Stochastic Cellular Automata Theory For Pedestrian Simulation

Case Studies - HS/2021

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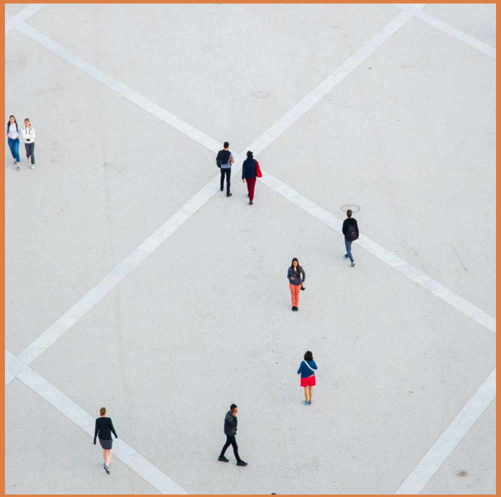
Motivation

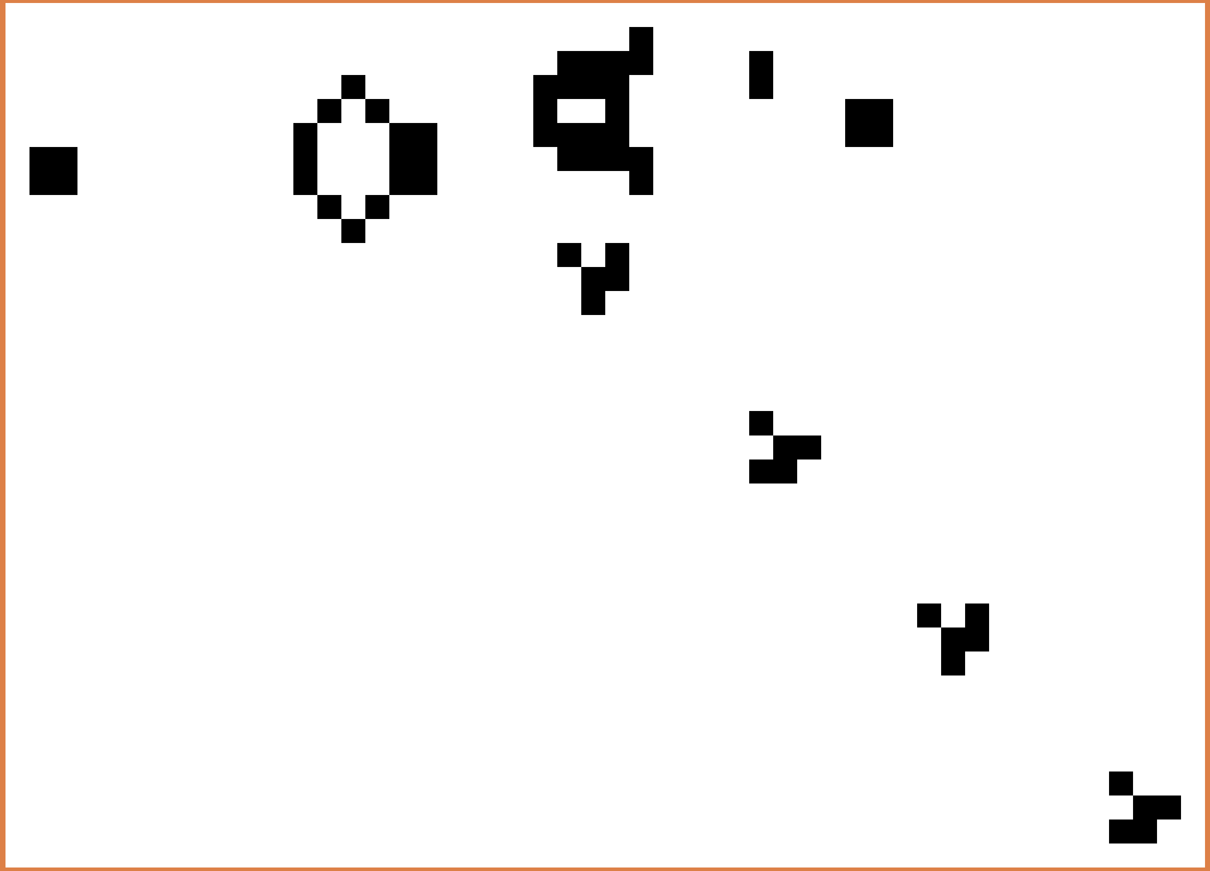
Courtesy- pexels.com

Motivation



Courtesy- pexels.com

Cellular Automata: What and why?



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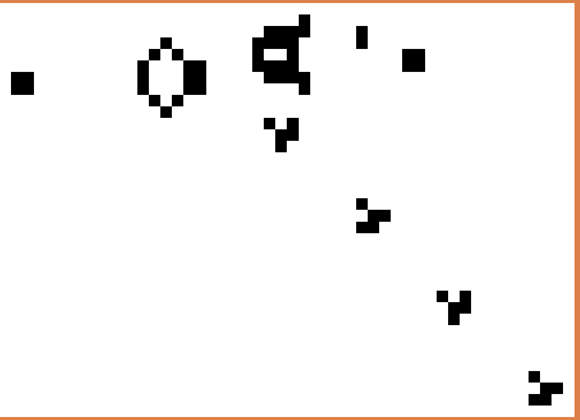

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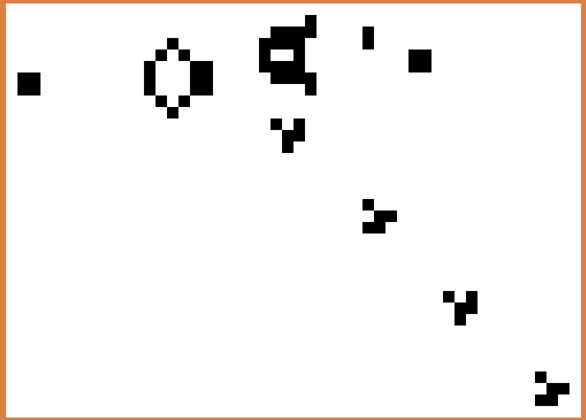

- Discrete State
- Evolution based on local rules
- Easy to implement deterministic and stochastic rules
- Lacks long-range interactions

CA vs DE

- Discrete State
- Evolution based on local rules
- Easy to implement deterministic and stochastic rules
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- Continuous models
- Evolution based on non-linear governing equations
- Adding stochastic elements is difficult
- Use of fields to model long-range forces

Model - Neighborhood

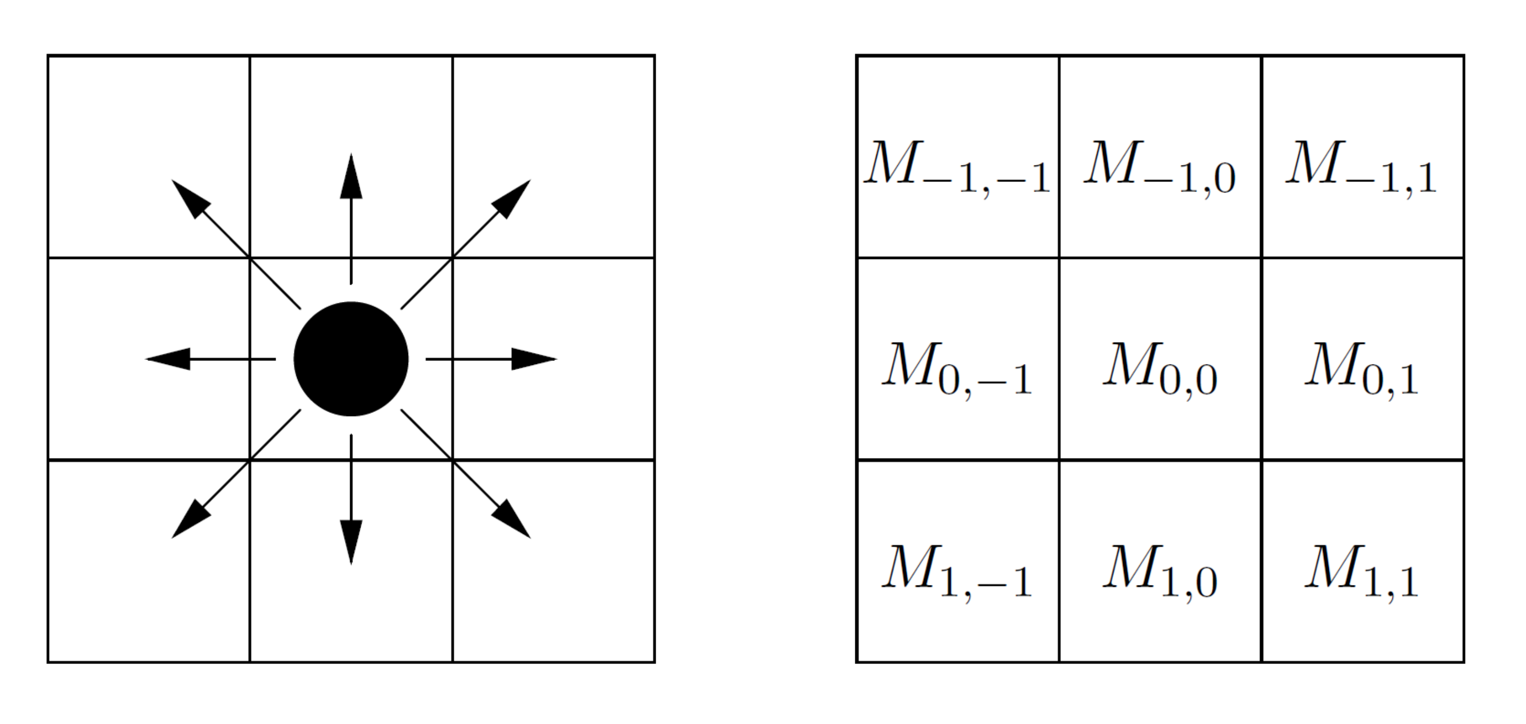


Figure: Pedestrian, their neighborhood and associated matrix of preferred direction (M_{ij}).

Model – Update Rule

Transition Probability (P_{ij})			
Local Interactions		Floor Field	
Preference Matrix (M_{ij})	Occupancy of neighbors (n_{ij})	Static Source (S_{ij})	Dynamic Source (D_{ij})
Initialized**	Depends on the current state	Initialized (according to the geometry of the problem)	Derived from the history of the state

$$p_{ij} = N M_{ij} D_{ij} S_{ij} (1 - n_{ij}).$$

Occupancy Matrix

- Encoding presence of other pedestrians in the neighborhood to avoid collisions

Static Floor Field

- Encoding the presence of either attractive or repulsive elements in the geometry (e.g.: emergency exits)

Dynamic Floor Field

- Encoding temporal history of pedestrian movement into spatial variations
- Coupled with the state of the system

Presence of pedestrians in previous state (ΔD) + Diffusion to neighboring cells (d) + Decay over time (δ) = Dynamic Floor Field ($d \cdot \Delta D + \delta . D$)

Final Update Algorithm

Step #0: Initialize state and static field

Step #1: Determine the dynamic field

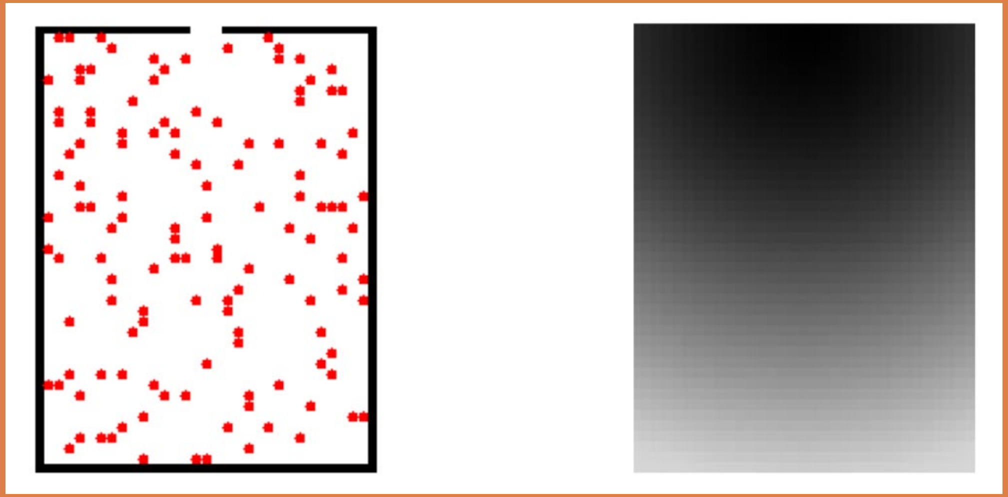
Step #2: Update positions

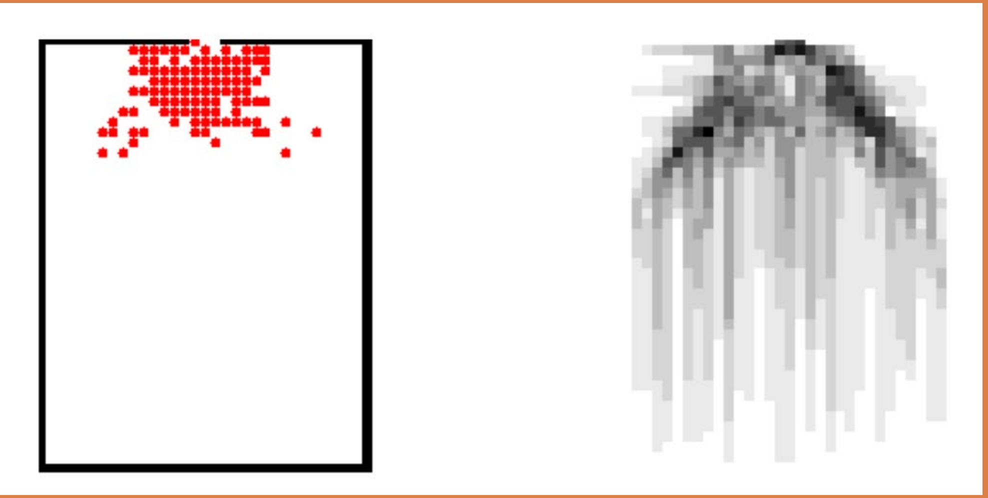
Repeat #1 & #2 for evolution

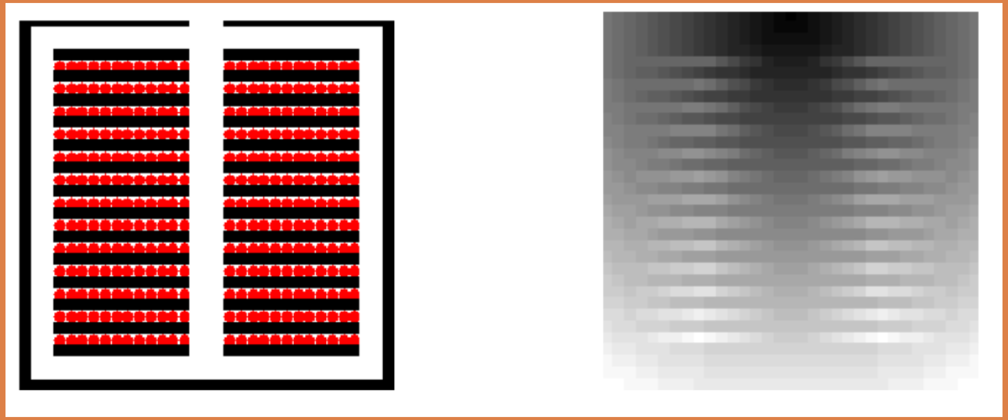
What did they achieve?

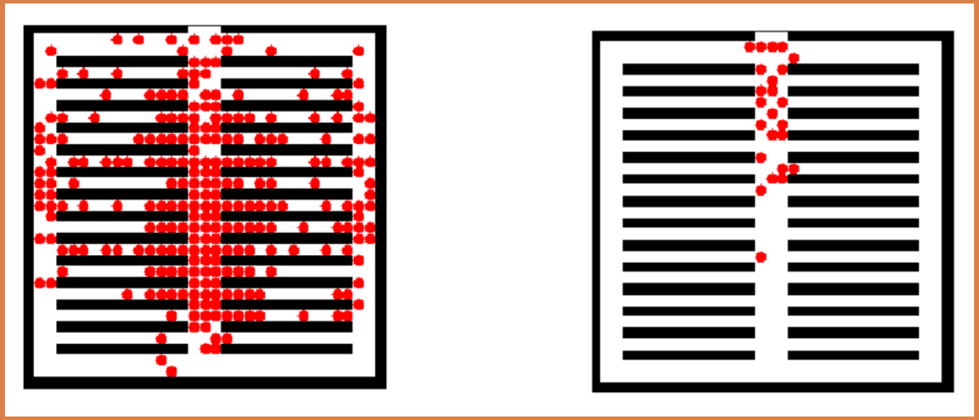
- Highly parallelizable → faster than real-time simulation
- Model (~)independent from the complexity of behaviour
- Use of Monte Carlo simulations for statistical description of problems
- Accurate representation of realistic behaviour

Some results









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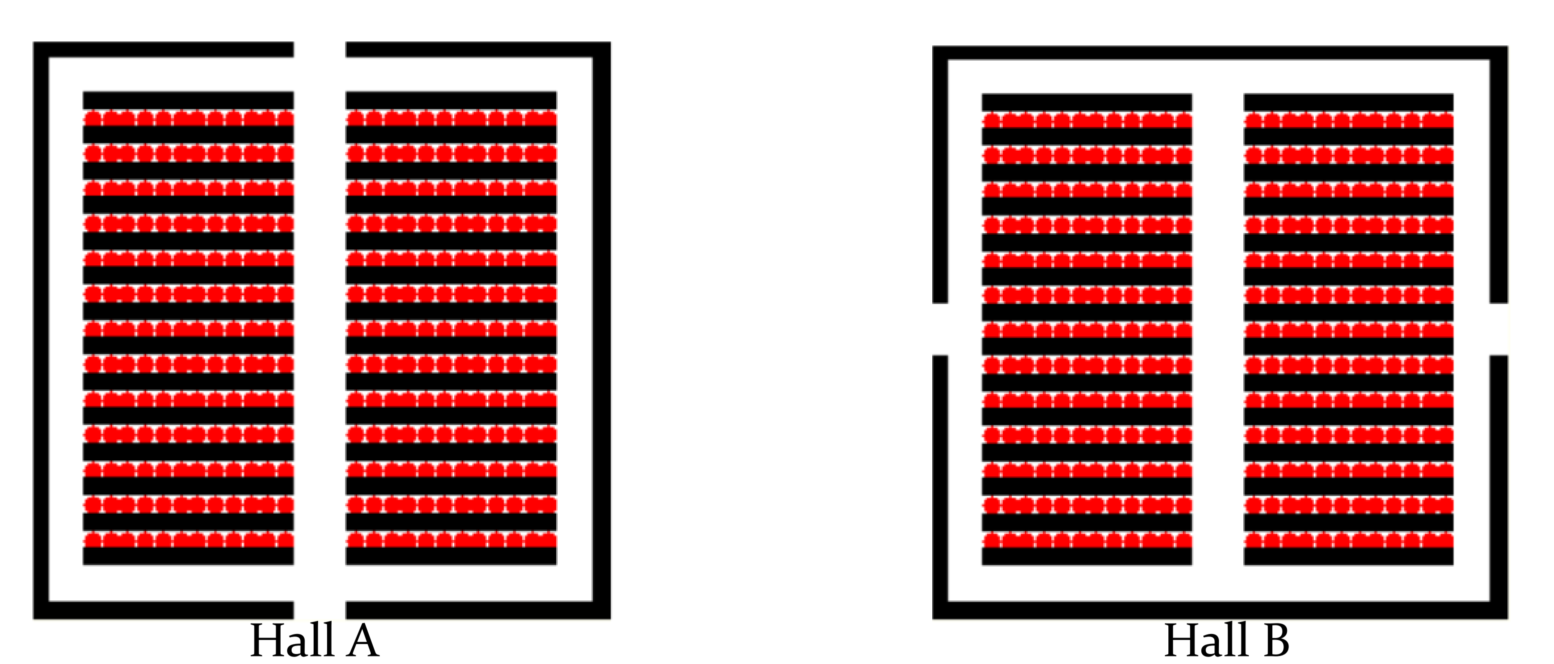

Units- Update steps	Hall A	Hall B
Mean Time to Evacuate	560	363
Variance	85	24

Thank you

Interested in further reading??

Check these out!

- Lenia
  - Lenia – Mathematical Life Forms
  - Lenia – Biology of Artificial Life
- Wolfram Physics Project
  - Introductory Blog
  - Project Website