ETH zürich

# Emergent gait periodicity in artificially evolved creatures on unknown terrains

Benjamin Ellenberger

# Contents

# Life as it is vs. life as it could be

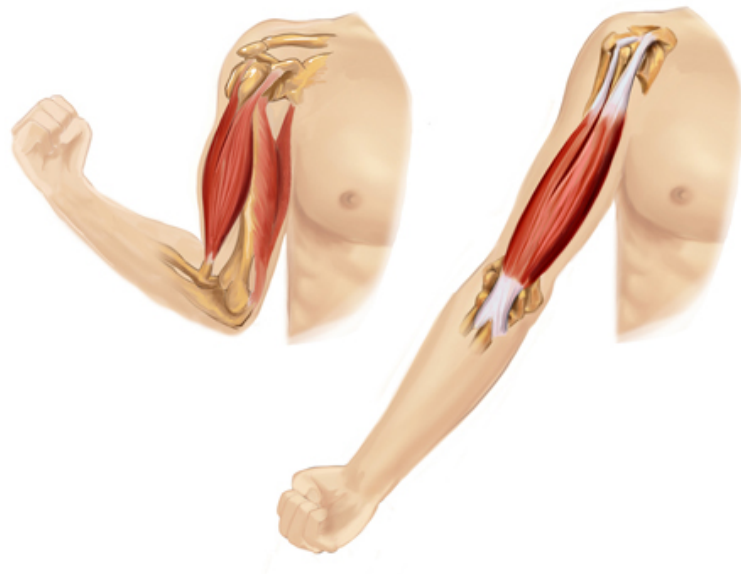
# Applications

- Build robots that are not only capable but also more adaptive (Engineering goal)
- Structures and strategies that always tend to evolve (Academic goal)

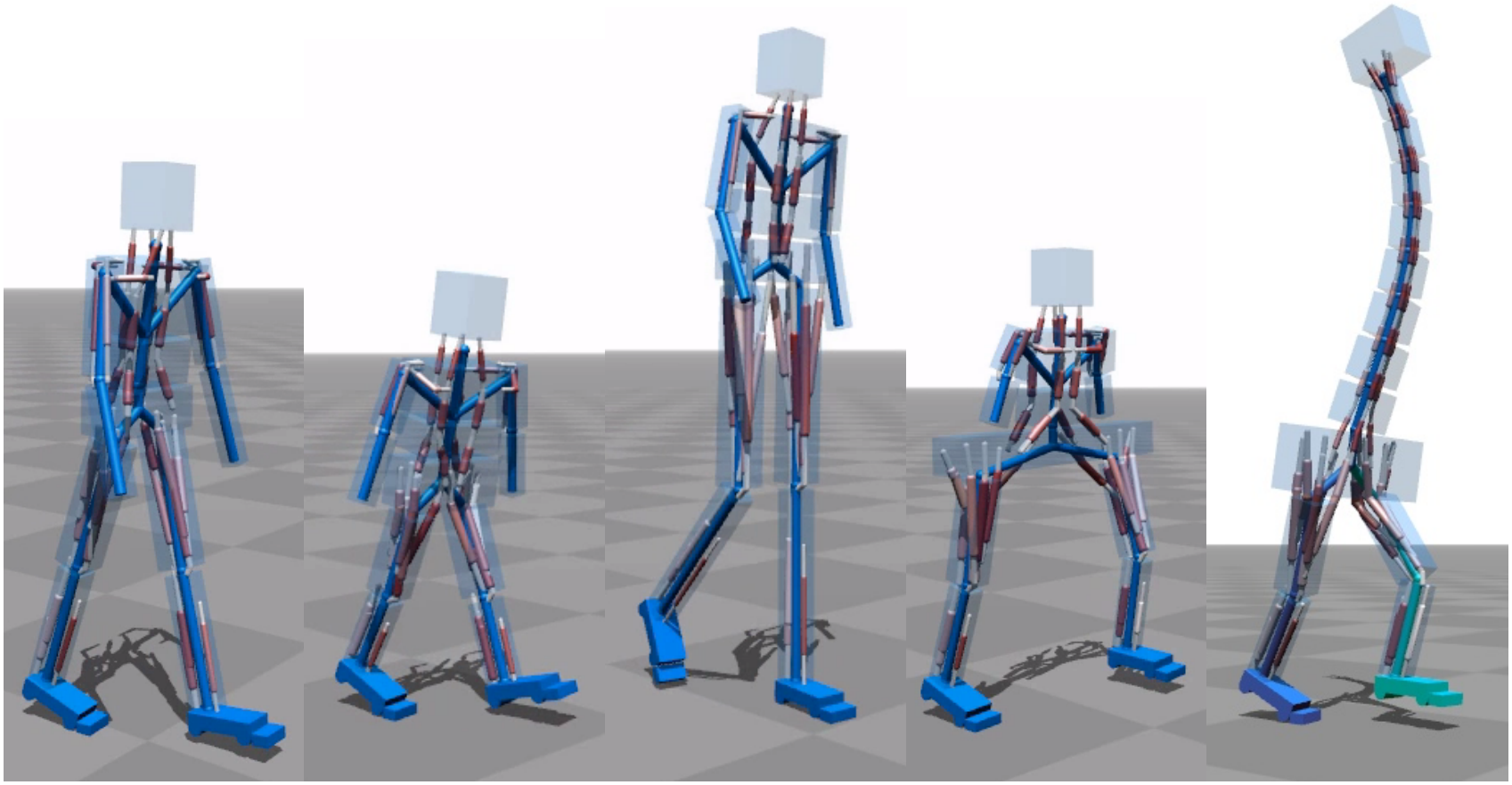
# Simple limiters

# Simple limiters in nature

- Muscle length & joint limits
- The weight of the limbs
- The relative position of limbs connected by joints
  (Direction of force applied to joints)



# Simple limiters cont.



# In silico[1]: Will they be used?

- 
- 

[1] In silico = in simulation

# Evolving Virtual Creatures

- a
- b
- c

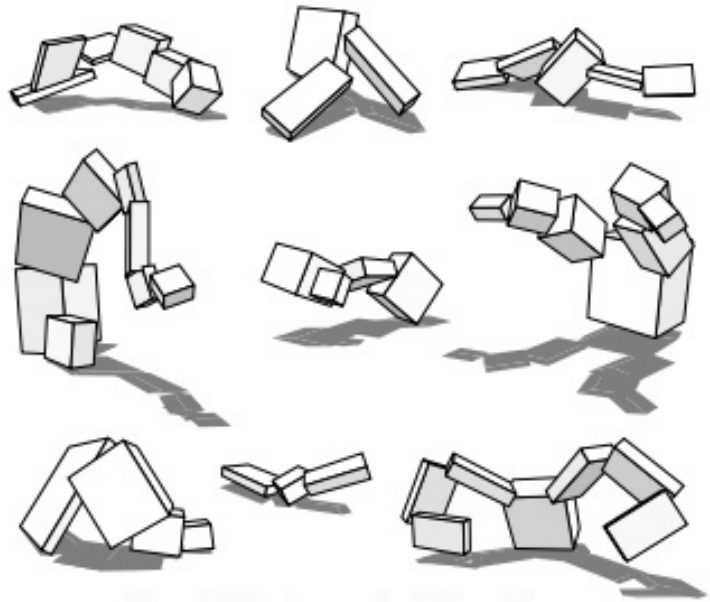


**Figure 7**: Creatures evolved for walking.

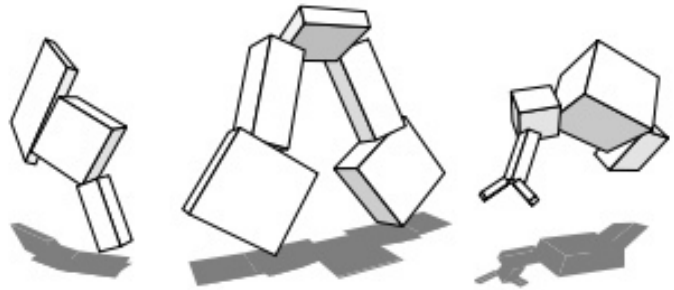
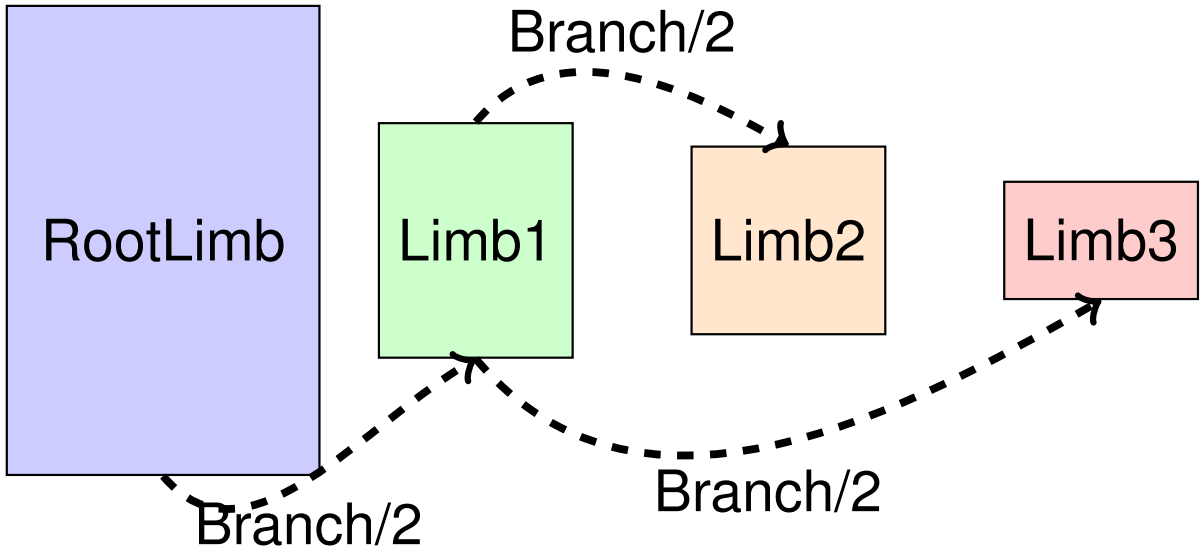


**Figure 8**: Creatures evolved for jumping.

# Contents

# Genetic language

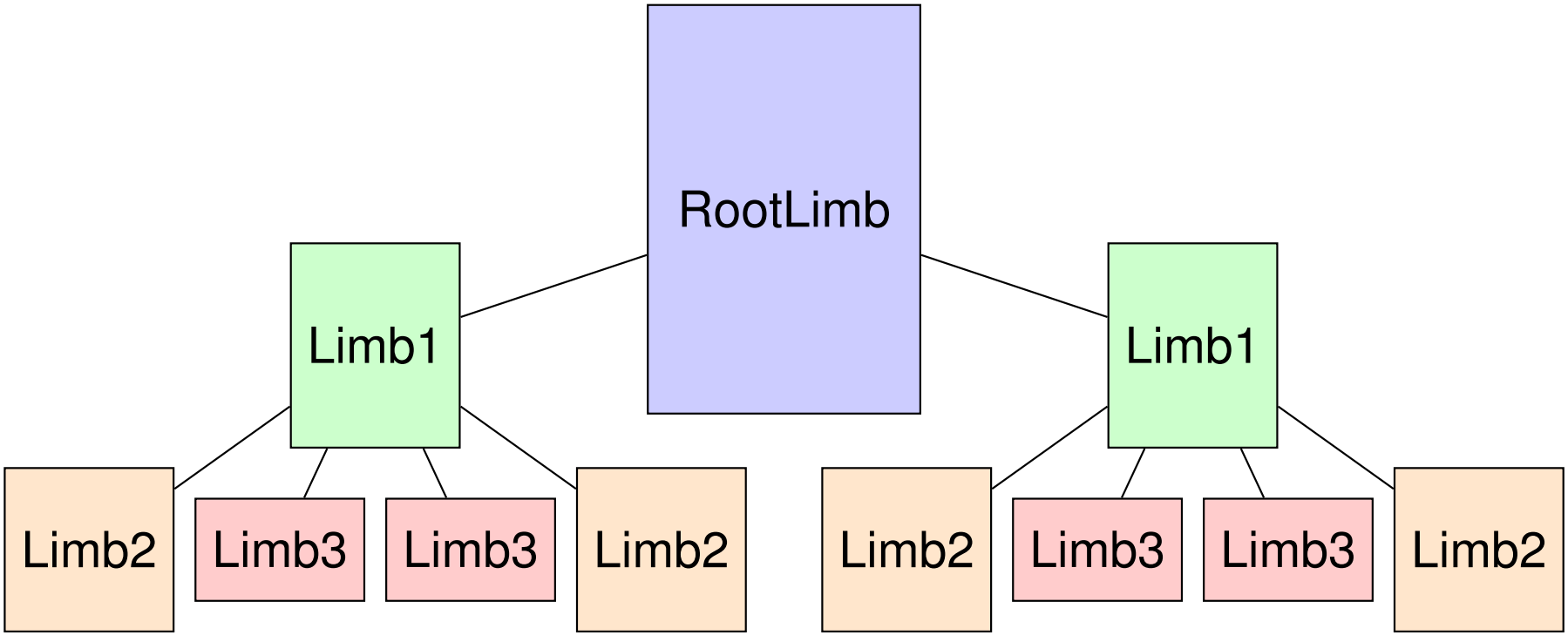



Genotype:

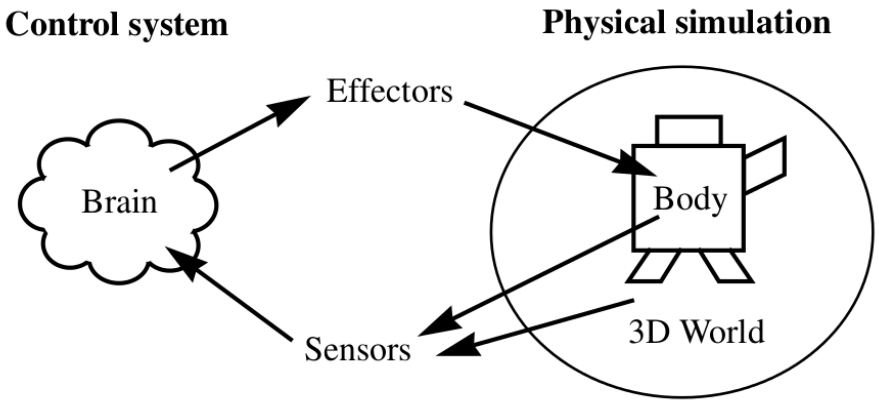
- **Limb** Part of creature body

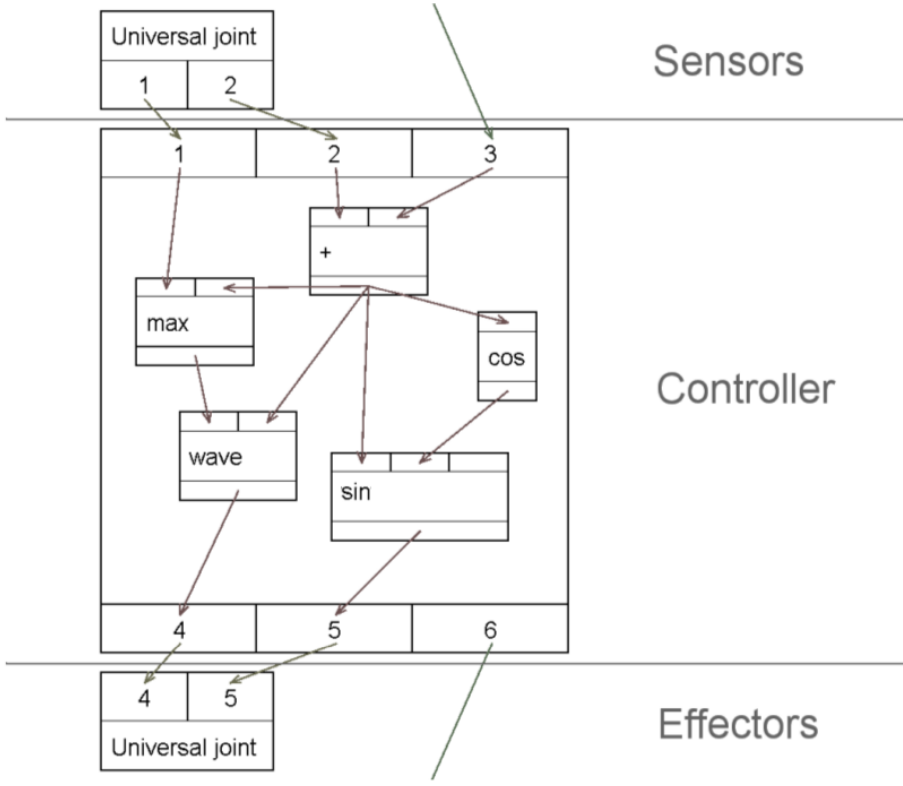
# Genetic language

Phenotype:



# Execution of creatures



# Fitness evaluation

- Fitness evaluation framework
- A creature is simulated for a certain evaluation time during which the fitness function measures the fitness of the creature
- Evaluates multiple fitness functions at the same time and combines them linearly

# Evolution

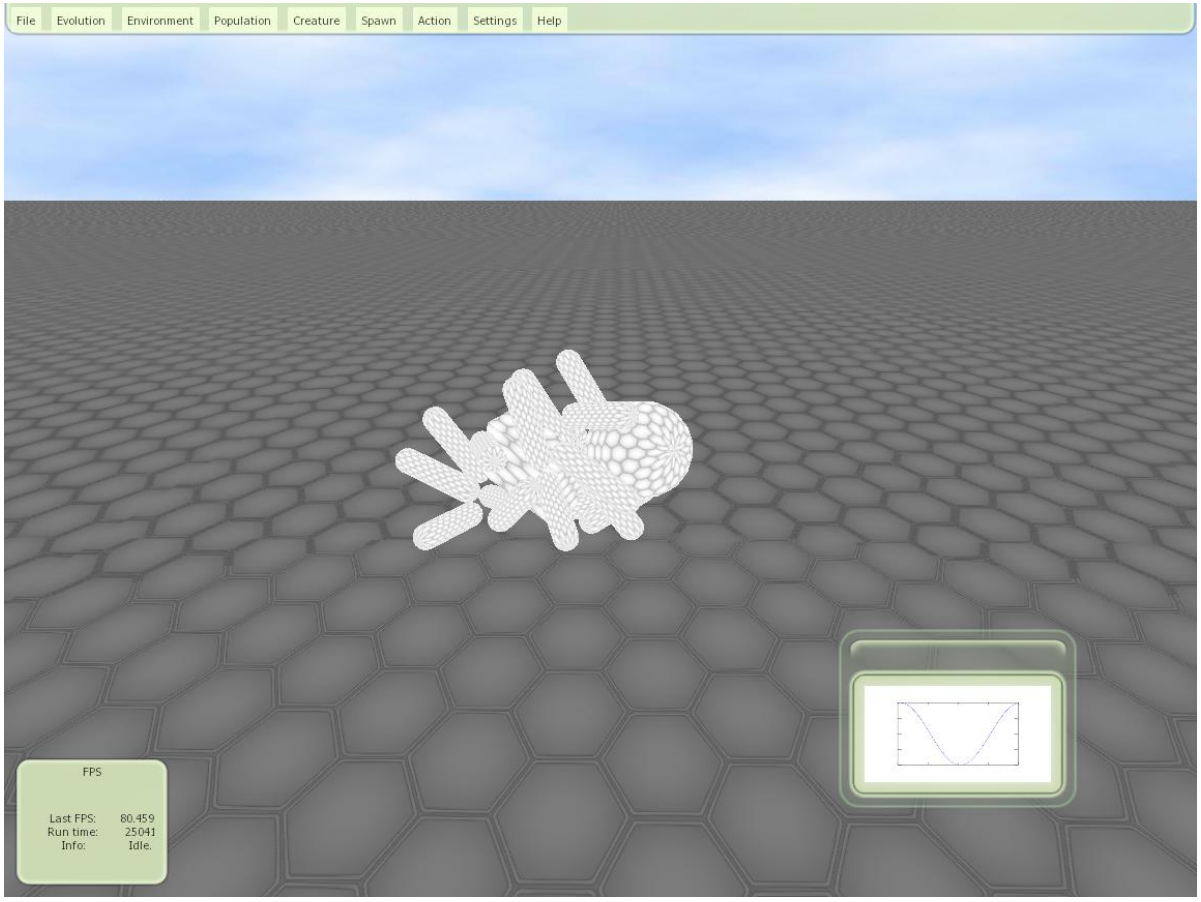
- Selection
  - Only a certain percentage of creatures are selected for new generation
- Cross-over
  - Only certain percentage of creatures are allowed to breed
- Mutation
  - Other creatures are subject to mutation
  - Mutation of gene
  - Mutation of gene attributes
  - Mutation of gene branches
- Successful creatures stay in the population and the population is refilled with new bred and mutated ones

# Contents

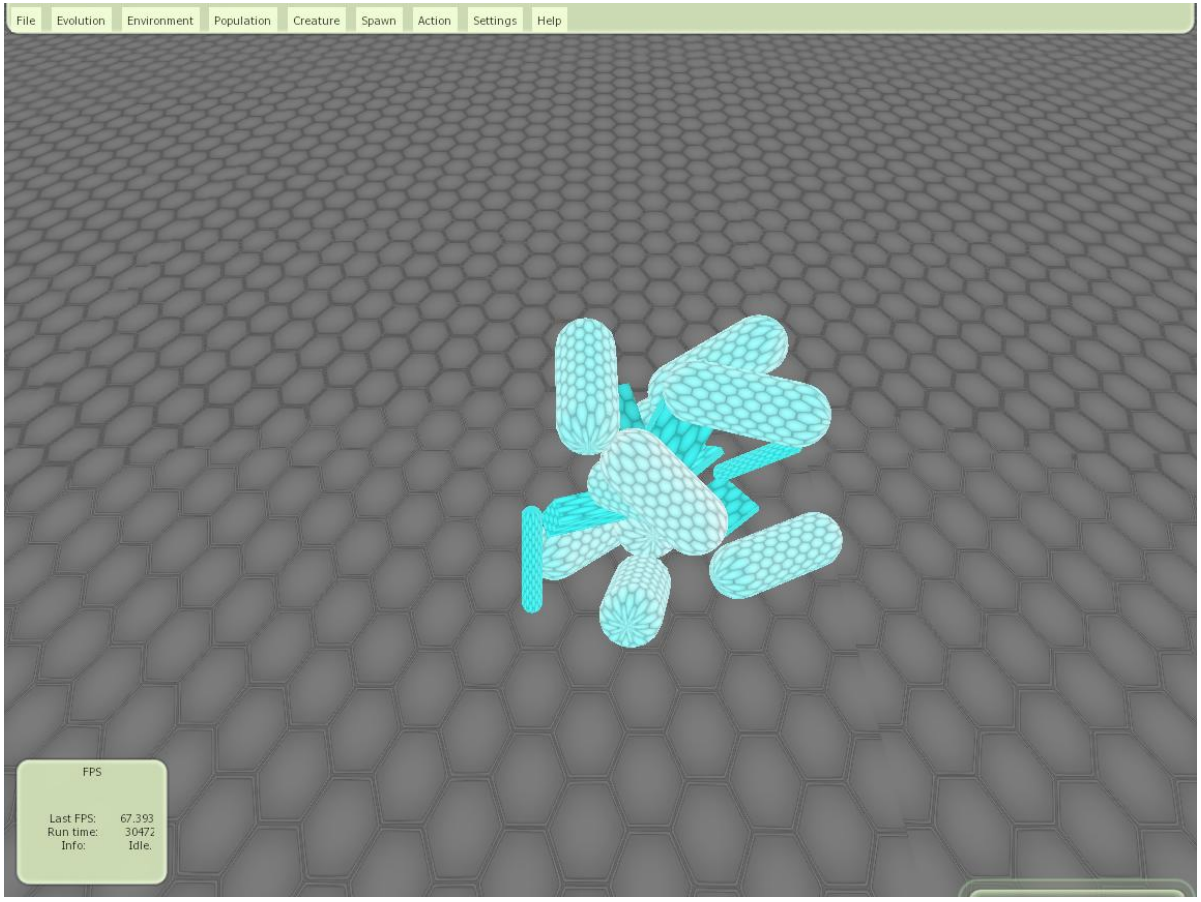
# Velocity as the fitness function

- Sampling of position over time
- Moved distance in a certain time interval
- Continuous average
- Expectations: Some really moving creatures and some finding the exploit that only the main body has to move.
  (main body = first limb in phenotype)

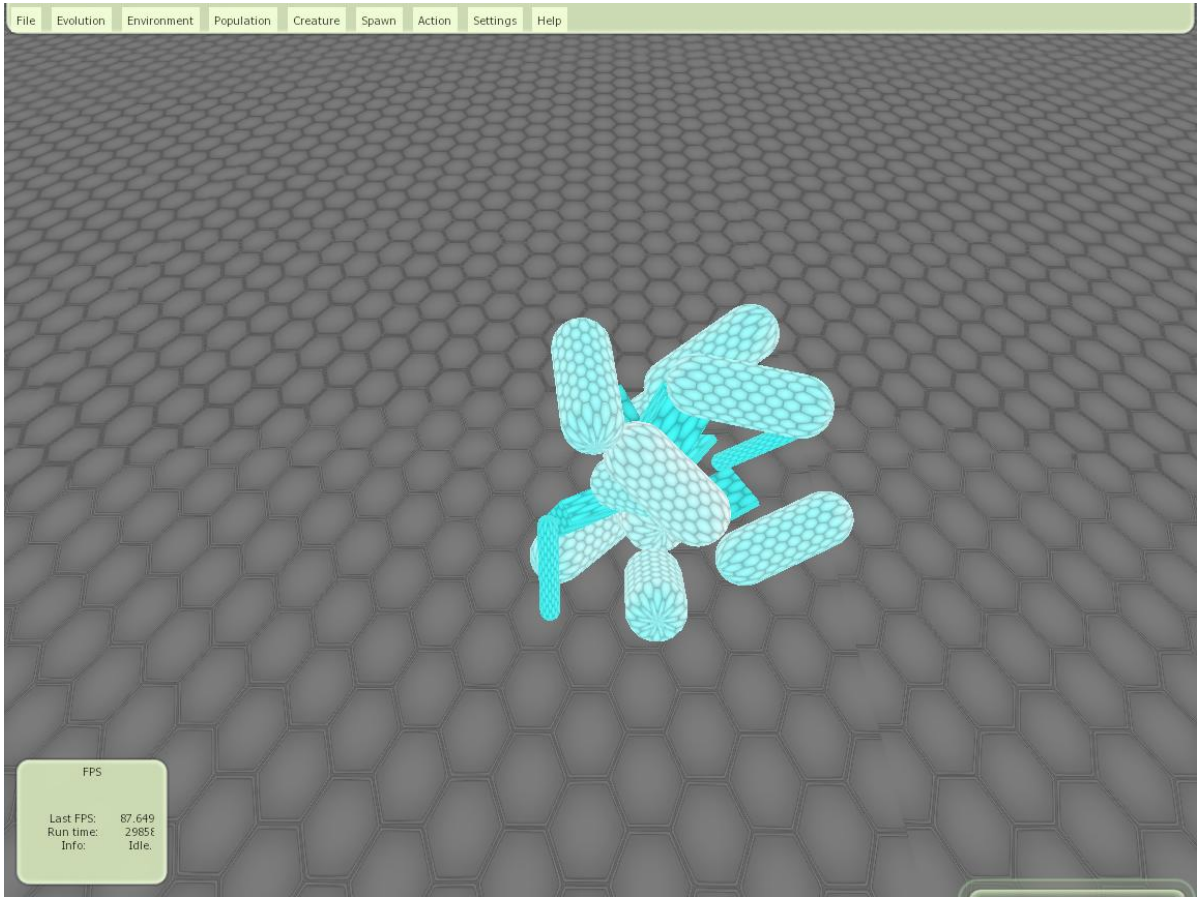
# Creatures


File
Evolution
Environment
Population
Creature
Spawn
Action
Settings
Help
FPS
Last FPS: 80.459
Run time: 25041
Info: Idle.

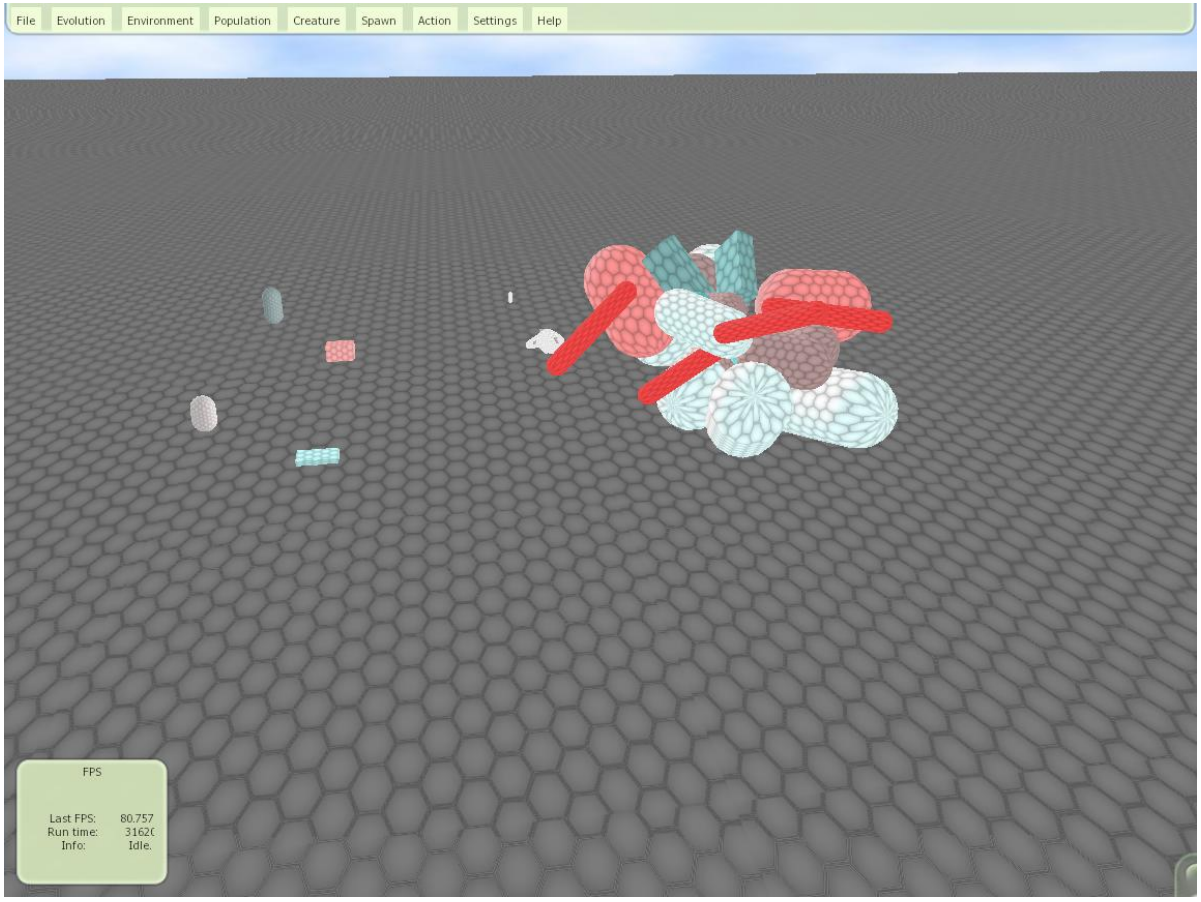
# Creatures


File
Evolution
Environment
Population
Creature
Spawn
Action
Settings
Help
FPS
Last FPS: 67.393
Run time: 30472
Info: Idle.

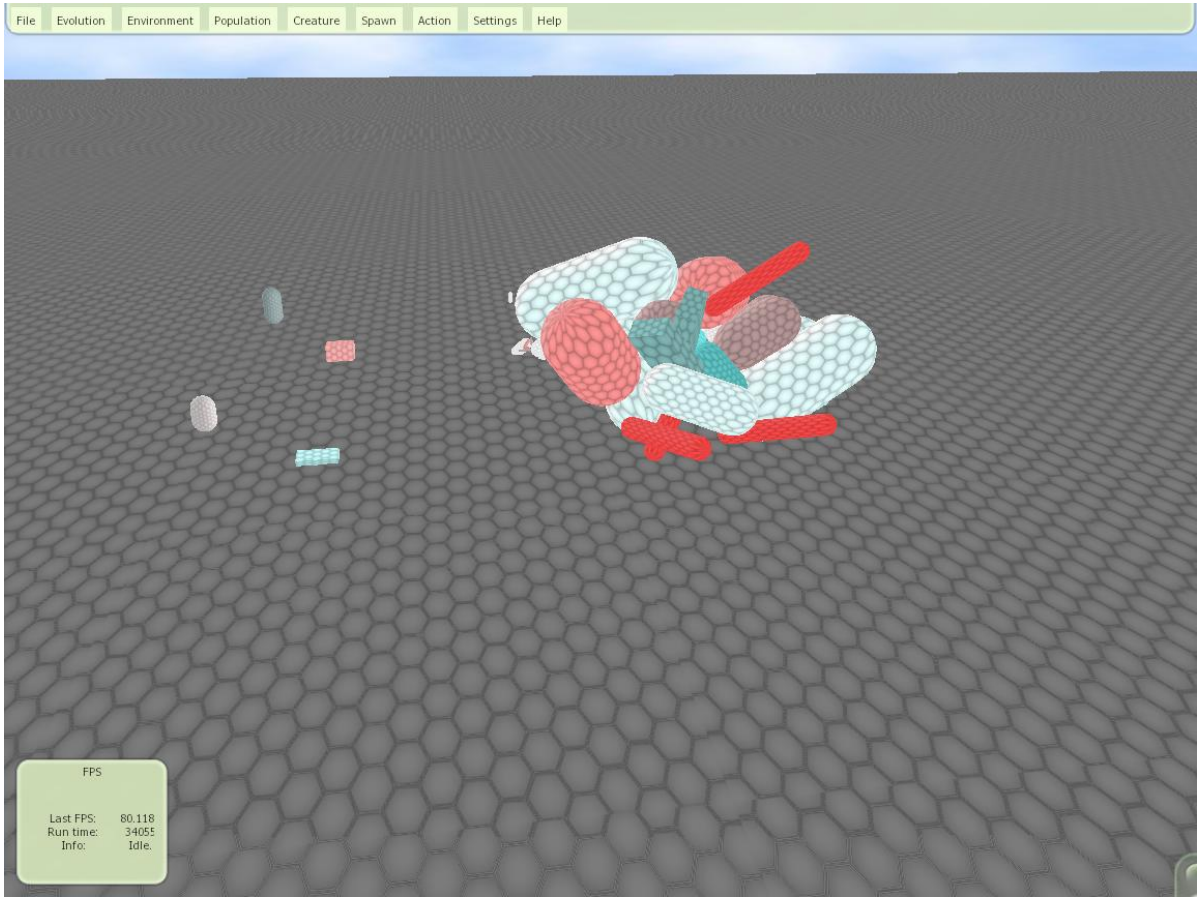
# Creatures


File
Evolution
Environment
Population
Creature
Spawn
Action
Settings
Help
FPS
Last FPS: 87.649
Run time: 2985
Info: Idle.

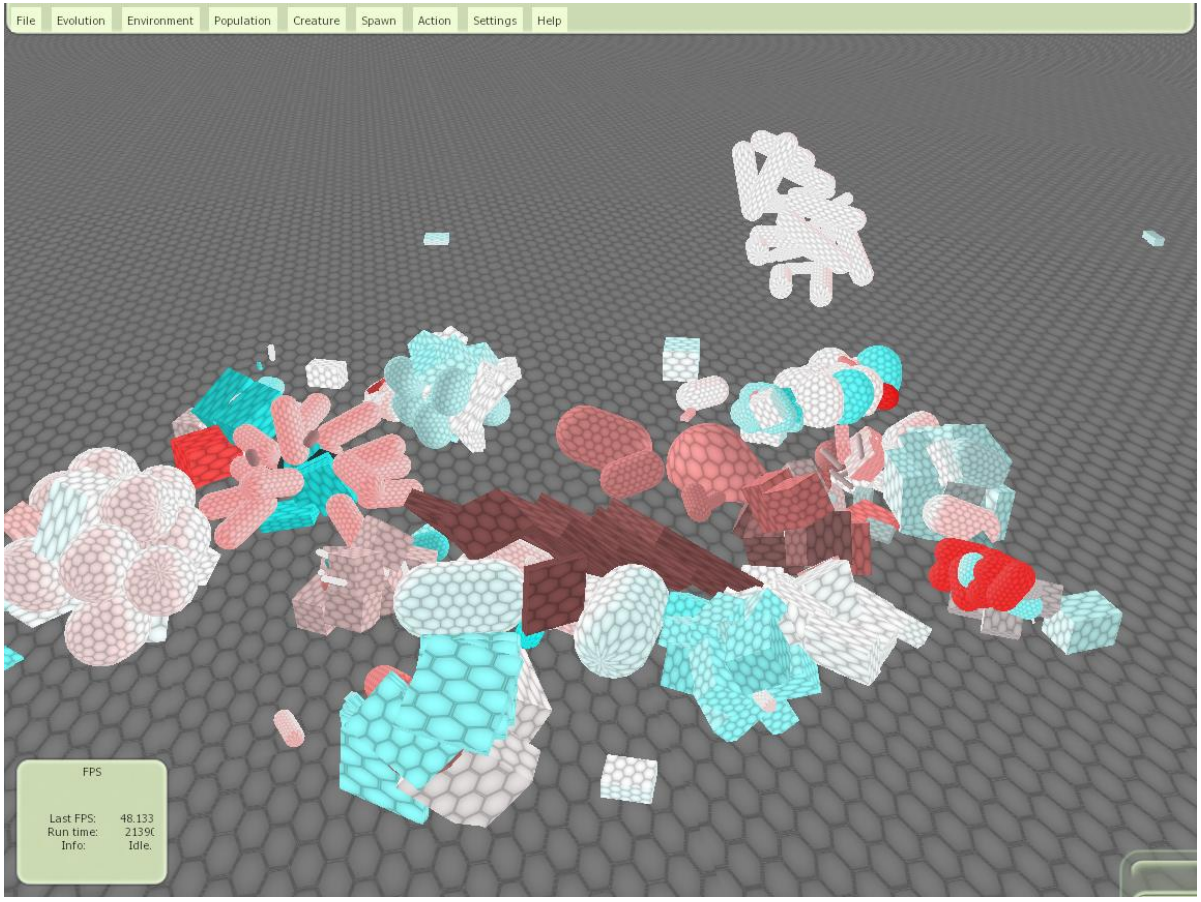
# Creatures


File
Evolution
Environment
Population
Creature
Spawn
Action
Settings
Help
FPS
Last FPS:
Run time:
Info:
Idle.

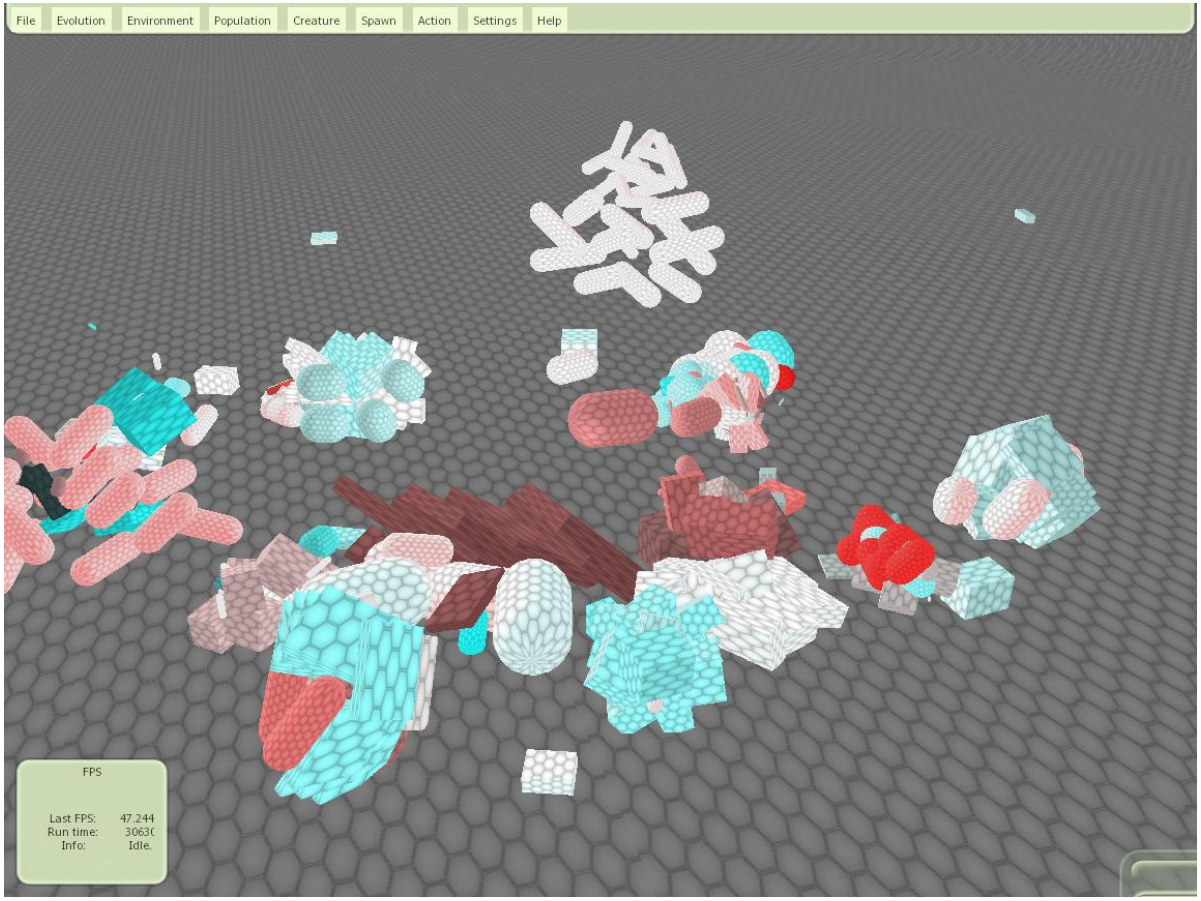
# Creatures


File
Evolution
Environment
Population
Creature
Spawn
Action
Settings
Help
FPS
Last FPS: 80.118
Run time: 34055
Info: Idle.

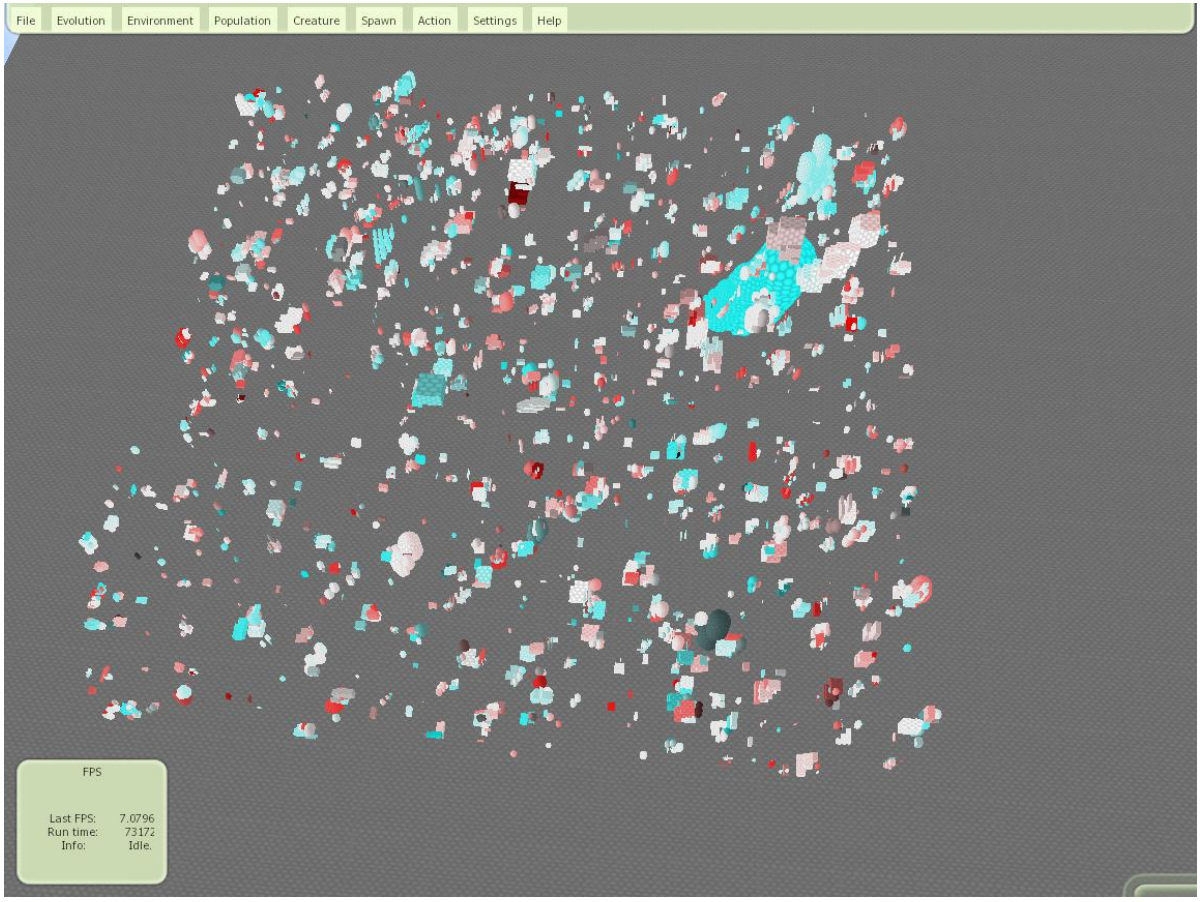
# Creatures


File
Evolution
Environment
Population
Creature
Spawn
Action
Settings
Help
FPS
Last FPS:
Run time:
Info:
Idle.

# Creatures


File
Evolution
Environment
Population
Creature
Spawn
Action
Settings
Help
FPS
Last FPS:
Run time:
Info:
Idle.

# Creatures


File
Evolution
Environment
Population
Creature
Spawn
Action
Settings
Help
FPS
Last FPS: 7.0796
Run time: 73172
Info: Idle.

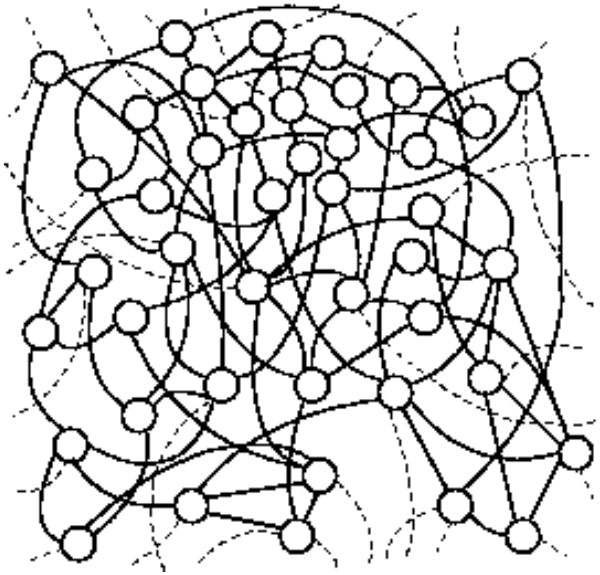
# Contents

# Optimization & Extension

- The framework was written in a quick & dirty manner
- Several components need to be reimplemented properly to provide a more scalable environment
- The system does not use any parallelization
- The phenotype could be more natural
- The genotype to phenotype transcription does not include any additional developmental parts (no embryogenesis)
- More sensor types
- More logging for data analysis

# Other settings & fitness functions

- Island genetic algorithm
- Competitions of individuals
- Implicit fitness functions (survival of the fittest in a virtual world)
- Information theoretic measures such as the transfer entropy



# References


- Sims K. - Evolving Virtual Creatures (1994)
- Sims K. - Evolving 3D Morphology and Behavior by Competition (1994)
- Krcah P. - Evolving Virtual Creatures Revisited (2007)
- Schmidt N. - Bootstrapping perception using information theory: case studies in a quadruped running robot running on different grounds (2013)
- Hill, A.V. The heat of shortening and dynamics constants of muscles (1938)
- Stoop R. - Theory and Simulation of Neural Networks (2014)

## Some mathematical specialities

**Theorem (Murphy (1949))**

*Anything that can go wrong, will go wrong.*

Proof.

A special case of Theorem 1 is proven in □

# Title Page

The title page is created using the `\titleframe` command.
The title page background can also be used on other frames (or for a customised title frame) using the `titlestyleframe` environment.

# Normal Frame

The normal frame looks like this. It is created using the `frame` environment.

# Inverse Slides

The inverted frame looks like this. It is created using the `inverseframe` environment.

# Minimal Frame

The minimal frame looks like this. It is created using the `minimalframe` environment.