EVOLVING AGGREGATION BEHAVIORS IN A SWARM OF ROBOTS

Vito Trianni, Roderich Groß, Thomas H. Labella, Erol Sahin and Marco Dorigo

Presented by

Humayra Tasnim

Mohammad Ashraf Siddiquee

TERMINOLOGIES

- Swarm-bots:
  - ❑ Self organizing and self assembling artifacts composed of swarms of s-bots.
- S-bots:
  - ❑ Mobile robots with the ability to connect/disconnect with each other.
  - ❑ Comprised of simple sensors and motors.
  - ❑ Limited Computational abilities.

TERMINOLOGIES

- Self Organization:
  - ❑ Global level order emerges in a system from the interactions among the system's lower level components.

- Self Assembling:
  - ❑ Connection with one another creating complex physical structures.

TERMINOLOGIES

- Artificial Evolution:
  - ❑ Controlled micromanipulation of genetic information from one generation to the next, where the first variational step is engineered and the second selection step is insured by genetics[1].
- Neural Controller:
  - ❑ Class of control techniques that use various artificial intelligence computing approaches.

1.https://www.ncbi.nlm.nih.gov/pubmed/9090159

MOTIVATION AND GOALS

- Aggregation is important in creation of functional group of individuals that emerge into various forms of cooperation.
- Develop swarm bots having the capability of aggregational behavior not driven by a central controller.
- Use artificial evolution for defining control system of the swarm-bot.
- Motivated from design and implementation of ‘Intelligent’ systems inspired by social insects and other animal societies.

AGGREGATION IN BIOLOGICAL SYSTEMS

Two basic mechanism:

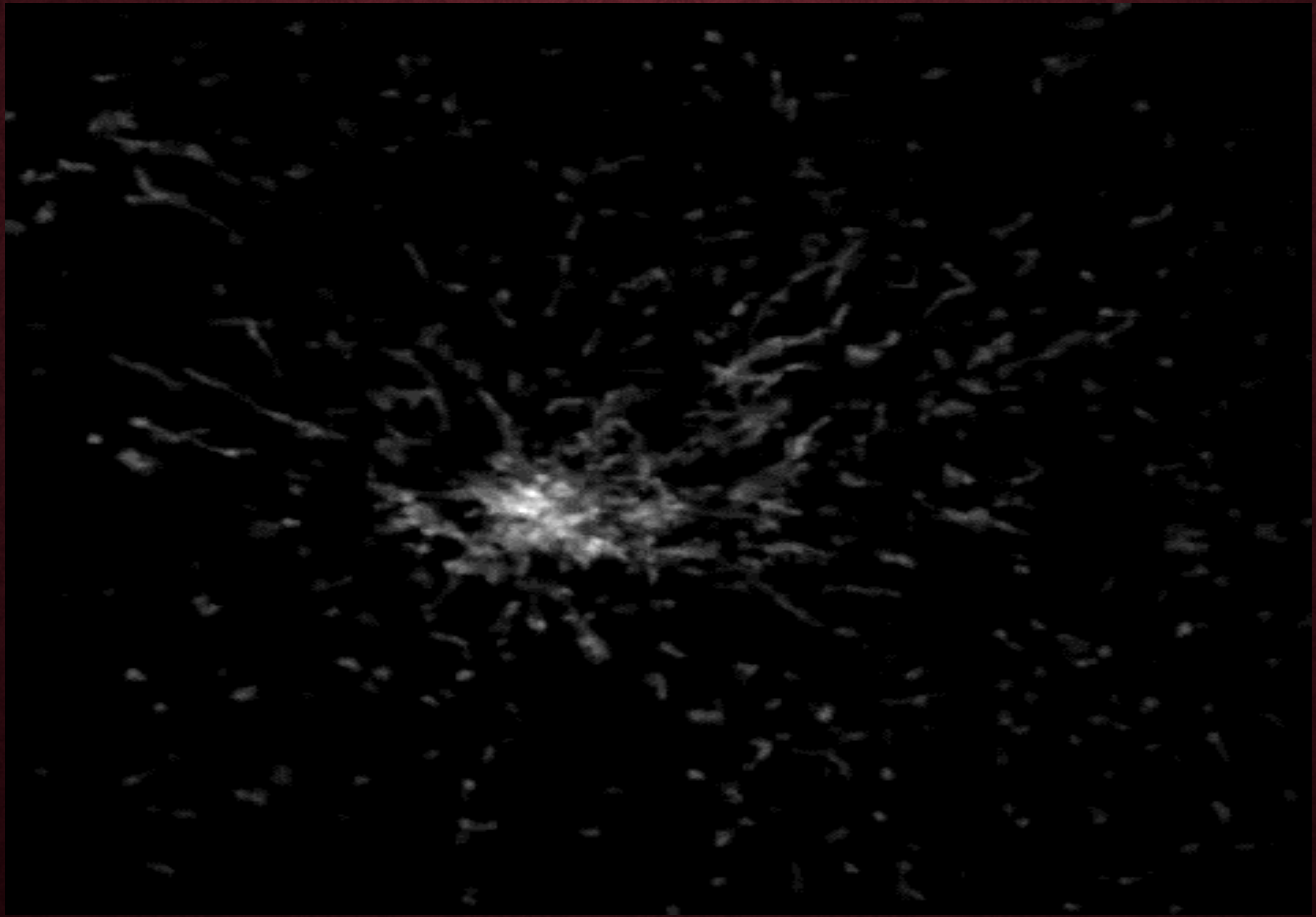
- Positive Feedback:

  Attraction toward a given signal source (e.g., chemical, visual, noise).

- Negative Feedback:

  Regulatory mechanism proving repulsion among the system components.

AMOEBA AGGREGATION AND SLIM MOLD FORMATION

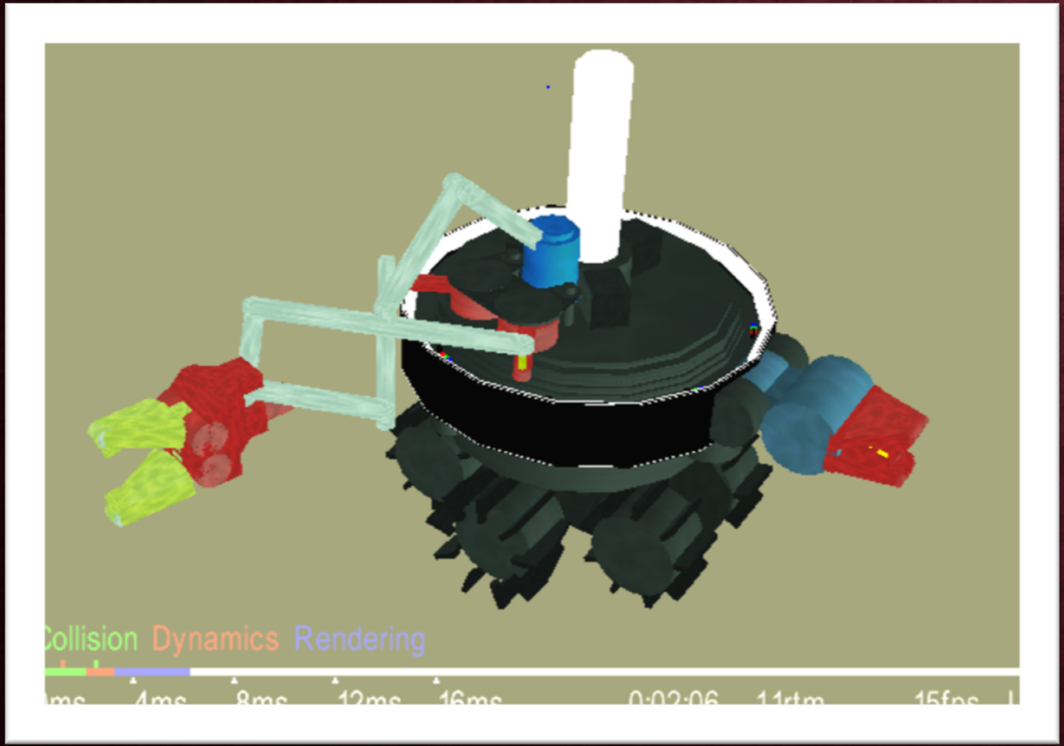


https://www.youtube.com/watch?v=GYu3F8VyGTQ

AGGREGATION EXAMPLES IN NATURE

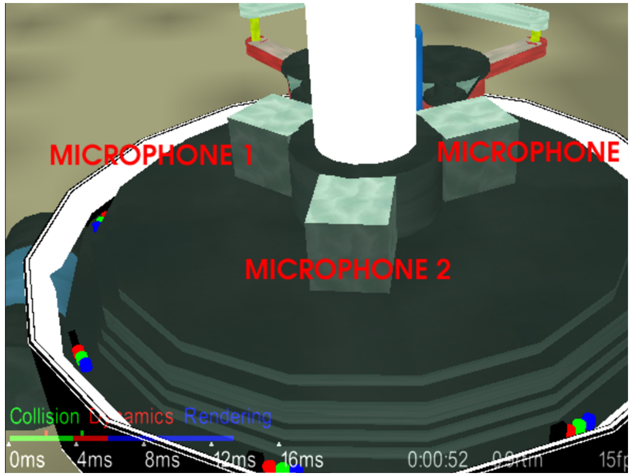
- Beetle *Dendroctonus micans.*
- Honey bees
- Young penguins
- Fish
- Birds
- Mammals

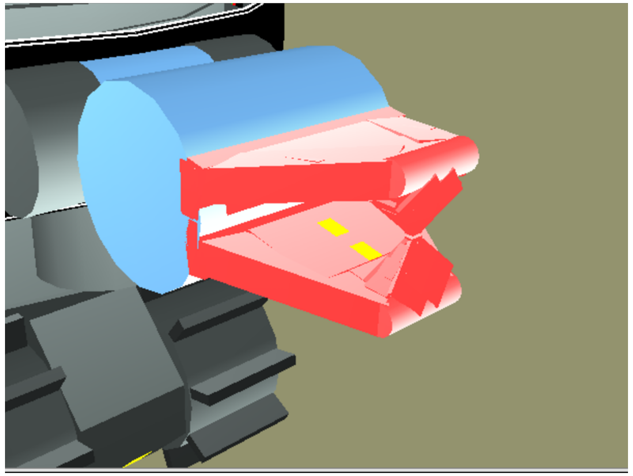
EXPERIMENTAL SETUP



- Dynamics simulator SDK Vortex.
- S-bot model:
  - Cylinder shaped (radius 12 cm, height 6 cm)
  - 2 motorized wheels
  - A Gripper
  - An Omni directional speaker.

Reference: http://www.swarm-bots.org/index.php@main=3&sub=33.html





S-BOT SPECIFICATIONS

- Each S-bot is equipped with:
  - Eight infrared proximity sensors.
  - Three directional microphones.
  - Three sensors
  - A gripper sensor.

- The arena is chosen to be 2x2 meters.

Reference: http://www.swarm-bots.org/index.php@main=3&sub=33.html

EVOLUTIONARY ALGORITHM

- The genotype specifies the connection weights of a simple perceptron having 17 sensory neurons that encode the state of the 16 sensors and a bias unit.
- Each sensory neuron is directly connected to 3 motor neurons, that control the gripper and the speed of the two wheels.
- Each connection weight ranges in the interval [-10, +10] and is represented in the genotype with 8 bits.
- Each genotype is mapped into a neural network that is cloned in every *s-bot.*
- Five s-bots compose the group and allowed to “live” for 10 “epochs” (each epoch consists of 600 cycles and each cycle simulates 100 ms of real time).

EVOLUTIONARY ALGORITHM

The fitness function

$$f_e(t) = \frac{1}{n} \sum_{i=1}^{n} \left(1 - \frac{d_i(t)}{50}\right)$$

- $f_e(t)$ is the average distance of the group from its center of mass:
- n is the number of s-bots
- $d_i(t)$ is the distance of the ith s-bot from the center of mass
- limited to 50 cm as upper bound to have fitness values in the interval [0, 1]

EVOLUTIONARY ALGORITHM

- Population contains 40 genotypes.
- Best 8 genotypes of each generation are allowed to reproduce, each generating 5 offspring.
- Per -bit (flip) mutation rate is 2/L.
- Parents are not copied to the offspring population.
- 100 generations.
- Replicated 10 times by starting with different randomly generated initial populations.

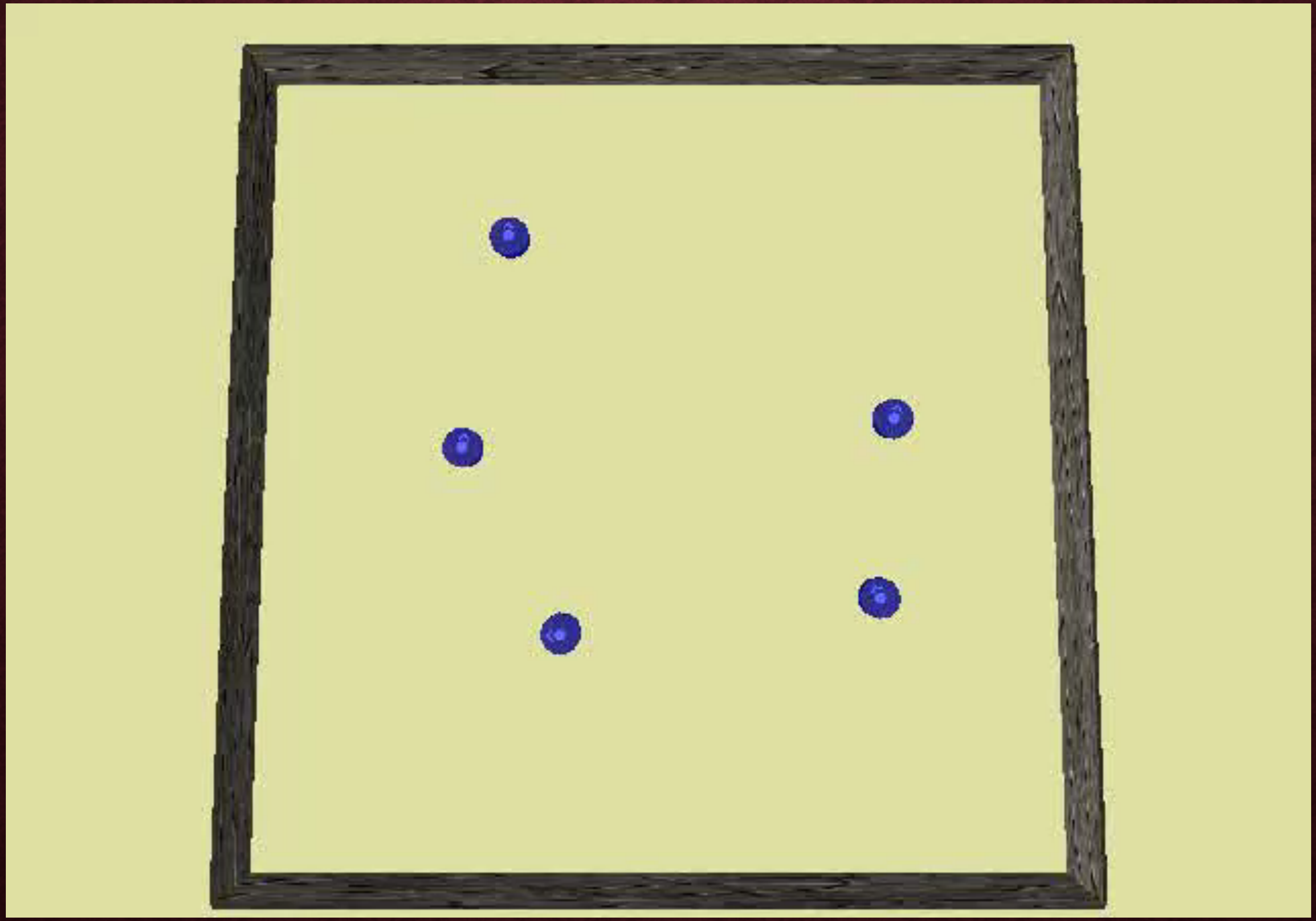
BEHAVIORAL ANALYSIS

- Static Clustering Behavior
- Dynamic Clustering Behavior

STATIC CLUSTERING BEHAVIOR

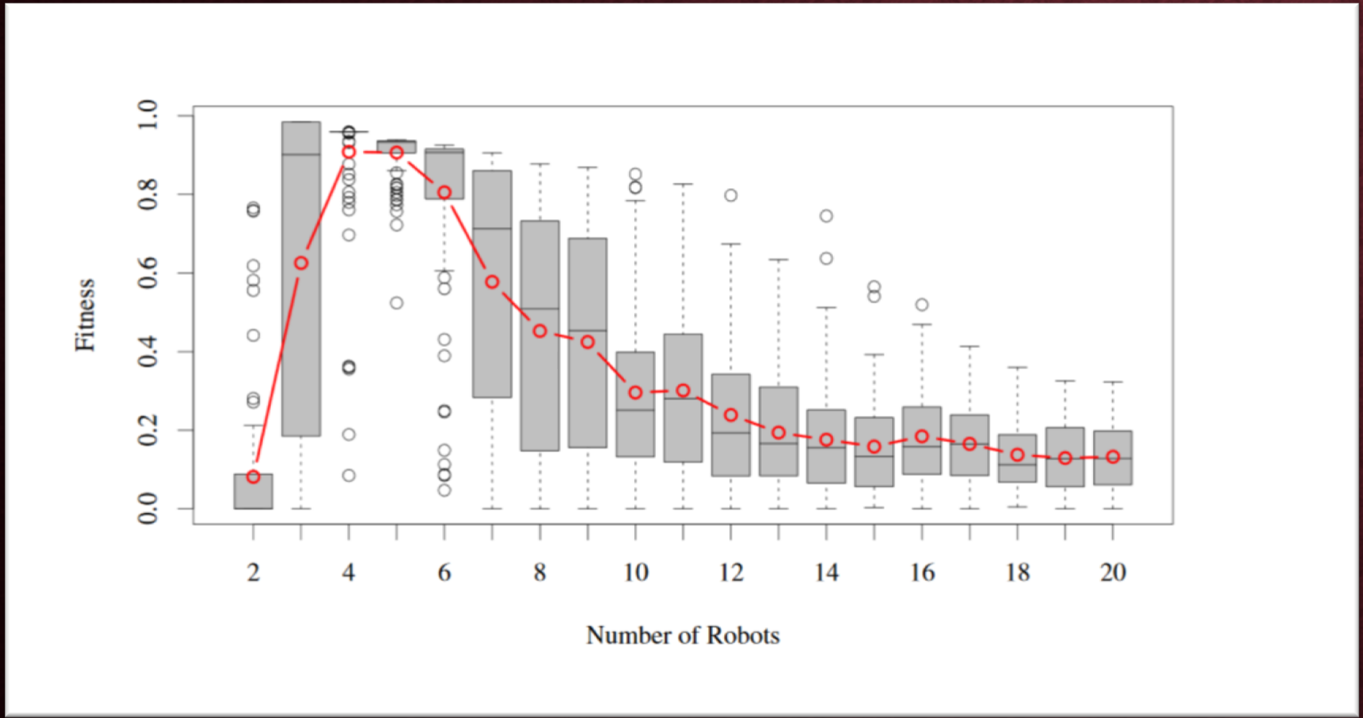
- Creates very compact clusters.
- Minimizes distance from the center of mass, thus maximizes the performance of neural controller w.r.t. given fitness measure.
- For small number of (i.e. 5) s-bots, clusters formed by majority (3 s-bots or more) are stable.
- Smaller clusters (2 -bots) easily disband.
- With increased group size, multiple smaller clusters will be formed.
- Not scalable.

STATIC CLUSTERING BEHAVIOR (CONT.)

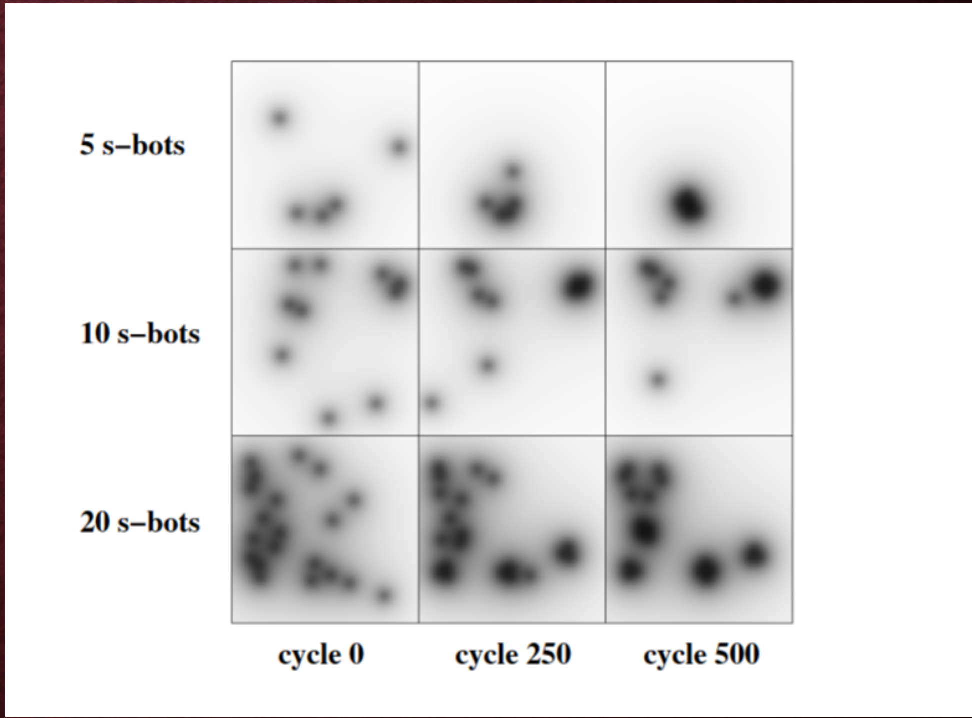


http://www.swarm-bots.org/index.php@main=3&sub=35&conpage=s25b.html

STATIC CLUSTERING BEHAVIOR ANALYSIS



Fitness evaluation

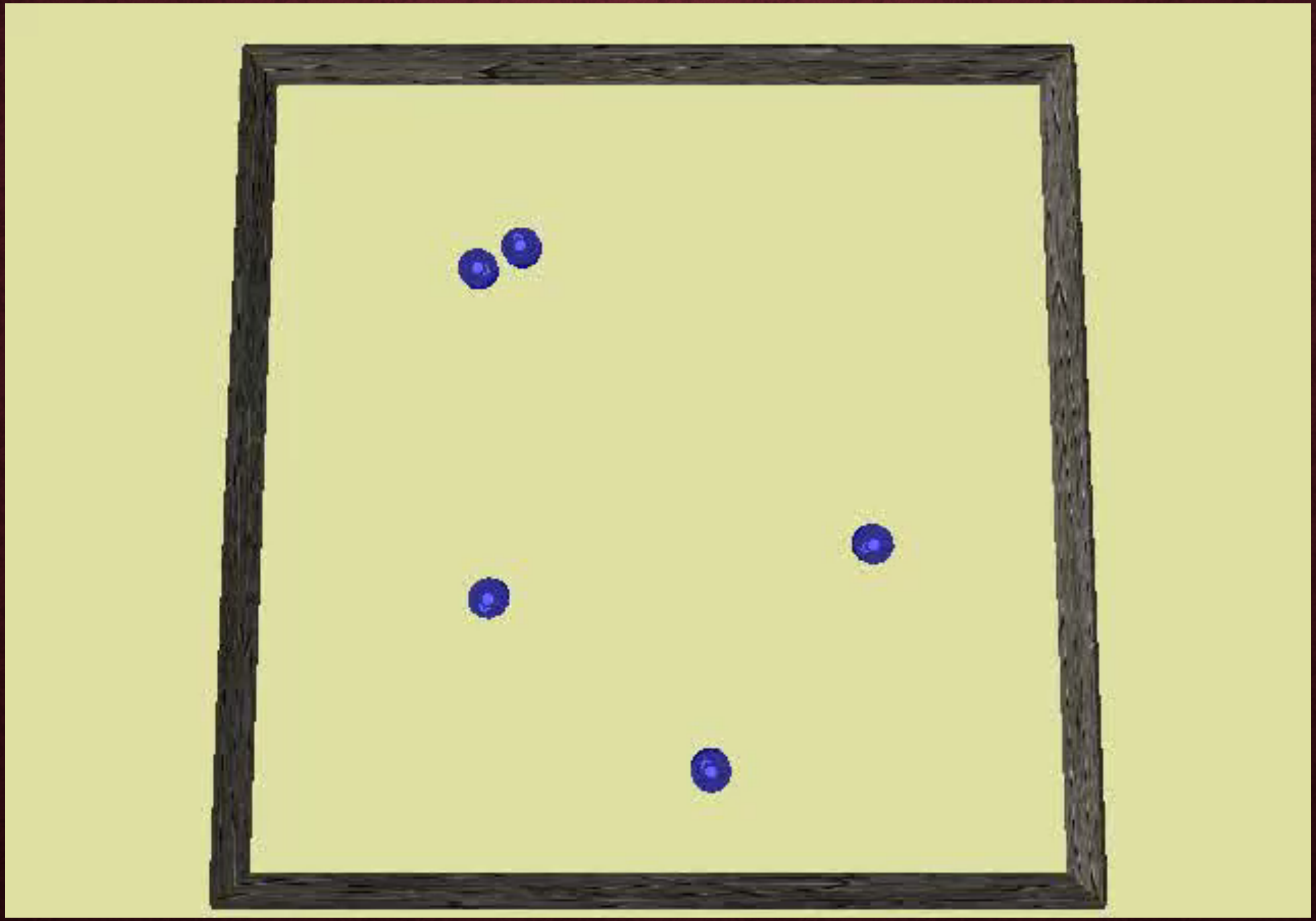


Sound fields

DYNAMIC CLUSTERING BEHAVIOR

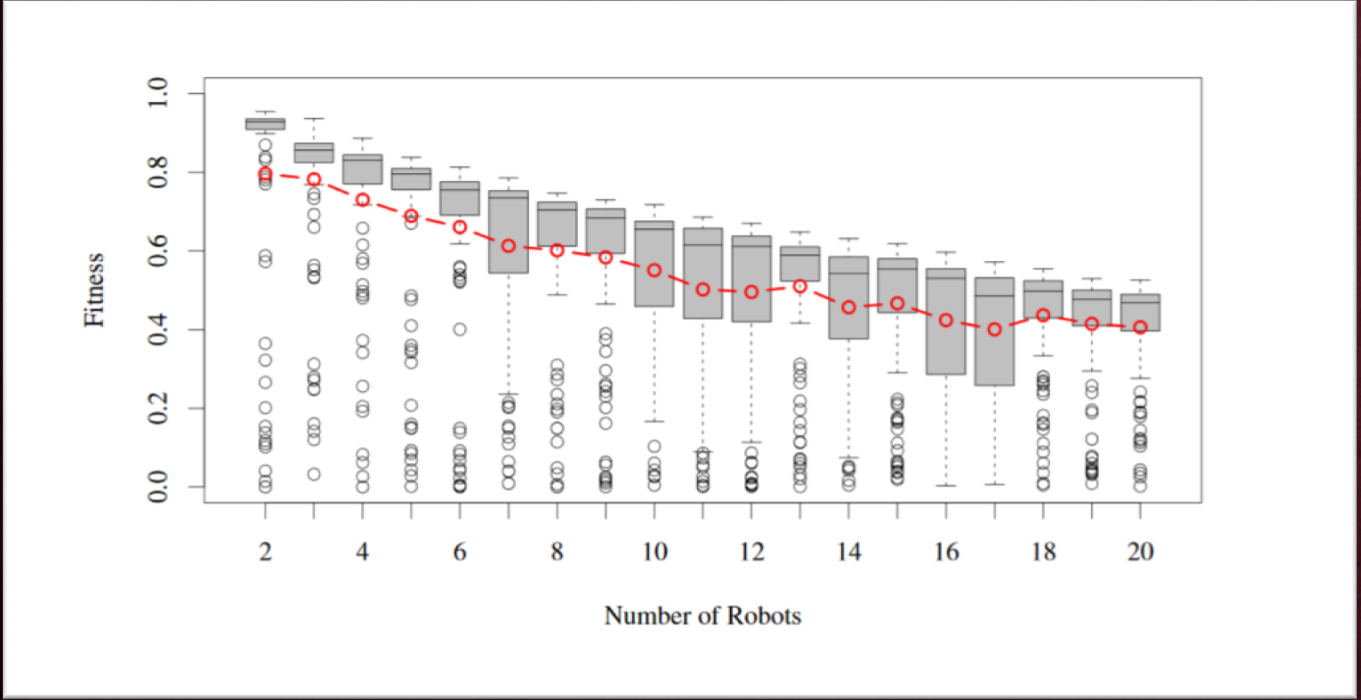
- Creates loose and moving clusters.
- Manifests ‘flocking’ behavior.
- Small clusters move across the arena.
- Increased chance to form larger clusters.
- Robust and scalable.

DYNAMIC CLUSTERING BEHAVIOR (CONT.)

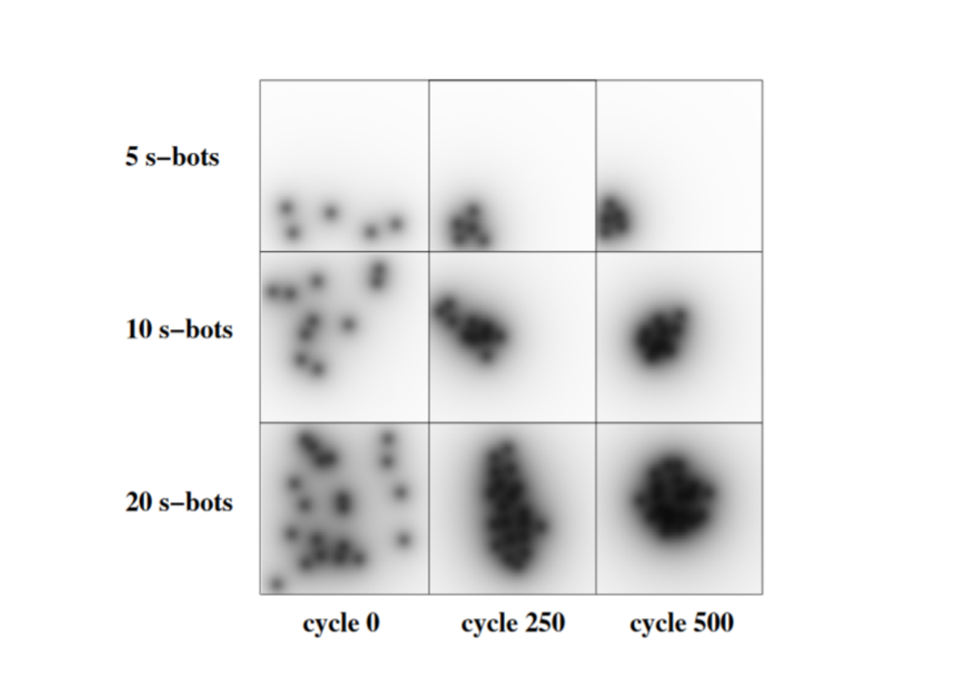


http://www.swarm-bots.org/index.php@main=3&sub=35&conpage=s25b.html

DYNAMIC CLUSTERING BEHAVIOR ANALYSIS



Fitness evaluation



Sound fields

DISCUSSION

- Static clustering behavior shows higher fitness values, but is tuned for a group of 5.
- Dynamic clustering behavior shows lower fitness values, but robust and scalable.
- We were interested in self-organized aggregation, not self-assembling aggregation.

RELATED WORKS & FUTURE WORKS

- Related work of Melhuish et al.: seeded aggregation and collective movement of minimal simulated agents.
- Related work of Yokoi et al.: amoeba-like robots composed of connected modules.
- Future work of aggregation around preys.

CONCLUSIONS

- Evolution can find solutions to the aggregation problems.
- Attraction to sound sources creates positive feedback.
- Repulsion between s-bots creates negative feedback.
- The dynamic interaction between s-bots makes it more similar to the processes observes in nature.

THANK YOU