Dialog – Developmental Systems and Swarms

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UiO : University of Oslo

What is in this interactive session?

- Mentimeter quiz
- Dialog and discussion
- Ant colony optimization
- Interactive demos
  - Ant colony optimization
  - Particle swarm optimization
- Development for evolving robots
- Summary

Mentimeter :

- Code **7912 9191**



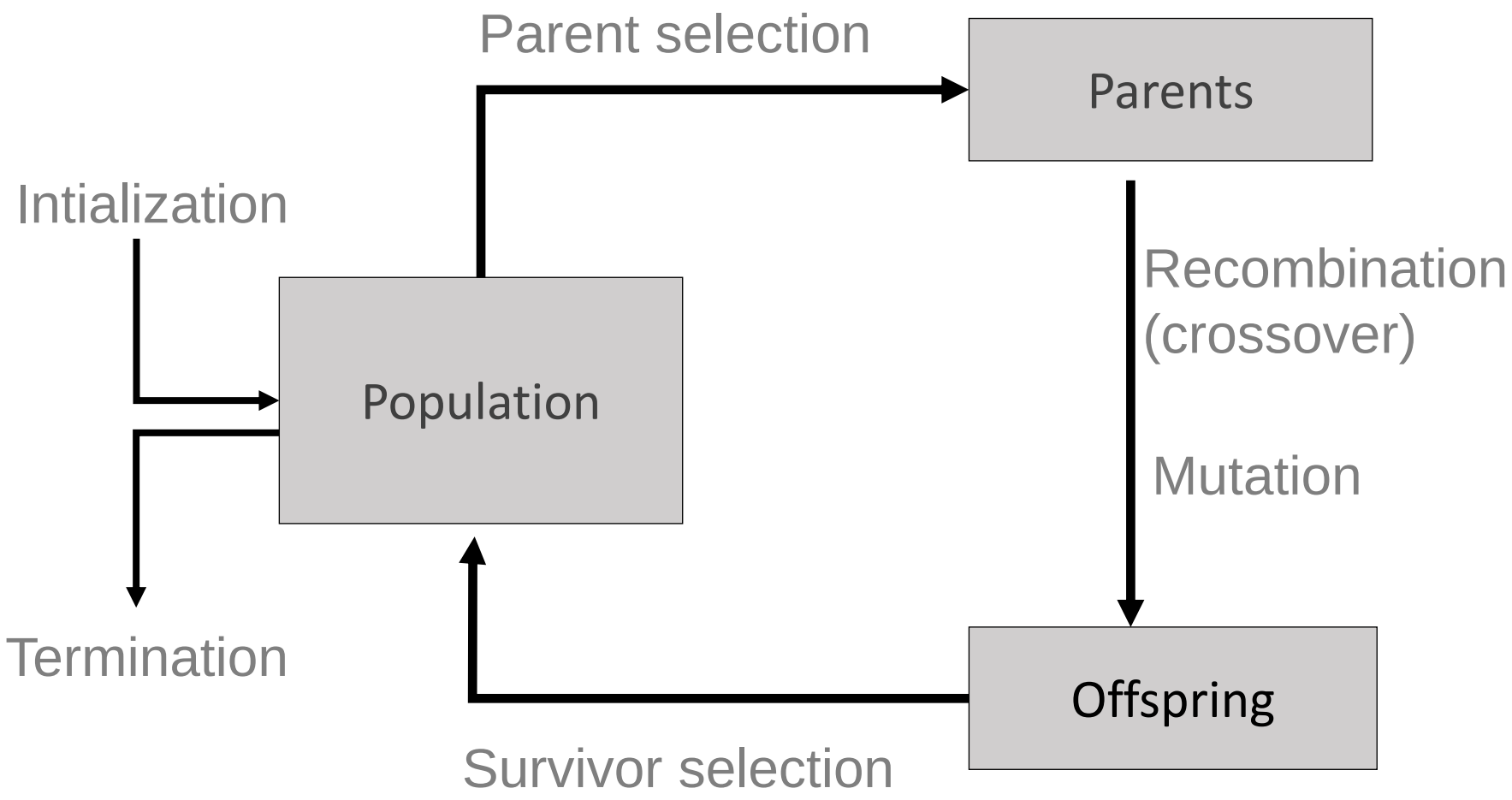
- Link: https://www.menti.com/gxuq6p9gzg

Putting things in context

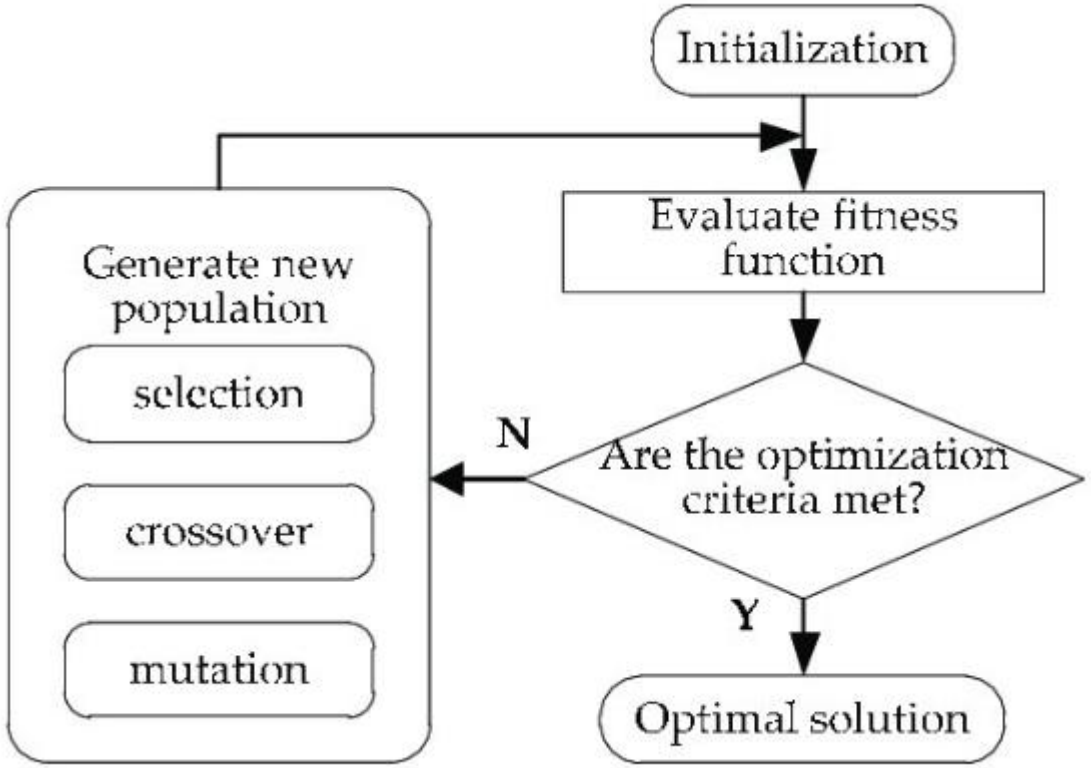
- This week's topics may seem a bit different than the other methods we have covered so far in the course.
- How (if at all) are **swarm intelligence** and **developmental systems** connected to the previous topics:
  - Optimization/Search
  - Evolutionary Algorithms
  - Supervised Learning
  - Unsupervised Learning
  - Reinforcement Learning

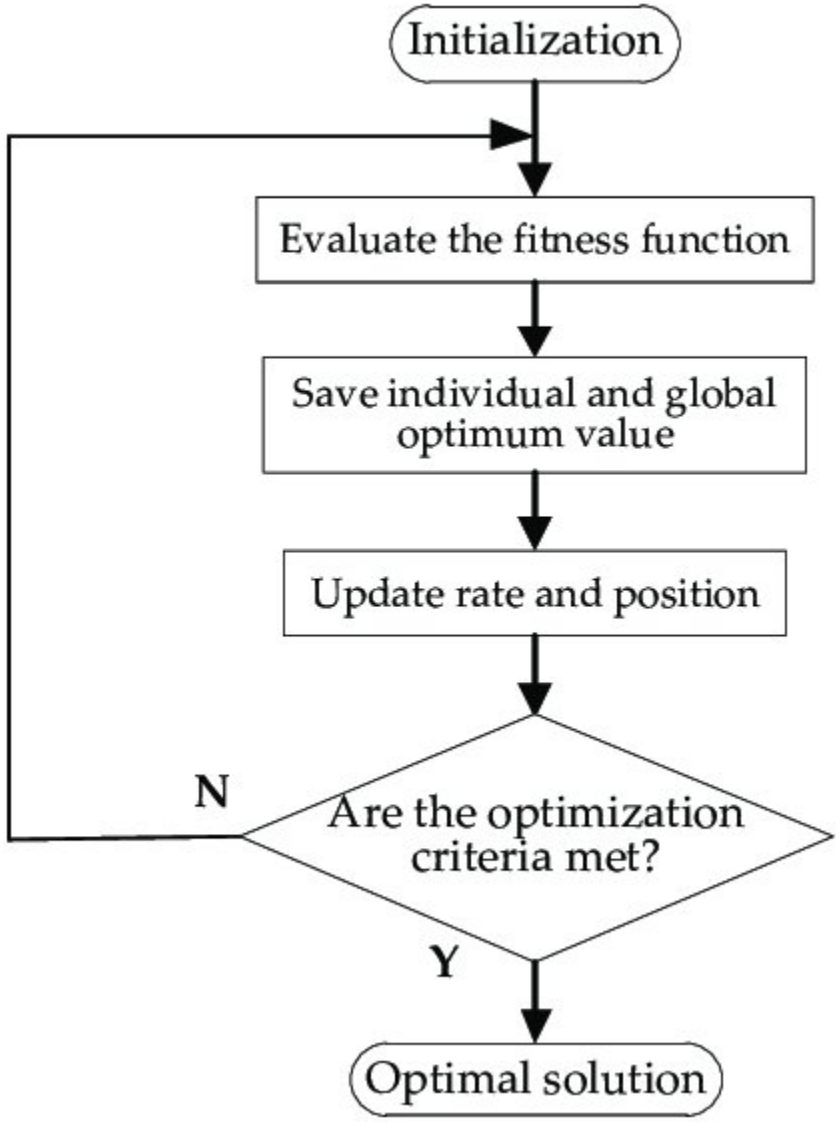
EAs vs Swarm Intelligence: Differences and Similarities

Reminder: How an EA Looks



EA vs PSO





Figures from Xiao, Yunqi, Yi Wang, and Yanping Sun. "Reactive power optimal control of a wind farm for minimizing collector system losses." *Energies* 11.11 (2018): 3177.

EAs vs Swarm Intelligence: Differences and Similarities

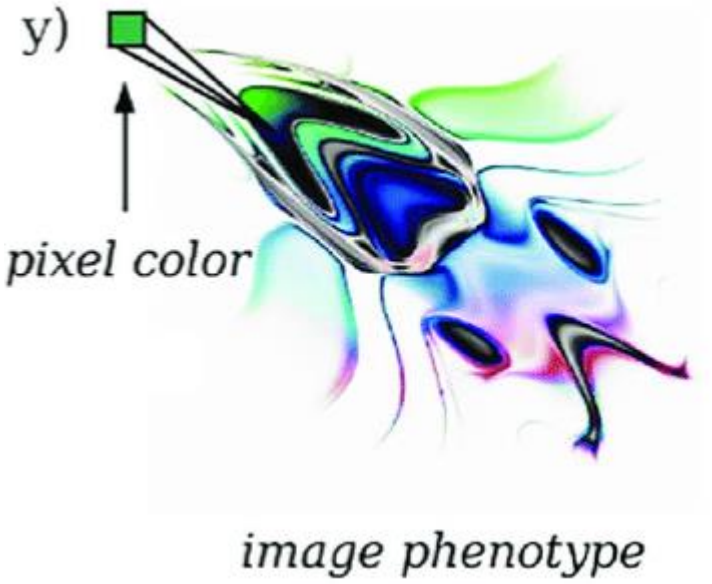
Similarities

Differences

Engineering vs understanding the world – the role of this week's concepts

- In this course (and most IFI courses), focus is on technology that we can use to build better (computer) systems

- Optimization, SL, UL, RL are clearly relevant there.



What is the role of this week's concepts in:

1) Broadening our understanding of natural phenomena?
2) As tools for engineering?
3) As «seeds» for future technology?

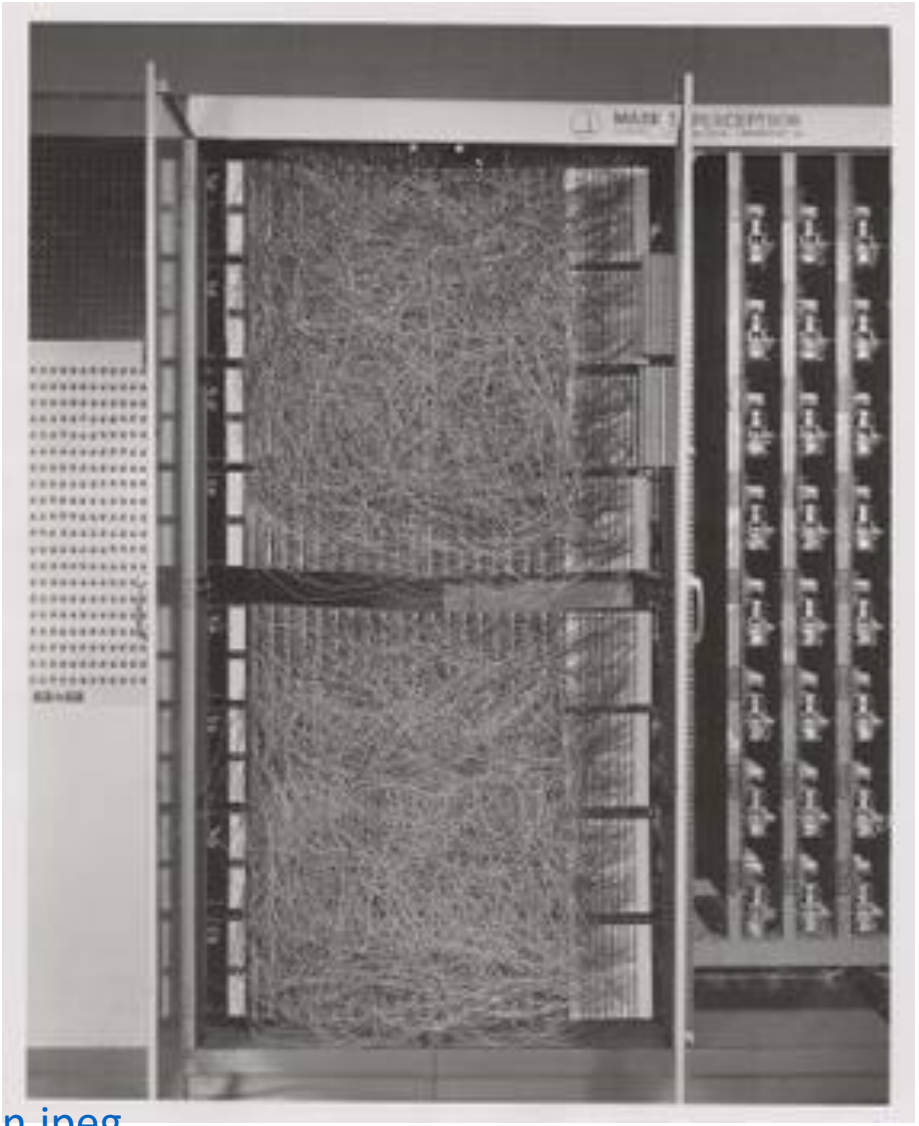
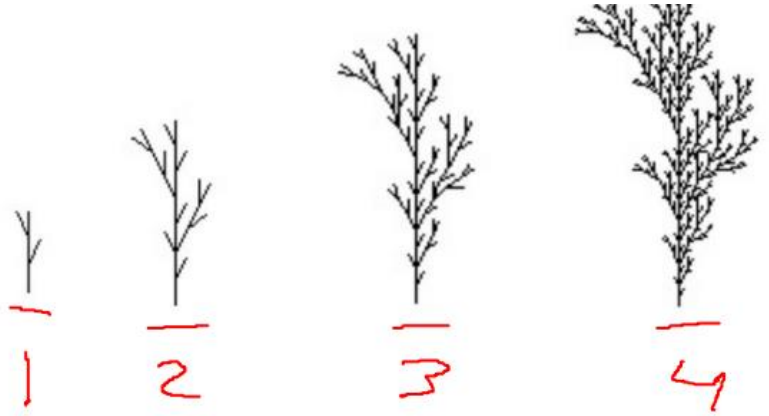


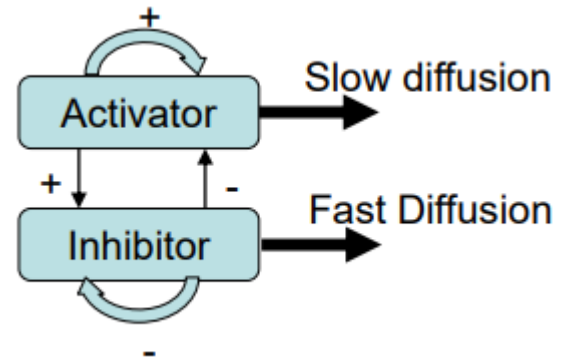
Image: https://en.wikipedia.org/wiki/Perceptron#/media/File:Mark_I_perceptron.jpeg

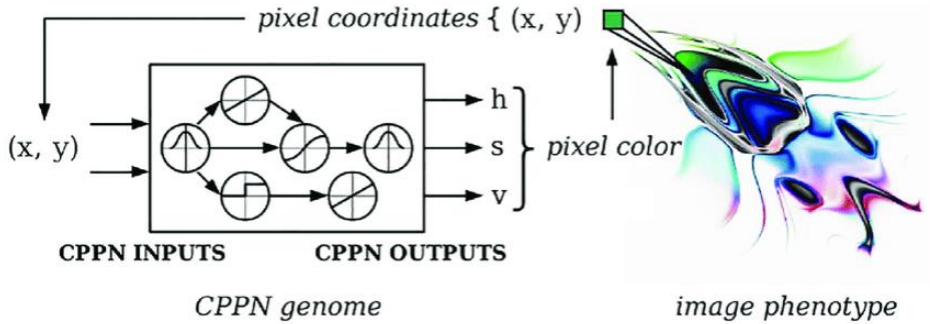
Types of developmental systems



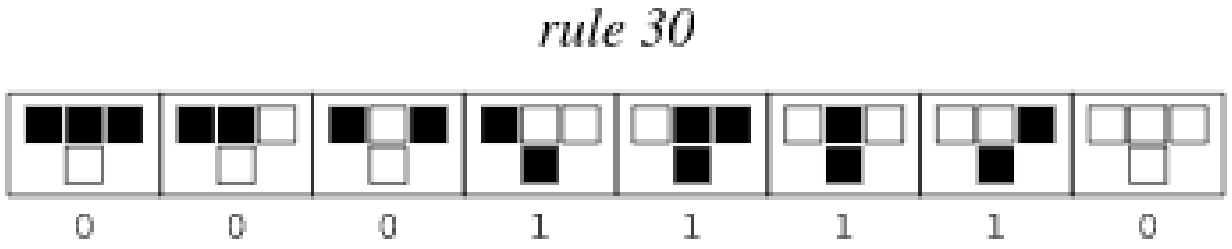
- L-systems
- Chemistry-based systems
- CPPNs,etc.

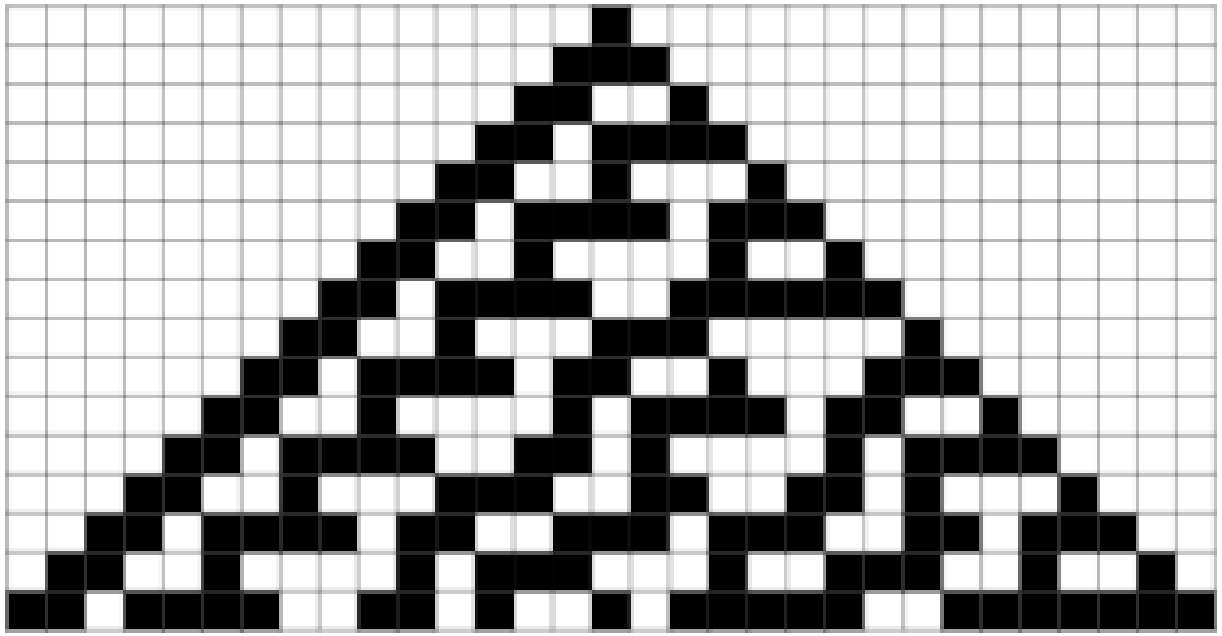
- Advantages/disadvantages? When to use each?

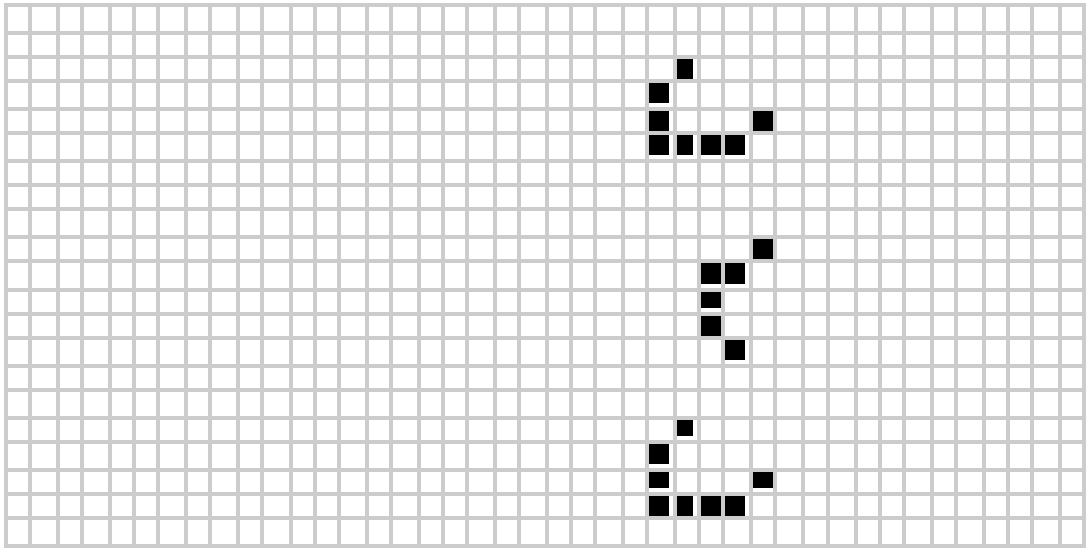




Cellular Automata

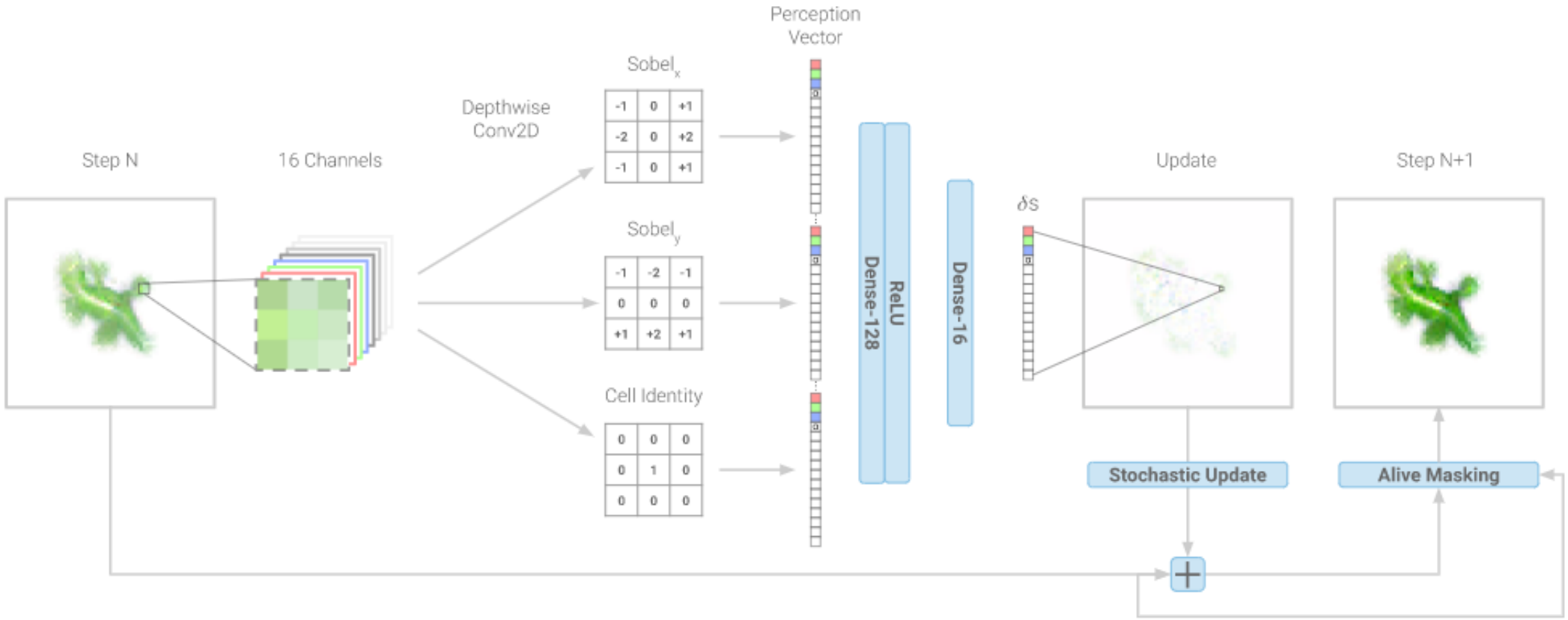






Source: https://mathworld.wolfram.com/CellularAutomaton.html

Neural CA's



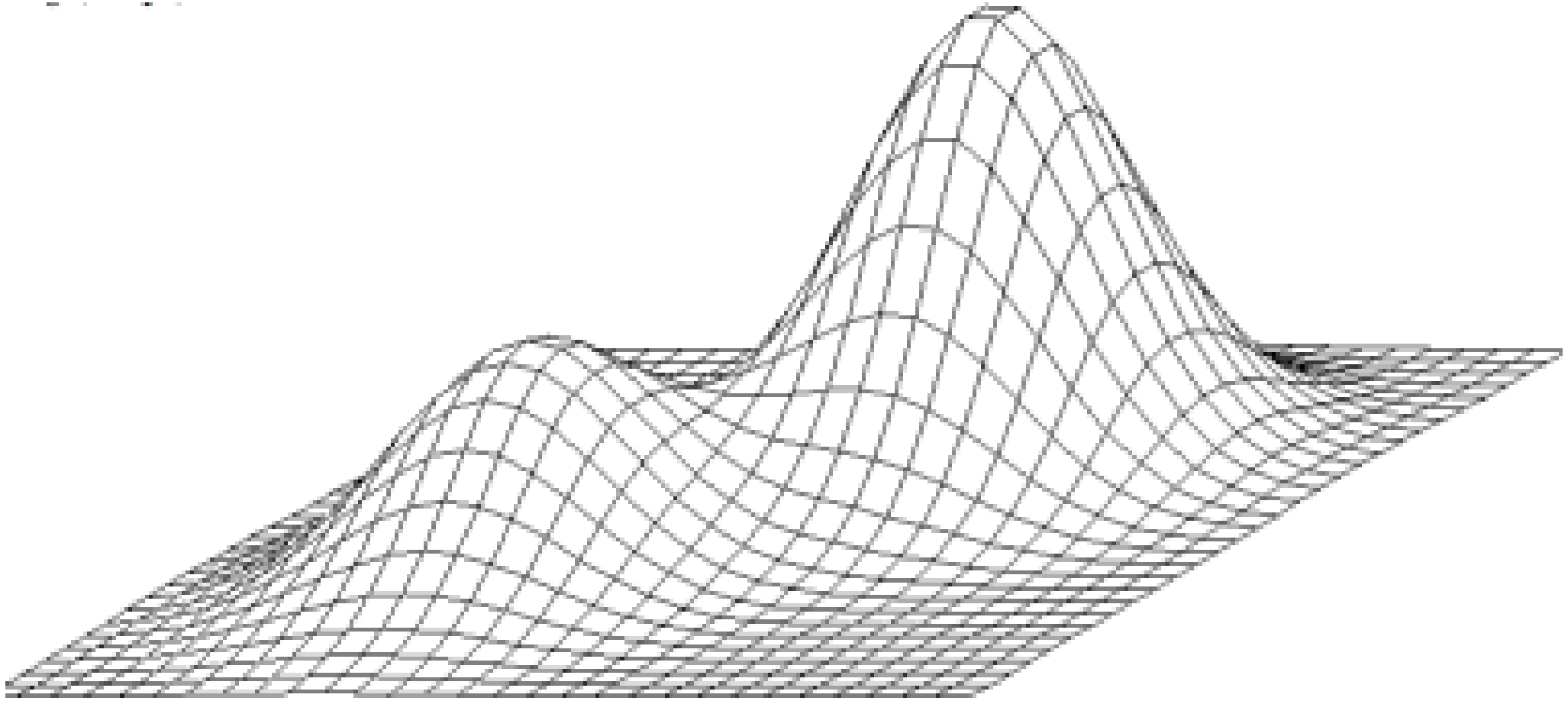
A single update step of the model.

https://distill.pub/2020/growing-ca/

Developmental systems and search

- How does development change the search landscape?
- How do developmental systems make sense when central to search is smoothly moving from neighbor to neighbor?

We normally want search to be smooth



However, in developmental systems, small genotype changes lead to large phenotype changes

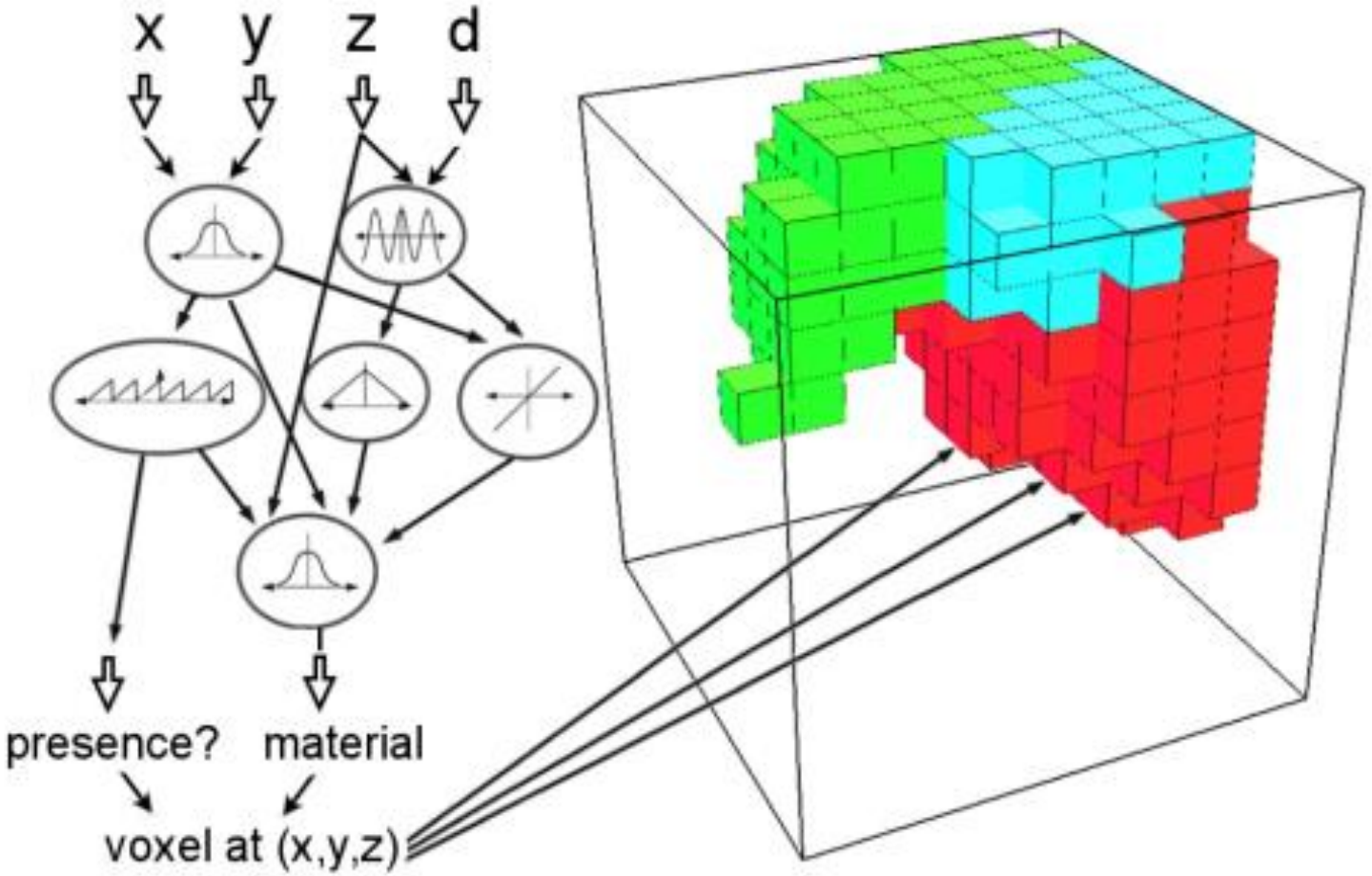
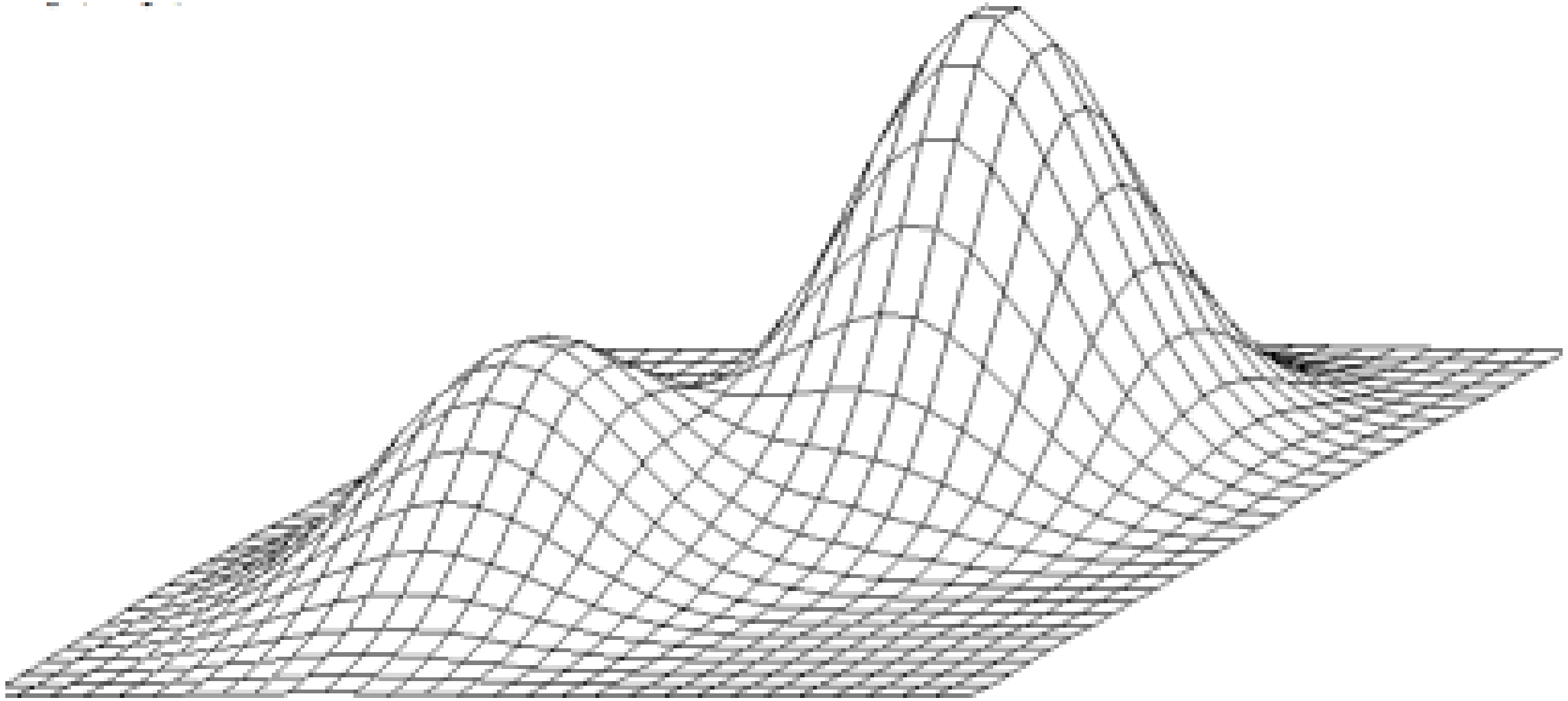
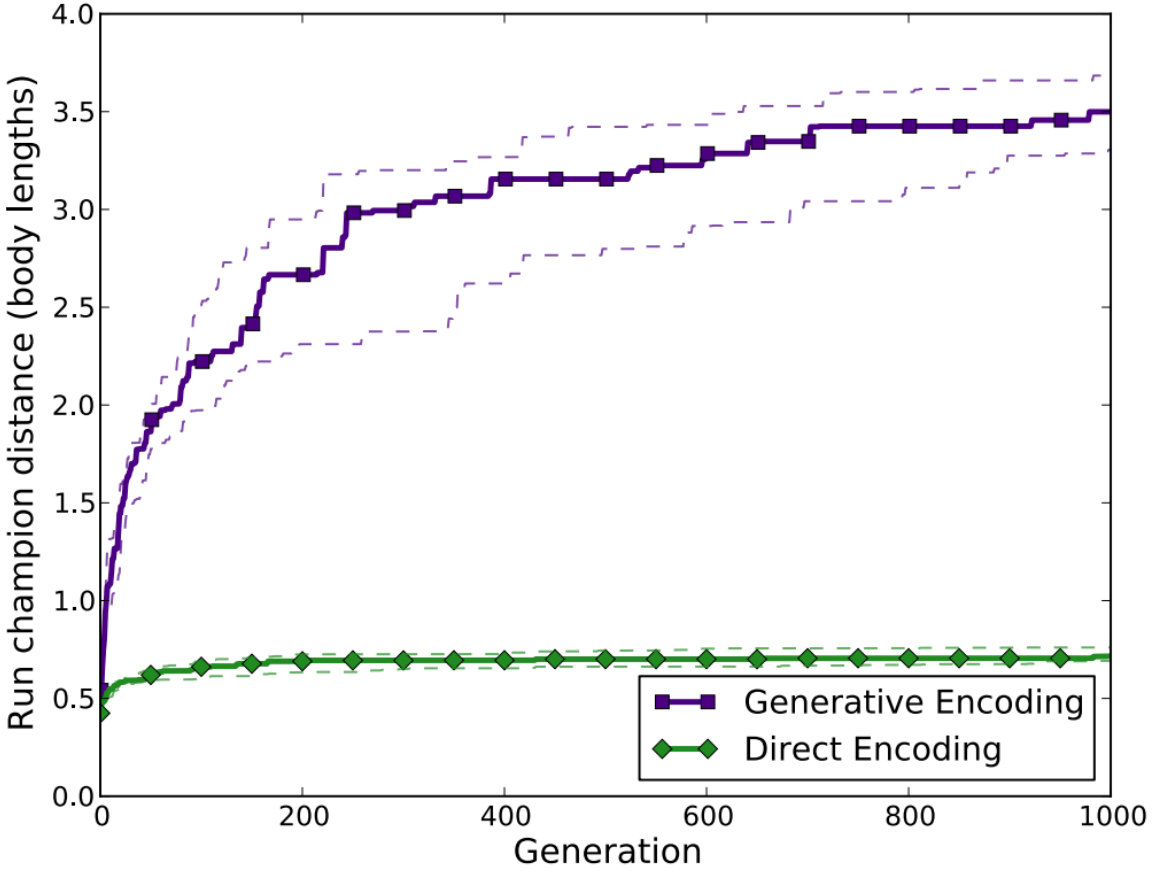


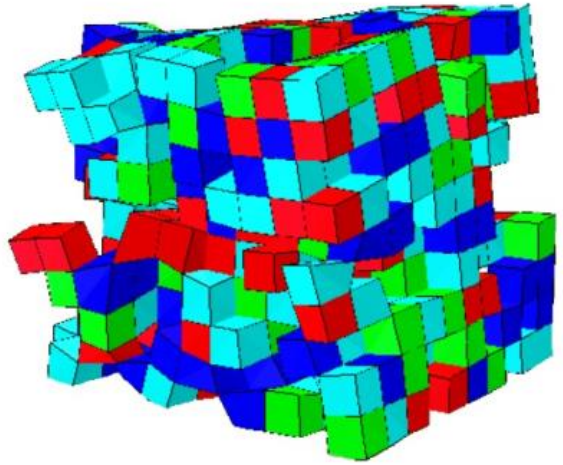
Image from «**Unshackling Evolution: Evolving Soft Robots with Multiple Materials and a Powerful Generative Encoding" by** Nick Cheney, Robert MacCurdy, Jeff Clune, Hod Lipson

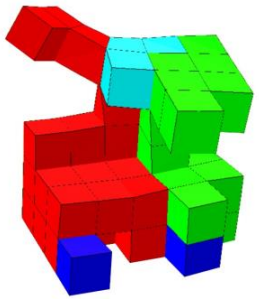
How can search with developmental encodings still be efficient?

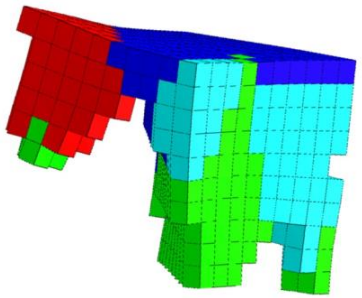


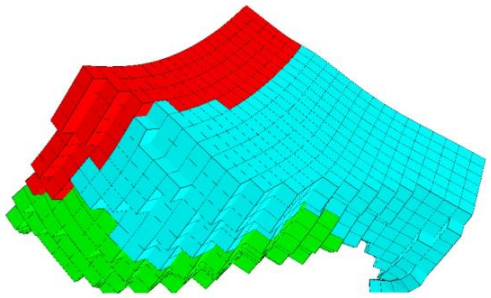
Example from evolving soft robots





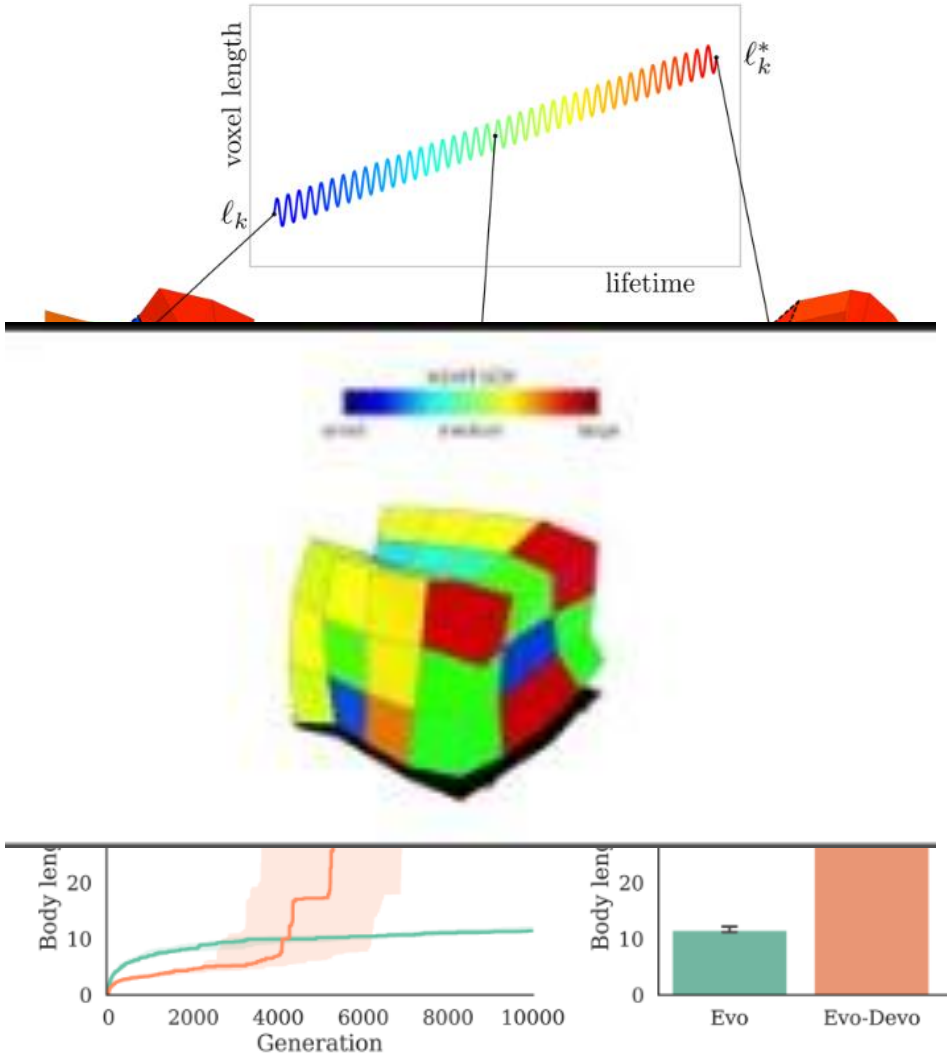




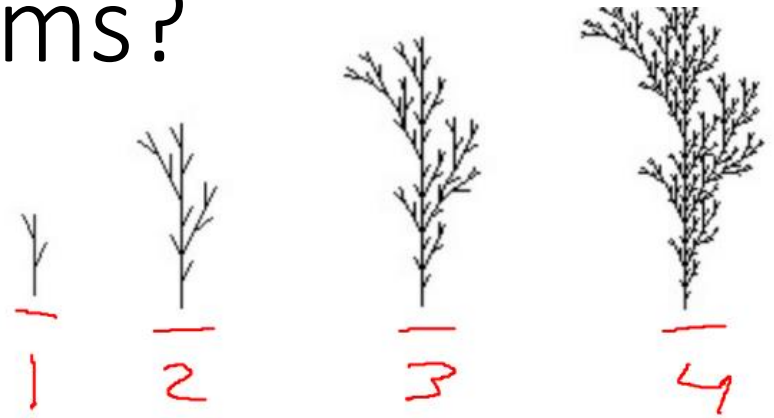


Controller ‘development’ during the robot’s life

- Sweeps values during lifetime
- Evolution will increase the time in the efficient zone

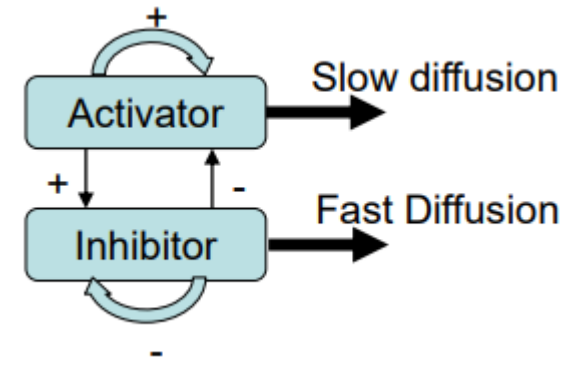


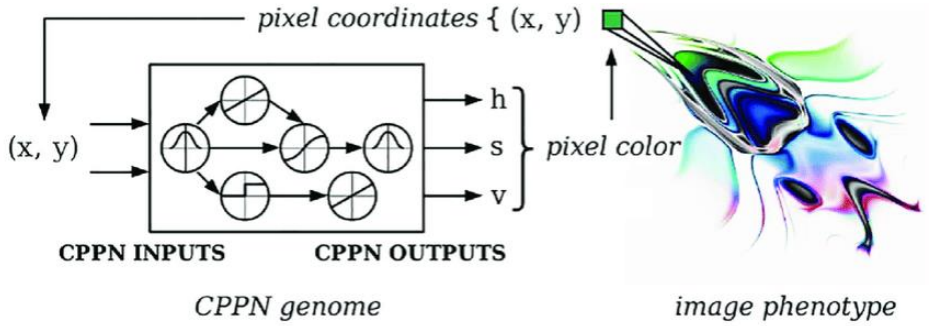
Are CA's developmental systems?



Which one are they most like?

- L-Systems
- Chemistry-based systems
- CPPNs,etc.



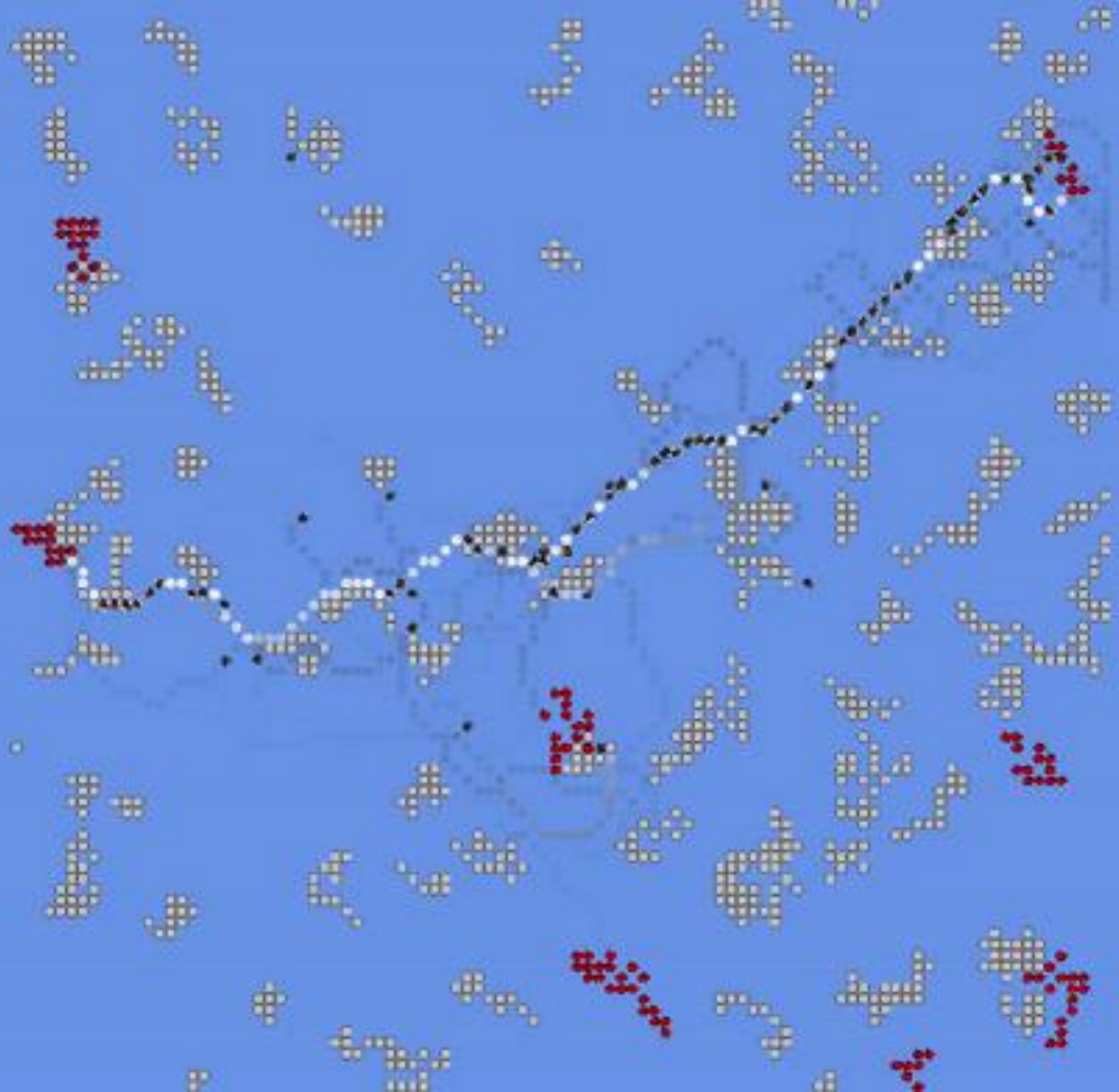


Ant Colony Optimization

Stigmergy: social communication through modification of the environment

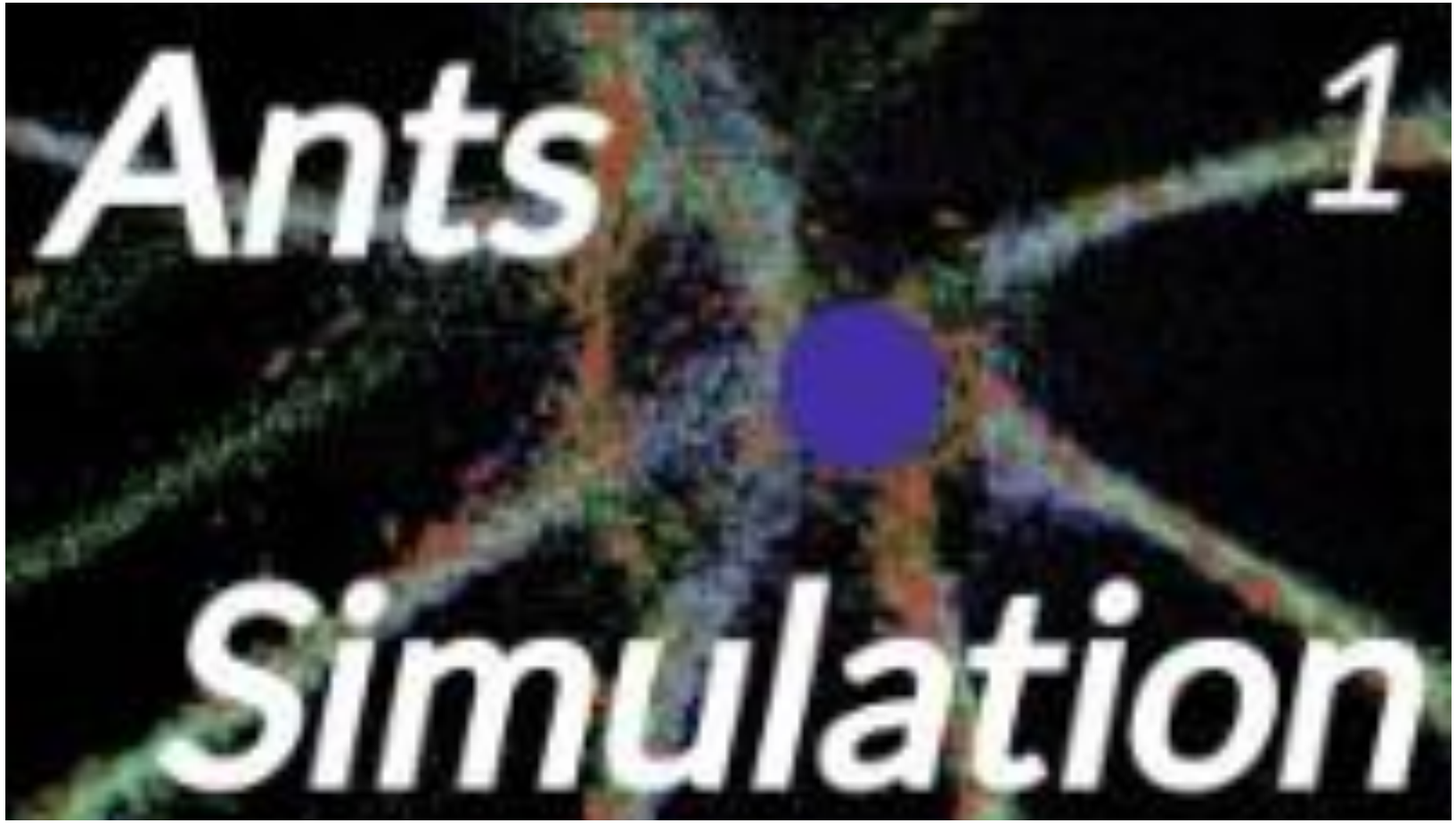
- An ant drops more ‘pheromones’ when it finds it’s objective
- Useful for finding paths through graphs
  (release pheromones on edges)

The example from the lecture



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

Ant Colony Optimization

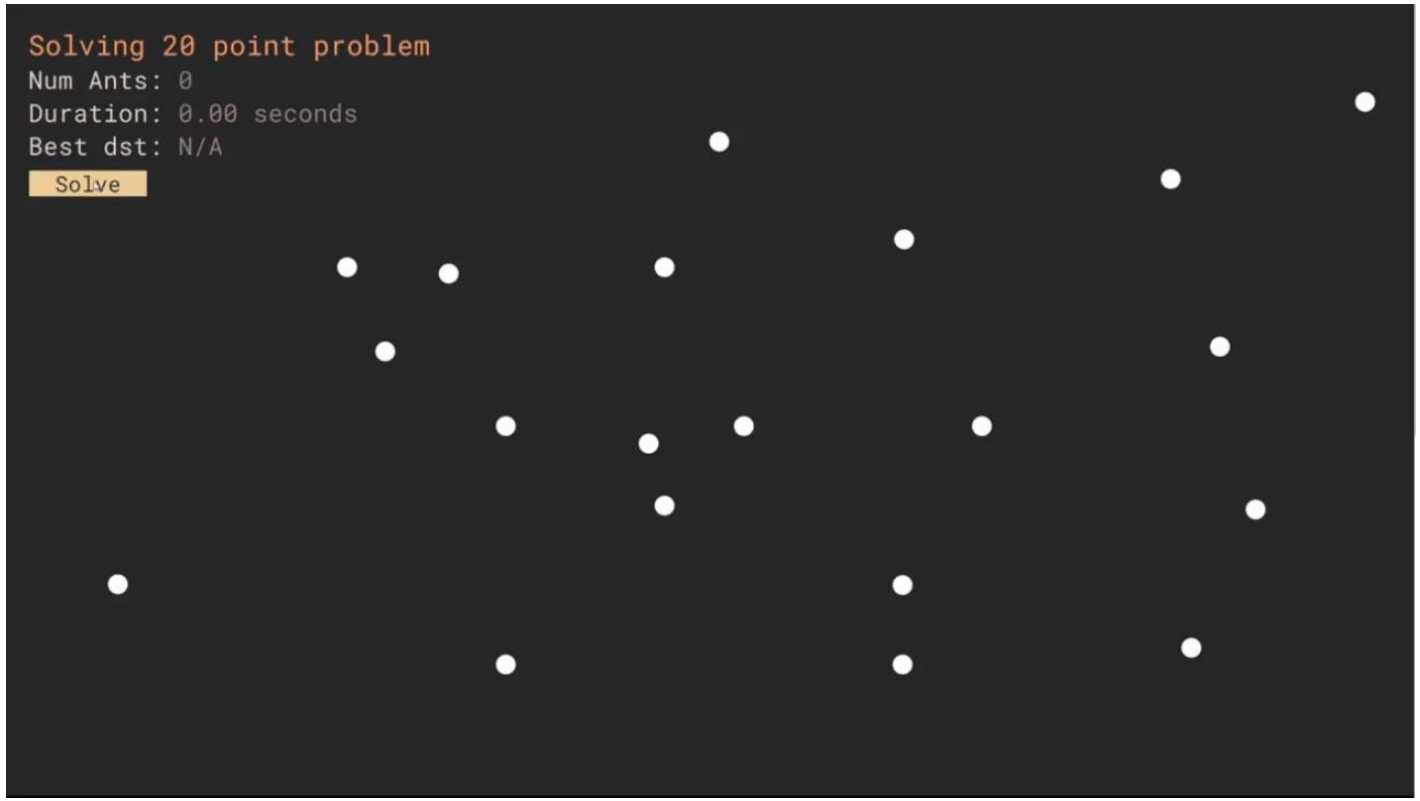


https://www.youtube.com/watch?v=81GQNPJip2Y

https://github.com/johnBuffer/AntSimulator

Ant Colony Optimization

- Vehicle routing problem (or tsp)



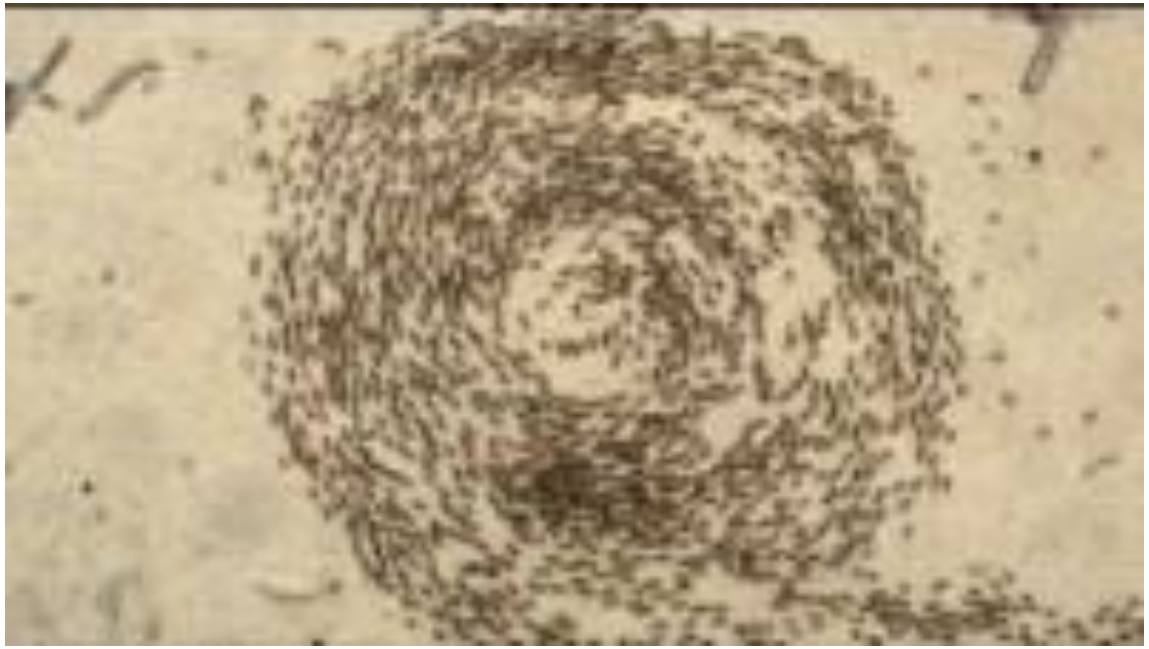
https://www.youtube.com/watch?v=X-iSQQgOd1A&t=204s

Demo

- Ants have a probability of choosing next destination based on:
  - Pheromones present on edges (Pheromone power)
  - The distance to other edges (Distance power)

What about real ants?



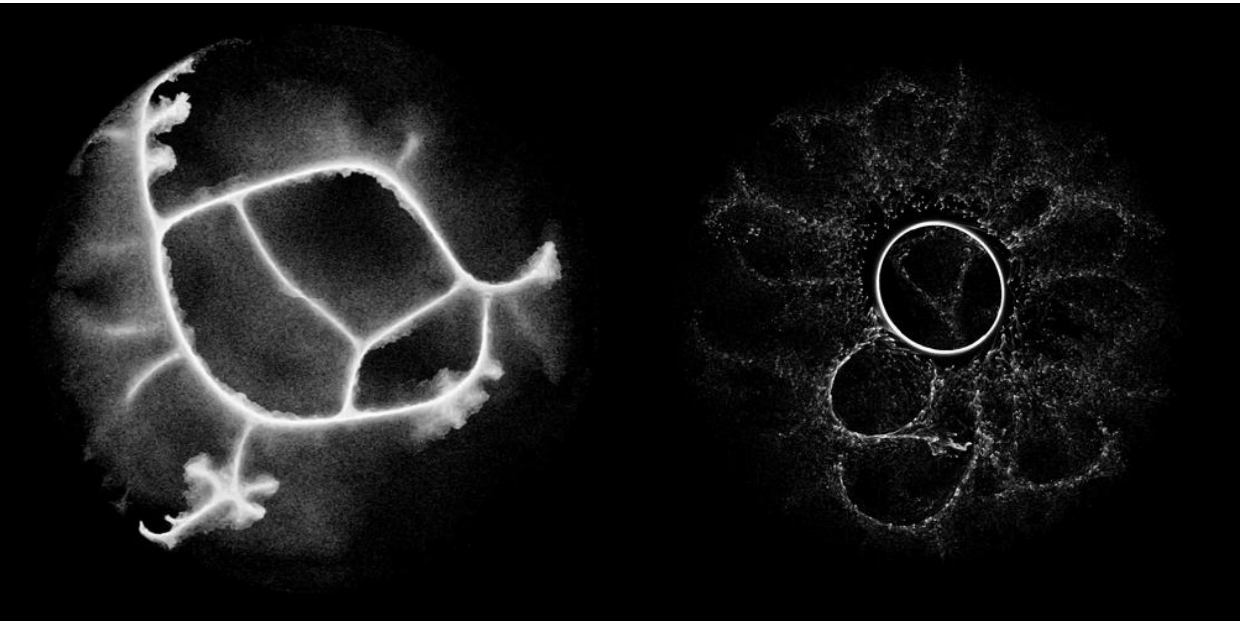


Slime Mould

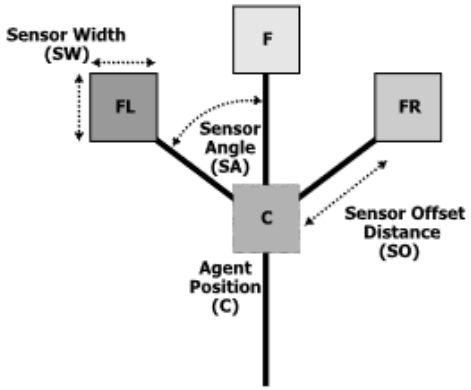


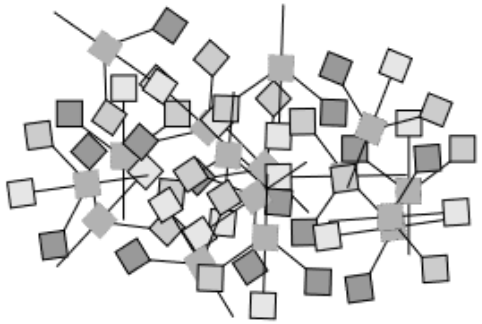
https://www.youtube.com/watch?time_continue=49&v=HyzT5b0tNtk&feature=emb_logo

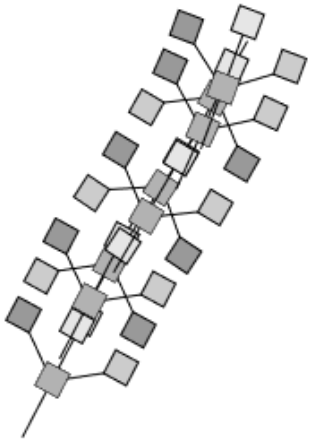
Slime Mould



```
[Motor stage]
        - Attempt move forwards in current direction
        - If (moved forwards successfully)
                Deposit trail in new location
        - Else
                Choose random new orientation
[Sensory stage]
        - Sample trail map values
        - if (F > FL) && (F > FR)
                - Stay facing same direction
                - Return
        - Else if (F < FL) && (F < FR)
                Rotate randomly left or right by RA
        - Else if (FL < FR)
                Rotate right by RA
        - Else if (FR < FL)
                Rotate left by RA
        - Else
                Continue facing same direction
```







https://sagejenson.com/physarum

Particle Swarm Optimization

$$x_{i,d}(it+1) = x_{i,d}(it) + v_{i,d}(it+1) \quad (1)$$

$$\begin{aligned} v_{i,d}(it+1) &= v_{i,d}(it) \\ &+ C_1 * Rnd(0,1) * [pb_{i,d}(it) - x_{i,d}(it)] \\ &+ C_2 * Rnd(0,1) * [gb_d(it) - x_{i,d}(it)] \end{aligned} \quad (2)$$

Caption:

i particle's index, used as a particle identifier;

d dimension being considered, each particle has a position and a velocity for each dimension;

it iteration number, the algorithm is iterative;

$x_{i,d}$ position of particle i in dimension d;

$v_{i,d}$ velocity of particle i in dimension d;

C_1 acceleration constant for the cognitive component;

Rnd stochastic component of the algorithm, a random value between 0 and 1;

$pb_{i,d}$ the location in dimension d with the best fitness of all the visited locations in that dimension of particle i;

C_2 acceleration constant for the social component;

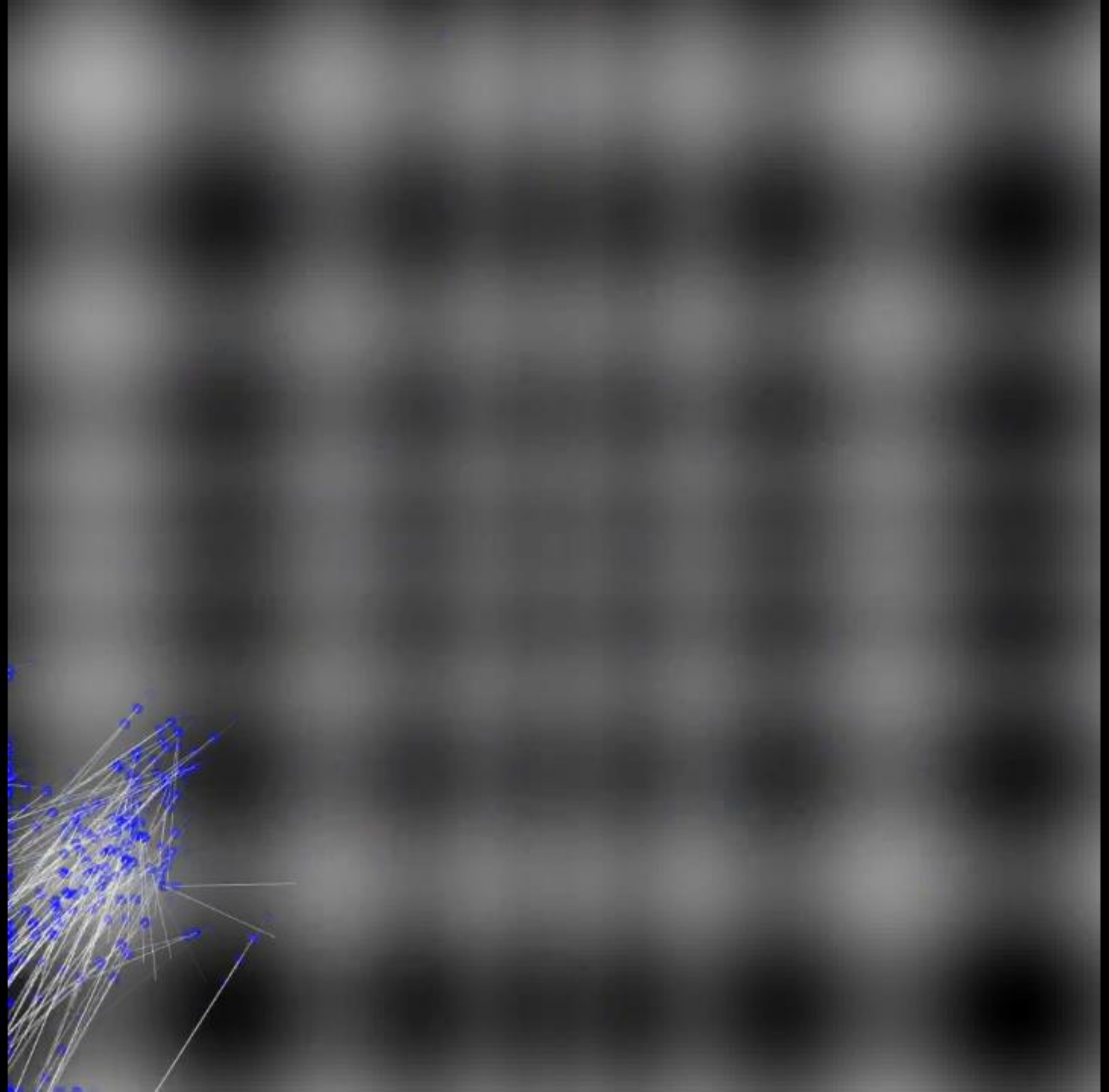
(1) $V_{ij}^{t+1} = \boldsymbol{w} V_{ij}^{t} + c_1 r_1^t \left(pbest_{ij} - X_{ij}^t\right) + c_2 r_2^t \left(gbest_j - X_{ij}^t\right)$

(2) $X_{ij}^{t+1} = X_{ij}^t + V_{ij}^{t+1}$

'w' can be tweaked to become more exploitative/explorative

https://www.intechopen.com/books/swarm-intelligence-recent-advances-new-perspectives-and-applications/particle-swarm-optimization-a-powerful-technique-for-solving-engineering-problems

Lighter Areas represent Higher Performance



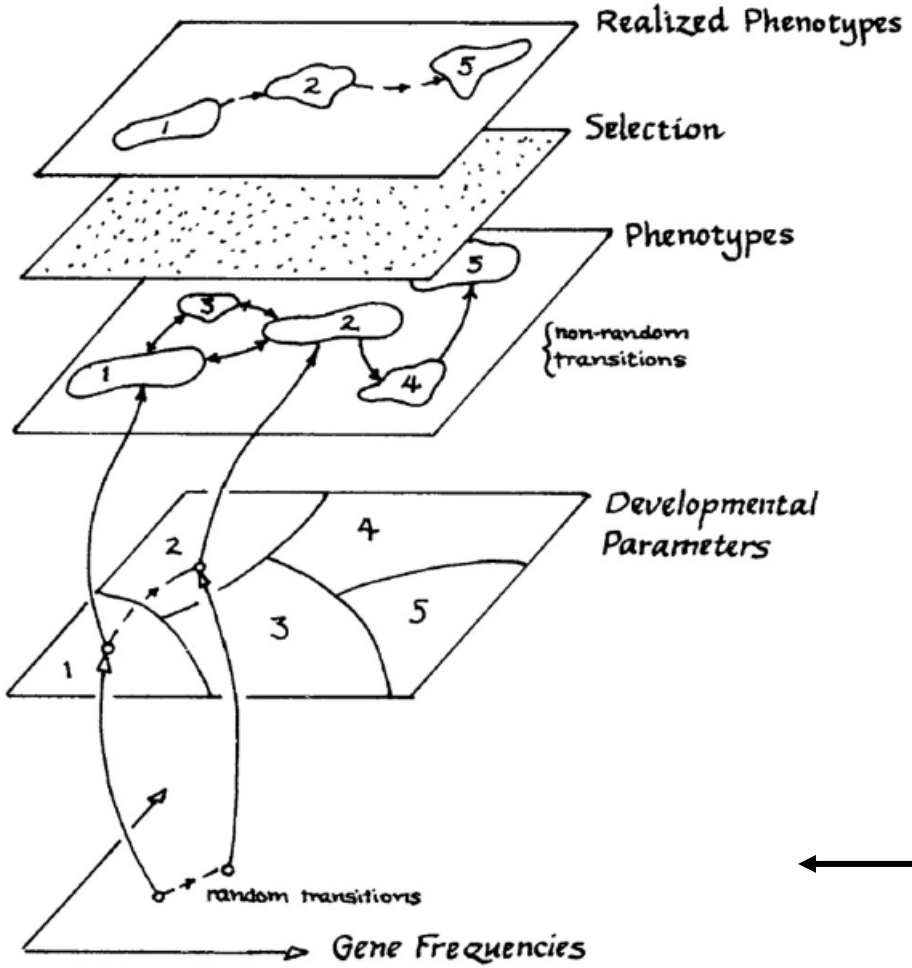
White lines represent directional vectors (velocity)

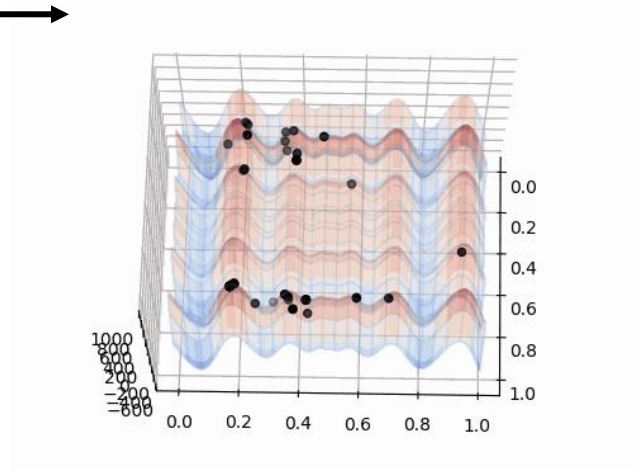
Boids

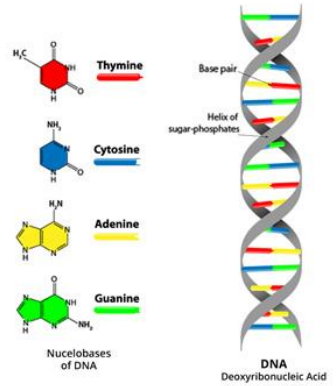


Sebastian Lague: https://www.youtube.com/watch?v=bqtqltqcQhw&t=396s

Genotype-Phenotype Mapping







Genotype-phenotype mapping

