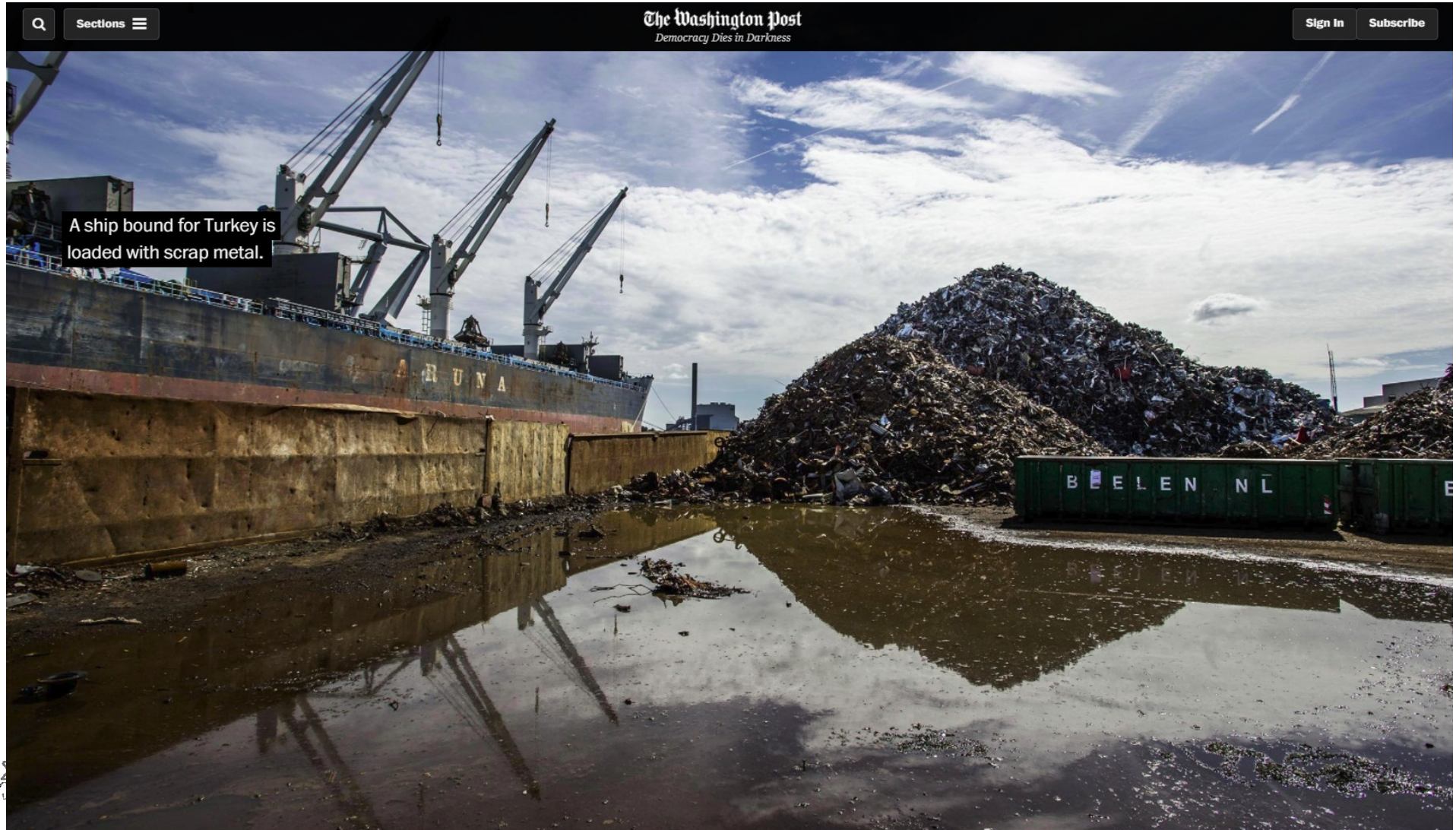
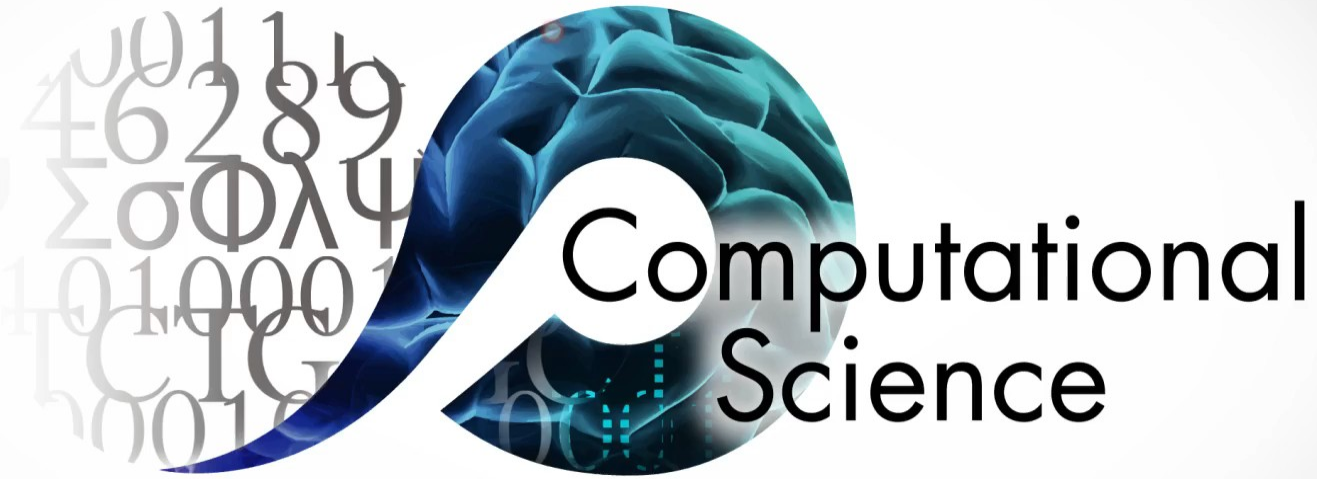
Drowning in garbage

https://www.washingtonpost.com/graphics/2017/world/global-waste

The Dutch throw away more than 400 thousand breads per day



Introduction
Computational Science



Introduction Computational Science

by Lera (Valeria) Krzhizhanovskaya

V.Krzhizhanovskaya@uva.nl

L5. 2D CA-based models. Traffic flow 1D model.

Computational Science

L1. Intro Computational Sci (recap)

- **The 3rd pillar of science**
  - Experiment
  - Theory
  - Modelling & simulation
- **Why model? and what?**
- **System, experiment, model, simulation**
  - Only an idiot uses simulation in place of <.?.>
  - Don't fall in love with your model! Danger!
- **Validation, verification**
- **Types of models**

L2. Cellular Automata. 1D (recap)

- **What is CA? Why study? Applications?**
- **Range *r*, Neighbourhood *N=2r+1*, *k* States Σ,**
- **Input alphabet α, Size $m=k^N$**
- **k^m Transition functions Δ (a.k.a. Rules)**
- **Rule numbering by "Wolfram code"**

Rule 30: $30 = 00011110_2$

111	110	101	100	011	010	001	000
0	0	0	1	1	1	1	0

- **Wolfram classes**

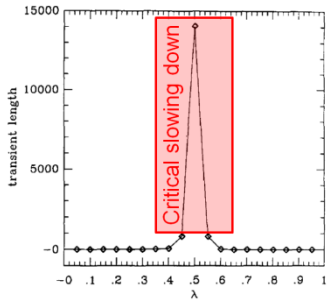
1 homogeneous, 2 stable pattern, 3 chaos, 4 complex

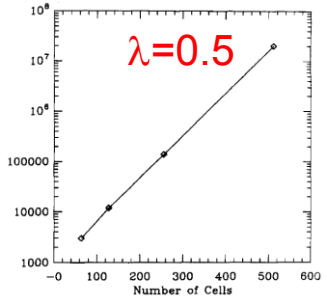
- **Transients and cycles** 001 → 011 → 101 → 110 → 011 → 101 →…

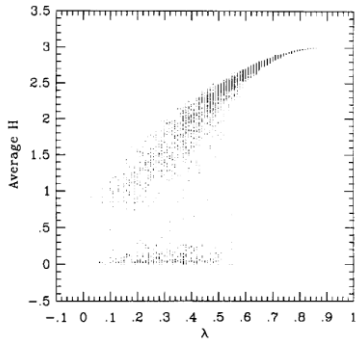
L3. CA quantify complexity (recap)

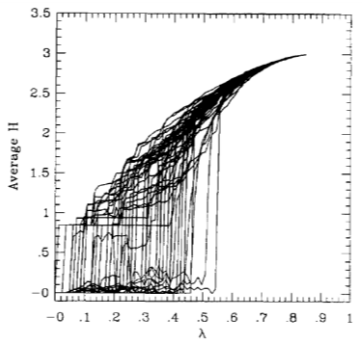
- **Langton parameter** $\lambda(\Delta) = \frac{k^N - n}{k^N}$
  - Limits: λ=0, λ=1, λ = 1-(1/k) equally represented
  - 2 sampling methods: random & walk-through
  - Where is the complexity observed?
- **Complexity measures**
  - Transient length
    - Critical slowing down
  - Shannon entropy

$$H(X) = -\sum_{x \in X} p(x) \log_2 p(x)$$



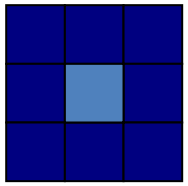




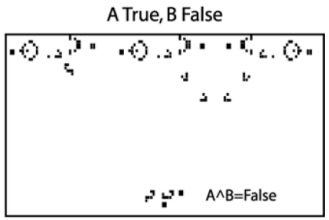


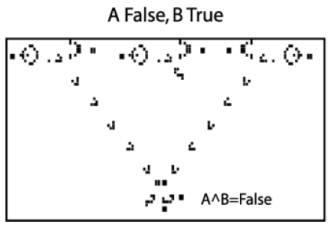
L4. 2D CA, GoL, Gates (recap)

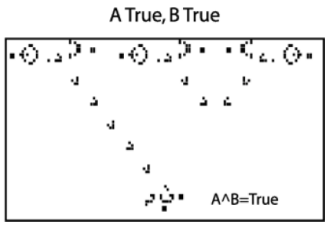
- **2D neighbourhoods:**
  - von Neuman, Moore, hexagon



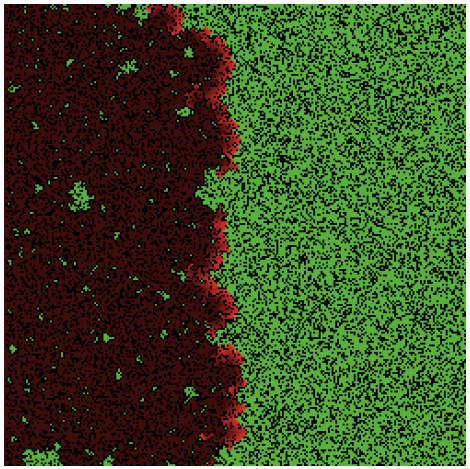
- **Game of Life**
  - Why is it interesting?
  - Rules, Patterns (3 classes) with examples
  - GoL = Universal Computer

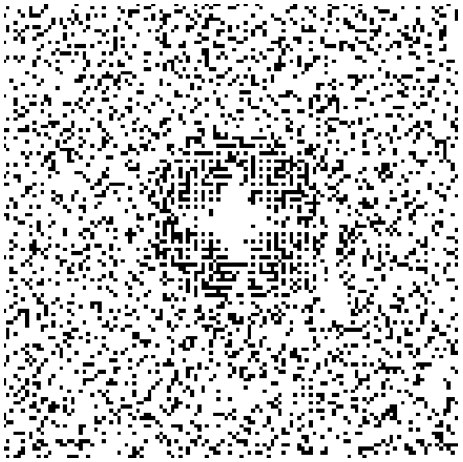


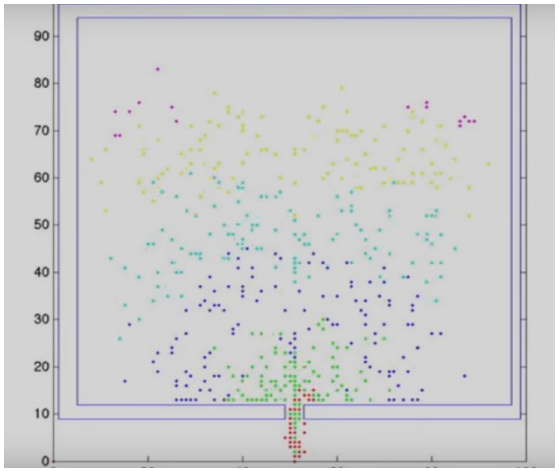




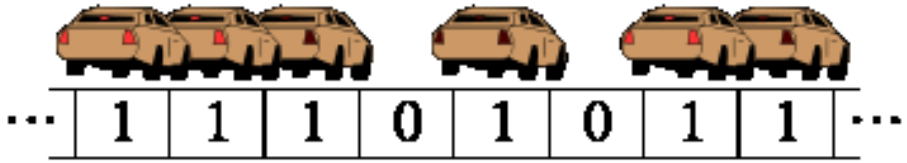
- **Boolean Functions, Logic gates** NOT, AND, OR ↔ NAND

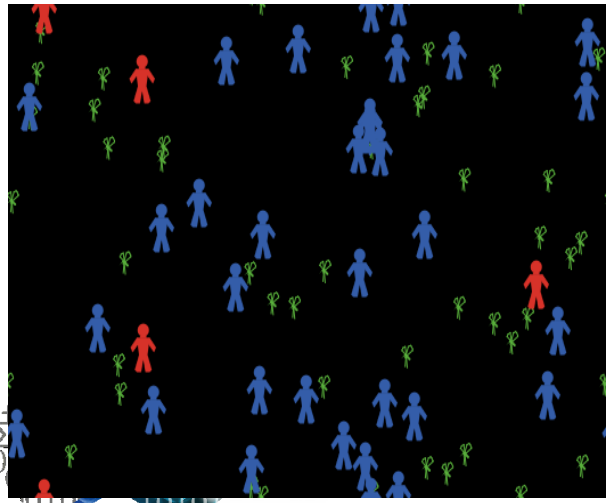


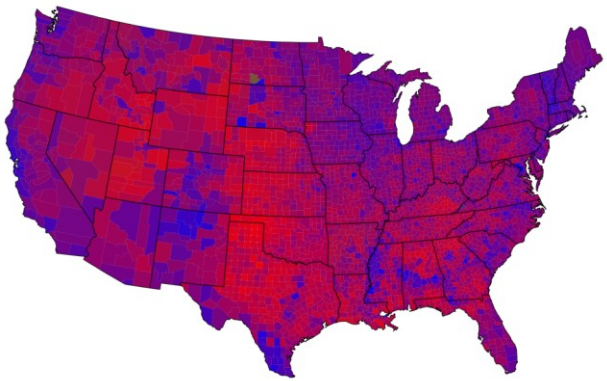


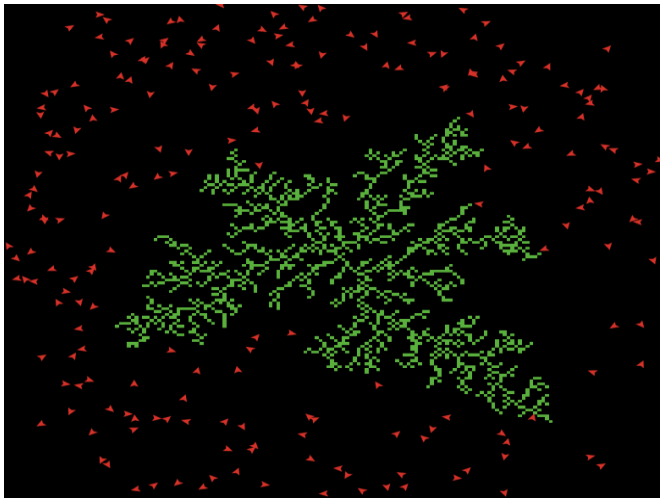


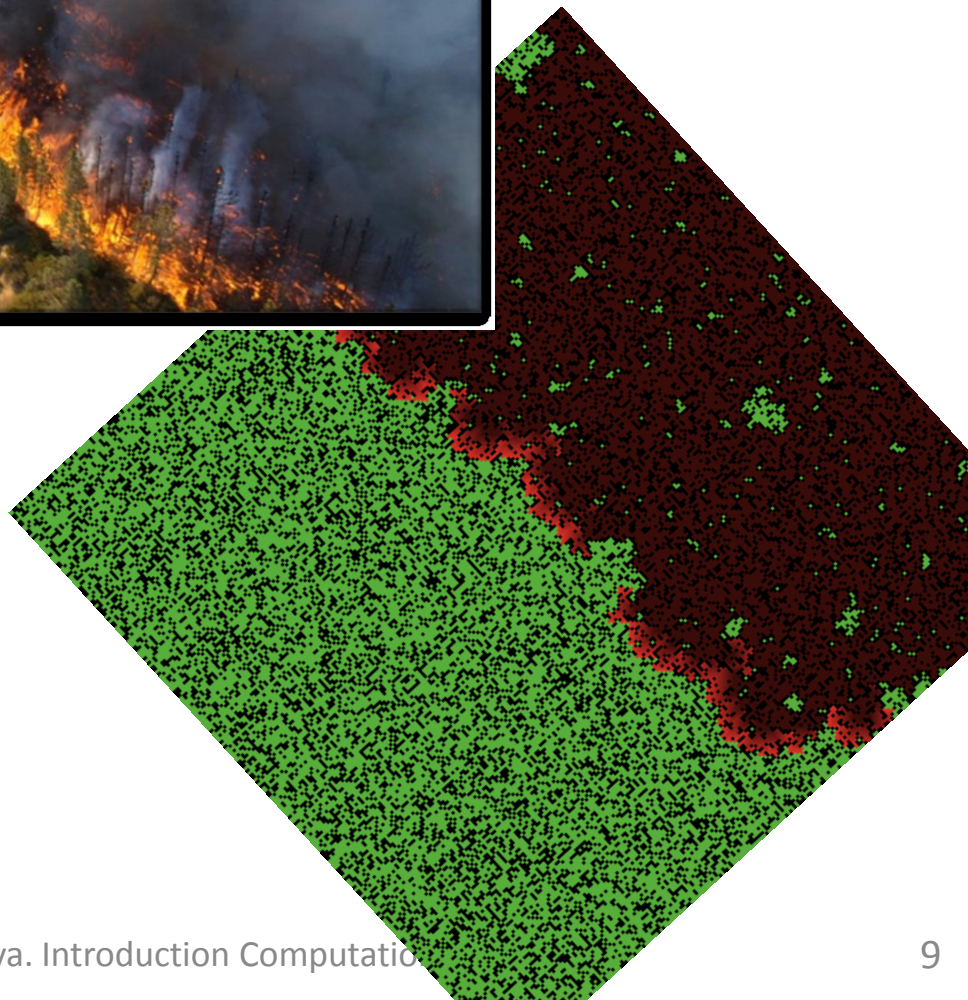
2D CA-based models and mean-field approximation











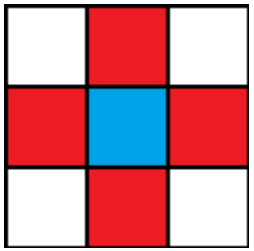
FOREST FIRE

Computational Science

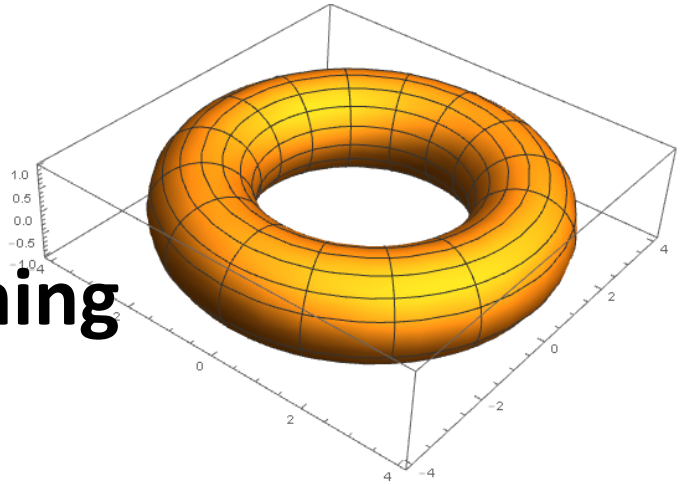
Forest fire: why model?

- **Questions:**
  - How will a fire spread?
  - How best to tackle fire?
    - targeted felling
    - fire fighting strategy
  - Is a forest at risk of complete destruction?
  - Early warning systems

Forest fire CA-based model



- **2D, NxN grid**
- **Von Neumann neighbourhood**
- **4 states:**
  barren (empty), tree, burning, burnt down

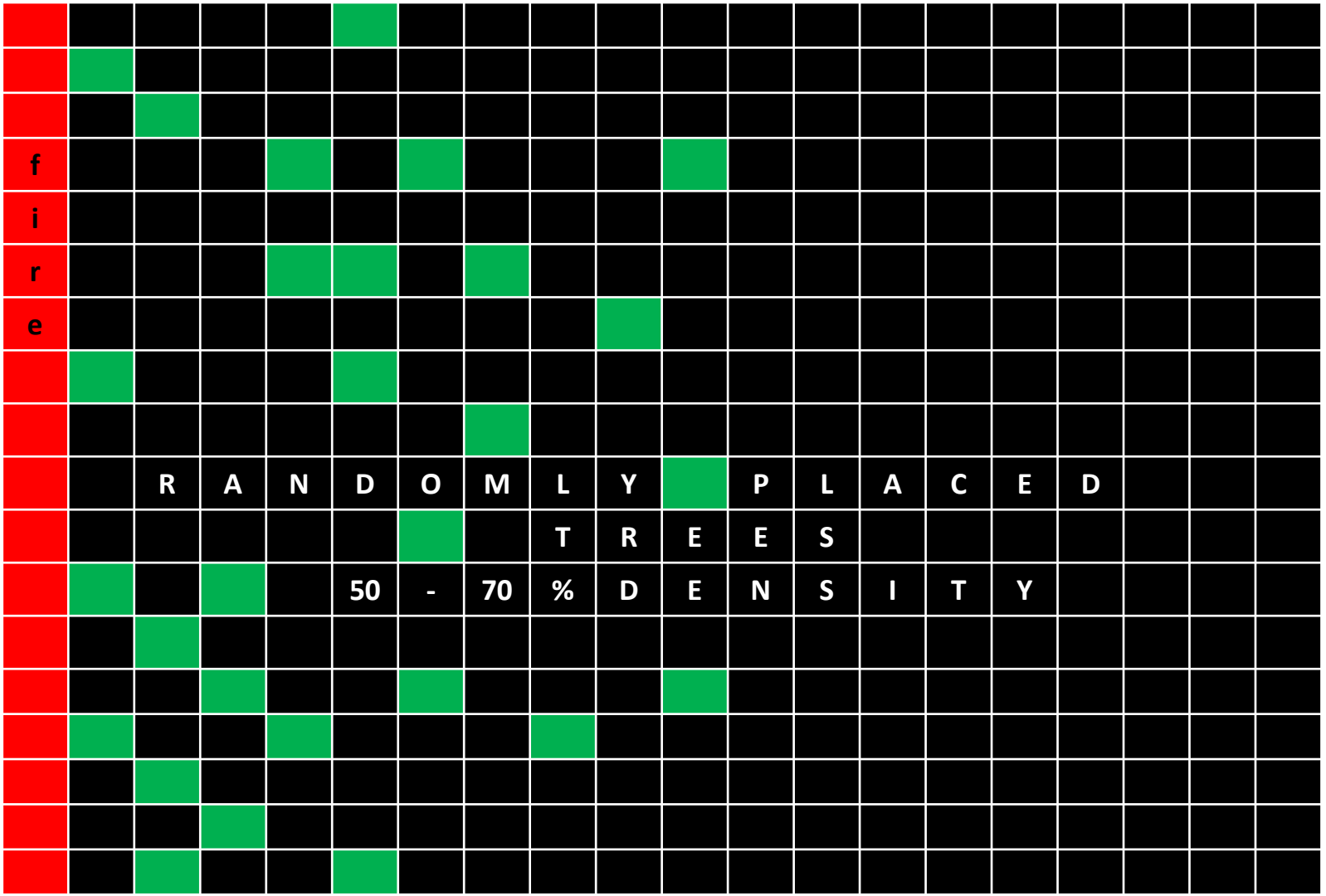


- **Periodic boundaries (torus)**
- **Tree ignites if neighbour is burning**
- **Fire lasts one time step**
  - Variations: variable fire intensity with “fading”, stochastic models

Computational Science

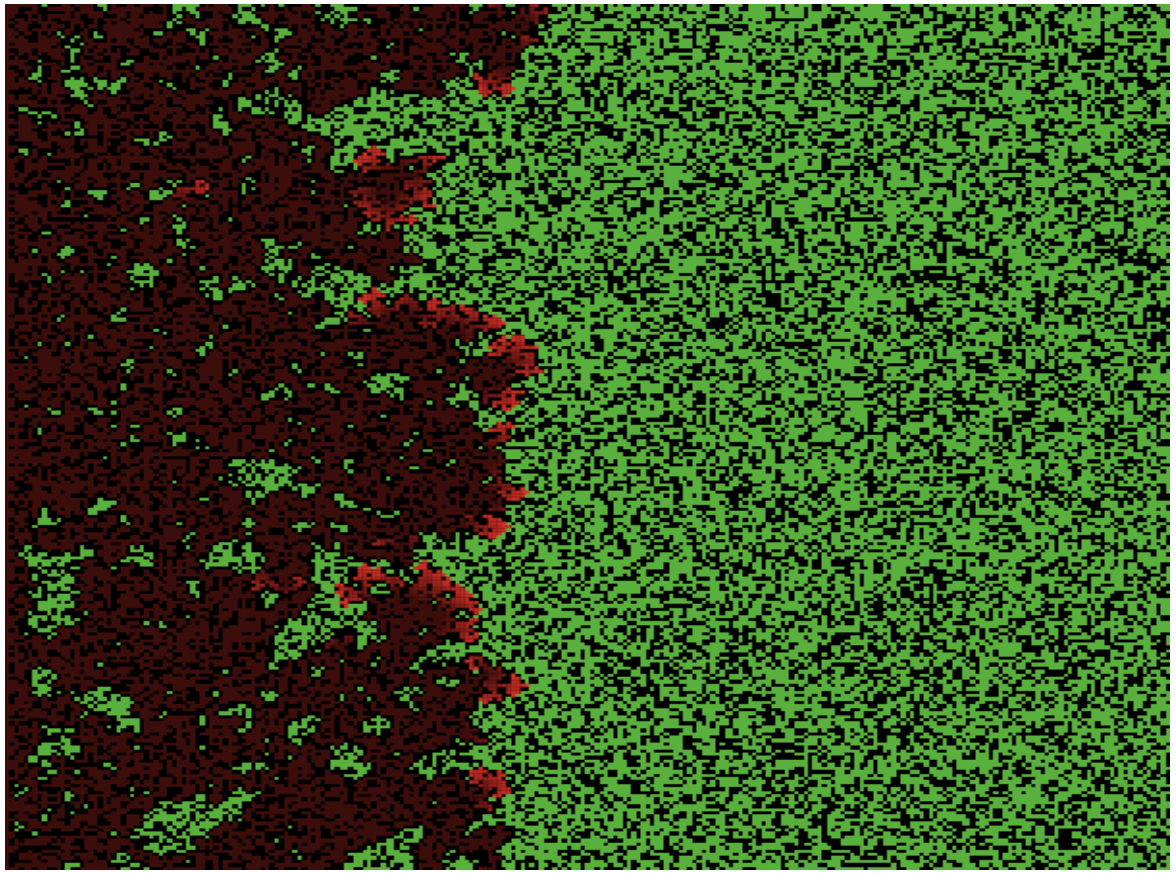
Rodolfo Maduro Almeida and Elbert E N Macau 2011 *J. Phys.: Conf. Ser.* **285** 012038 doi:10.1088/1742-6596/285/1/012038

Forest fire area

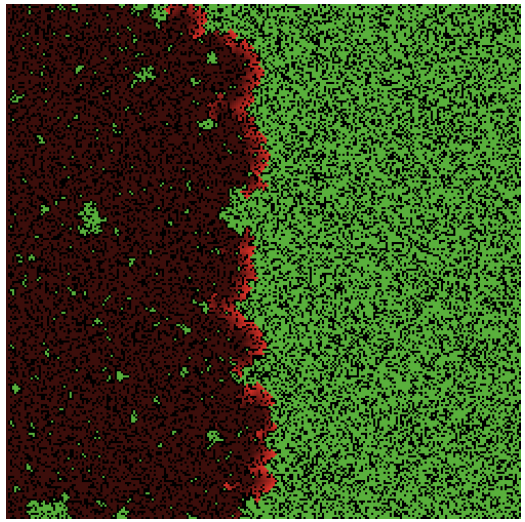


Details

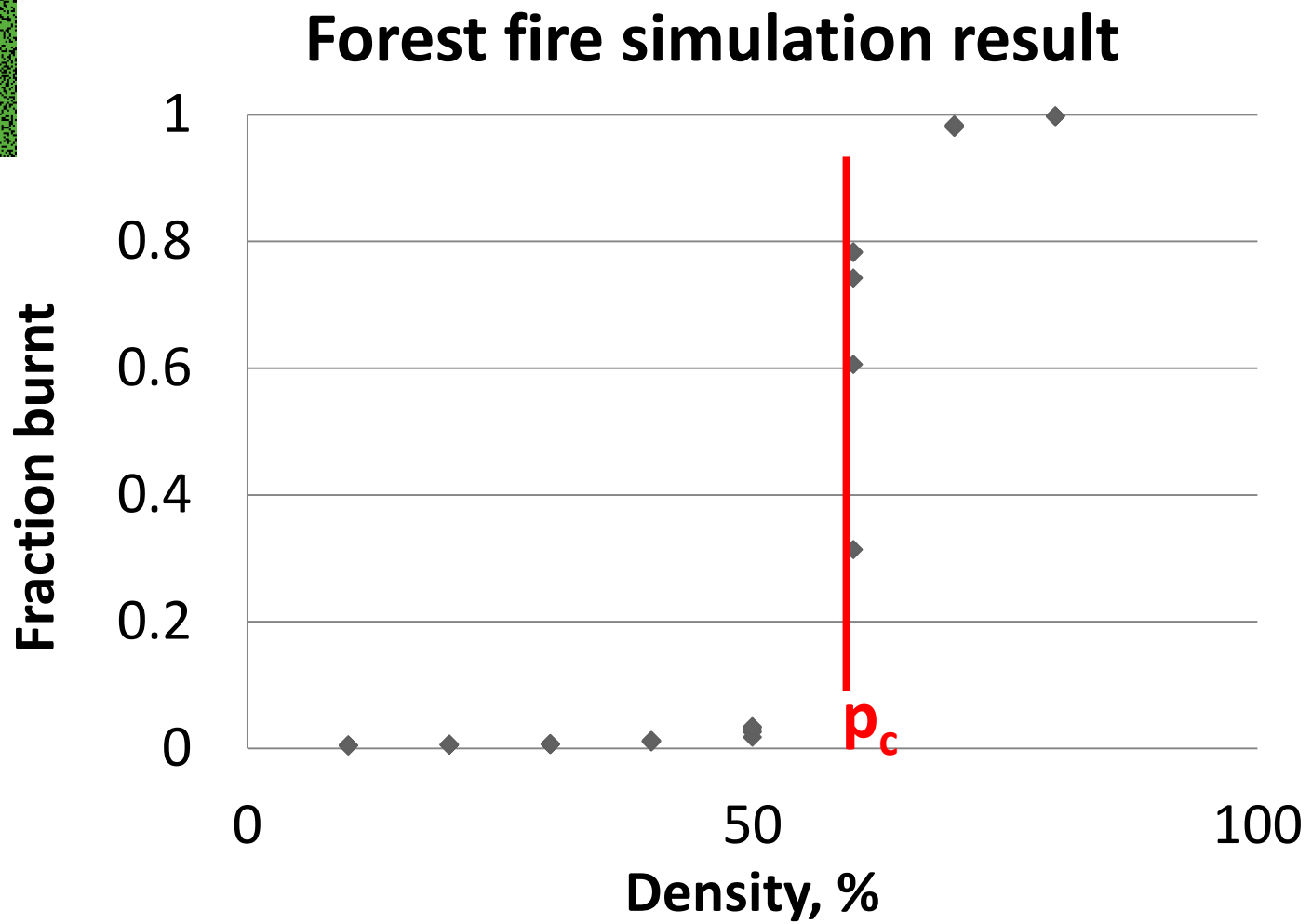
- Simulation on 250x250 grid
- Simulation tracks only burning cells (the others do not change anyway)

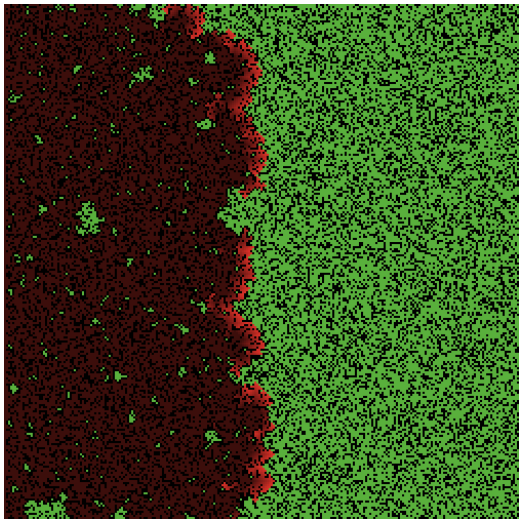


Computational Science

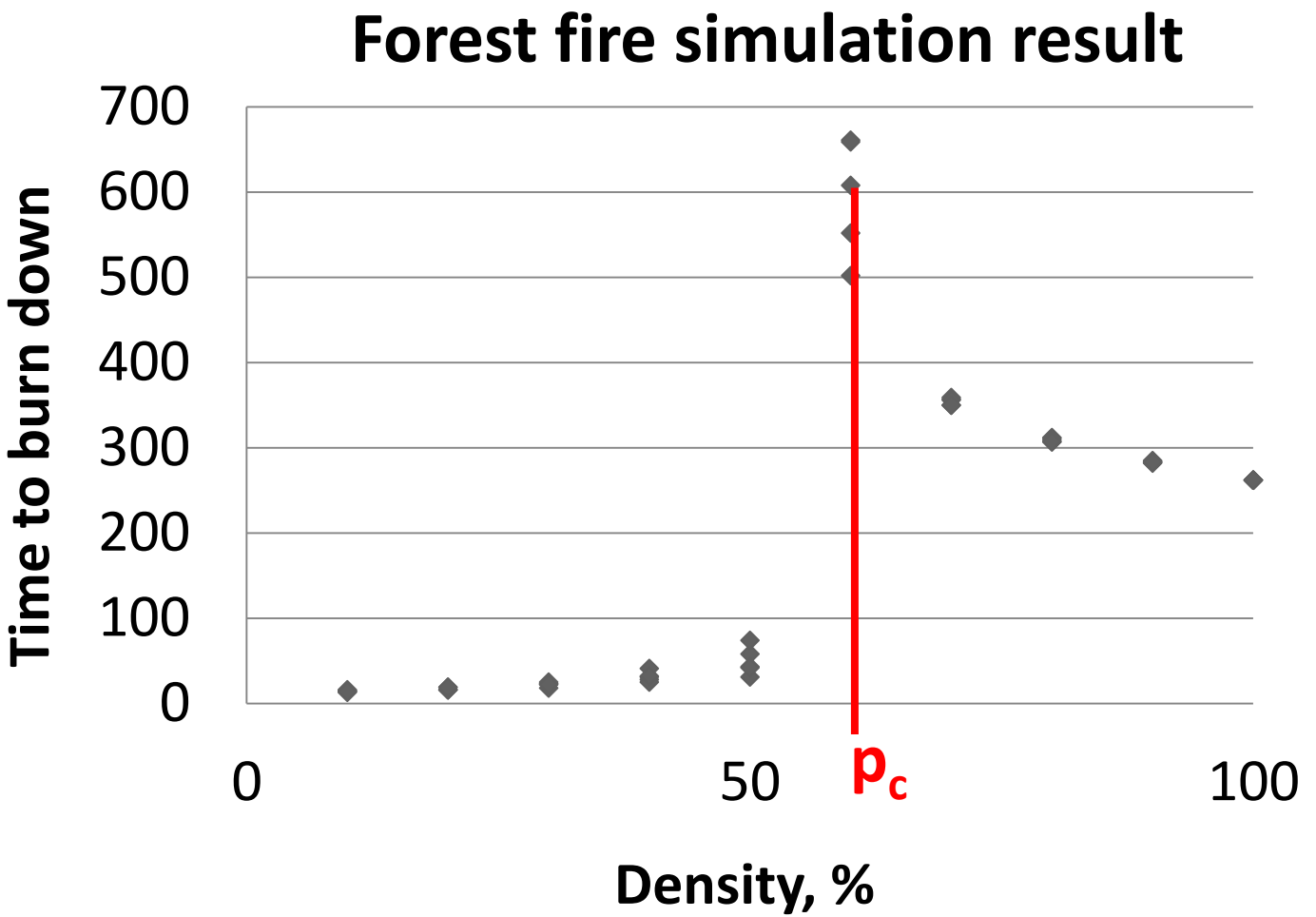


NetLogo - try


Forest fire simulation result
Fraction burnt
1
0.8
0.6
0.4
0.2
0
0
50
100
Density, %
p_c

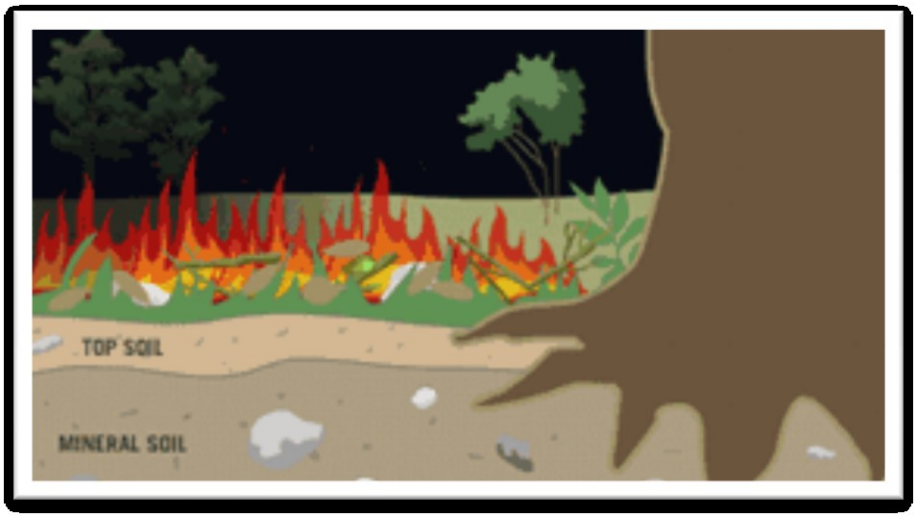


NetLogo - try


Forest fire simulation result
Time to burn down
700
600
500
400
300
200
100
0
0
50
p_c
100
Density, %

Forest Ecology

- **Many ecosystems, particularly prairie, savanna, chaparral and conifer forests, have evolved with fire as a necessary contributor to habitat vitality and renewal.**



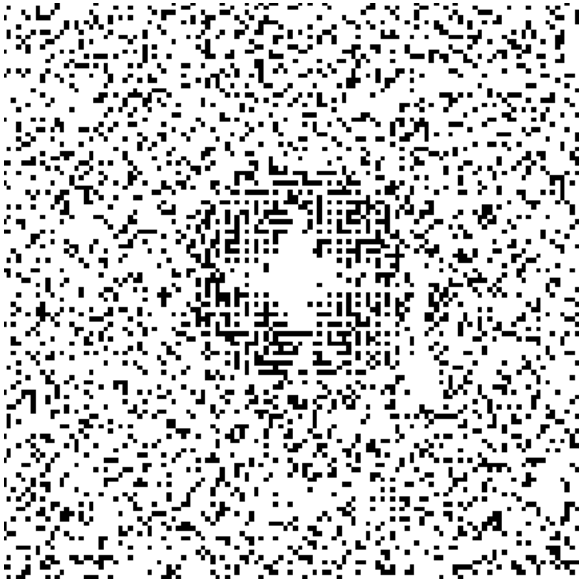
https://www.nps.gov/fire/wildland-fire/learning-center/fire-in-depth/ecology.cfm

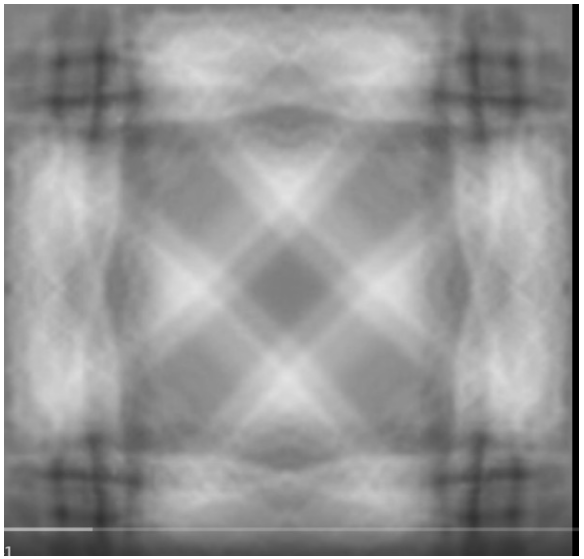
Fire ecology advanced model

http://ccl.northwestern.edu/netlogo/models/community/Fire%20Ecology

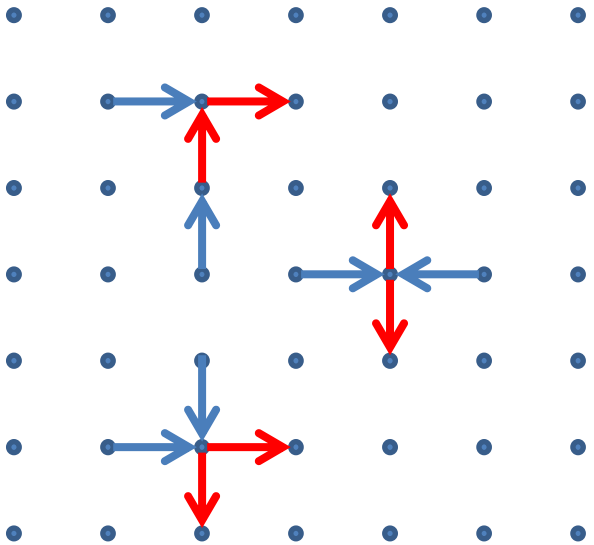
- The model calculates the number of lightning strikes occurring on dry days, based on the length of the fire season, the number of days it rains, the time it takes for the landscape to dry after a rain, and the number of lightning strikes per season.
- Each lightning strike occurring on a dry day then has a certain probability of igniting a fire, which is based on the age of the patch of forest struck, and the flamability (Fm) of the forest type. Ignited fires spread from patch to patch based on the same parameters.
- As in a real forest, a patch can't burn for a certain amount of time after it's burned already (set by variable Lag). In addition, forests become more flammable as they age, modeled by the Mature_Age variable; the longer it takes to reach Mature_Age, the slower the flammability of the forest increases.
- Finally, the model includes an approximation of (human) fire suppression effort. The higher the value of the Suppression variable, the more burning pixels will be targeted for suppression (whether suppression is successful is random). As a result of this design, even a small amount of suppression will likely be effective as long as there are only a few burning pixels. If a fire chances to get rather large, however, the suppression effort quickly becomes ineffective.

LATTICE GAS





Lattice gas

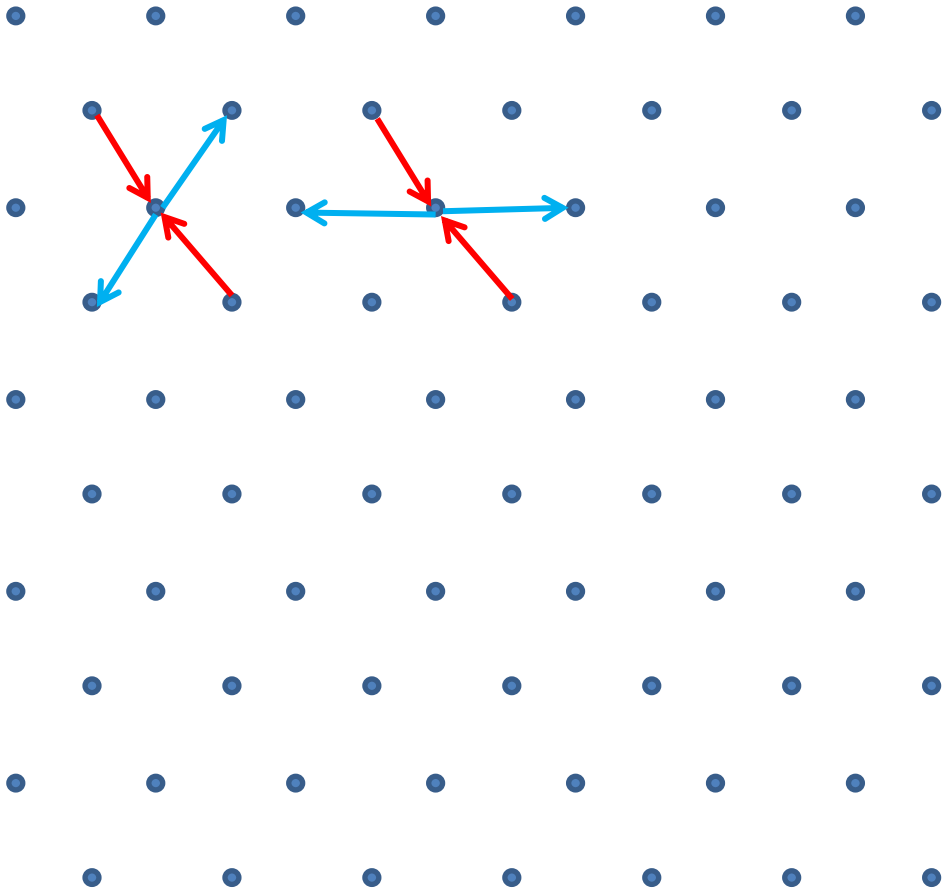


- **States: particle + velocity**
- **Steps:**
  1. propagation (along the links)
  2. collision
- **Conditions:**
  - Only 1 particle moves along 1 link in 1 direction
  - Mass and momentum conservation
- **Fair simulation of gas (➔Navier-Stokes eqs)**
- **Developed into "Lattice Boltzmann"**
- **Disadvantages: noisy, anisotropic**

Lattice gas Netlogo

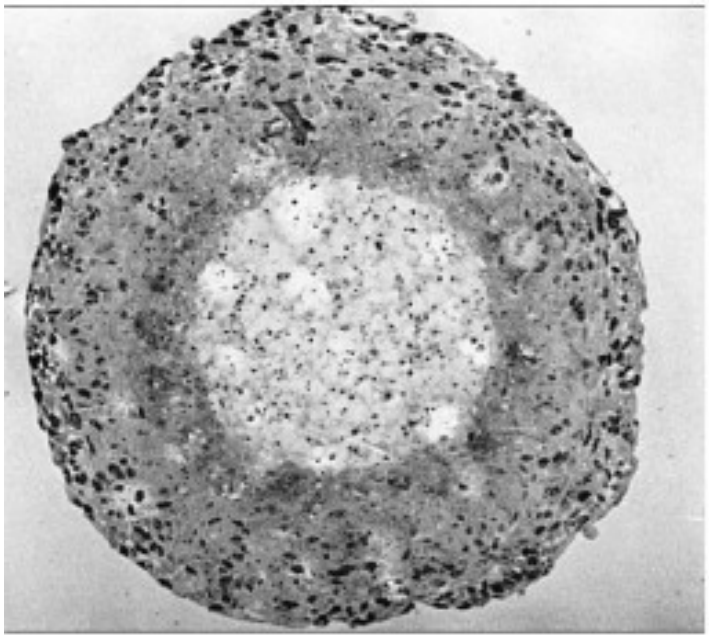
On a hexagonal grid

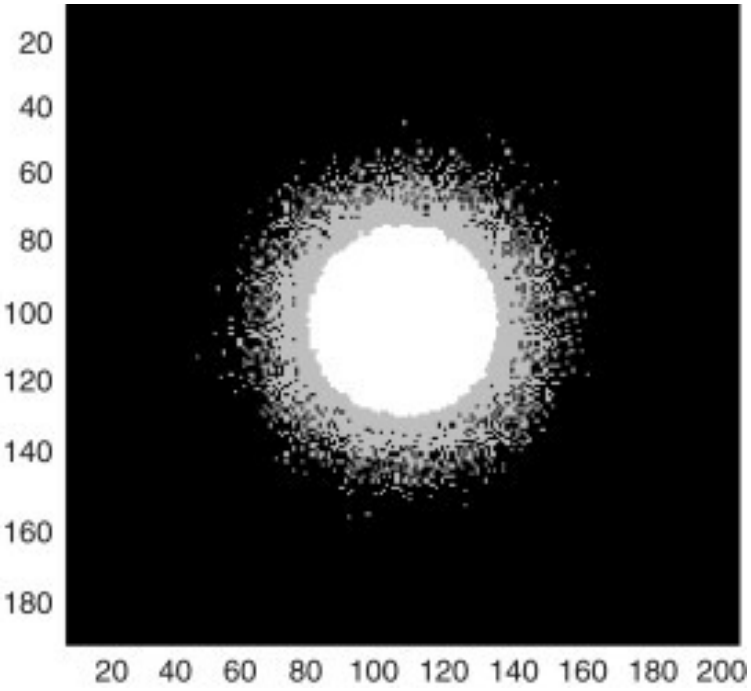
- **Better isotropy**
- **Random choice must be made for head-on collisions**
- **Multi-particle collisions**



OTHER GRID-BASED MODELS

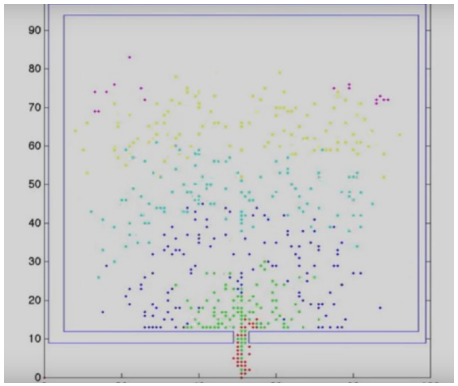
Cancer growth model



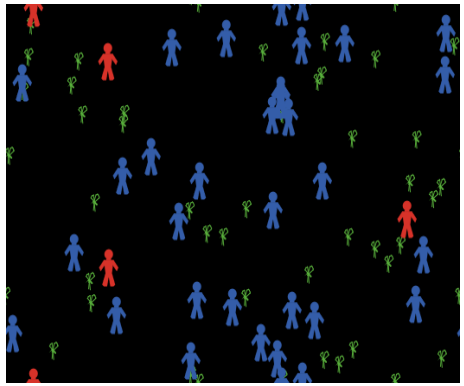


Other examples

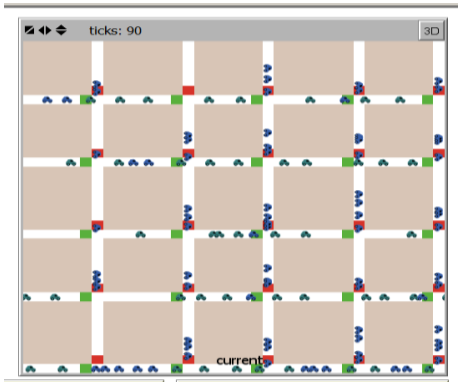
- Crowd evacuation



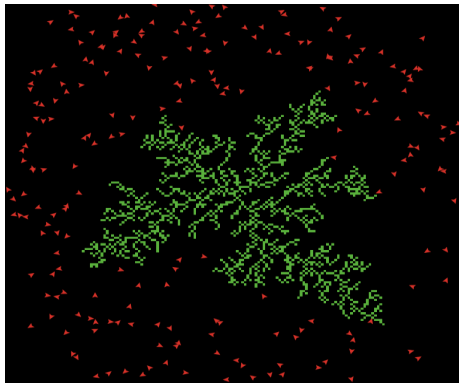
- Malaria spread



- Traffic in a city



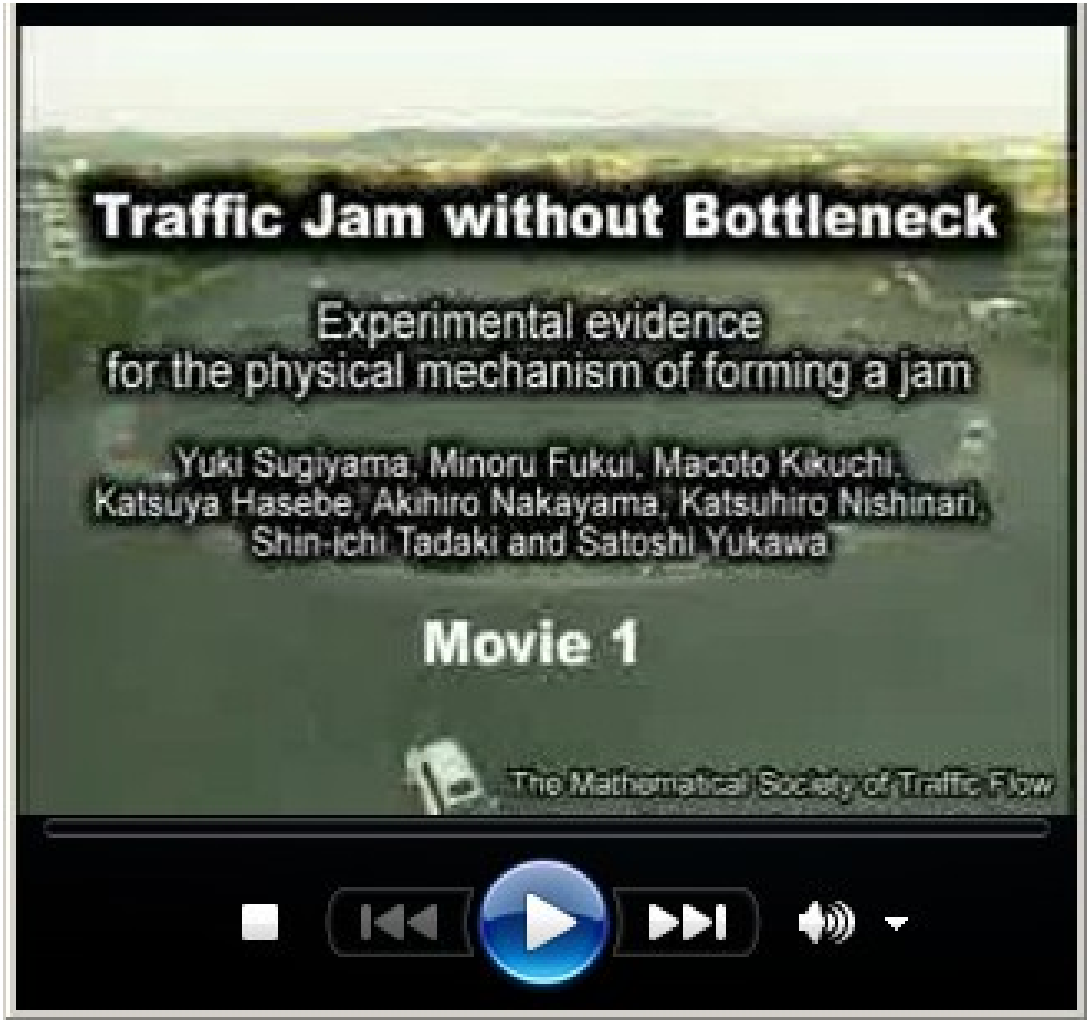
- Diffusion limited aggregation



Assignment CA4

TRAFFIC FLOW

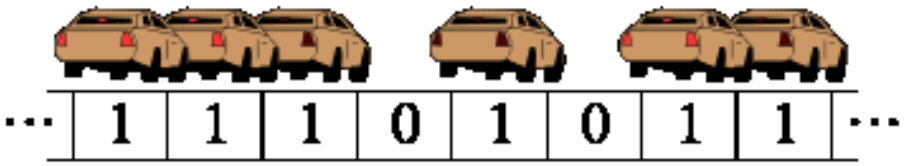
Problem: traffic jams



https://www.youtube.com/watch?v=7wm-pZp_mi0

Traffic 1D CA model

- **Rule 184 simulates traffic flow**
- **Each cell = a car**
- **Cars move forward only if there is open space in front of it**

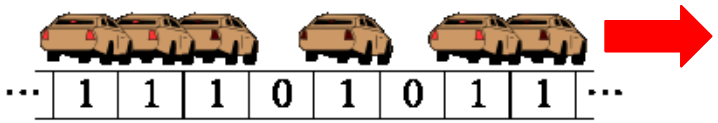


- **Simple rule ➔ realistic complex features:**
  - (1) clusters of freely moving cars separated by stretches of open road when traffic is sparse;
  - (2) waves of stop-and-go traffic when traffic is dense.

Rule 184

current pattern	111	110	101	100	011	010	001	000
new state	1	0	1	1	1	0	0	0

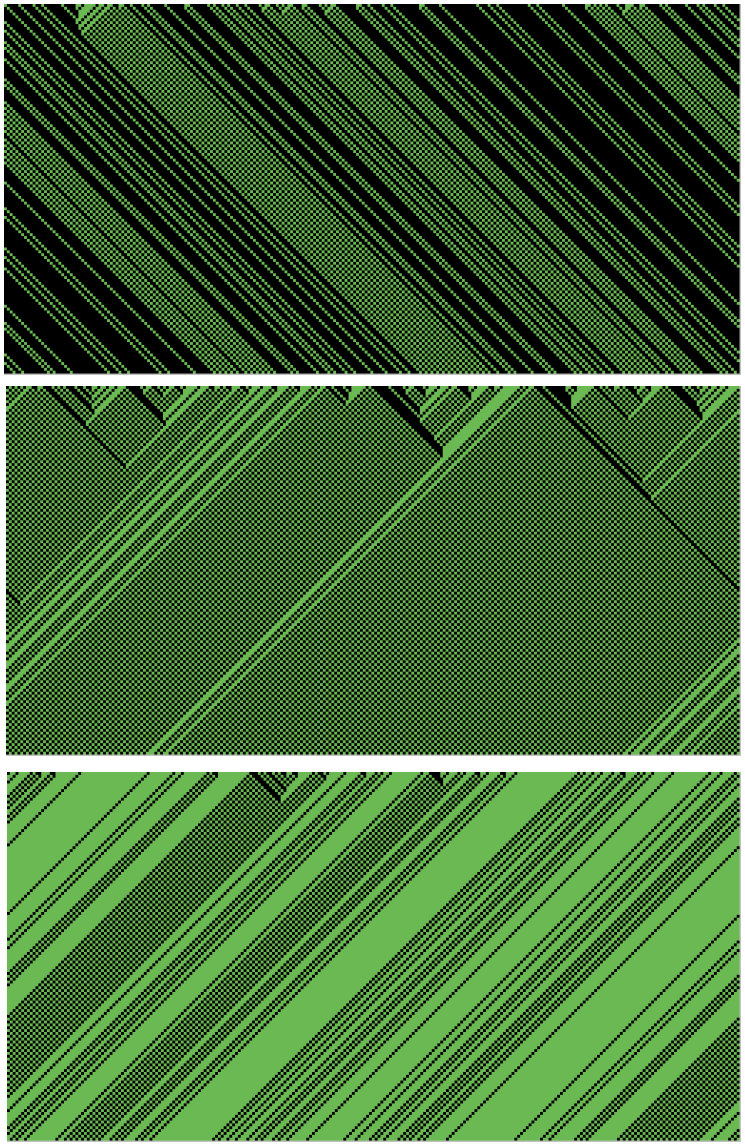
- **At each time step:**



  - if a cell with value 1 has a cell with value 0 to the right then 1 moves rightwards, leaving a 0 behind
  - 1 with another 1 to its right remains in place
  - 0 that does not have a 1 to its left stays a 0

Traffic flow phases

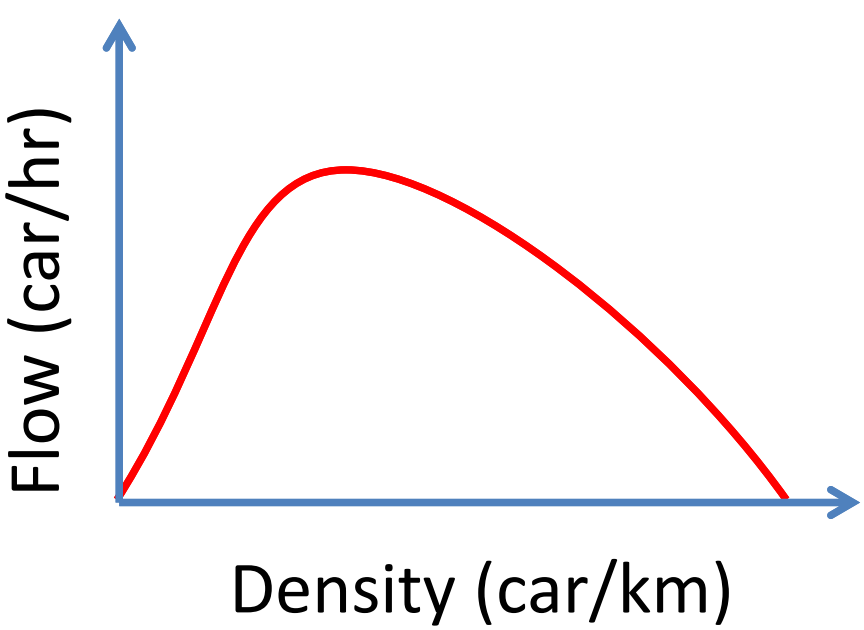
- **25% density: free flow**
  - Clusters of 100 move right
- **50% density: critical phase**
  - Clusters of 0101 move leftwards/rightwards
- **75%: jammed phase**
  - Clusters of 011 move left

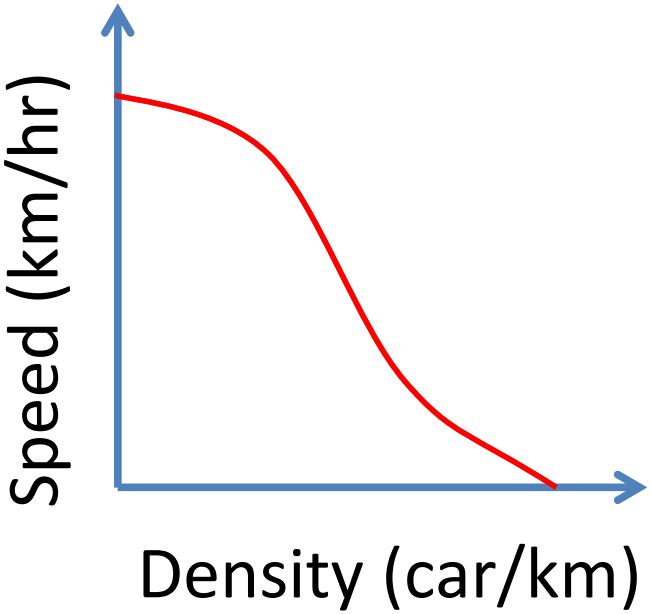


Read also: Nagel–Schreckenberg model

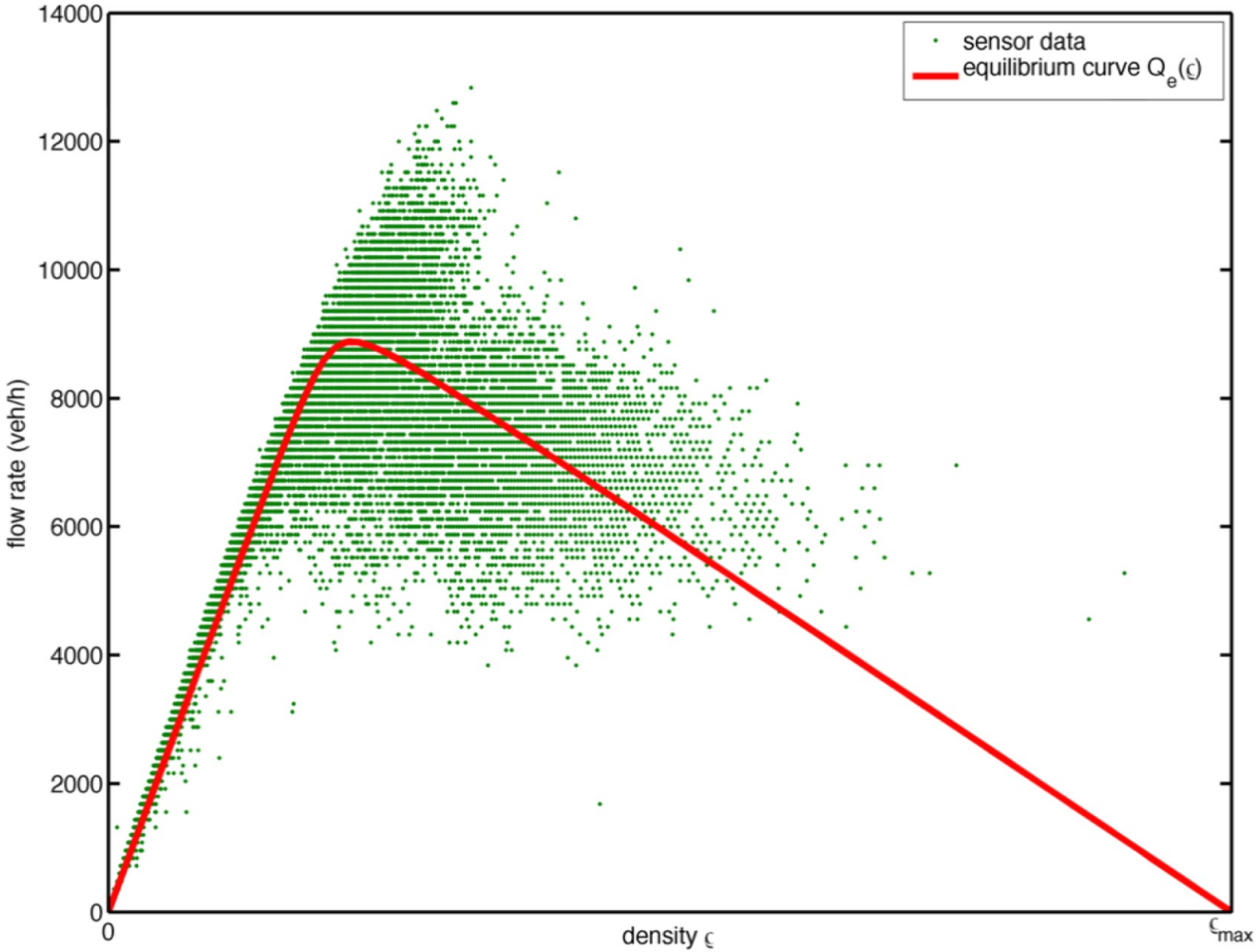
Traffic Validation

- ***The fundamental diagram of traffic flow:*** **relation between traffic flux and traffic density**



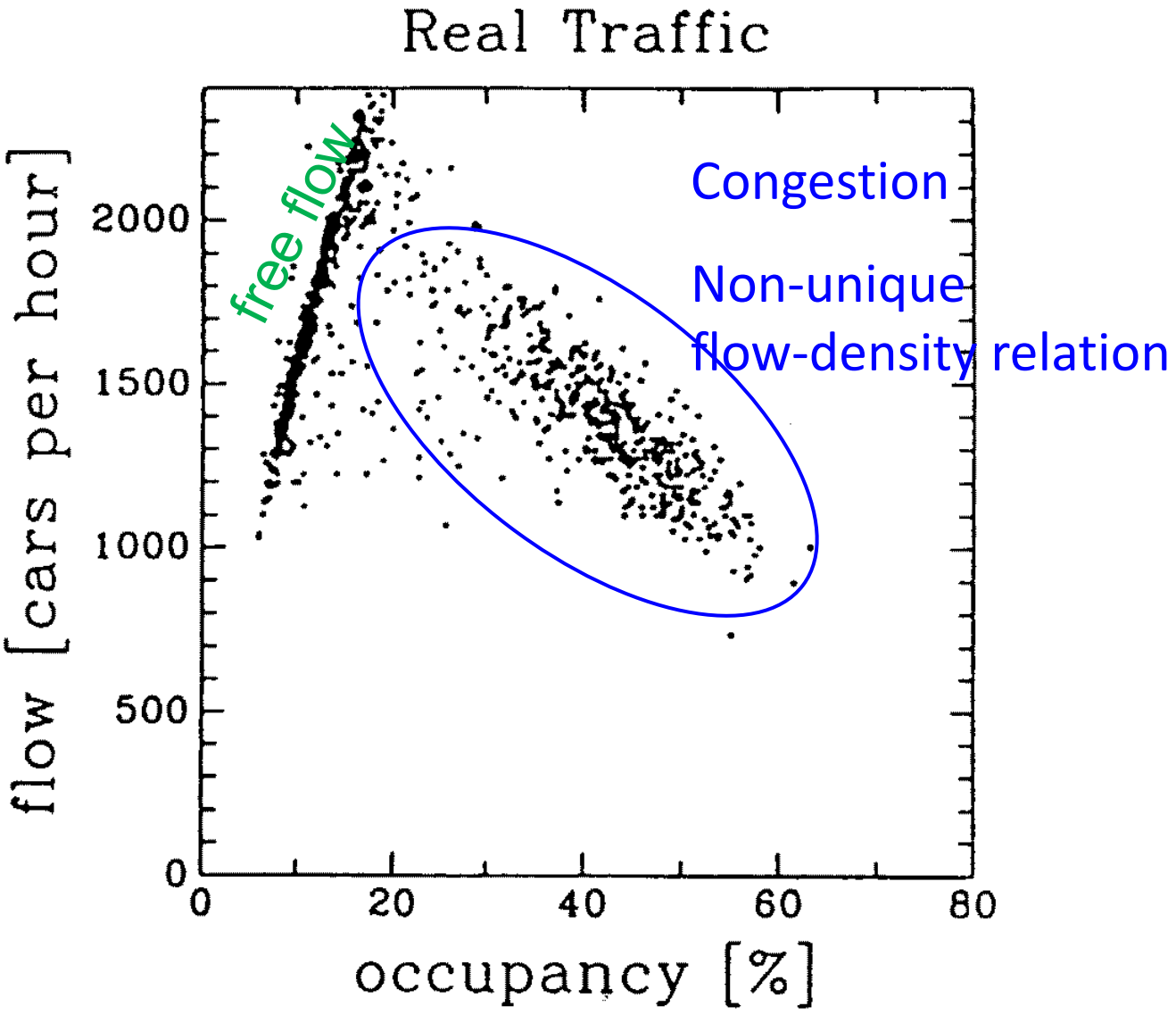


Validation



https://math.temple.edu/~tub00072/traffic_flow.html

FD features

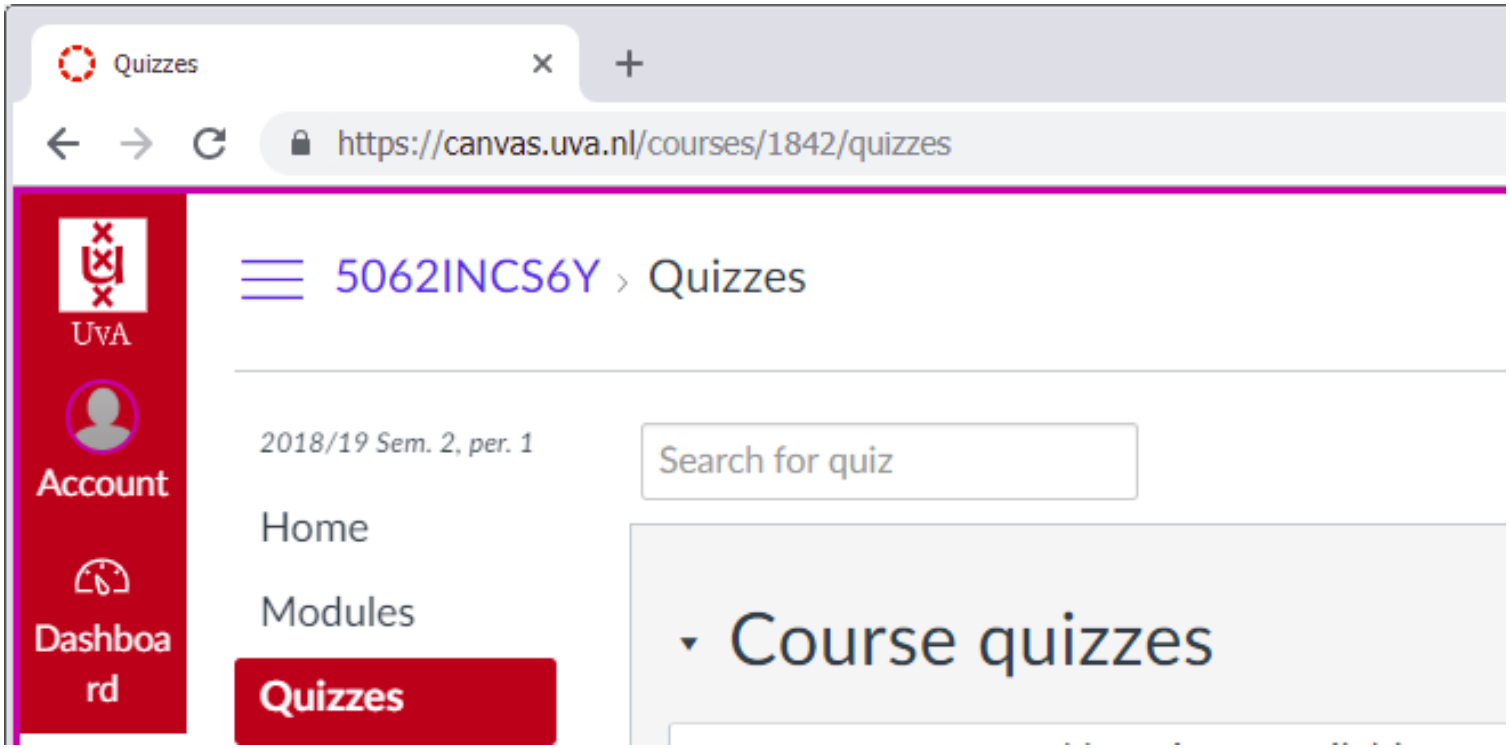

Real Traffic
flow [cars per hour]
0
500
1000
1500
2000
0
20
40
60
80
occupancy [%]
free flow
Congestion
Non-unique
flow-density relation

More on traffic modelling

http://www.youtube.com/watch?v=MKp495ECbOA

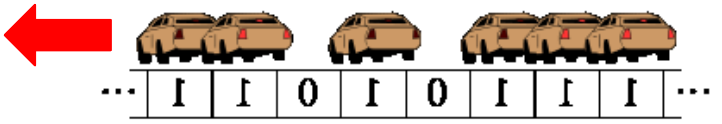
Quiz: L5Q1

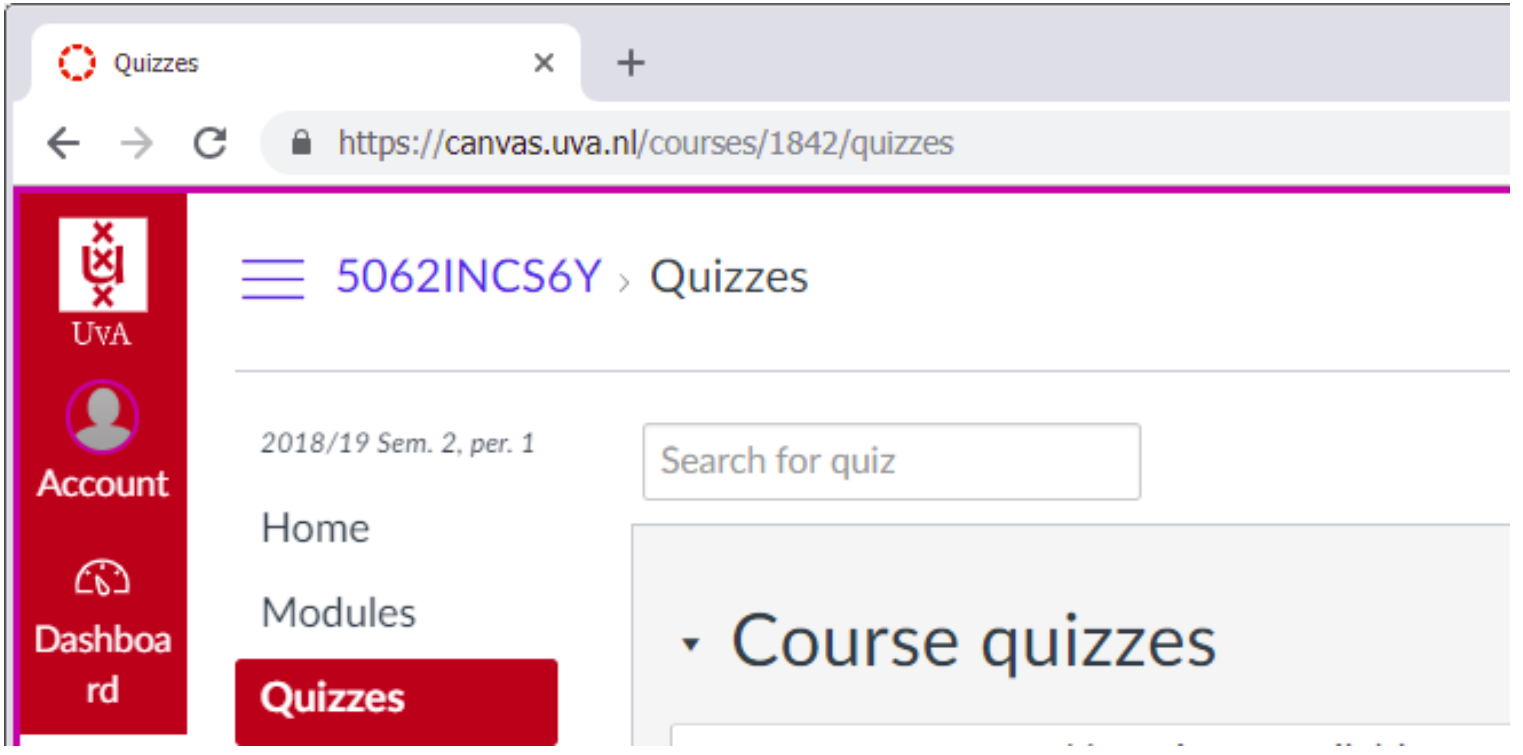
The fundamental diagram of traffic flow tells us that … (select all correct answers)



Quiz: L5Q2

current pattern	111	110	101	100	011	010	001	000
new state	?	?	?	?	?	?	?	?





Computational Science

Coming next:

TUE: Work session for questions on CA3 assignment

THU: Lecture on mean field, reversibility, ergodicity

Computational Science