

# Experimental Validation of mEDEA on Pogobot Swarms

Luiz Felipe Nery  
Thomas Marchand  
Ekaterina Antipova  
Enzo Pinho Fernandes

# Motivation & Goal

## Why swarm adaptation matters ?

- Swarm robots must adapt in dynamic, unpredictable environments.
- No global controller or explicit fitness is often feasible.
- mEDEA offers decentralized, online adaptation.

## Goal ?

Implement mEDEA on Pogobots and validate in Pogosim

# A Minimal EDEA Algorithm (mEDEA)

A local evolutionary algorithm copied across all agents, where each agent exchanges and stores incoming genomes through a communication routine.

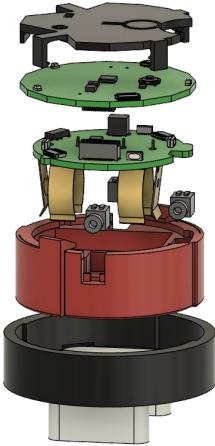
## Algorithm 1 The MEDEA algorithm

```
genome.randomInitialize()
while forever do
    if genome.notEmpty() then
        agent.load(genome)
    end if
    for iteration = 0 to lifetime do
        if agent.energy > 0 and genome.notEmpty() then
            agent.move()
            broadcast(genome)
        end if
    end for
    genome.empty()
    if genomeList.size > 0 then
        genome = applyVariation(select_random(genomeList))
    end if
    genomeList.empty()
end while
```

## Operators

Selection	Simple random sampling from imported genomes
Variation	Conservative Gaussian mutation, tuned through a $\sigma$ parameter
Replacement	Delete current genome, then randomly pick a received genome as the next active one

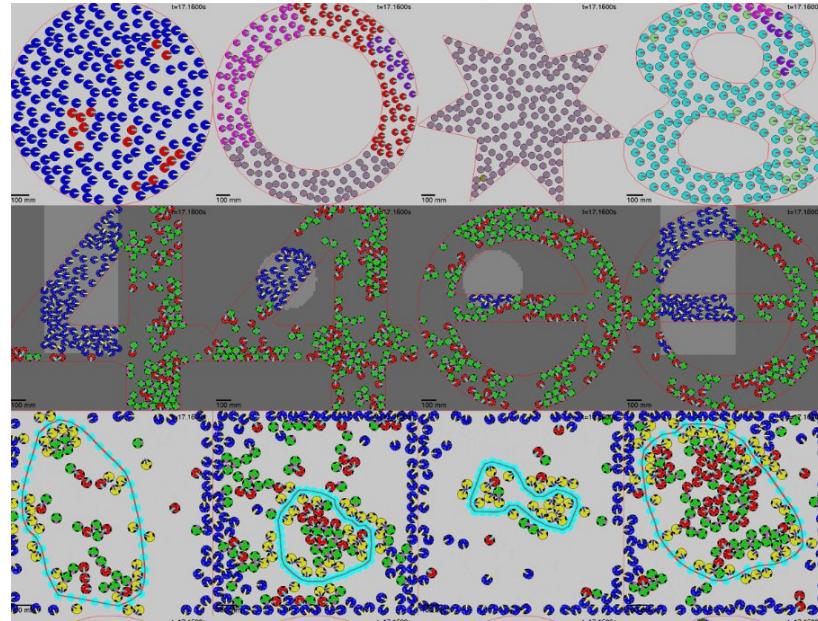
# Pogobot and Pogosim



- Protective Hat
  - Head
  - Belly
  - 3 Motors
  - Capsule
  - Skirt
  - Toothbrush feet

# Pogobot

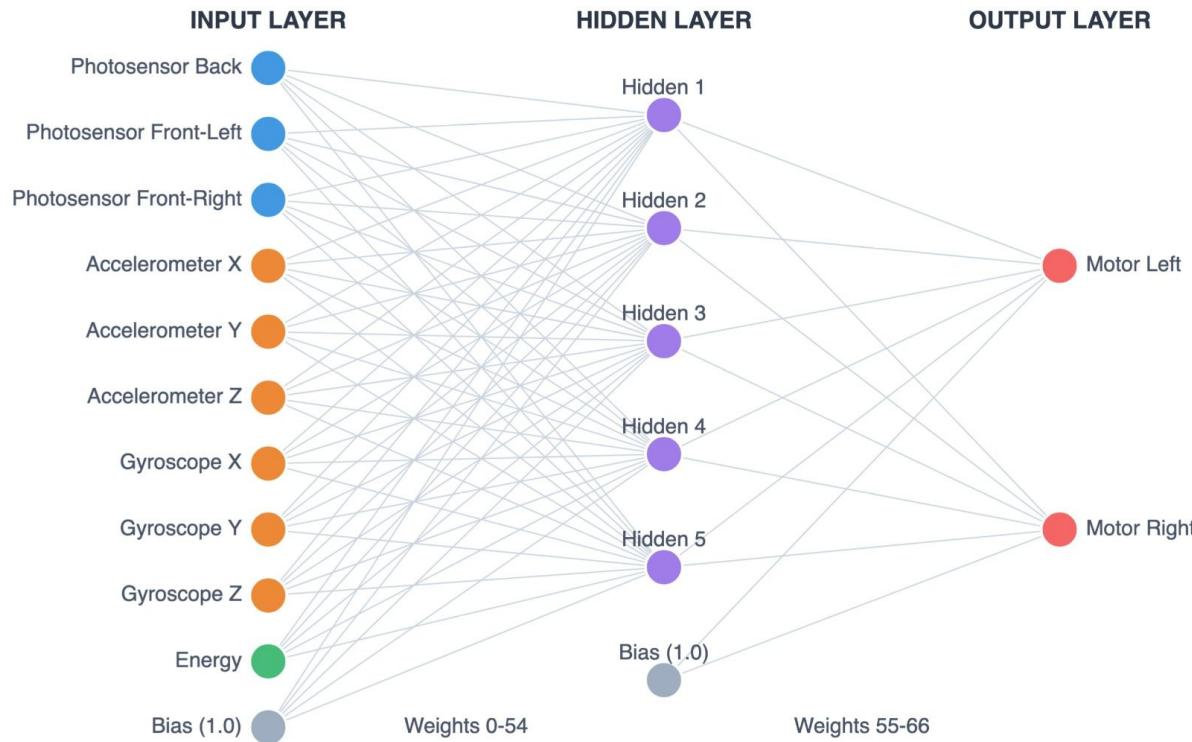
Low-cost swarm robot : IR comms, photosensors, 3-axis gyroscope and accelerometer, two motors...



# Pogosim

Faithful simulator for large batches and repeatability.  
Our code works for both simulation and real robots.

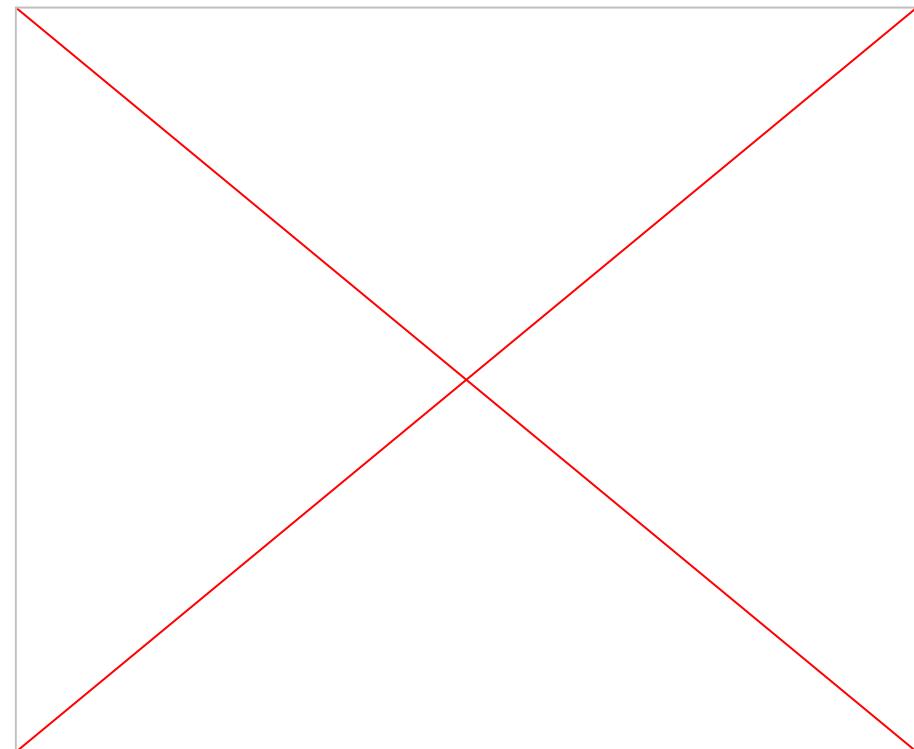
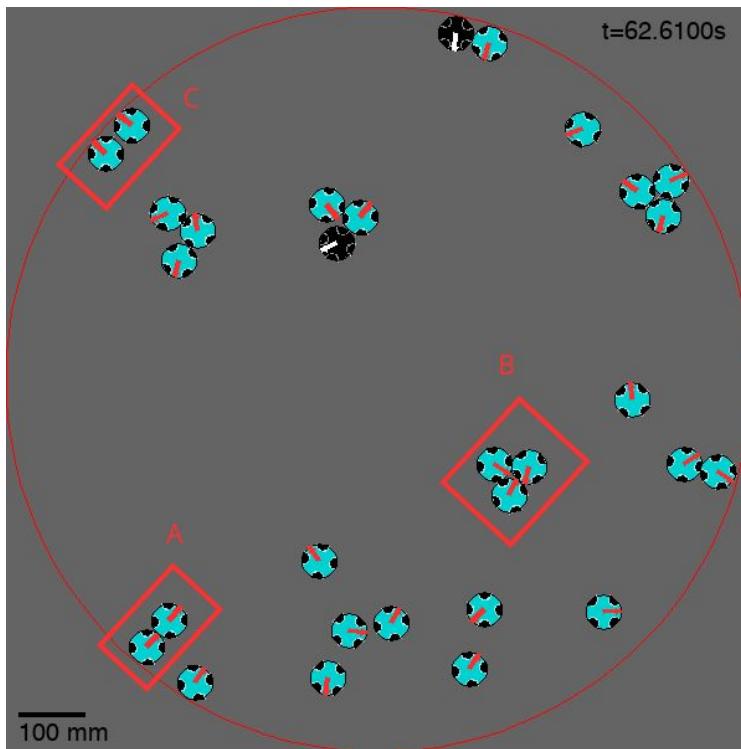
# mEDEA adaptation from the paper



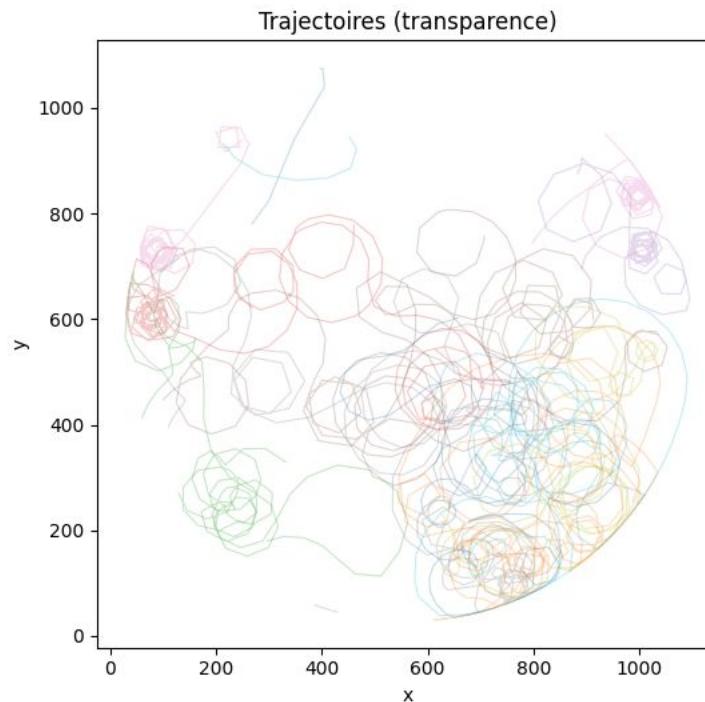
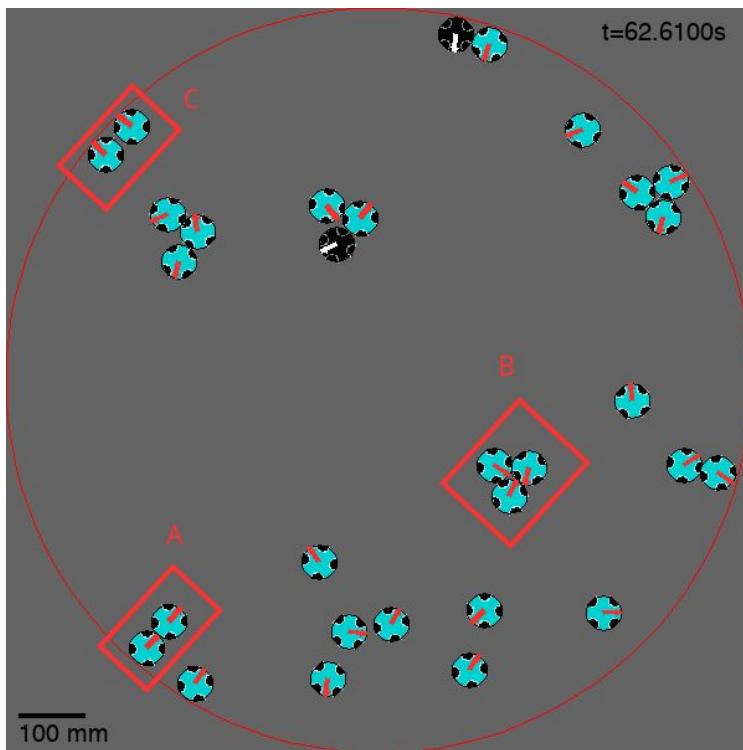
## What adaptation ?

- Same mEDEA cycle.
- The genome encodes a small neural controller using the specificities of Pogobots.
- Mutation is a fixed Gaussian noise ( $\sigma = 0.02$ ).

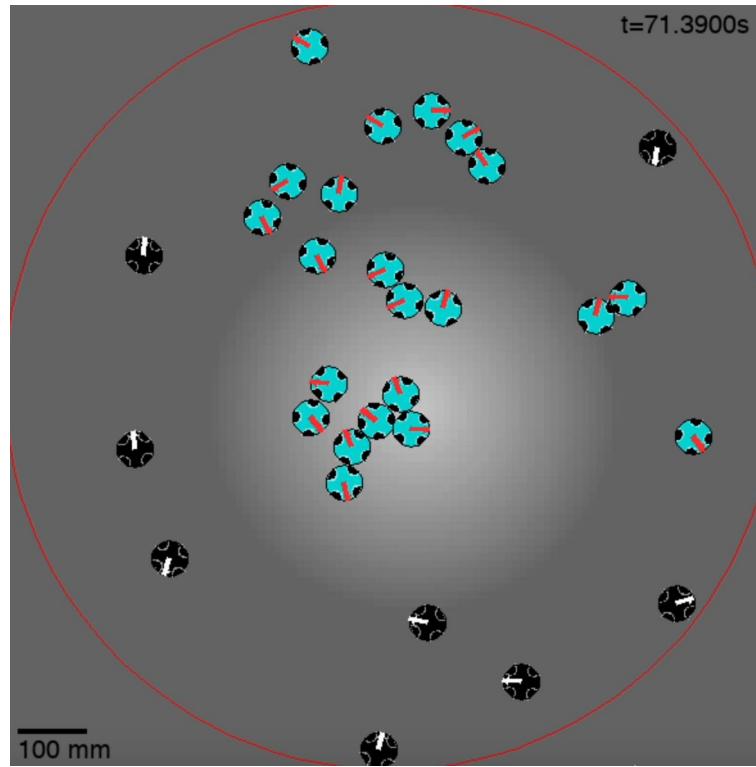
# Baseline: environment and trajectories



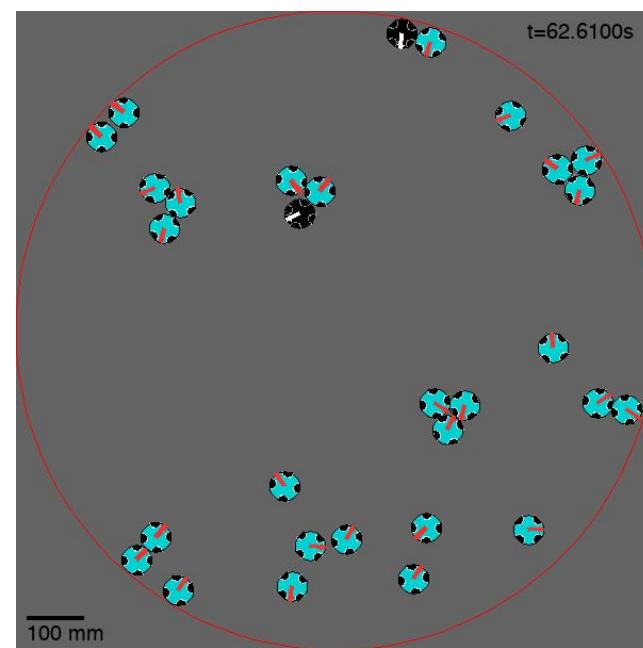
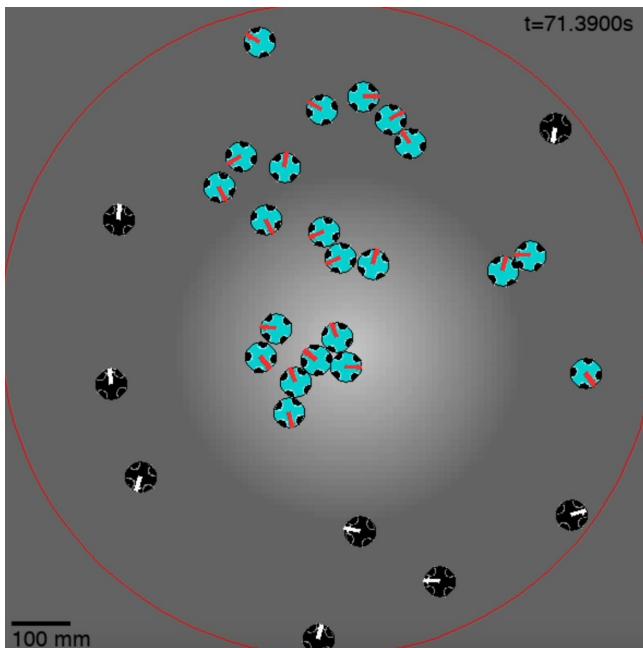
# Baseline: environment and trajectories



# Disk arena with gradient light

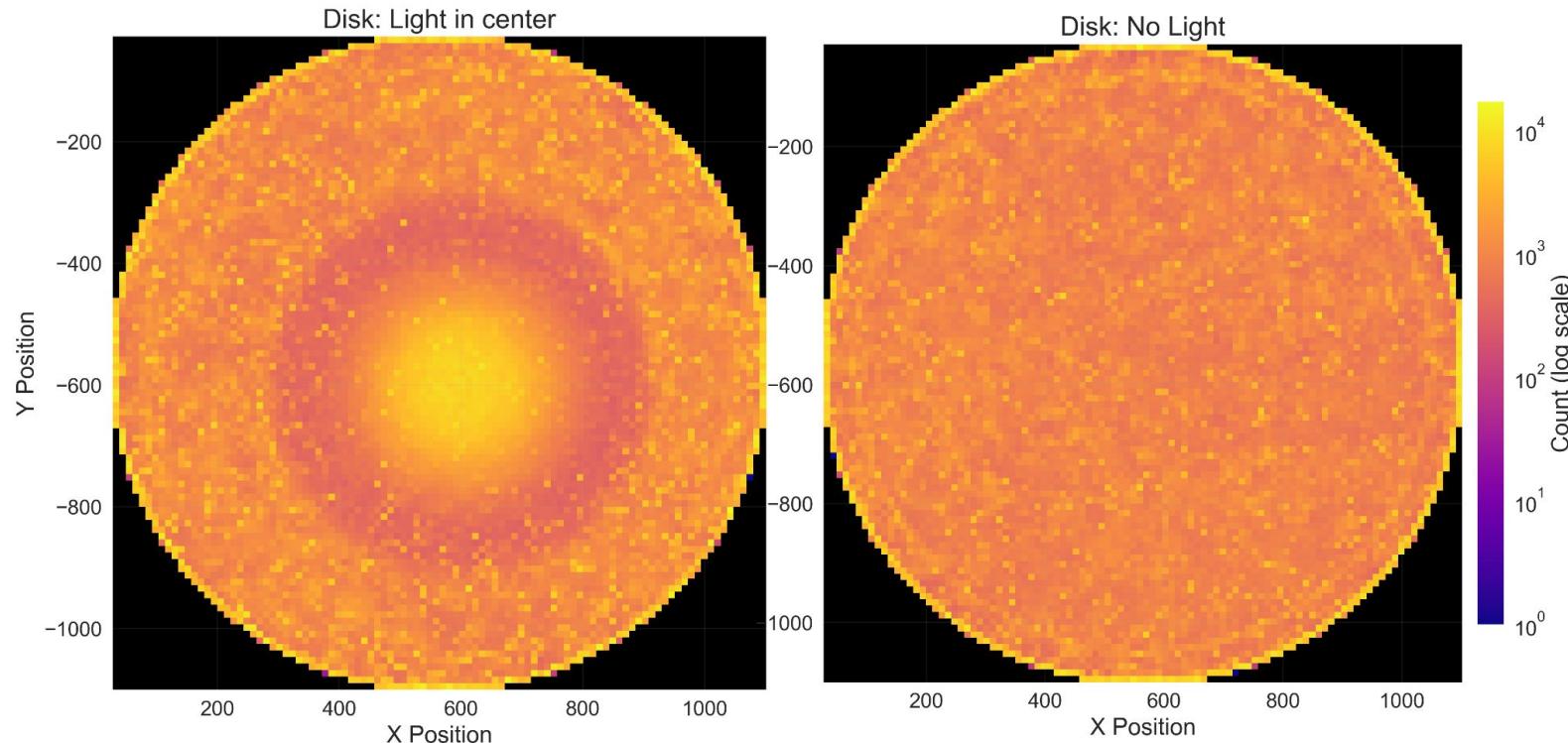


# Disk arena with and without Gradient Light

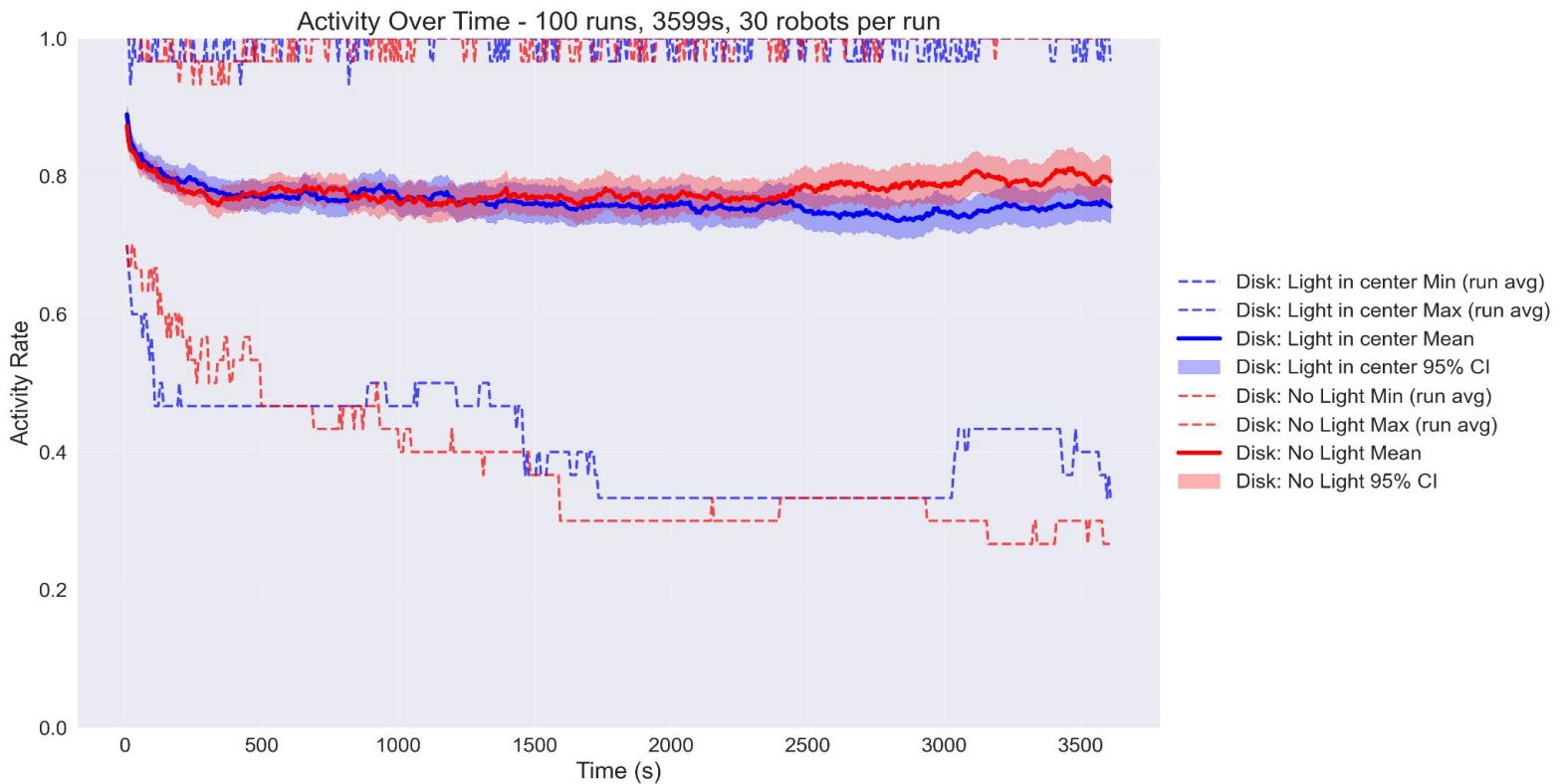


# Disk arena with and without Gradient Light

Position Heatmaps Comparison - 100 runs, 3599s, 30 robots per run



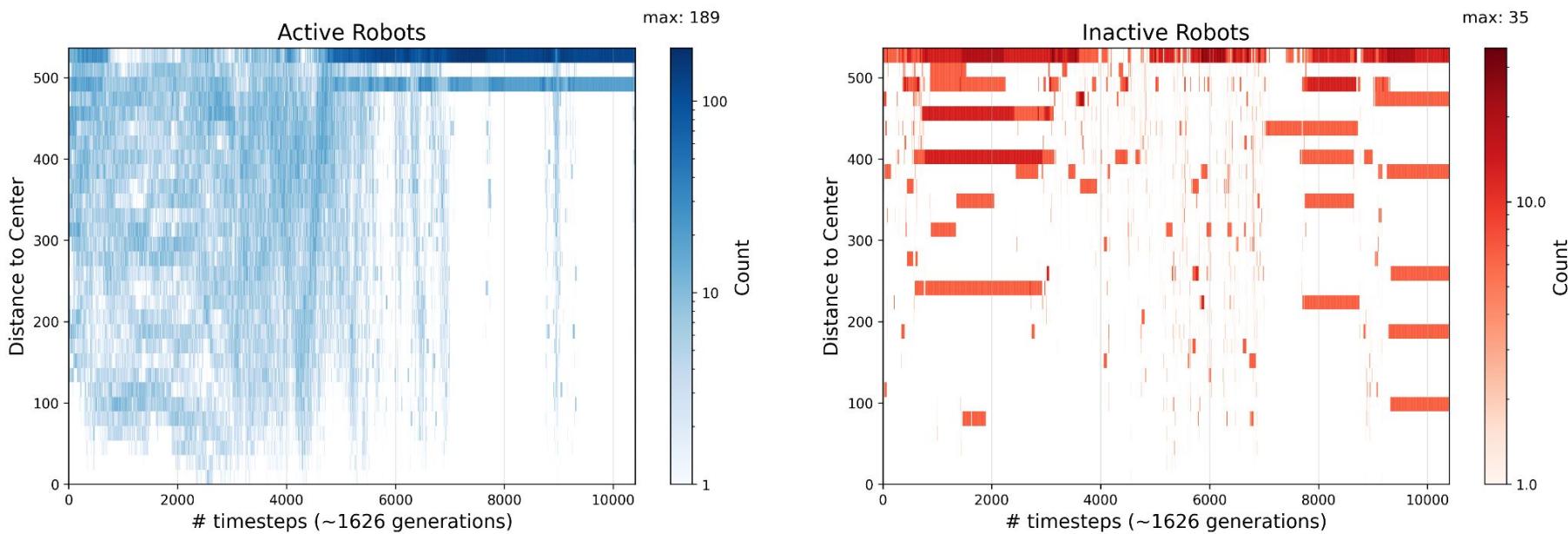
# Disk arena with and without Light



# Disk arena - No Light

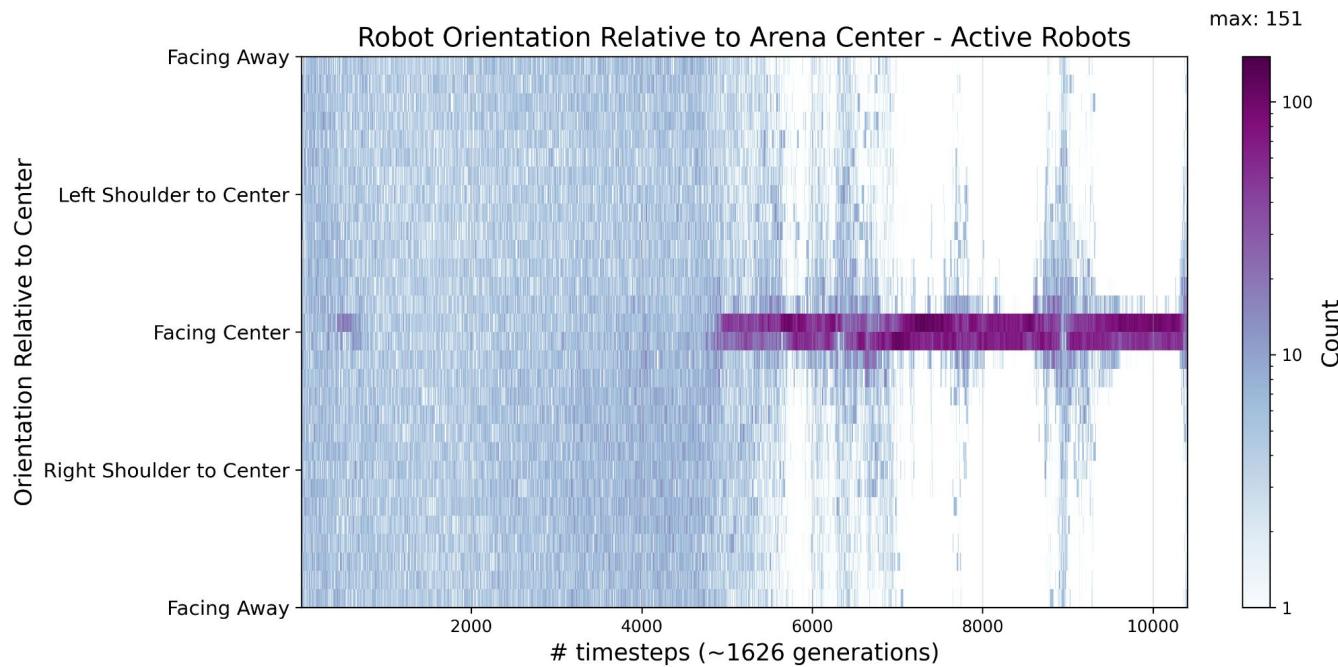
Example run showing typical behaviour

Distribution of Distance from Center - Active vs Inactive Robots



# Disk arena - No Light

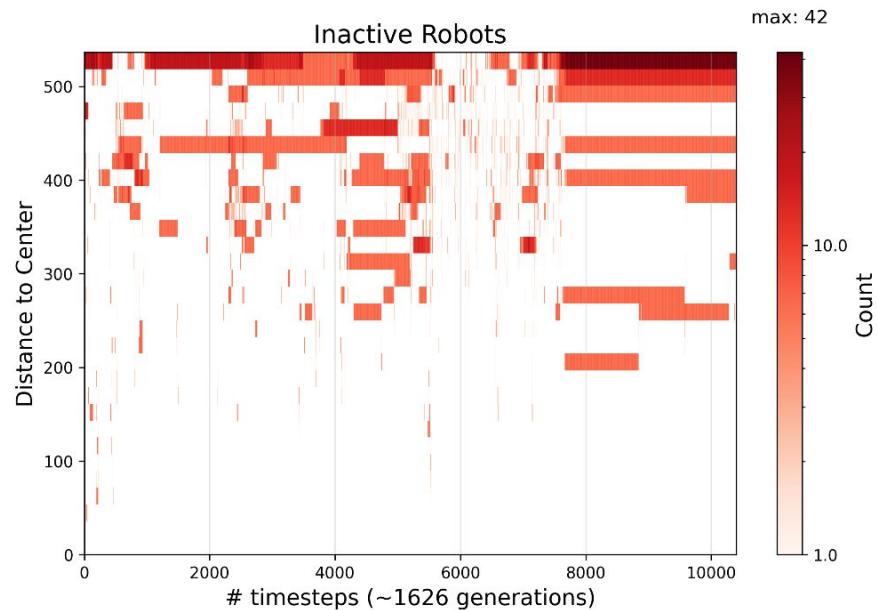
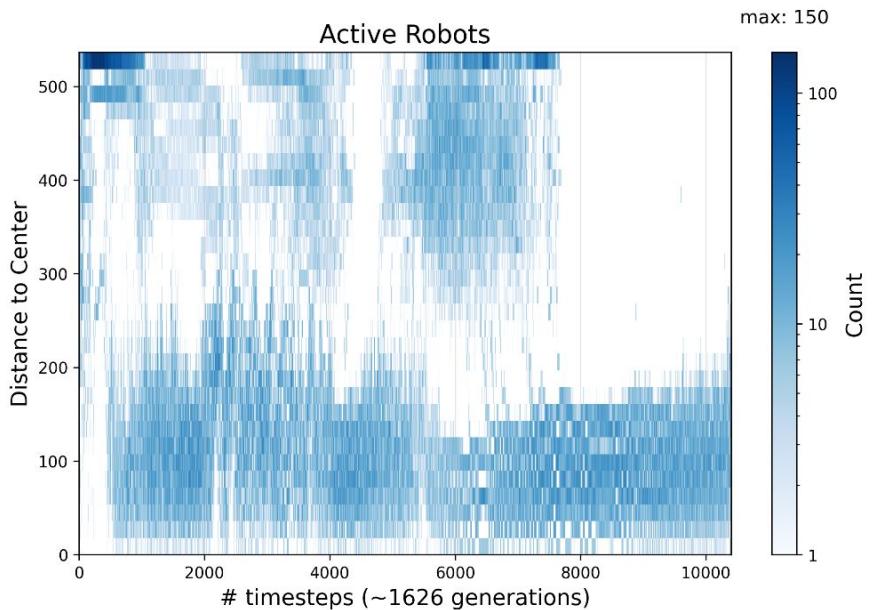
Example run showing typical behaviour



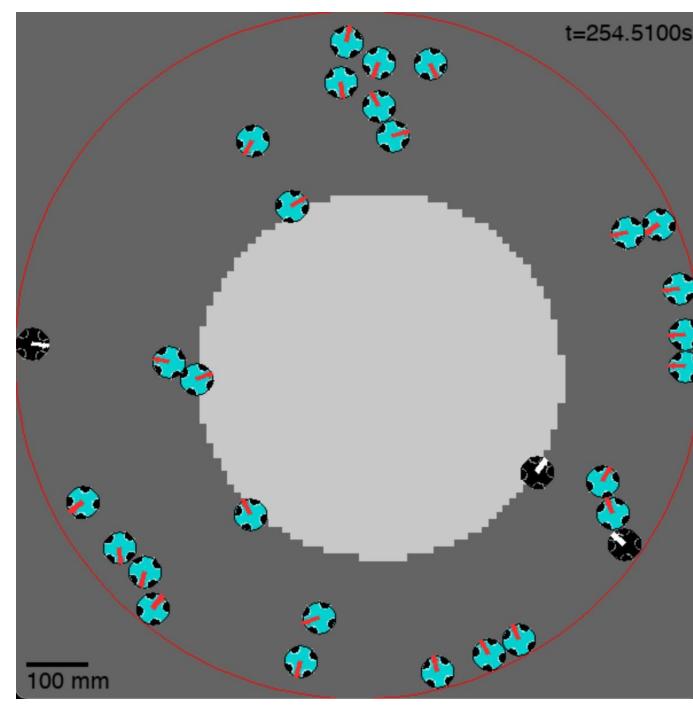
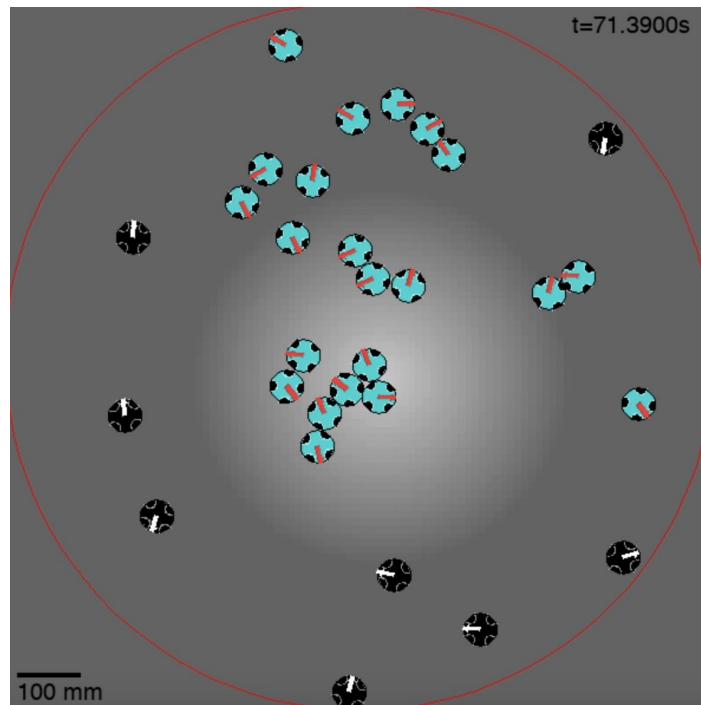
# Disk arena with Soft Light

Example run showing typical behaviour

Distribution of Distance from Center - Active vs Inactive Robots

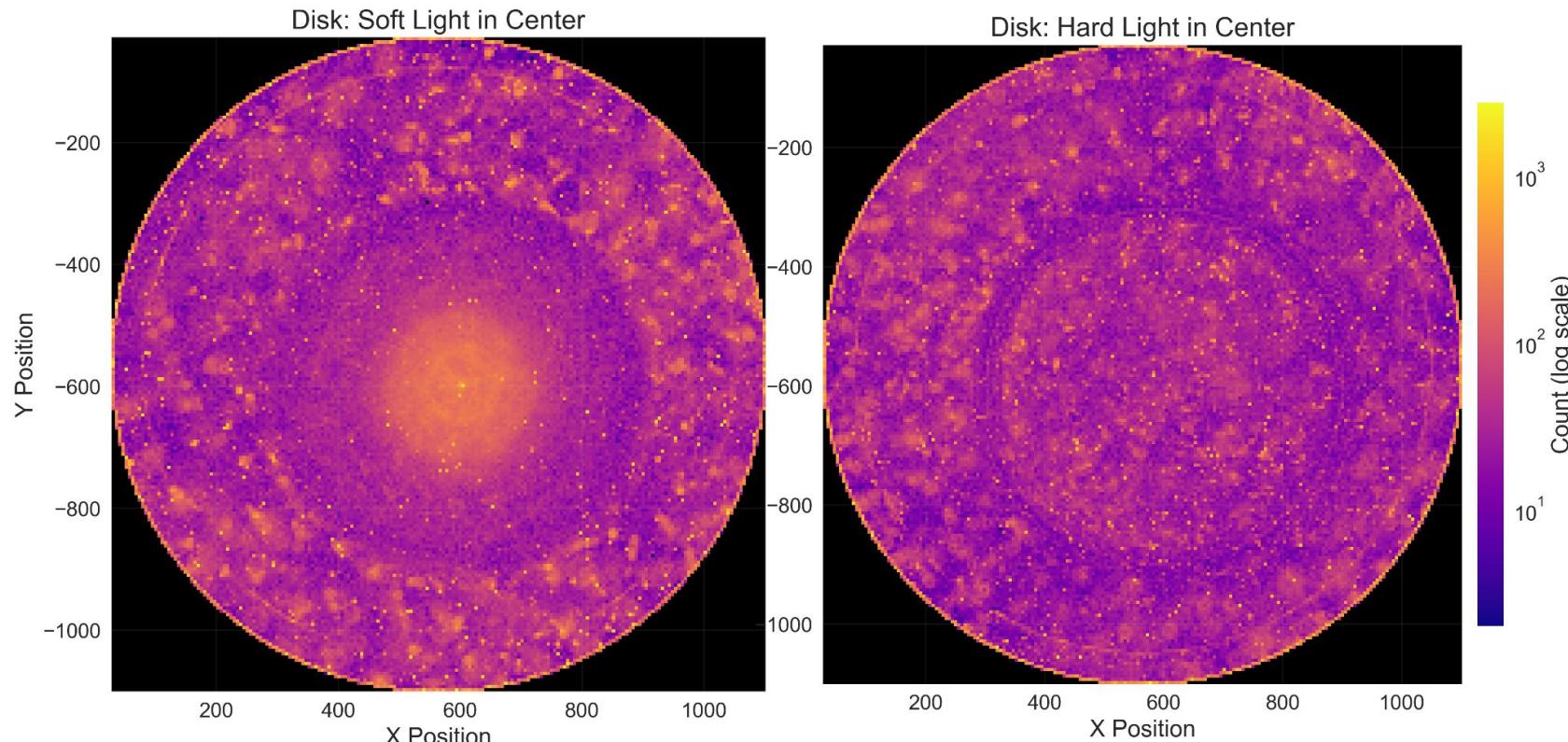


# Disk arena with Soft and Hard light



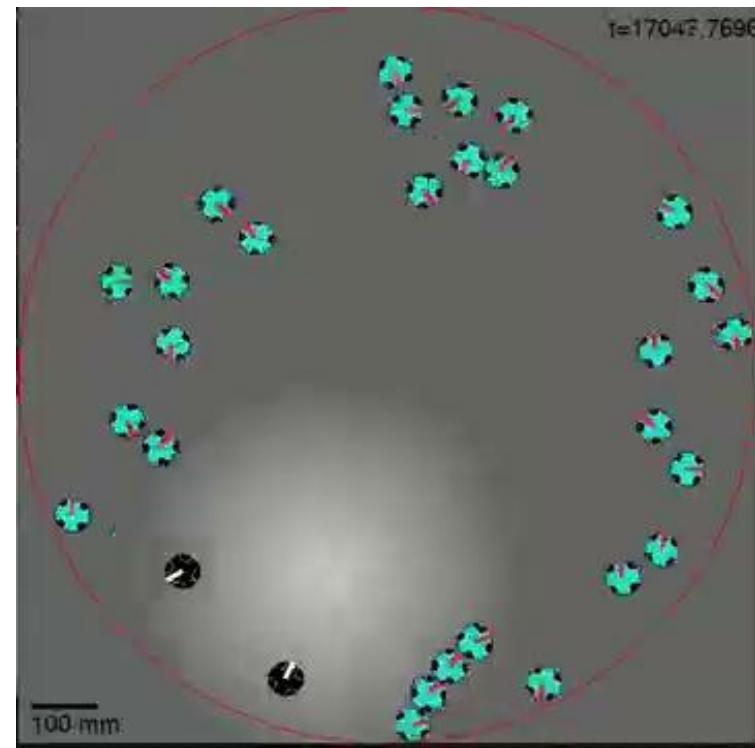
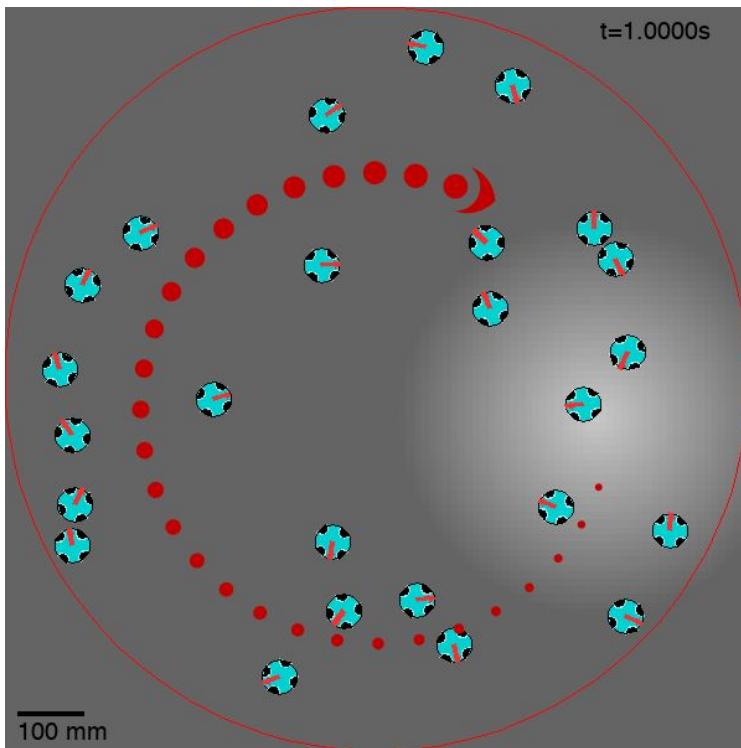
# Disk arena with Soft and Hard light

Position Heatmaps Comparison - 30 runs, 1799s, 30 robots per run

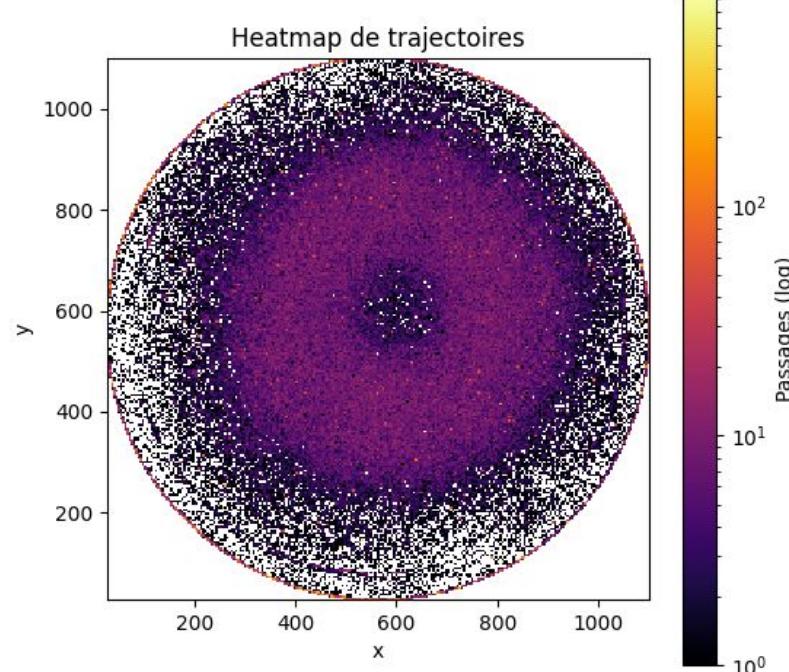
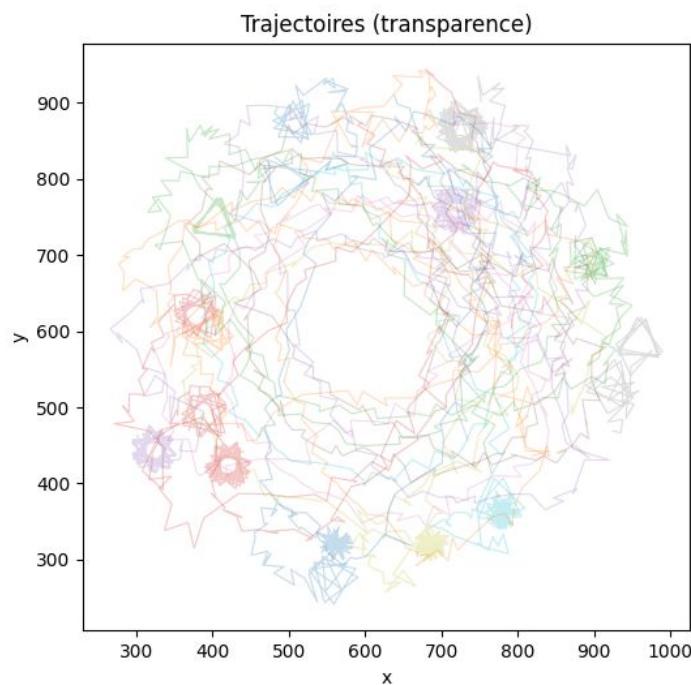


# Orbiting Gradient Light

Fork: <https://github.com/luiznery/pogosim>



# Orbiting Gradient Light



# Behavior under constraint

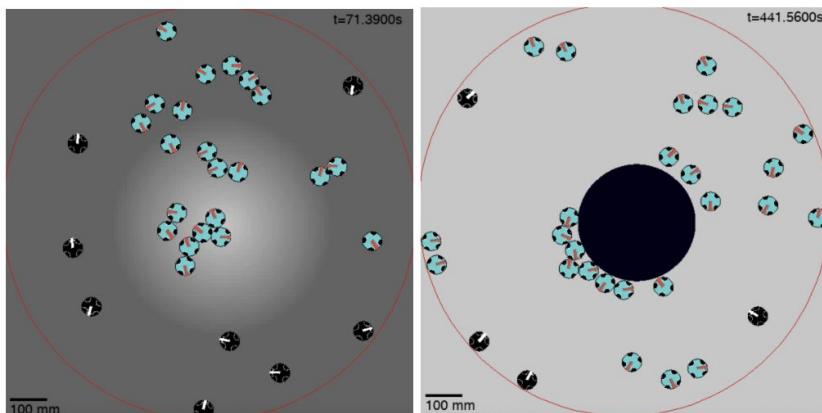


Figure 19: Arenas A and B

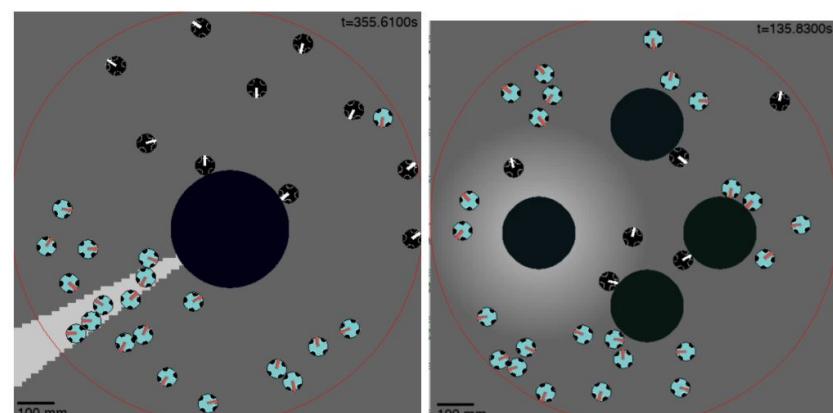


Figure 20: Arenas C and D

# Behavior under constraint

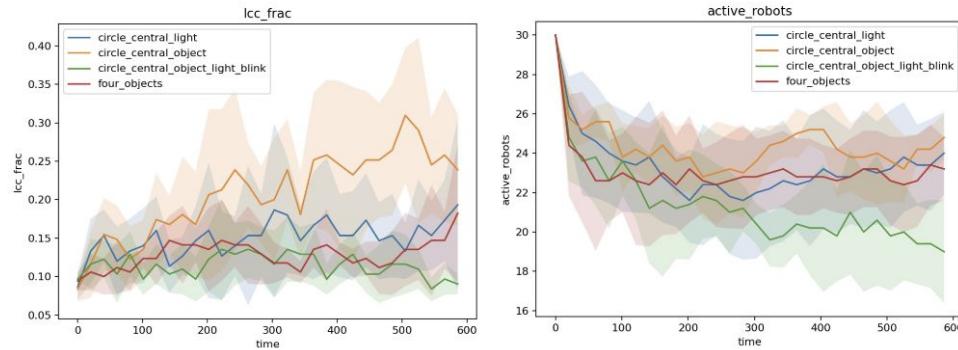


Figure 21: Average largest connected cluster per arena (left), share of active robots per arena (right)

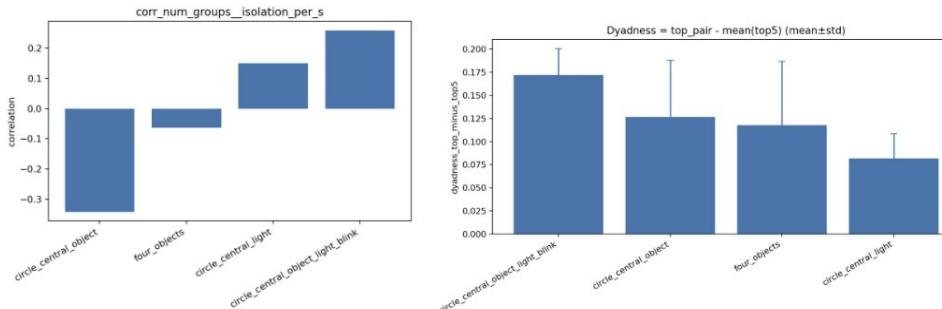


Figure 22: Correlation between the number of groups and isolation per second (left), Dyadness (right)

# Conclusion & Future work

- The pogobots under with mEDEA look for reference points/regions to match and share their genomes
- Very sensible to environment params
- The light works reference point, in particular, gradient light
  - The pogobots follow this light when it's moving in a regular pattern
- Pogobots form larger clusters under favourable conditions and smaller groups under adversity
- Future work
  - Test it in real conditions
  - Explore the behavior of robots under adversity and the success of different genomes under various conditions
  - Explore other sizes od NN
  - Explore explicability to check which inputs and weights are important to make each decision
    - Example: follow the light

Thank you for listening!

Merci!

Obrigado!

Спасибо!

ありがとう！

# Resources

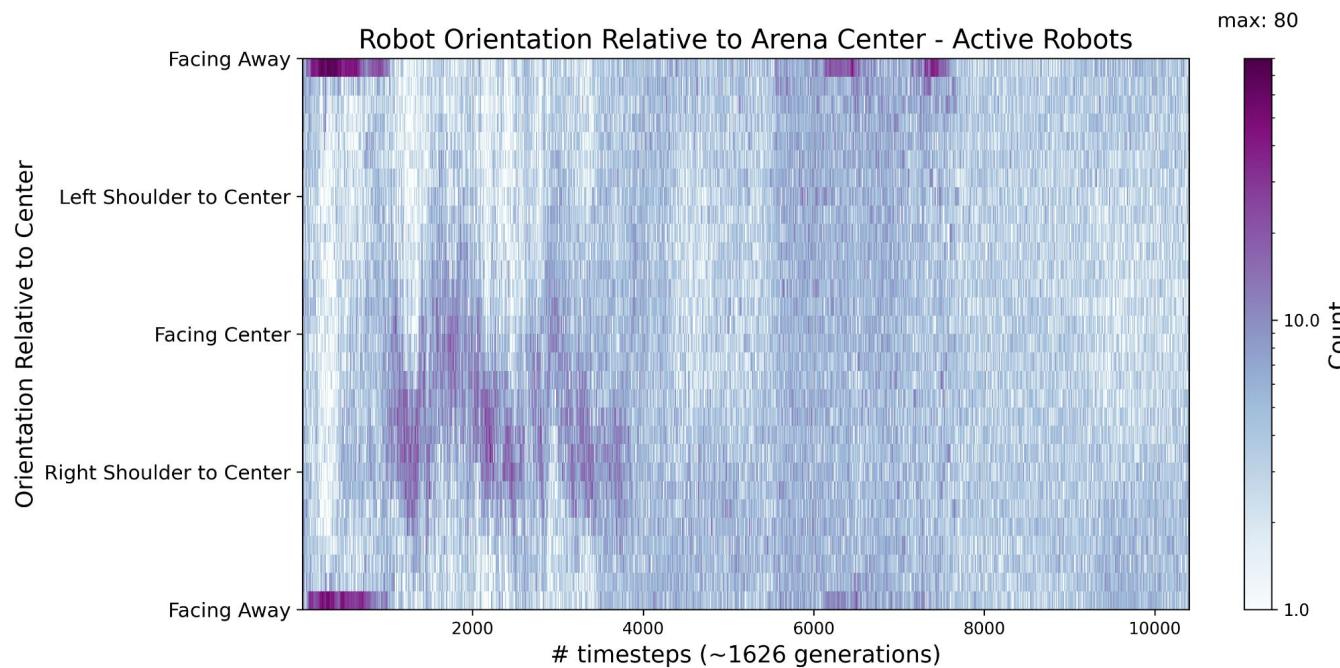
- N. Bredeche and J.-M. Montanier, “Environment-driven Embodied Evolution in a Population of Autonomous Agents,” in *Parallel Problem Solving from Nature*, Krakow, Poland, Sep. 2010, pp. 290–299.
  - <https://inria.hal.science/inria-00506771>
- Pogobot website and github repositories
  - <https://pogobot.github.io/>
  - <https://github.com/nekonaute/pogobot>
  - <https://github.com/nekonaute/pogobot-sdk>
- Pogosim website and github repository
  - <https://github.com/Adacoma/pogosim>
  - <https://adacoma.github.io/pogosim/>
- **Our project repository** and fork of Pogosim (modified)
  - <https://github.com/Stalkyyy/pogobot-swarm-mEDEA>
  - <https://github.com/luiznery/pogosim>
    - Modification: <https://github.com/Adacoma/pogosim/compare/main...luiznery:pogosim:main>

# Extra Slides

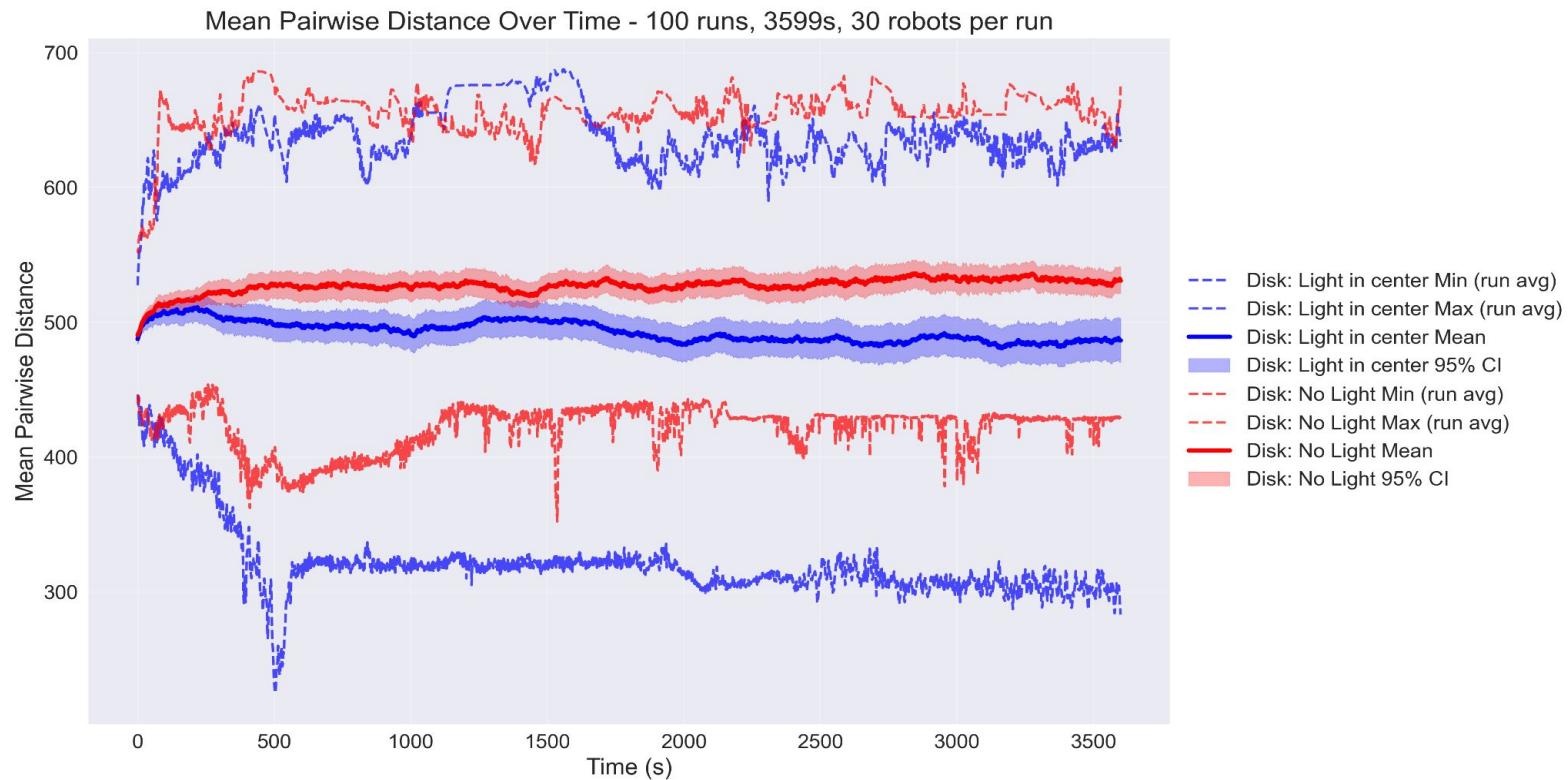
For questions etc

# Disk arena with Soft Light

Example run showing typical behaviour



# Disk arena with and without Light



# Disk arena with and without Light

