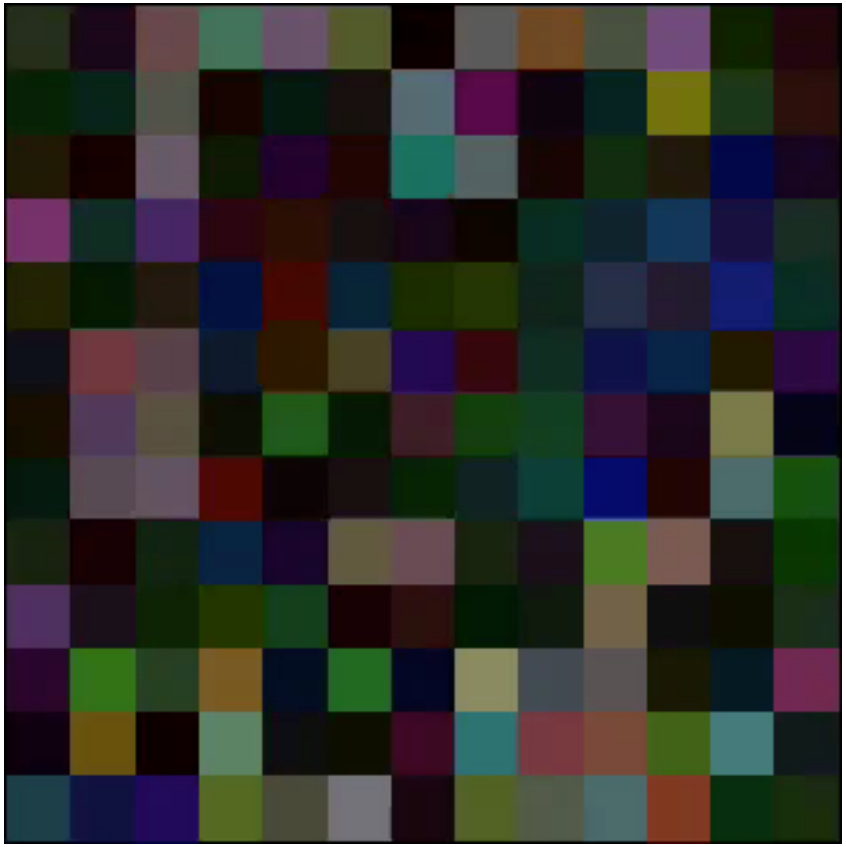
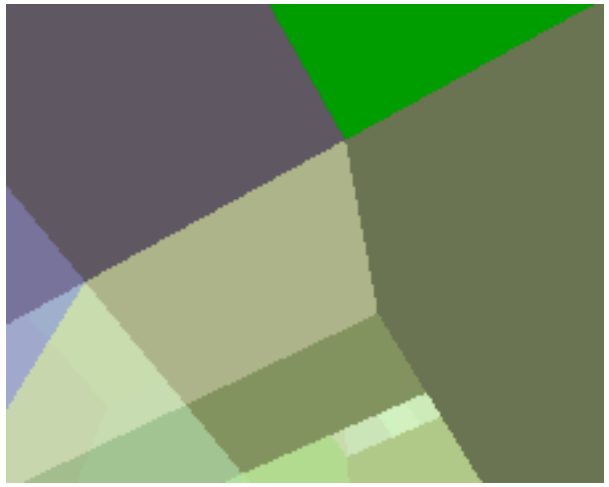
Check out https://pmneila.github.io/jsexp/grayscott/

Albers Automaton



CA3D



Golly! An Assignment!

- **Get** http://golly.sourceforge.net
- **Create** and **observe** patterns
- **Consider**: What is life here? What is death here? Could a pattern feel happiness or sadness? Could it dread death?
- **Produce** something that presents your work and thoughts