Adaptive optimization of complex processes

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Outline

- Vehicular traffic as a complex process
- Modeling vehicular traffic
- Approximating traffic-related high-level complex concepts from sensory data
- Adaptive optimization of vehicular traffic

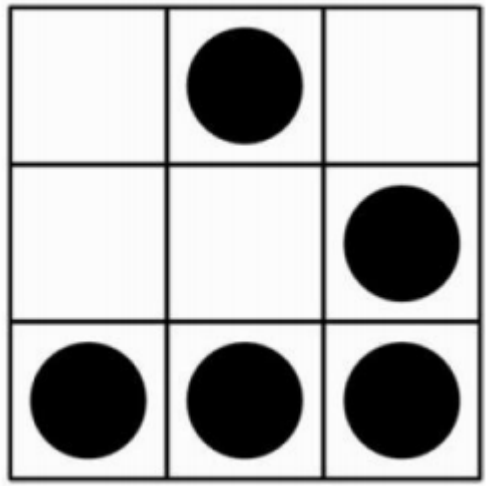
Vehicular traffic as a complex process

- The traffic consists of a large number of independent agents which try to realize a specific goal, e.g. reaching a destination point as fast as possible

- Agents interact with each other and with the environment which may lead to emergence of some complex patterns, behaviors, e.g. formation of traffic jams

- Large traffic congestion in cities is a civilizational and commercial problem

Modeling vehicular traffic

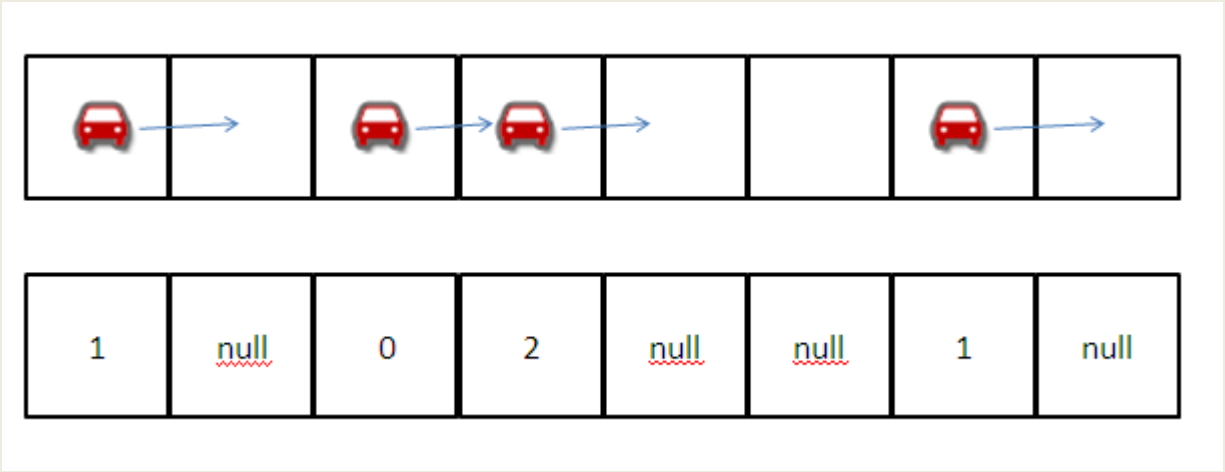


Nagel-Schreckenberg Model:

• Probabilistic cellular automaton, cells form a tape

• State of a cell = every cell may be empty (null) or occupied by a single car (the state is a car's velocity from the set $\{0,1,\ldots,V_{MAX}\}$)

• Cars are indistinguishable



Modeling vehicular traffic

Transition rules in the Na-Sch Model:

1. $V_{MAX} := min(V_{MAX}, V_i + 1)$ *(accelerating)*

2. $V_i := min(V_i, d_i)$ *(safety:* $\boldsymbol{d_i}$ *– distance to the car ahead*)

3. $V_i := max(0, V_i - 1)$, *with probability* $\boldsymbol{p}$ *(randomness)*

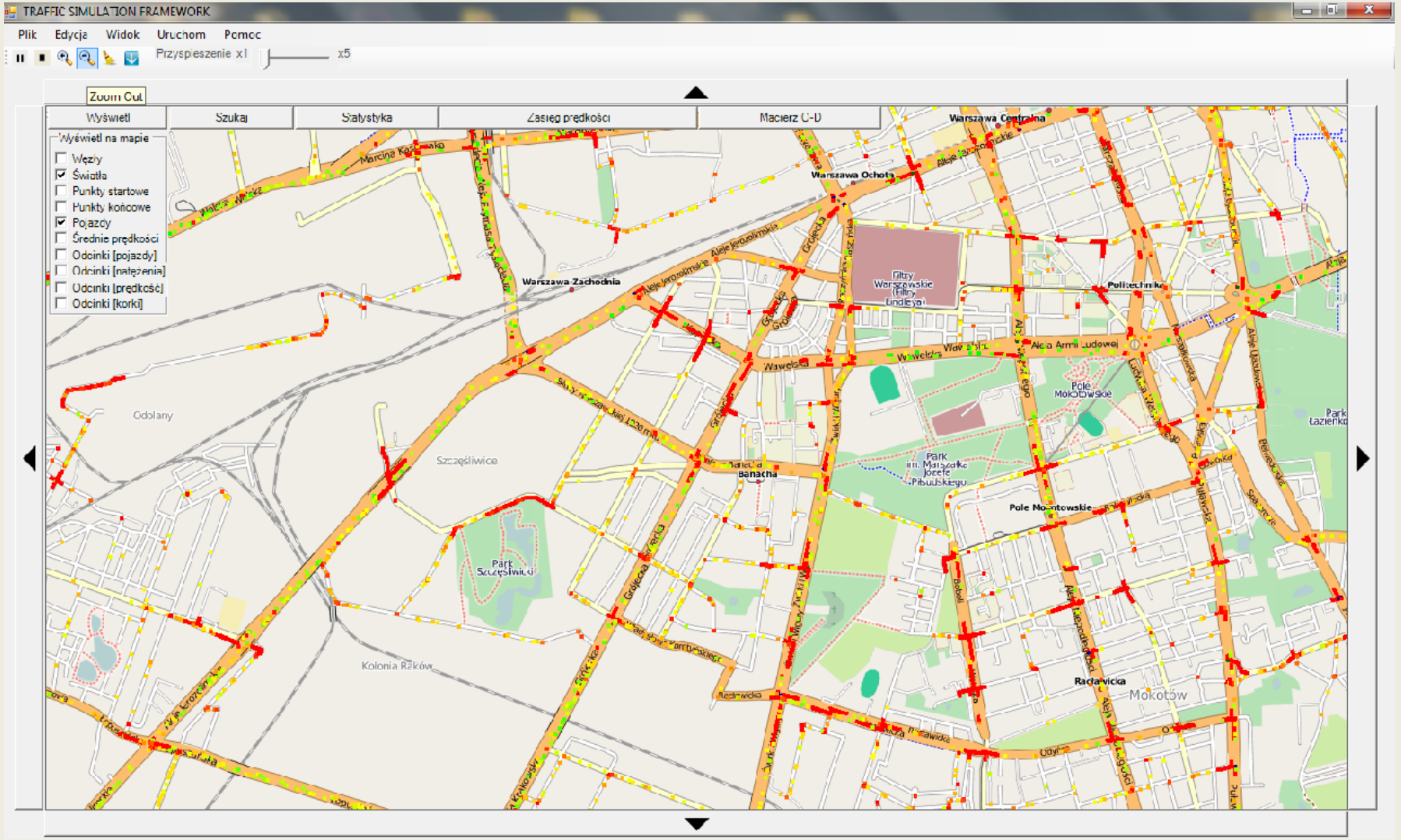
4. *Car* $\boldsymbol{i}$ *moves* $\boldsymbol{V_i}$ *cells forward*

Modeling vehicular traffic

I extended the Na-Sch model to enable simulating traffic on a real road network. Developed model takes into account:

- Crossroads with traffic lights
- Reducing speed before the crossroad
- Different profiles of drivers
- Different types of roads (many lanes, different maximal speeds)
- Profiles of distributions of starting points and destination points

Traffic Simulation Framework



Traffic prediction

- I coorganized a contest on traffic prediction being a part of the IEEE ICDM 2010 Conference
- The goal was to predict traffic congestions, traffic jam occurrences and average velocities, based on historic data
- Many participants (575 scientists) and interesting algorithms

Approximation of traffic-related complex, vague concepts

- I am going to construct classifiers to approximate traffic-related, complex, spatio-temporal concepts, such as traffic jam, large traffic congestion on a single crossroad

- I am acquiring domain knowledge by interaction with experts using traffic simulations

- Domain knowledge from experts may be used to construct training set for our domain-oriented classifiers and classifiers itself

Adaptive optimization of vehicular traffic

- Such classifiers may be later used to induce models of traffic-related complex, high-level concepts

- We may be able to predict undesired situations (e.g. formation of traffic jams) and activate complex actions to prevent such situations, optimize the traffic and make it safer

- Among optimization techniques I consider mostly applications of evolutionary algorithms in finding suboptimal configurations of traffic lights

Optimizing the traffic

- I tested a genetic algorithm for optimizing vehicular traffic in cities
- A single genotype encodes configurations of phase transitions between traffic lights on crossroads
- The goal is to find a suboptimal configuration for a given fitness function (e.g. average speed, average travel time)
- The fitness function is calculated by running computer simulations using the Traffic Simulation Framework software
- Conducted experiments gave promising results (3% improvement of values of fitness functions in 9th generation)

Conclusions

My research:

- I developed model for simulating vehicular traffic in cities based on probabilistic cellular automaton
- The model was implemented in the software Traffic Simulation Framework
- The software was used to test a genetic algorithm for optimization of vehicular traffic
- The software was used to organize contest on traffic prediction
- The software is being used to obtain traffic-related domain knowledge and construct training set for classifiers that may approximate traffic-related complex-vague concepts
- The software is being used by few other scientists from different countries, mostly in work on traffic prediction from sensory data

Thank you for your attention!

- Questions?
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