Simulating Realistic Traffic Flow in a Smart City

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Traffic control is nowadays one of the most important problems related with the urban development. New trends are based on the use of smart traffic lights and signals as a part of smart cities projects.

Different cities are nowadays involved in the design and implementation of smart traffic control. Nowadays, Málaga (Spain) belongs to the Smartcity project.

Since the cost of the physical installation of such systems is very high, accelerated-time simulations of traffic flow using smart traffic lights and signals are welcome.
Background

- Cellular automaton
- GRAM Model
- ATISBAT Model
Cellular automaton

- Conway’s Game of Life
- Rule 184: (Wolfram)
- Nagel-Schereckenberg Model (NS)
- Knospe-Santen-Schadschneider-Schreckenberg Model (KSSSS)
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Rule 184

```
1 1 1 1 1 0 1 0 0 1 1 0 0 0 1 0 0 0
```

Direction of traffic

```
  1 1 1 1 0 1 0 0 1 1 0 1 0 0 1 0 0 0
   0 0 0 0 0 0 0 0 0 0 0 0
```

Rule 184

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Simulating Realistic Traffic Flow in a Smart City
Model of Nagel-Schreckenberg (NS)

- A section of highroad is divided into $N$ cells.
- At time $t$, each cell can be:
  - Empty.
  - Busy by a car with velocity $v \in \{0, 1, v_{max}\}$.
- At any step the state of a cell is updated in parallel by using 4 rules:
  - **Acceleration**: Each car increases its velocity until the maximum allowed is reached: $v_0(t + 1) = \min\{v(t) + 1, v_{max}\}$
  - **Braking**: Each car adapts its velocity to the gap ($b$) with the previous one: $v_1(t + 1) = \min\{v_0(t + 1), b\}$
  - **Random braking**: With a probability $p$ the velocity is reduced by 1. ($p = 0 \Rightarrow$ deterministic model): $v(t + 1) = \max\{v_1(t + 1) - 1, 0\}$
  - **Updating**: $x(t + 1) = x(t) + v(t + 1)$
GRAM model: ACA 2011
GRAM Model

- GRAM model was presented in ACA 2011.
- Each cell in every instant of time can be associated with a car/driver in a motorway.
- The vector describing the state of each car is updated depending on its previous state vector, the outputs of the other cars and traffic area conditions.
- It shows real traffic characteristics such as: waves, collapses, low traffic, . . .
- It allows to essay some different motorway conditions and traffic rules obtaining both macroscopic and microscopic traffic parameters.
ATISBAT Model

- ATISBAT model was presented in ACA 2012.
- Each cell in every instant of time can be associated with a piece of baggage in the handling system of an airport.
- The vector describing the state of each piece of baggage is updated depending on its previous state vector, the outputs of the other pieces of baggage and traffic area conditions.
- It shows real traffic characteristics such as: waves, collapses, low traffic, ... 
- It allows to essay some different configurations of the handling systems: change the number and distributions of the entries and exits, security parameters, etc.
ATISMART model
General ideas

- ATISMART combines ideas from cellular automaton methods and neural networks. So cells are considering but special characteristics of each item in the cells (cars) are stored in its state vector.

- At every step, each cell changes its value depending on the neighbour cells values and the individual characteristic of the item.

- Parameters of the system are flexible and completely configurable.

- Maps can be easily adapted to the characteristics of the city.
Configurable parameters

- Input distributions.
- Street directions.
- Timing of traffic lights.
- Maximum number of cars within the system.
- Setting a car in the system with specific input and output streets.
Computing the path of a car

- Cars can be both: randomly introduced in the system with random input and output or set by the user with a given input and output.
- The car decides its path by using Dijkstra’s algorithm.
- Since the characteristics of the map (graph) can be dynamically changed, the car recomputes the path in each crossover.
Why using a CAS?

- Previous work made to sample random distributions with a CAS (DERIVE).
- Possibility of using ad-hoc distributions (using antiderivatives).
- Exact computation produce better results than approximating generated values of distributions.
Random distributions using a CAS

- In ACA 2009 we presented a Derive utility file to simulate different random distributions.
- Now we are implementing in Maxima algorithms for:
  - Generating random numbers of an uniform distribution (with a very large period).
  - Generating samples of random variable distributions.
  - Generating samples from any particular density function.
Random distributions using a CAS
Random distributions using a CAS
ATISMART model
Conclusions

- The use of cellular automata together with individual information is a good tool for simulating traffic in different environments.
- The use of CAS (Maxima) in the simulations allows obtain exact distribution functions even from the density function.
- Many characteristics of the car traffic in a smart city can be simulated in order to improve the design of the parameters of the system in an easy and cheap way.
Conclusions

- The application has been implemented using independent modules which allow to adapt ATISMART to any specific requirement.
- ATISMART can be used both as an aid during the smart signal design process and to optimize the use of an already built smart traffic lights and signals in a specific map.
- The graphic interface produces important visual information about the simulation. This graphical approach is very useful, since the effects of making any change can be visually shown immediately.
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