Simulating Realistic Traffic Flow in a Smart City

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Contents

Motivation

- 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

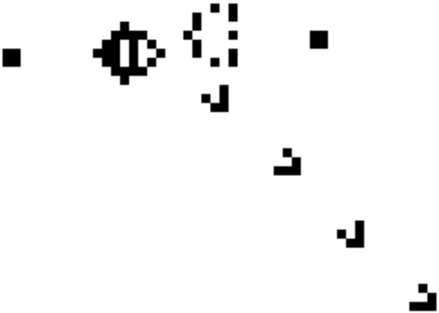
- **Cellular automaton**
- **GRAM Model**
- **ATISBAT Model**

Cellular automaton

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

Conway's Game of Life

Conway's Game of Life



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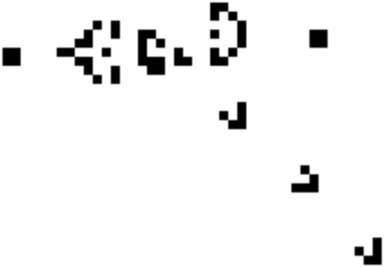

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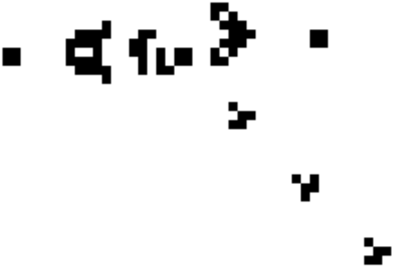

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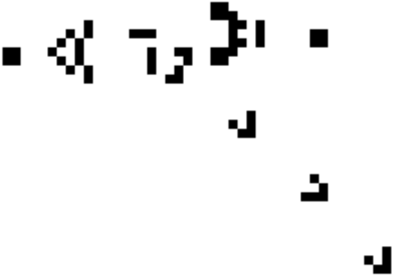

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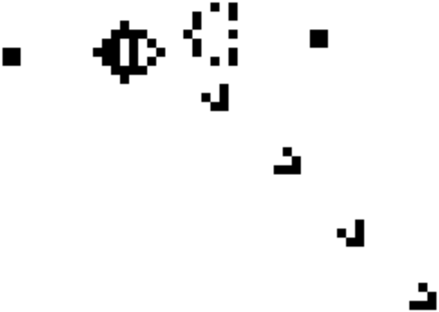

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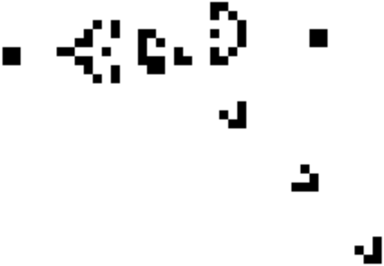

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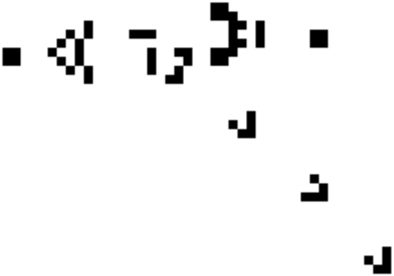

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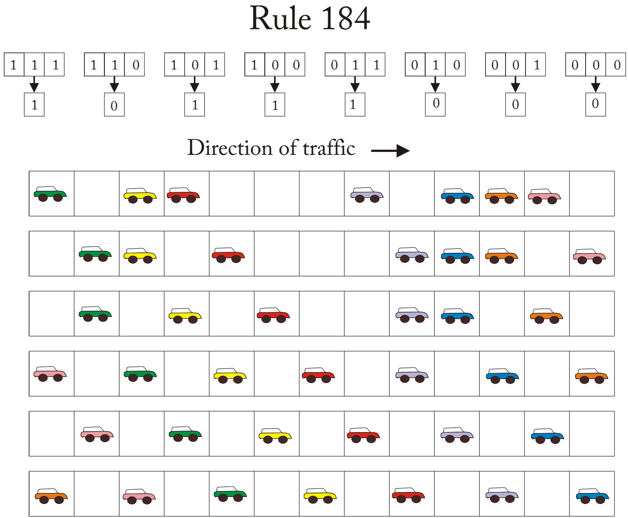
Rule 184


Rule 184
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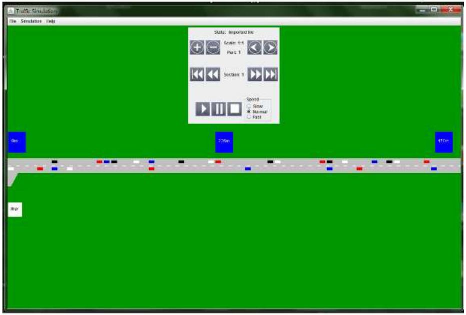
1 1 0
0
1 0 1
1
1 0 0
1
0 1 1
1
0 1 0
0
0 0 1
0
0 0 0
0
Direction of traffic

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:** $x(t+1) = x(t) + v(t+1)$

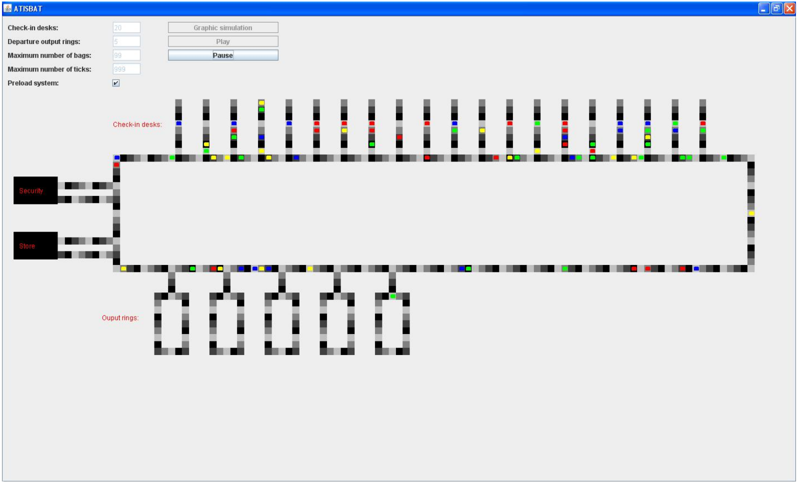
GRAM model: ACA 2011



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.

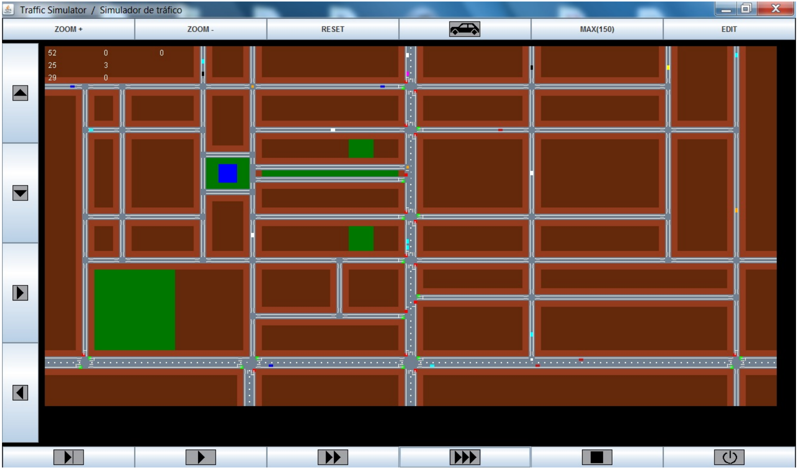
ATISBAT model: ACA 2012



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 configutations of the handling systems: change the number and distributions of the entries and exits, sequrity 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.

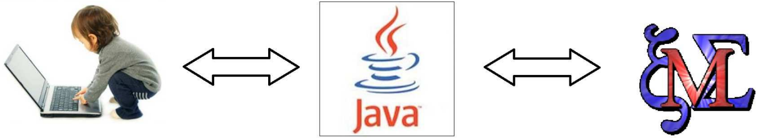
Configurable parameters

- 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 ouput.
- 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.

Interface Human - Java - Maxima



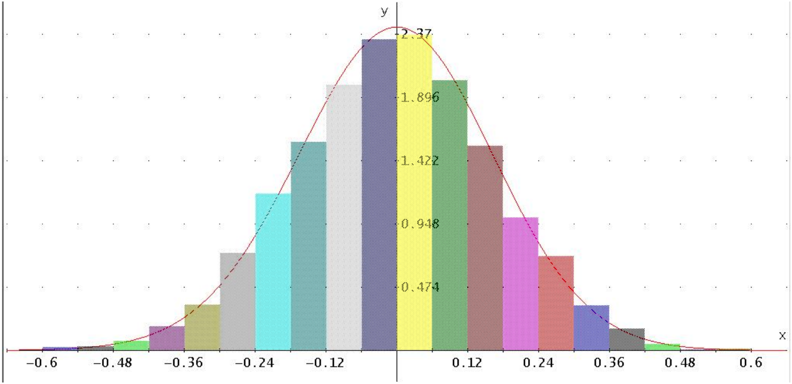
Why using a CAS?

- 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.

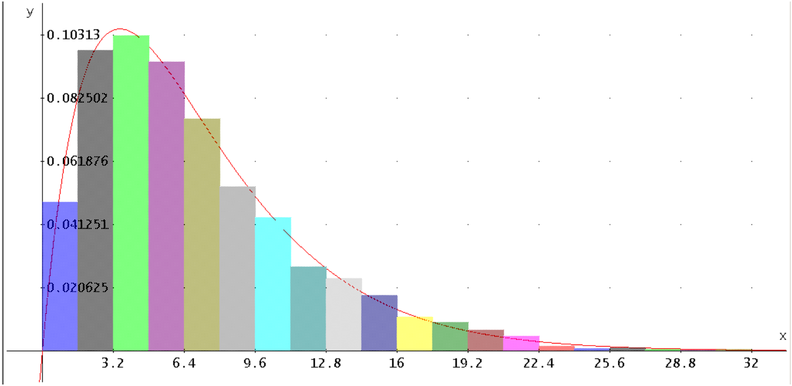
Random distributions using a CAS

- 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.

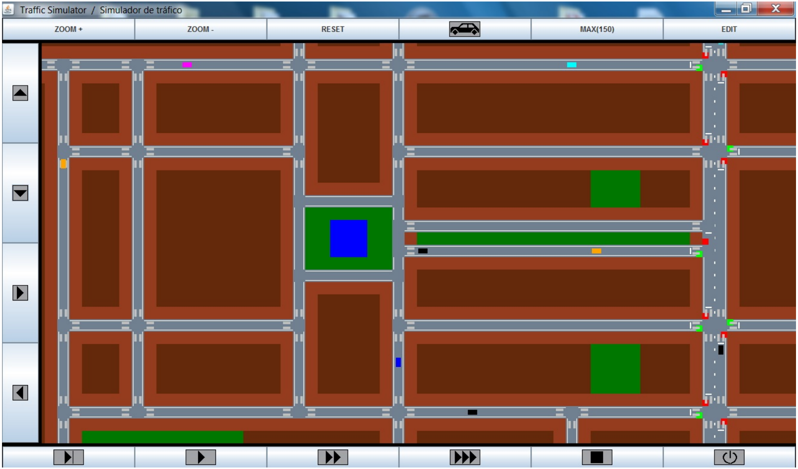
Random distributions using a CAS



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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