

A Simple Traffic Model Including Possibility of Overtaking

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Abstract: Previously we examined different parameters relevant to traffic flow. For illustrative purposes we considered a specific case of approaching a city. The case involves a traffic light where one continues on the main road, into which additional cars are entering at the light. At this intersection an alternative route begins, which is longer but into which no additional cars are entering. In addition to the “Slow to move” model we add here a possibility of “overtaking”, which is quite artificial as our model is one dimensional. Still we think that this gives fair results.

Key words: Cellular automata, traffic flux, overtaking.

1. Introduction

Empirical observations of traffic show that at high enough densities the behaviour of traffic becomes quite complex. Therefore, Cellular Automata is one of the most used methods for evaluating traffic and that is because of their speed and complex dynamic behaviour. Cellular automata were first studied by Ulam and von Neumann [1]. An important contribution to the field was in the work of Wolfram [2] who introduced classifications, used in the present study. The elementary Cellular Automaton is a collection of cells arranged on a one dimensional array. Each cell can obtain just two possible numbers: one and zero. The “time” is discrete and at each time step all the cell values are updated synchronously. The value of each cell depends just on the values in the previous step of that cell and its two neighbours. Wolfram names each elementary Cellular Automaton with a binary numeral, which he calls: “rule”. This value results from reading the output when the inputs are lexicographically ordered. This will become clearer when we explain the rules which we use.

The most basic model, for traffic, was the paper by Biham et al. [3]. This model consists of a one dimensional chain of sites on which particles are distributed according to their density. At each time step each particle can move to the right if that site is not occupied. This model enabled to distinguish between free flow at low densities and a jammed region for high densities of particles. A more realistic model was suggested by Nagel and Schreckenberg [4] who introduced several modes for the car velocity. A different approach was taken by M. Takayasu and H. Takayasu [5] who introduced the effect of delay by allowing a car to move only if the next and after the next site are empty. More recently introducing additional connection sites into essentially the Nagel-Schreckenberg model was suggested by Nassab et al. [6].

In a previous study [7], we examined a specific traffic problem. In that study we added to previous calculations the “slow to move” model [8]. This gives us a delay just as in the previously described models and seems to us simpler. The feature which we added in this study is a sort of “overtaking” which is somewhat artificial as we are considering just one lane traffic. We will explain later the method. It seems to us that this model gives the main features of previous studies but is

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simpler.

To make our exposition clearer we describe again the procedure given in our previous study. The rules we used are taken from the cellular automata model as proposed by Gershenson and Rosenblueth [9]. Our main interest in this paper is to see how the “overtaking” changes the traffic flux.

2. The Model

Our highways are represented by an array of cells, each cell has the values zero or one. One represents a vehicle and zero an empty portion of the highway. We assume that the magnitude of a cell corresponds to the average length of a vehicle. In Fig. 1, we show the layout of our model. At a certain point we have a bifurcation where there are two different ways to proceed and at a later point where they merge again. This model represents in a simplistic way the possibility of using two alternative routes (the main route and the “bypass”) when approaching a city from a certain direction of suburbs. We add the possibility that additional cars are coming into the main road and are removed when approaching the city. So that overall the number of vehicles is preserved.

In Fig. 1, “IN 1” is the main car movement and we assume that the main outflow (“OUT 1”) of cars is the same as the number entering. The first junction is light 1 and after the intersection additional cars enter (“IN 2”), this is the same number of cars as leaving at “OUT 2”. This procedure keeps the overall number of cars constant. At light 1 we have the possibility of cars to move to the bypass at light 2 they again combine with the main road.

In this paper we have one modification, we assume that for a certain percentage of the cars there is a possibility to “jump” three spaces in advance if in front of the car there is one car and two empty spaces before it.

The rules, which are the same as used by Gershenson and Rosenblueth [9], are given in Table 1.

In Fig. 2, we show schematically how the rules

which are used in our calculations are implemented.

2.1 Measures

The density, p , is given by the ratio between the number of “ones” (i.e. vehicles) and the total number of cells. Initially we take this value to be the same for all regions. We check how this value changes in the different regions. Here we are interested only in the equilibrium values. The velocities, v , denoted by vt , for the velocity after the second traffic light, is given by the number of cells which change in one step from 0 to 1.

In our calculation, space and time are just abstract quantities. Still if concrete numbers are desired, one

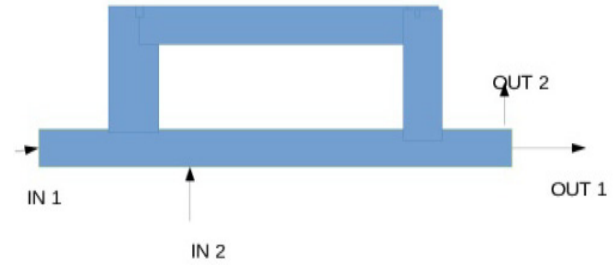


Fig. 1 The movement of vehicles.

Table 1 Wolfram rules used in this model.

$t-1$	t_{184}	t_{252}	t_{136}
000	0	0	0
001	0	0	0
010	0	1	0
011	1	1	1
100	1	1	0
101	1	1	0
110	0	1	0
111	1	1	1

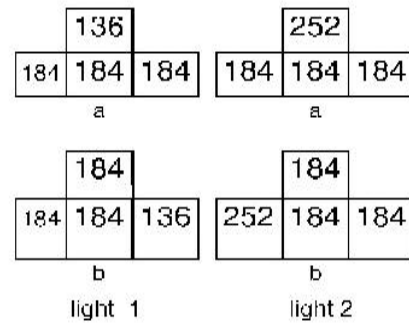


Fig. 2 The movement of vehicles.

can quote [9] were the “length” of one cell is given by five meters, and a time step is given by a third of a second. As the usual movement of “cars” is one cell per time step, these values give us a speed of about 50 km/hour, roughly the speed limit within a city.

The time going on the bypass may be longer or shorter than the one going straight on the main road. We will check the ratio between these two times and denote it by “q:pe”.

We have a parameter telling us the amount of “cars” added to the main road at the junction of the bypass. This same amount is deducted from the “main road” farther away and is done in order to preserve the total number of vehicles. The actual addition of cars is governed by a random number which depends on a parameter (i.e. the percentage of cycles when a car is added). We have a parameter telling us what part of cars do not move even when they could move according to our rules. We denote this parameter by *crr*, and it changes between zero and one. The last parameter which we add in this section is the percent of cars which can jump: “pc-skip”.

2.2 The Grid

A general view of the grid is given in Fig. 3.

The figure showed that we denote the cells on the main route by *ip* and the cells on the bypass by *iq*. The cells between $ip = istop1$ and $ip = istop2$ we denote by *ipe*. The cells after $ip = istop1$ we denote by *ipt*. At $ip = istop$ the vehicles move on the main road or on the bypass according to the “lights”.

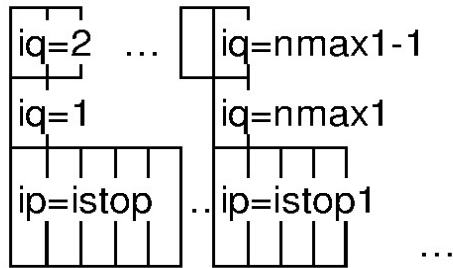


Fig. 3 The grid.

3. Results and Discussion

We used a fixed grid: The main road was comprised of 1,200 cells, the “by pass” 300 cells and the distance between the two lights was 120 cells. We used the “green wave” regime. As we have just two lights it was shown by Gershenson and Rosenblueth [9], that in this case one does not get different results using the “self-organizing” regime.

The number of cycles we have to use in order to obtain significant results depends on the parameter we wish to calculate. For calculating the velocity or the flux 32,000 cycles give quite accurate results. We determine the number of cycles needed by taking a second sample, with different random numbers, and comparing the values thus obtained. To be on the safe side we used 64,000 cycles on the here presented results.

We introduce a vehicle on the first intersection for 40% of the steps and we eliminate the same number of vehicles on the last point of our main route, again per unit time.

In Fig. 4 and Fig. 5 we show the results, for a specific density, of the velocity and flux as a function of the part of cars which are allowed to overtake. In these figures the density was taken as $\rho = 0.6$ and the part of cars which are slow to move by $crr = 0.5$.

Fig. 6 shows the ratio of time it takes to go on the main road compared to the time to go by the “bypass”. It is interesting to note the big difference in the result as a function of the part of cars which are allowed to overtake.

The understanding of the change in velocity as a function of the “pc-skip” shows us the possible gain compared to the danger of overtaking on rural roads. It shows us that in many cases the gain is quite small compared to the increase in the danger of collision.

In conclusion, we can say that our calculations give us a wide range of information which can be applied for specific cases. It shows us the importance of modifying the simple rule by adding modifications to the study presented by Gershenson and Rosenblueth [9].

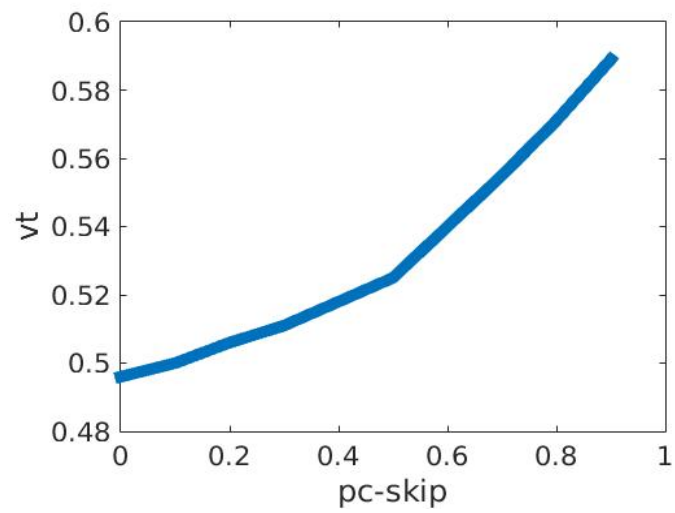


Fig. 4 The change in velocity as function of the cars which are allowed to overtake.

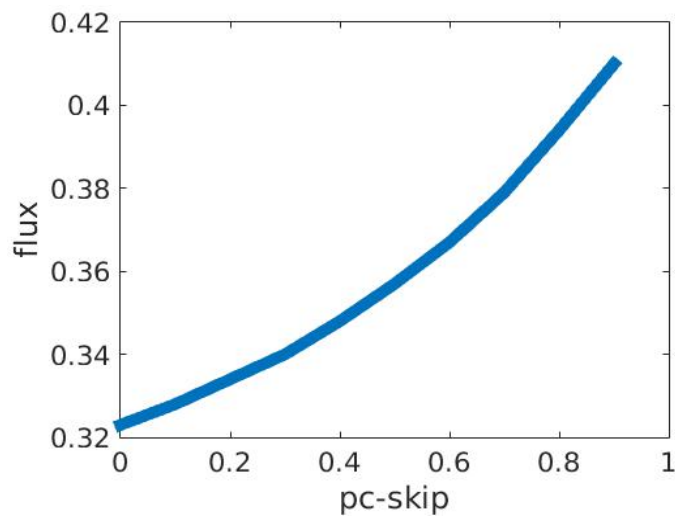


Fig. 5 The change in flux as function of the cars which are allowed to overtake.

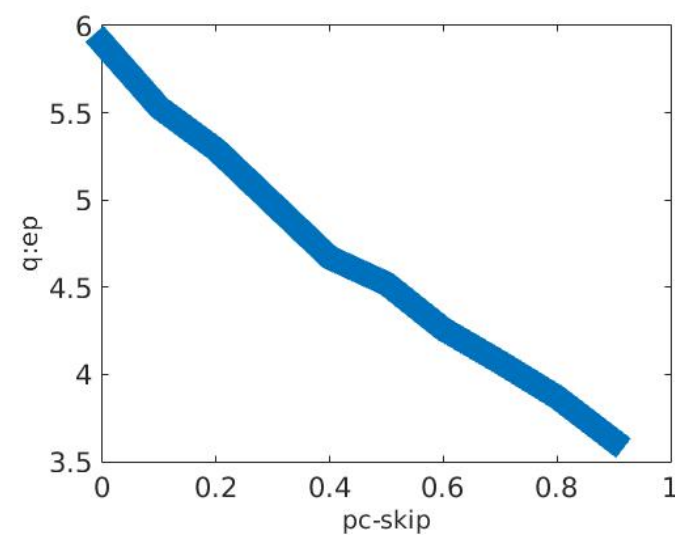


Fig. 6 The values of $q:pe$ as a function of pc-skip.

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