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Dynamic Traffic Cellular Automata Model to Express the Congestion at One Lane Highway Traffic System

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Abstract. Highway congestions can cause considerable impact on loss of time and delays displacement. This article introduces a new method of explanation of the congestion in contrast to conventional method of vehicles capacity on the highways. This method is primarily based on the Cellular Automata (CA) concept introduced by Nagel and Schreckenberg in 1992 [1]. Dynamic Traffic Cellular Automata (DTCA) is also explained with emphasis on the acceleration, the deceleration, and the reaction factors. Different in speeds changing and delays in start-up are discussed for being important reasons of the highway congestions.

Keywords. Cellular automata (CA), Dynamic Traffic Cellular Automata (DTCA), Congestion.

1. Introduction

For several years, we have been developing a general purpose road-traffic simulation system to analyse road traffic jam. This paper describes the concept of the system using the running line model, and a case study for general purpose simulation with Dynamic Traffic CellularAutomation model, which is modify from Cellular automata model[1]. In order to simulate congestion of road traffic system, it is essential to describe vehicles having their own decision-making capabilities, and to have detailed and exact road condition data on the road system[2].

Several studies have been doneto realize road traffic simulation by a microscopicmodel. For example, there is a flattery model of avehicle by a fuzzy theory and various theories suchas a neural network work and cellular automata[2].

The Cellular Automata model had been suggested by Nagel and Schreckenberg in 1992. It was first used to study the congestion on the one lane highways[1]. Since then the model has been modified to study two and three lane highways [3-6]. Original CA model contains of one-dimensional array of L number of cells. Each cell is 7.5m and may be occupied or not. The velocity of the *i*th vehicle, v_i, is an integer between “0” to maximum speed, “V_{max}.” Updating is carried out if the system consists of the following steps:

(1) **Acceleration:** if the velocity v_i of a vehicle is lower than V_{max} and if the distance to the next car a head is larger than v_i+1, the speed is advanced by one [$v_i \rightarrow v_i+1$].

(2) **Slowing down (due to other cars):** if a vehicle *i* sees the next vehicle at site $i+j$, where *j* is the gab a head, (with $j \leq v_i$), it reduces its speed to be [$v_i \rightarrow j-1$].

(3) **Randomization:** with probability *p*, the velocity of each vehicle (if greater than zero) is decreased by one [$v_i \rightarrow v_i - 1$].

(4) **Car motion:** each vehicle is advanced *v* cells.

This paper investigates congestions on the one lane highway traffic system by using Dynamic Traffic Cellular Automata (DTCA) model. [1],[3],[6],[7].

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In this article a brief explanation about Cellular Automata (CA) has been given in the introduction. The follow part provides the details about A Dynamic Traffic Cellular Automata (DTCA), and final part clarifies the new concept on congestion. In this article there are two reasons that create the congestion.

2. Dynamic Traffic Cellular Automata (DTCA)

A Dynamic Traffic Cellular Automata (DTCA) that has been suggested in this paper can be compared with the original CA model. Basically it offers three main differences:

1) In the CA the road is divided into equal length cells, each cell being 7.5 m. A cell may or may not be occupied. The CA model assumes that a vehicle is restricted by fixed position, while the position of the vehicle in the DTCA is not limited with fixed cells on the highway. However, the vehicle in the MCA is viewed as a cell 7.5 m moving through the highway.

2) Nagel and Schreckenberg [1] used fix amount of acceleration and declaration, equal to 1 cell (±7.5 m/s^2). According to Bansal and Brar maximum deceleration is explained in Equation 1.

$$dec_{\max} = G\left(r\cos\theta_v + \sin\theta_v\right) \tag{1}$$

Where G is the gravity (9.81m/s$^{2)}$, r is friction coefficient for dry seal roads (0.6) and θ_v is vehicle angle of inclination of the plane of the horizontal. It is assumed that ε equal to "0". This equation indicates that declaration cannot be greater than 5.886 m/s^2 while in Nagel and Schreckenberg model assumes 7.5 m/s^2, cell length, at all times [8].different decelerations are achieved by different driver habits, road and traffic condtiones. These diffrences are stated by deceleration factor (β). β gives the proportionof the $dec_{\max}$, and it will be $0 \le \beta \le 1$.

$$dec = dec_{\max} \times \beta \tag{2}$$

Similarly, the maximum acceleration ($acc_{\max}$) is 4.905 m/s^2, which is equal to 17.658 km/hr^2. Maximum acceleration leads moving the vehicle from zero to 17.658 km/hr speed in first second. In six second with maximum acceleration the vehicle can approach 106 km/hr, which is reasonable for most vehicles. However, different accelerations are achieved by different driver habits, road and traffic condtiones. These diffrences are stated by acceleration factor (α). α gives the proportionof the $acc_{\max}$. for example α is equal 1then acc will equal to $acc_{\max}$, and it will be $0 \le \alpha \le 1$.

$$acc = acc_{\max} \times \alpha \tag{3}$$

3) The original CA uses one randomazation factor (p) while MCA uses three independent randomazation factors (α, β and p_d). α is acceleration facor, β is decleration factor and p is driver reaction factor. Those factore describe the driving satuation on highways. α and β are very issential to mange of zero or no movment.

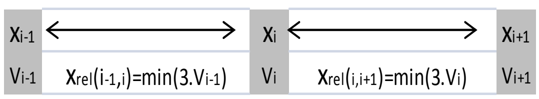

Fig. 1: Relation between the Velocity and the Gabs between the Vehicles on the highway

- Changes in speed due to acceleration

$$\begin{aligned} &\textit{if } v_{i,n} < V_{\max} \ \&\ \varphi \cdot x_{\text{rel}}(i,i+1) > v_{i,n} \\ &\quad \text{then } v_{i,n+1} = v_{i,n} + T \cdot acc \end{aligned} \tag{4}$$

Where i is a cell number

n the sequence number

T is the fixed time and we assume it equal to "1" second

φ is safety factor

- Deceleration

$$if\ v_{i,n} \le \varphi \cdot x_{\text{rel}}(i,i+1)$$
$$\text{then}\ \ v_{i,n+1} = \max\left(v_{i,n} - T \cdot dec_{\max}\ \text{or}\ \varphi \cdot x_{\text{rel}}(i,i+1)/T\right) \tag{5}$$

- Randomization

$$if\ v_{i,n} > 0\ \text{with probability}\ \beta$$
$$\text{then}\ \ v_{i,n+1} = v_{i,n} - T \cdot dec \tag{6}$$

- Car motion

$$x_{i,n+1} = x_{i,n} + T \cdot v_{i,n} \tag{7}$$

2.1 Simulation

We consider *k*cars moving on a strait road, with no inclination, perfect weather and road conditions. The boundary condition adopted in this work is periodic. Since real traffic data can be well described by the parameters $V_{\max}$ = 110 km/h or 30.6 m/s, p = 0.5 and α and β=N(0.4, 0.2). We assume these parameters in our implementation. The length of the evolution time is 2000s.

3. Congestion

Best way to observe the congestion is looking at the:

$$decs(t) = \left| acc_d(t) - acc(t) \right| \tag{8}$$

Where $decs$ is deceleration strength, acc_d is acceleration to desired velocity

$$decs(t) = \left| \frac{dv_d(t)}{dt} - \frac{dv(t)}{dt} \right| \tag{9}$$

Where $V_d(t) \approx V_{\max}$

$$decs(t) = \left| 0 - \frac{dv(t)}{dt} \right| \tag{10}$$

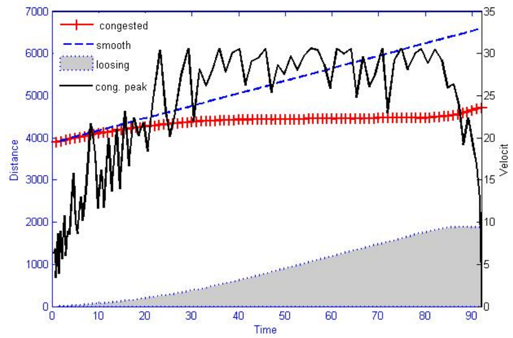

Fig. 2: congestion loos

From the Figure (2) the black curve shows $decs(t)$. There are two things could get it from $decs(t)$ curve: 1) the limits of congestion (where the congestion starts and where it finishes). 2) Observing who the strength of congestion is and when that happened.

Another factor needs to notice is losing (LOSS)

$$LOSS = \int_{t_0}^{t_e} V_d - v(\mathrm{t})\,dt \tag{11}$$

Where t_0 is the time starting congestion and we will assume it as 0, and $t_e$is the time of finishing of congestion. While $V_d \approx V_{\max}$

$$LOSS = \int_0^{t_e} V_{\max} - v(\mathrm{t})\, dt \qquad (12)$$

$$LOSS = V_{\max} - \left(x(t_e) - x(t_0)\right) \qquad (13)$$

$$LOSS = v_{\max} - x(t_e) \qquad (14)$$

Figure (3) illustrates the overview of traffic system in the simulation. It shows the shape and behaviour of congestion in time on the highway. The global observation of the congestion lets us to investigate the reasons why congestions take place and how they are dispersed.

In this figure the movement of vehicle on the highway can be recognized by time and the position at the road. From Figure (3A), it can be observed that the vehicle (1), (**Bolded**), movement during the experiment and it can be recognized the movement through the congestion. Focusing on just small part of Figure (3A) to be appear in Figure (3B), which helps to understand the cluster of vehicles and how each of them can impacts on the next one, also by spotlight on one vehicle and how is it moving with the cluster to understand the reasons of creating of congestions, as well as peaking in demand and a bottleneck regarding to peter [9]. Figures (3 A&B) expressing the essential reasons of congestion, which are speed conflict and delay of start-up movement.

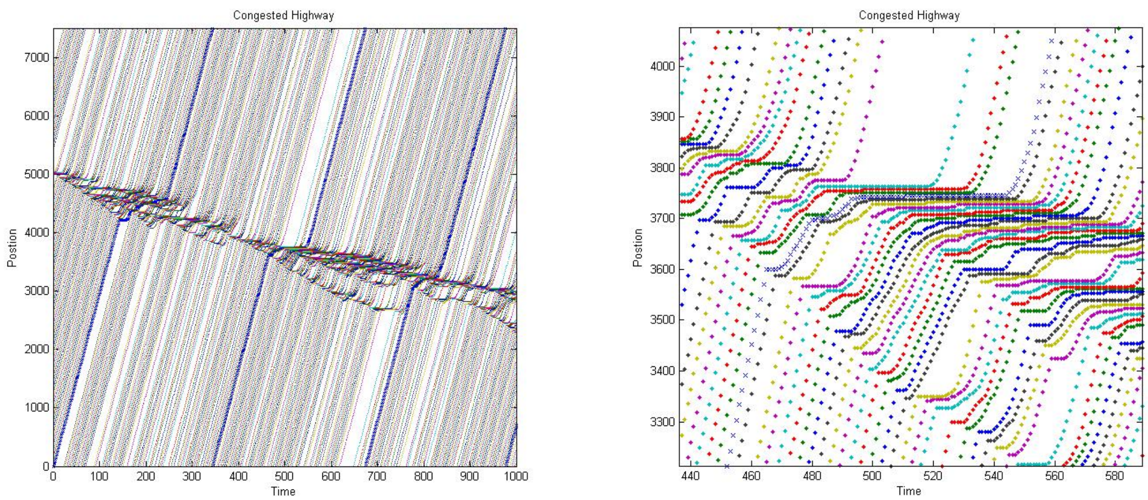

Fig.2: A: congested Highway, B: congested High way foucusing on the congestion

Referring to Figure (2) shows the vehicle (1), in the Figure 3A, movement in two scenarios: 1) during the congestion and 2) during freeway. From the Figure (2), it can be seen the position difference. Congestion in this figure can be explained as time and position delay comparison to desired position at the same time. The gap between the curves of congested and desired vehicles is expanding from starting the congestion to be end. It is also can be observed the strength of congestion for individual vehicle and it is losing.

4. Conclusion

In this article, Dynamic Traffic Cellular Automata has been discussed cooperation with Nagel and Schreckenberg CA model.Finding the time and distance loss equation as result of compression between congested and free highways.Defined acceleration and deceleration factors respectively.

5. Referencing

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