Cellular Automata Modeling for Traffic Flow

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History

- 1930's: Scientific study of traffic flow begins. (Greenshields 1935) (Adams 1936)
- 1955: The oldest macroscopic model based on fluid-dynamic theory. (Lighthill & Whitham)
- 1986: Simplest cellular automata model for traffic flow. "Rule 184." (Wolfram)

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- 1992: The paper *A cellular automaton model for freeway traffic* (Nagel & Schreckenberg) was published. The model in this paper is regarded as the prototype cellular automata model, and is what we based our project on.

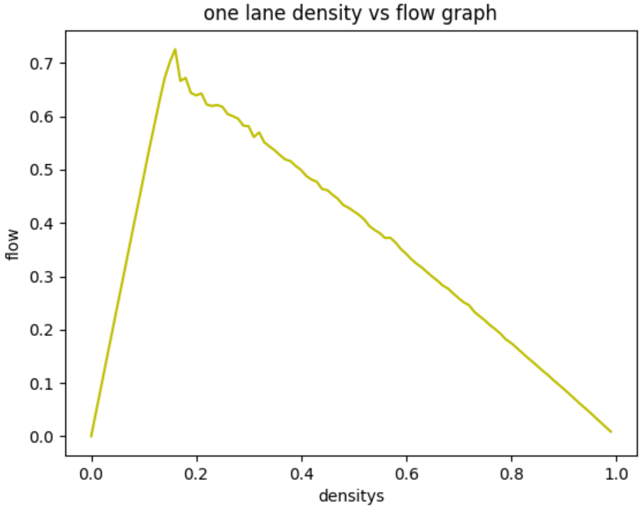
The Nagel & Schreckenberg Model

The model from *A cellular automaton model for freeway traffic* consists of four steps which are executed in the following order.

1. **Acceleration:** If the velocity v of a vehicle is less than v_{max}, and the distance to the next car is greater than $v+1$, then the speed is increased by one . $[v \mapsto v+1]$
2. **Slowing down (due to other cars):** If a vehicle at site i sees the next vehicle at site $i+j$, and $j \leq v$, then it reduces its speed to $j-1$. $[v \mapsto j-1]$
3. **Randomization:** With probability p, the velocity of each vehicle (if greater than 0) is decreased by one. $[v \mapsto \max(0, v-1)]$
4. **Car motion:** Each vehicle is advanced v sites.

We first implemented this model with periodic boundary conditions in python.

Fundamental Diagram



Position of Cars Over Time

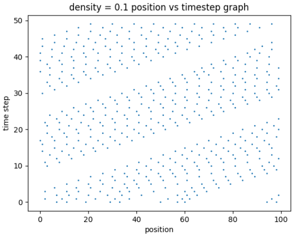


Figure 1: density = 0.1

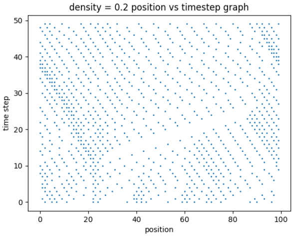


Figure 2: density = 0.2

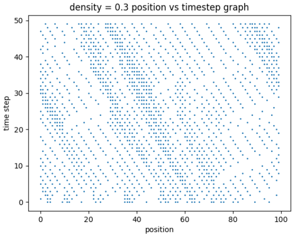


Figure 3: density = 0.3

Position of Cars Over Time

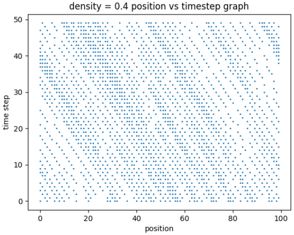


Figure 4: density = 0.4

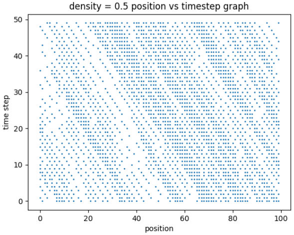


Figure 5: density = 0.5

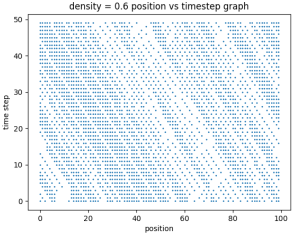


Figure 6: density = 0.6

Position of Cars Over Time

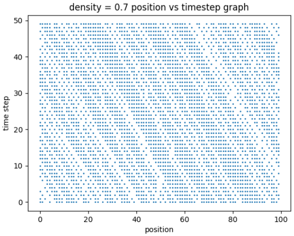


Figure 7: density = 0.7

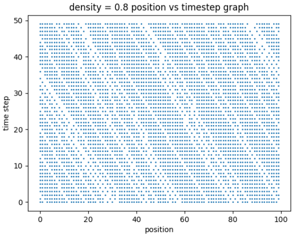


Figure 8: density = 0.8

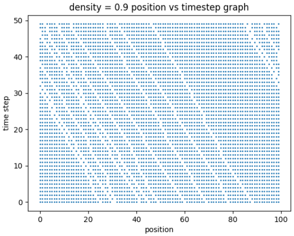


Figure 9: density = 0.9

Traffic in a Bottleneck Situation (Open System)

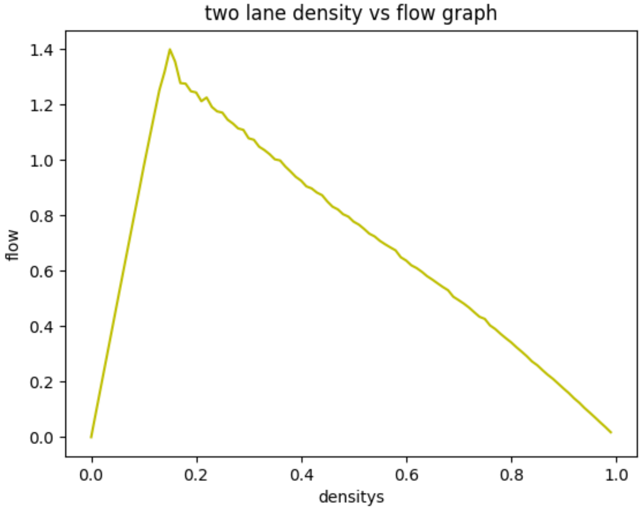
This implementation is meant to model traffic flow in a bottleneck situation where multiple lanes of traffic merge into one lane for a period of time, then split off into multiple lanes again. We use the following boundary conditions.

1. When the leftmost (first) site on the road is empty, we occupy it with a new car with velocity 0.
2. When a car reaches one of the rightmost (last) 6 sites on the road, it is removed from the road.

The two lane model

1. **Lane Changing:** A vehicle at site i with velocity v changes lanes if the following conditions are met:
   1.1 The velocity of the next car in the current lane is less than v.
   1.2 Site i in the other lane is not occupied.
   1.3 The distance to the next vehicle in the current lane is less than $\frac{v_{max}}{2}$.
2. **Acceleration:** If the velocity v of a vehicle is less than v_{max}, and the distance to the next car is greater than $v+1$, then the speed is increased by one . $[v \mapsto v+1]$
3. **Slowing down (due to other cars):** If a vehicle at site i sees the next vehicle at site $i+j$, and $j \leq v$, then it reduces its speed to $j-1$. $[v \mapsto j-1]$
4. **Randomization:** With probability p, the velocity of each vehicle (if greater than 0) is decreased by one. $[v \mapsto \max(0, v-1)]$
5. **Car motion:** Each vehicle is advanced v sites.

Fundamental Diagram Two Lane

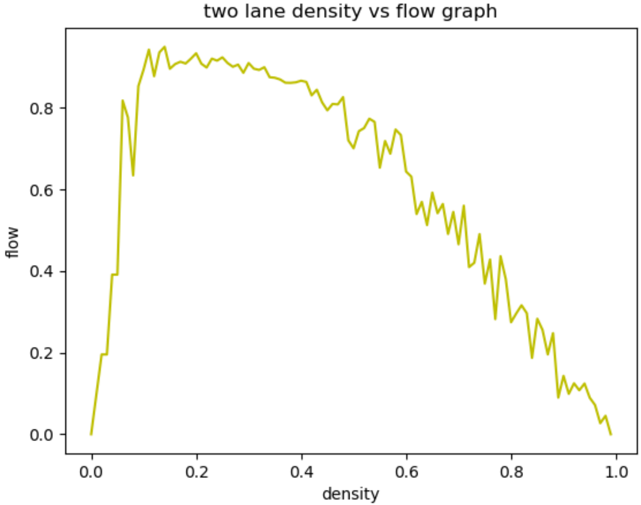


The two lane model: second method

1. **Lane Changing:** A vehicle at site i with velocity v changes lanes if the following conditions are met:
   1.1 There is a larger distance in the second lane
   1.2 The distance to the next car in the current lane is $\leq v_{max}$.

   A car that is changing lanes is considered to be at both lanes at once.
2. **Acceleration:** If the velocity v of a vehicle is less than v_{max}, and the distance to the next car is greater than $v+1$, then the speed is increased by one . $[v \mapsto v+1]$
3. **Slowing down (due to other cars):** If a vehicle at site i sees the next vehicle at site $i+j$, and $j \leq v$, then it reduces its speed to $j-1$. $[v \mapsto j-1]$
4. **Randomization:** With probability p, the velocity of each vehicle (if greater than 0) is decreased by one. $[v \mapsto \max(0, v-1)]$
5. **Car motion:** Each vehicle is advanced v sites.

Fundamental Diagram Two Lane



Reference

Kai Nagel, Michael Schreckenberg. *A cellular automaton model for freeway traffic*
Journal de Physique I, EDP Sciences, 1992, 2 (12), pp.2221-2229.

Femke van Wageningen-Kessels,Hans van Lint, Kees Vuik, Serge Hoogendoorn.
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