Computer modeling of complex systems

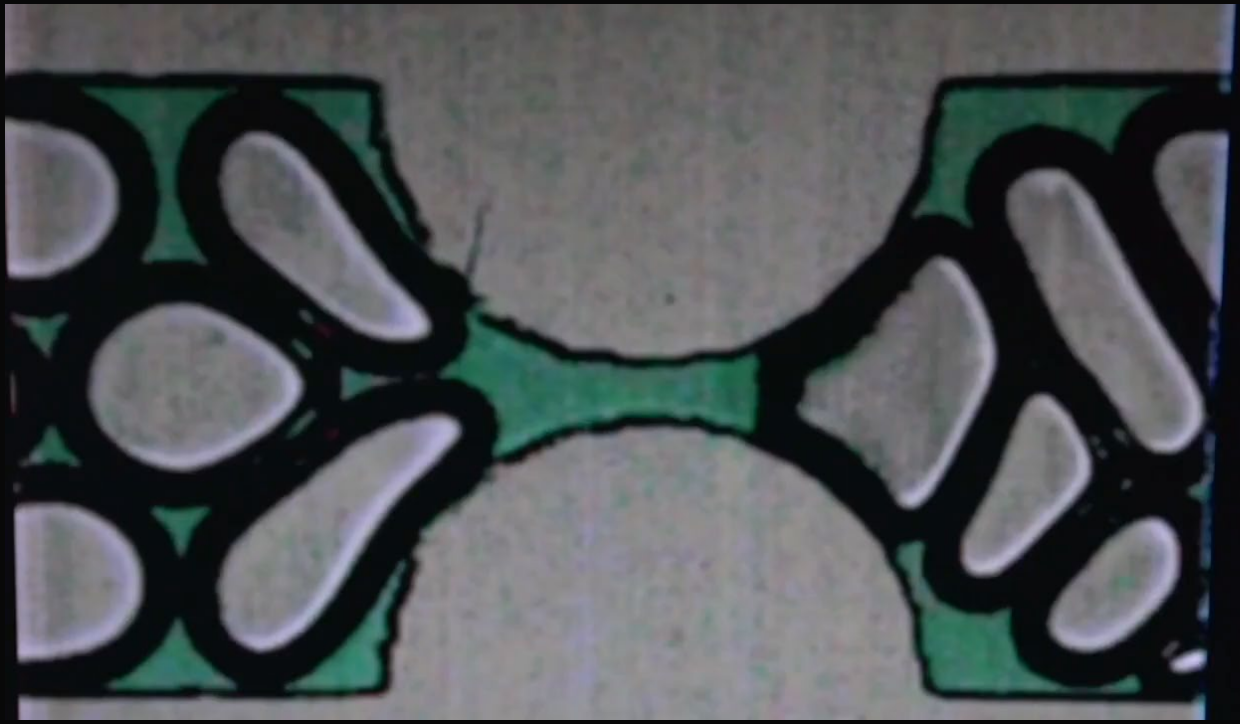
Lecture II: Things in motion

Sheep vs droplets

Sheep:

Sheep vs droplets

Droplets:



A fundamental question

Can the collective motion of a large numer of macroscopic objects (herd od sheep, swarm of insects, crowd of people, cars) be described in terms of simple interactions between these entities?

Physics of sheep?

Hydrodynamics of a dense flock of sheep: edge motion and long-range correlations

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Abstract.

Sheep are gregarious animals, and they often aggregate into dense, cohesive flocks, especially under stress. In this paper, we use image processing tools to analyze a publicly available aerial video showing a dense sheep flock moving under the stimulus of a shepherding dog. Inspired by the fluidity of the motion, we implement a hydrodynamics approach, extracting velocity fields, and measuring their propagation and correlations in space and time. We find that while the flock overall is stationary, significant dynamics happens at the edges, notably in the form of fluctuations propagating like waves, and large-scale correlations spanning the entire flock. These observations highlight the importance of incorporating interfacial dynamics, for instance in the form of line tension, when using a hydrodynamics framework to model the dynamics of dense, non-polarized swarms.

Keywords: swarming, collective motion, sheep, self-organization, animal behavior, shepherding

arXiv:2002.09467v1 [physics.bio-ph] 21 Feb 2020

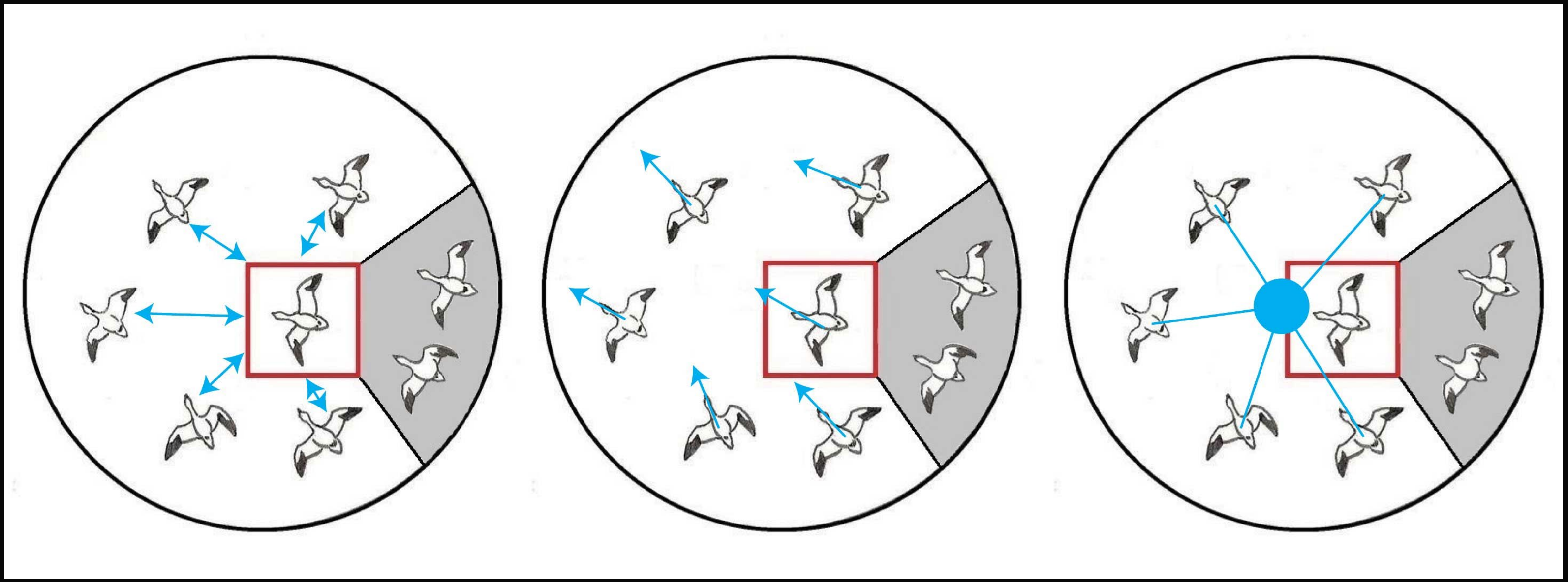
Herds, swarms, flocks, schools...

http://www.hintsandthings.co.uk/kennel/collectives.htm

Starlings

Fish

Reynolds model

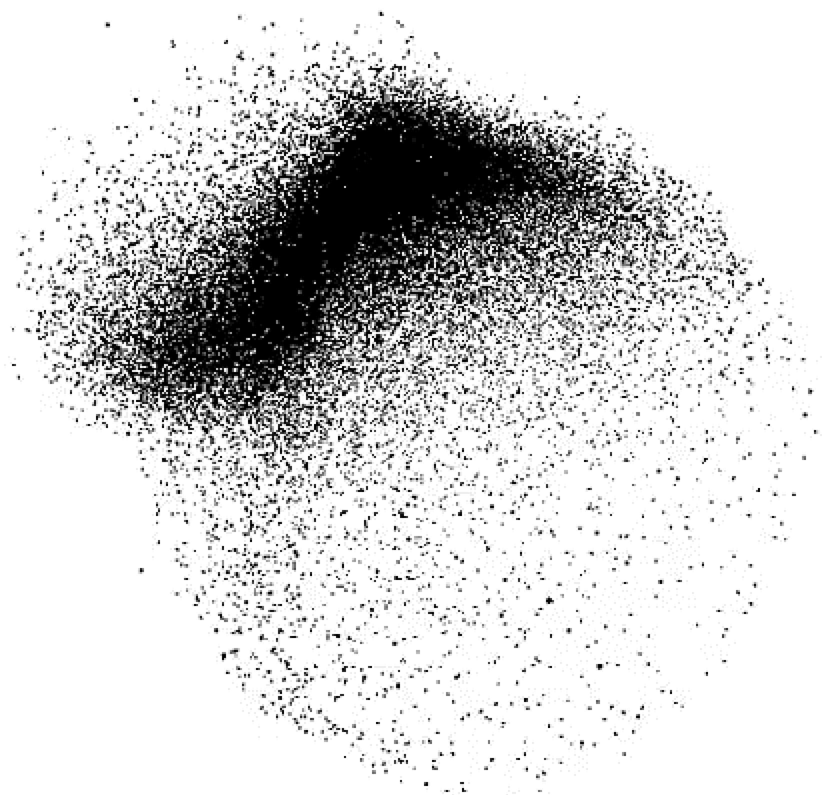


1) Separation: Move to avoid crowding local flockmates

2) Alignement: Match orientation and velocity of the neighbours

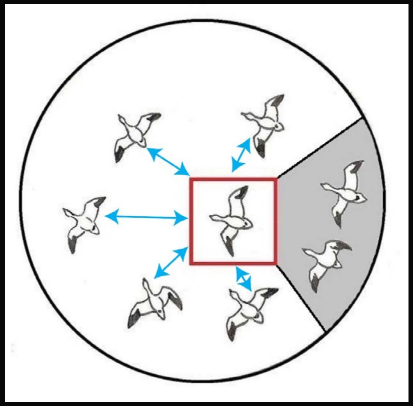
3) Cohesion: Move towards the average position of the neighbours

C. W. Reynolds. Flocks, herds, and schools: A distributed behavioral model, *Computer Graphics*, 25, 1987



Self-organization of the flock

- the flock behaves like a living creature, with structures or waves appearing within it on the scale of tens or even hundreds of meters
- individual starlings interact with their local flockmates only and follow simple rules



Emergence

Applications

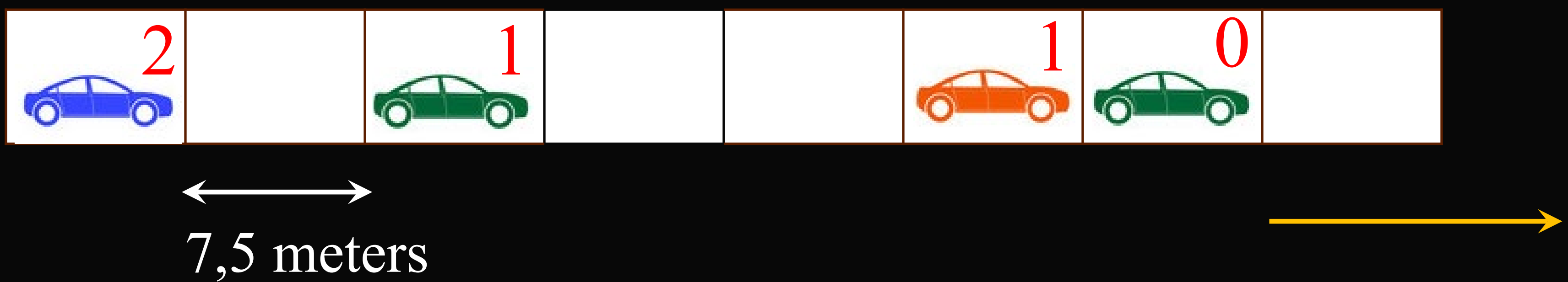
Applications (2)

"Franchise Freedom" (festiwal Burning Man)

Physics of traffic

Nagel-Schreckenberg model

Cellular model:



- Velocity is measured in cells per second (7,5 m/s = 27 km/hr)
- Cars are moving from one cell to another, like the pieces in a boardgame

K. **Nagel** and M. **Schreckenberg**, J. Phys. I 2, 2221 (1992)

Model: rules

- accelerate:

  - if only you can accelerate - do it

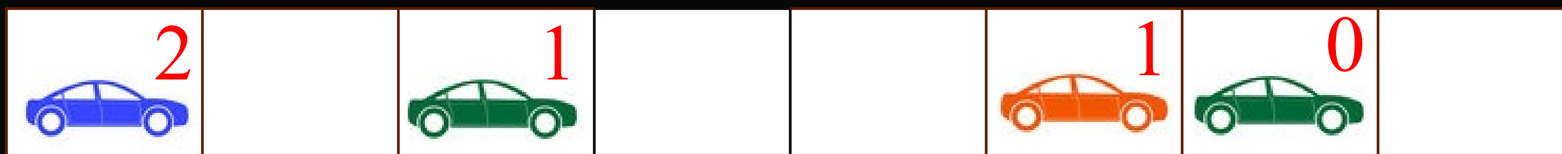
- braking:

  - if you are in danger of collision, reduce speed to the safe one

- randomness:

  - from time to time random slowdown ('absent-minded driver')

Rules

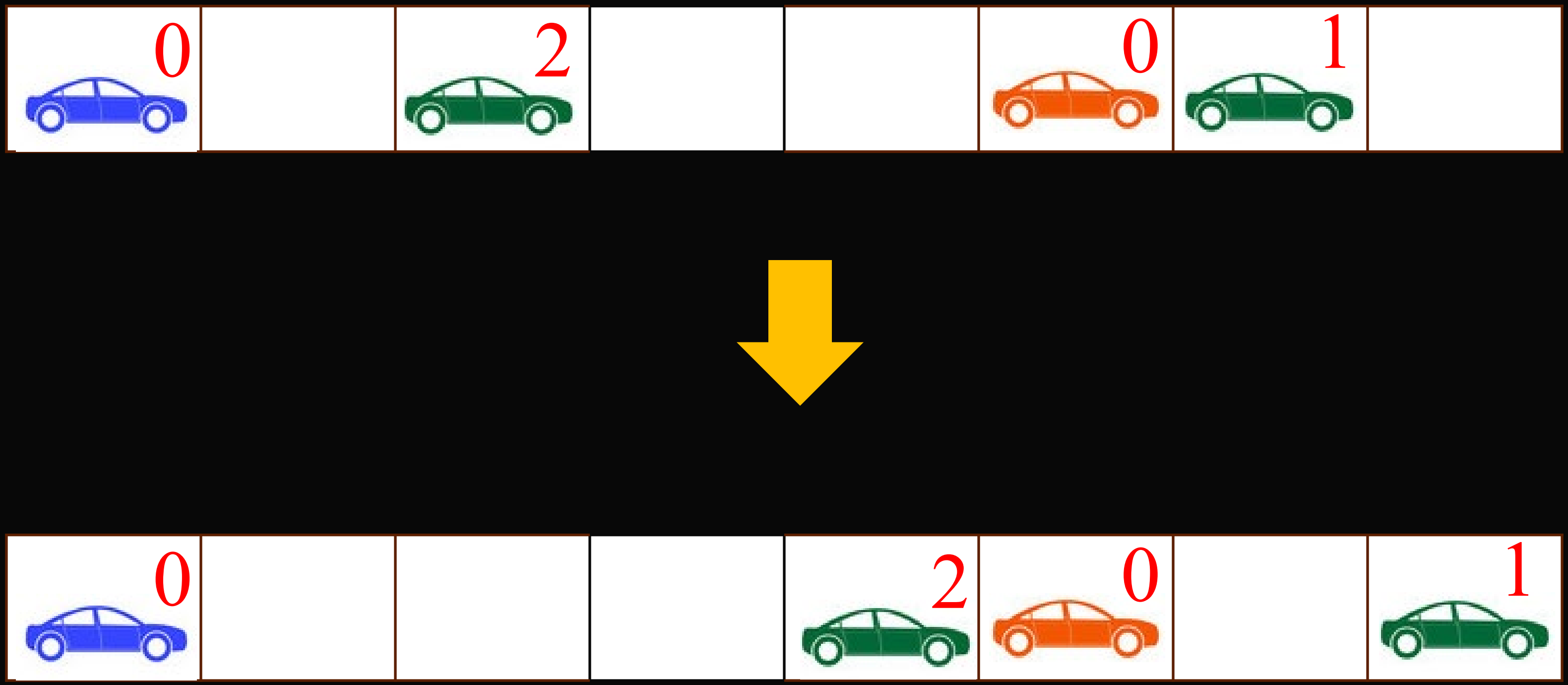


- acceleration:

- braking:

- randomness:

Motion

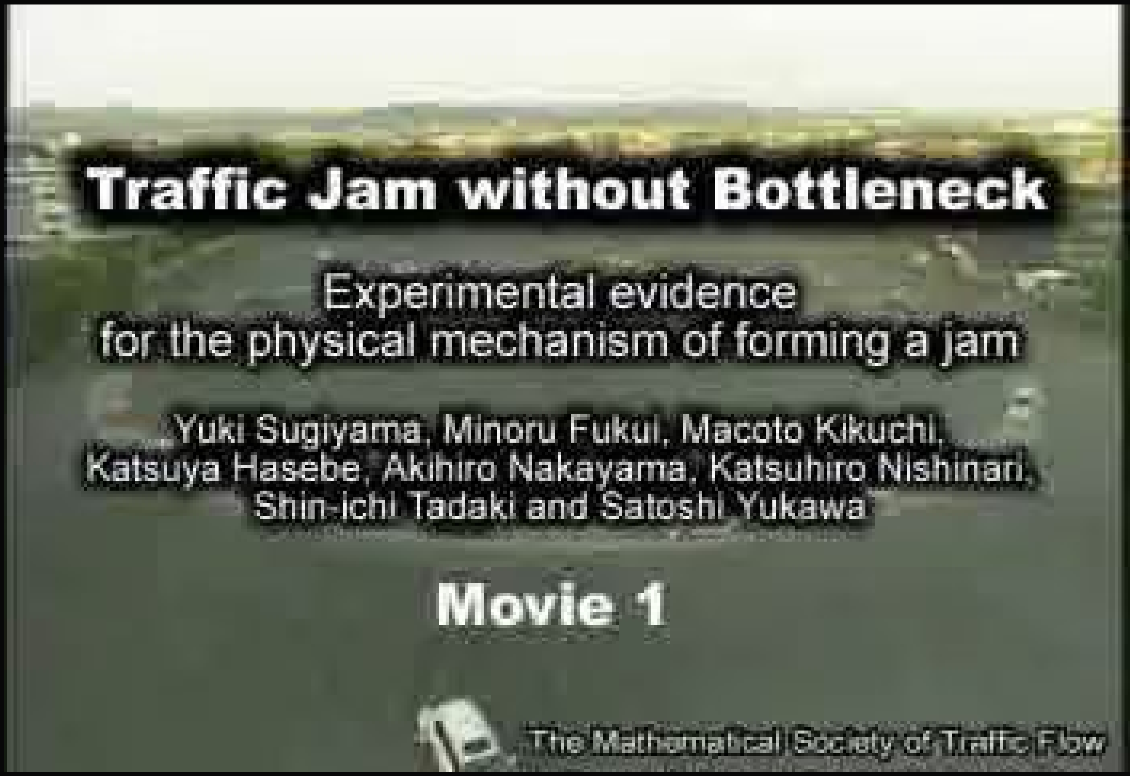


Phantom traffic jams

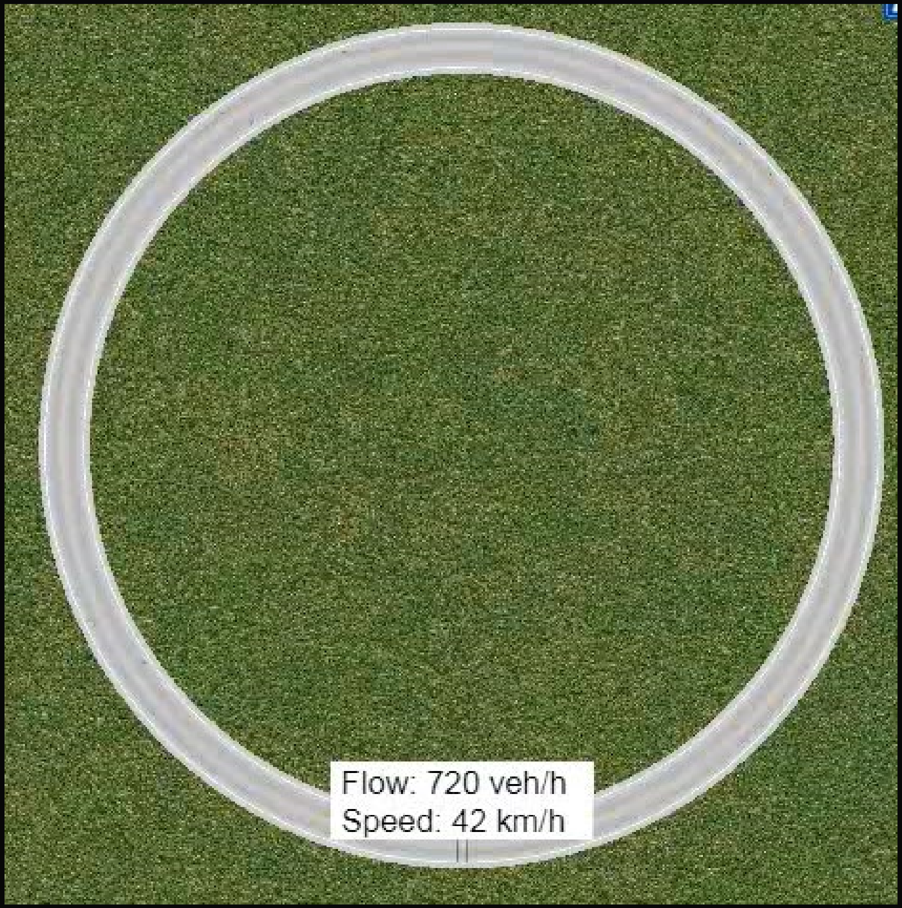
emergent property of the flow of
vehicles down a highway

Stau aus dem Nichts

Nagoya experiment

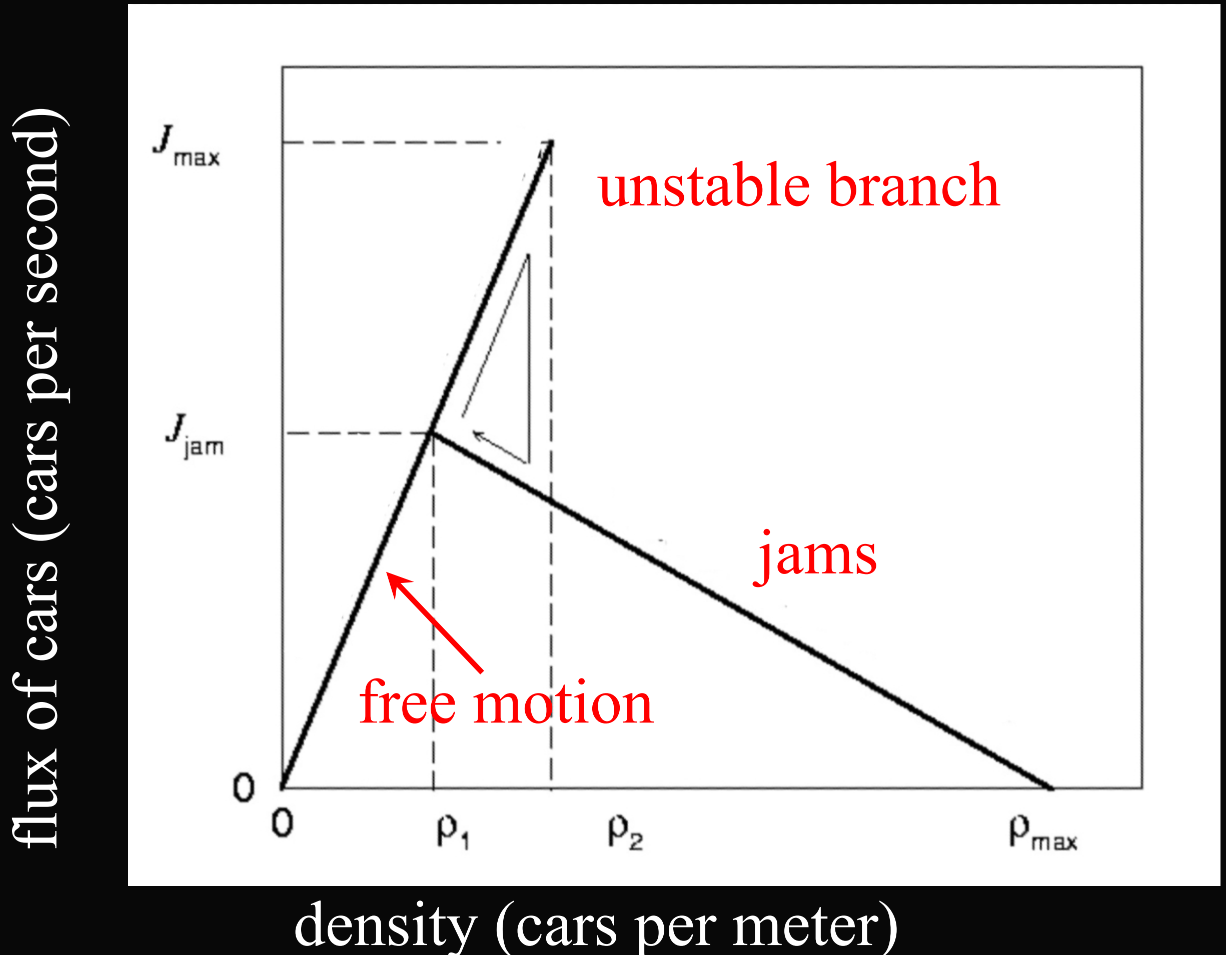


Simulation



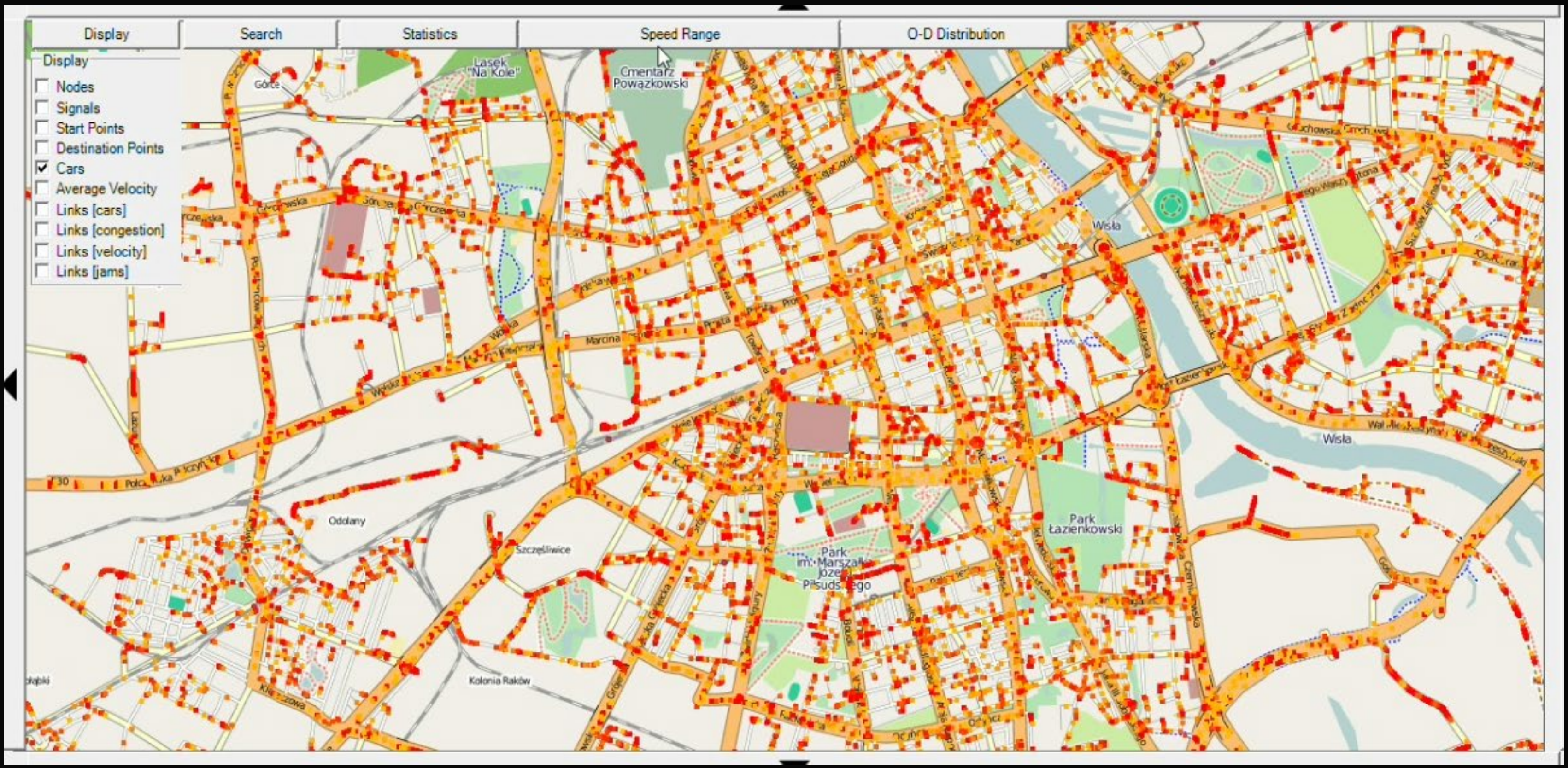
- spontaneous traffic jams are propagating in the direction opposite to the car motion with a velocity of 15 km/h (universal!)

Fundamental diagram



- at a certain critical density the free branch becomes unstable - the traffic jams appear

Warsaw simulator



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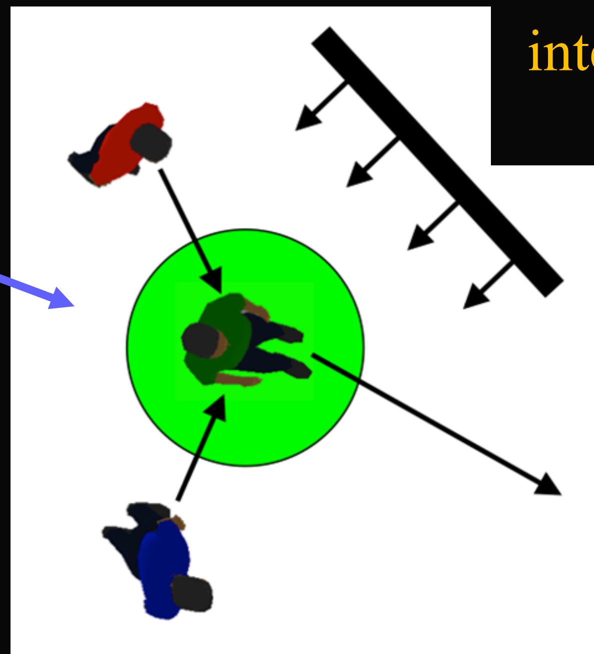
Pedestrian motion

Lane formation

The Model

external factors
(fire etc)



interaction with obstacles
(repulsion)

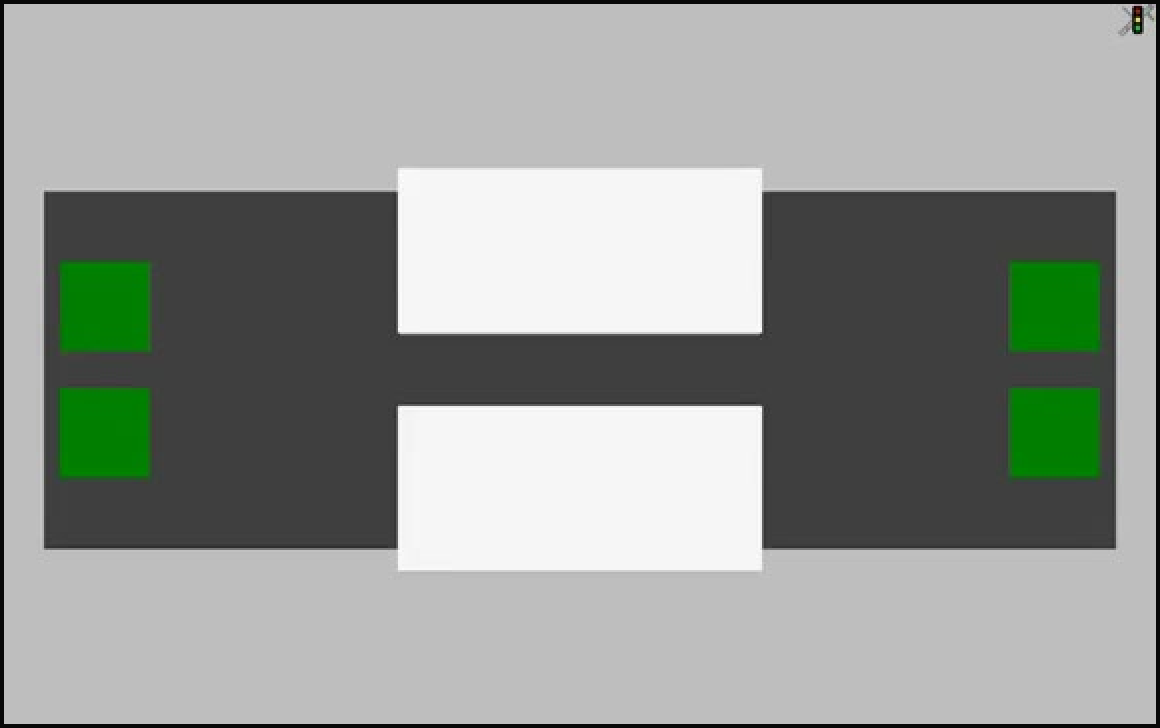
attraction towards the target

interactions with other
pedestrians (repulsion)

+ random fluctuations

pedestrians navigate the obstacles (including other pedestrians) while trying to get to the target as fast as possible

Lane formation



The motion self-organizes - the emerging mode of traffic is more effective than the random mode

Summary

Simplicity in complexity: simple rules under complex motion