

Integrated Seminar: Intelligent Robotics

Robots & Cellular Automata

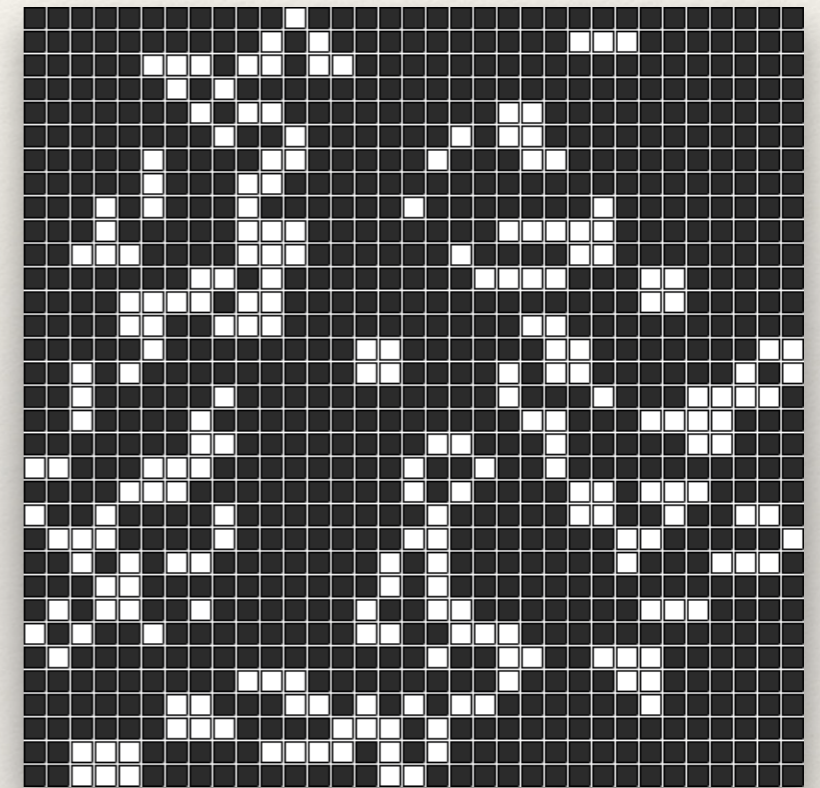
Julius Mayer

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Introduction

- ❖ spatiotemporal system of simple units
 - ❖ deterministic and homogeneous finite state machines
- ❖ locally interconnected
- ❖ no central controller
- ❖ commonly represented by single squares forming a two-dimensional mesh
- ❖ evolves through discrete time steps
- ❖ changing its state by an iterative application of the cell update rule
- ❖ similar to many physical and biological systems



Cellular System

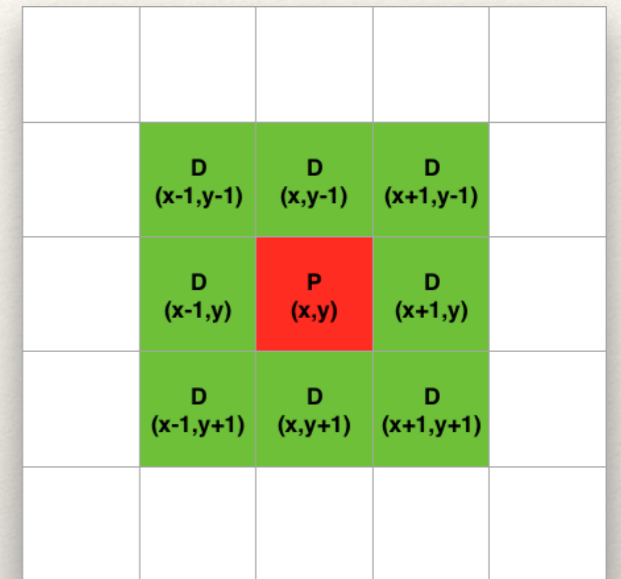
Neighborhood

- ❖ spacial region around a cell
- ❖ identical
- ❖ theoretically unbounded
- ❖ Von Neumann neighborhood

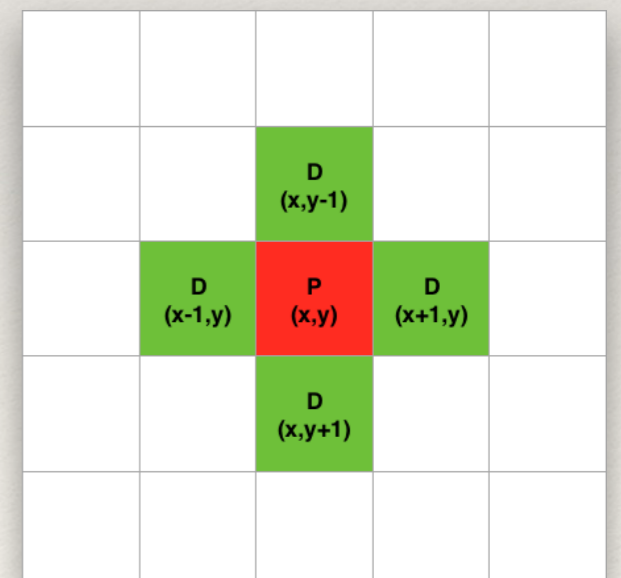
$$N^V_{x_0,y_0} = \{ (x,y) : |x-x_0| + |y-y_0| \leq r \}$$

- ❖ Moore neighborhood

$$N^M_{x_0,y_0} = \{ (x,y) : |x-x_0| \leq r, |y-y_0| \leq r \}$$



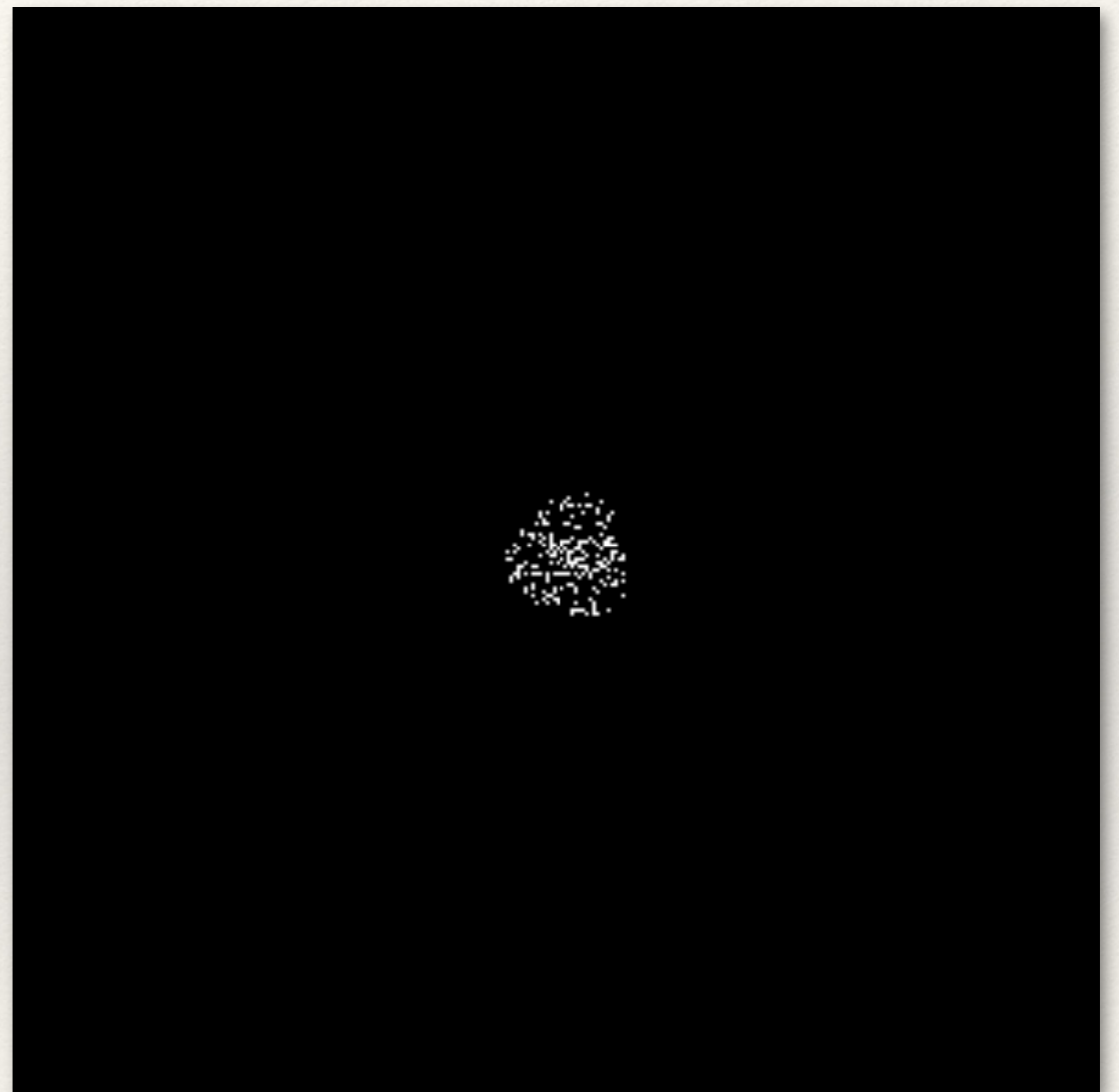
Von Neumann neighborhood



Moore neighborhood

Update Rule

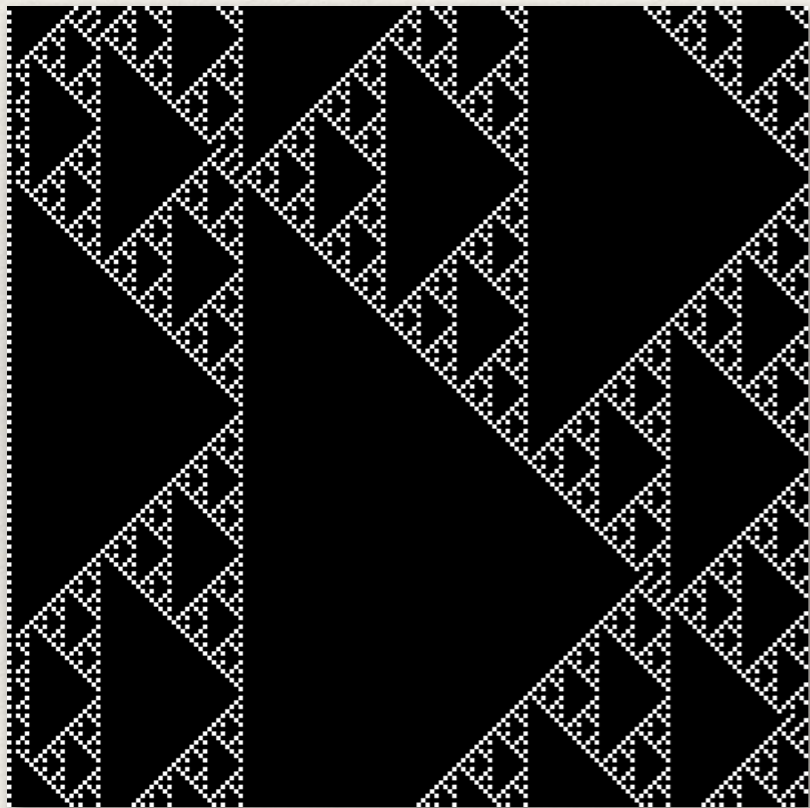
- ❖ function of the current states in the cells' local neighborhood
- ❖ identically for all cells
- ❖ followed by them simultaneously
- ❖ turning on or off in response to the neighborhood
- ❖ process information decentralized and distributed
- ❖ able to create unpredictable complex and chaotic global behavior



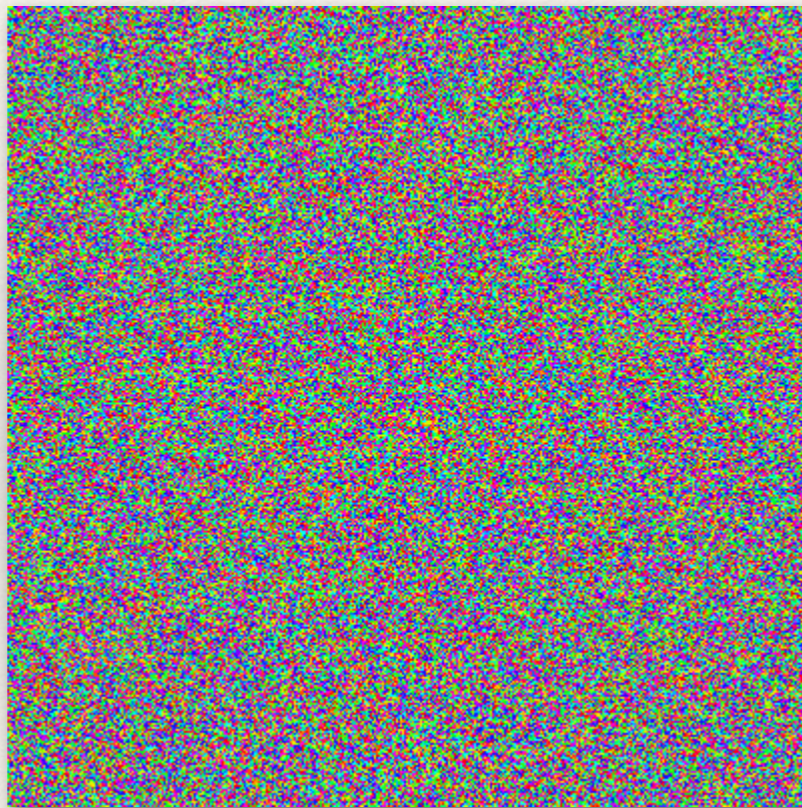
John Conway's Game of Life

Examples

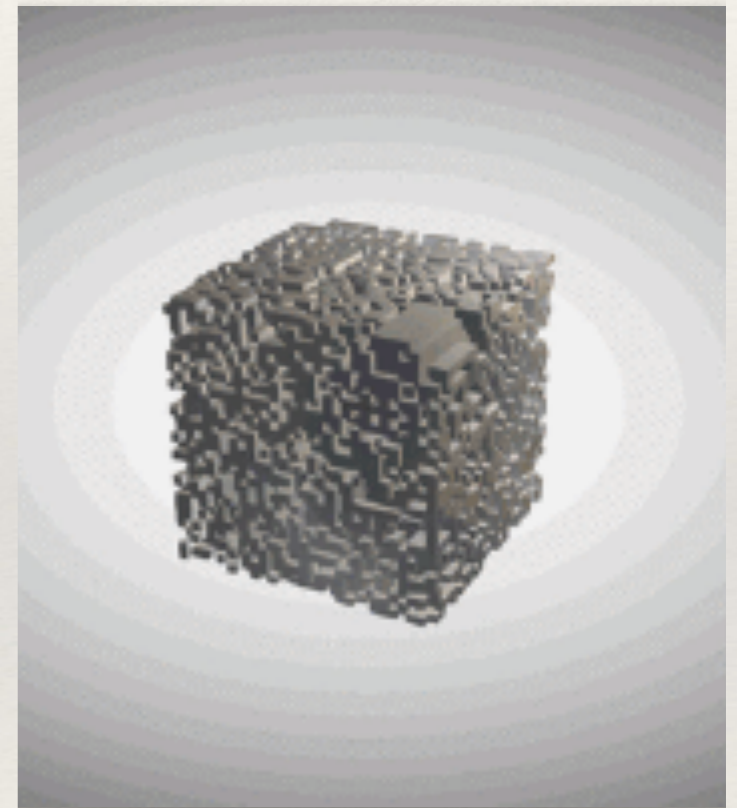
1D



2D

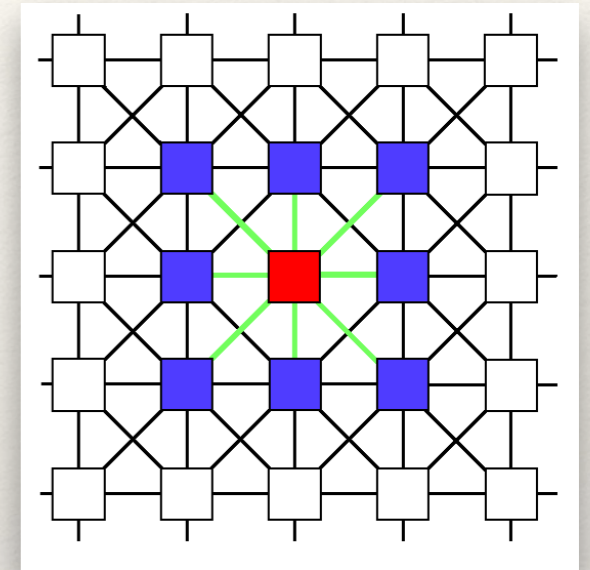


3D

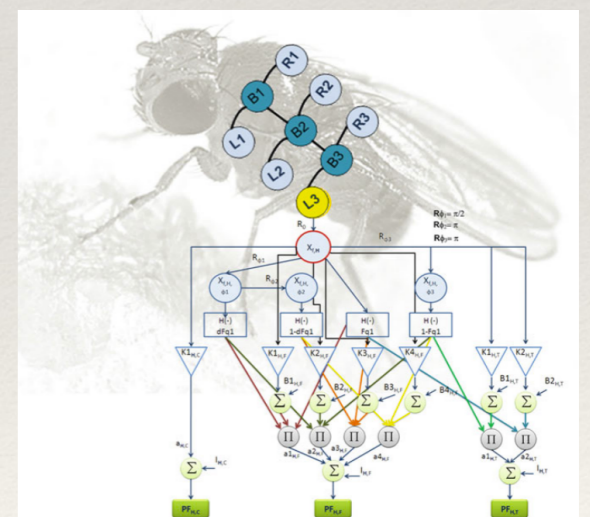


Cellular Neural Network

- ❖ parallel computing paradigm similar to neural networks
- ❖ local communication only
- ❖ global information exchange through diffusion
- ❖ weights are used to determine the dynamics of the system
- ❖ real-time, ultra-high frame-rate processing



CNN



locomotion control

Self-reconfigurable Robots

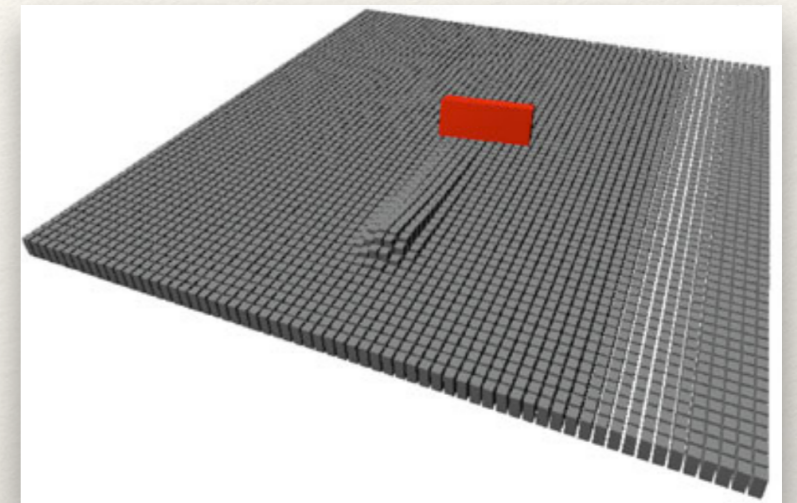
- ❖ built from robotic modules
- ❖ modules
 - ❖ complete robots
 - ❖ automatically connect to / disconnect from neighbor modules
 - ❖ move around in the lattice of modules
- ❖ change its own shape
- ❖ adapt to the environment
- ❖ response to new tasks



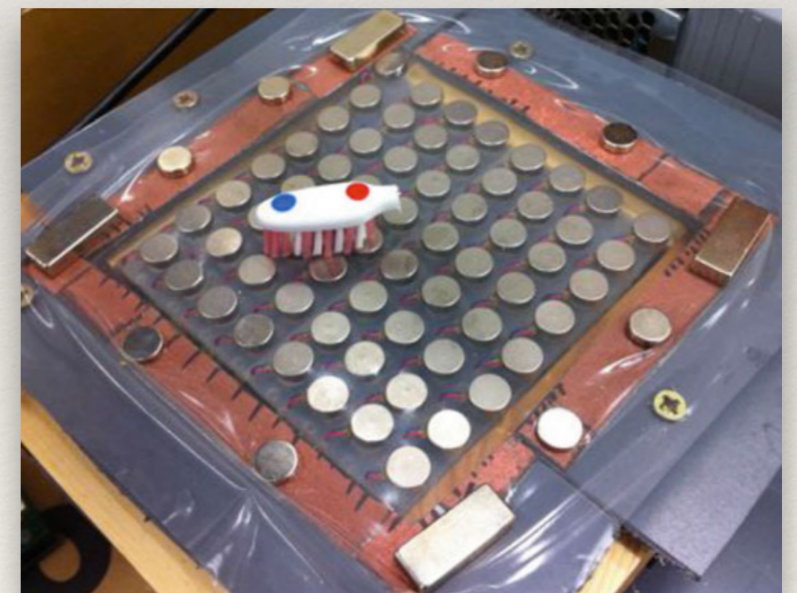
hybrid system: ATRON

Manipulator Array Controller

- ❖ array of simple actuators
- ❖ actuators
 - ❖ have some computing power
 - ❖ sensing
 - ❖ communicate to neighbors
- ❖ generate coordinated manipulation forces
- ❖ collective location, transportation, orientation and position of objects
- ❖ operate within constrained physical settings



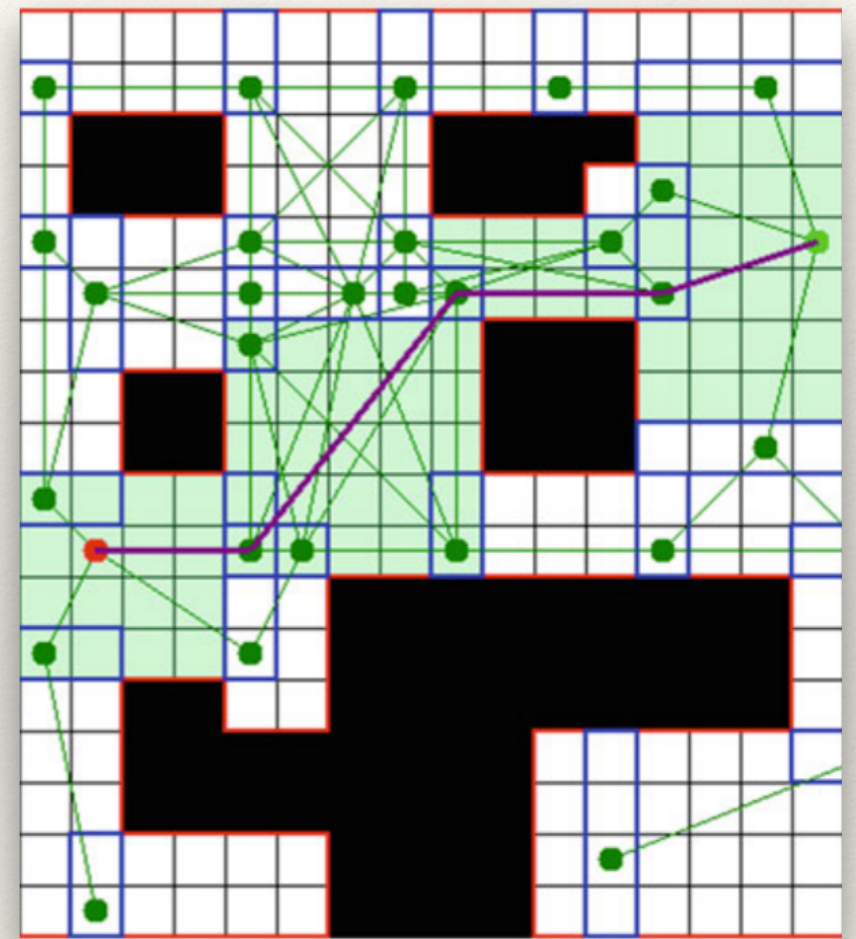
simulation



actuator array

Path Planner

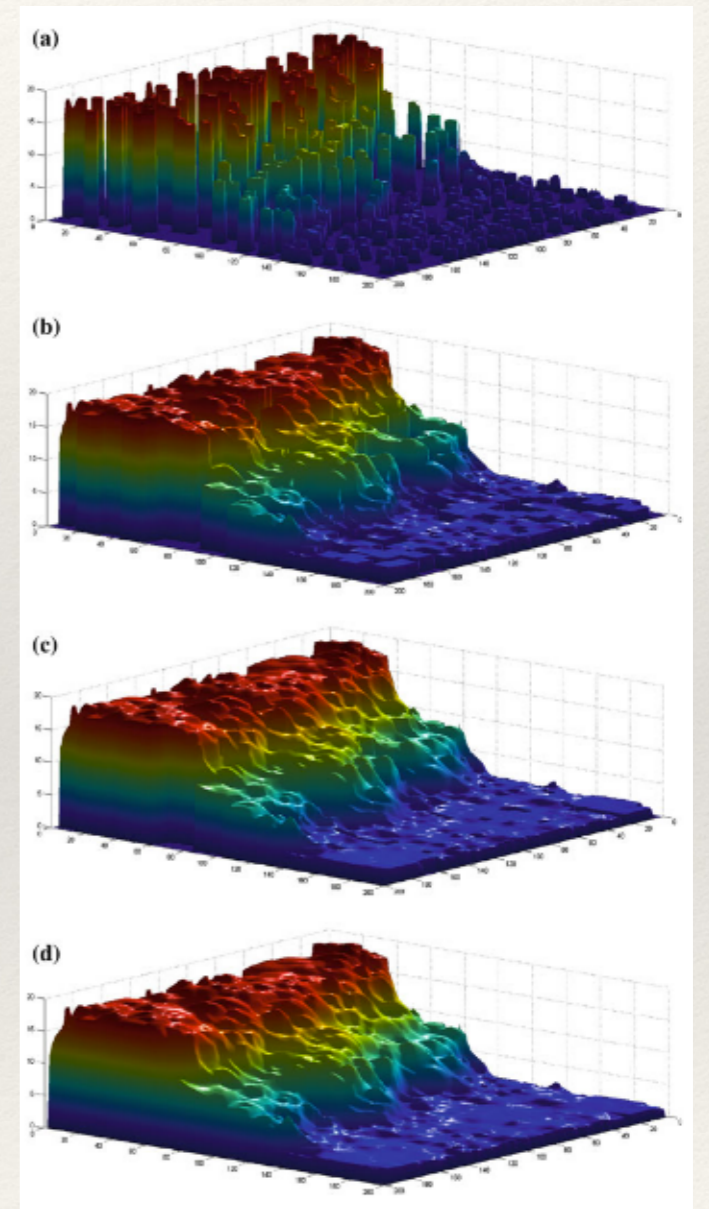
- ❖ local and global
- ❖ producing collision free trajectories
- ❖ coordinated motion of a Multi-Robot System
- ❖ operate in wide spaces



Topological path

Map Generation

- ❖ map area can be considered as a 2D Cellular Automaton
- ❖ value at each CA cell represents the height of the ground
- ❖ set of measurements form the original state
- ❖ rules are responsible for generating the intermediate heights
- ❖ maintain an accurately reconstruction



incremental evolution

Conclusion

- ❖ variety of applications in robotics
- ❖ implemented in different media
 - ❖ software
 - ❖ hardware
- ❖ useful when
 - ❖ medium can be discretized
 - ❖ space is large
 - ❖ multiple local computations are need
- ❖ drawbacks
 - ❖ costly depending on the amount
 - ❖ limitations when used control physical robots
- ❖ all applications are easy scalable



Image Sources

- (1) scholarpedia.org/article/Cellular_neural_network
- (2) modular.tek.sdu.dk/index.php?page=robots
- (3) Georgilas, I., 2015. Cellular Automaton Manipulator Array. In Sirakoulis, G.C. & Adamatzky, A. eds., Robots and Lattice Automata. Springer
- (4) Athanasios Ch., 2015. Employing Cellular Automata for Shaping Accurate Morphology Maps Using Scattered Data from Robotics' Missions. In Sirakoulis, G.C. & Adamatzky, A. eds., Robots and Lattice Automata. Switzerland Springer
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- (7) giphy.com/gifs/processing-fractal-4cZspmcX3AvV6
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- (11) img07.deviantart.net/ccab/i/2012/345/5/7/walle_and_r2d2_by_ctomuta-d5nq97c.jpg
- (*) pictures were made by the author of the presentation

References

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- ❖ Marchese, F. M., 2015. Multi-Resolution Hierarchical Motion Planner for Multi-Robot Systems on Spatiotemporal Cellular Automata In Sirakoulis, G.C. & Adamatzky, A. eds., *Robots and Lattice Automata*. Switzerland Springer