A New Cellular Automata Model for Two Lane Traffic System Incorporating Sensitive Driving and Traffic Light Signals

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***Abstract*- Increasing human population causes rise in many problems and huge traffic on the roads. Many techniques have been used in past to model the traffic flow specially on roads of big cities. Cellular Automata (CA) based models are the best ones to represent the traffic flow in a very realistic way by taking into account the behaviour of individual vehicles. By using CA, different types of traffic flows have been modelled i.e., single-lane traffic, two-lane traffic, sensitive driving in two-lane etc. But now a days traffic lights are essential part of traffic system, so a new model is required which can encompass not only sensitive driving in two-lane but can also take into account the behaviour of vehicles in the presence of traffic lights. In this paper a new novel model is presented for two-lane traffic which incorporates the behaviour of vehicles when traffic light signals are part of traffic system. Proposed model is an enhancement of cellular automata model for two lane traffic based on anticipation effects, information interaction and sensitive driving.**

Keywords-**Cellular Automata, Two Lane Model,**

I. INTRODUCTION

Traffic flow modelling is an important step in the design and control of transportation systems. A distinctive feature of Cellular Automata (CA) models is that they can capture micro-level dynamics and can use this information to state the behaviour of macro-level traffic flow. CA models can represent the complexity of a traffic flow system in a very compact way by taking into account vehicle's different behaviours like acceleration / deceleration, lane changing, reaction due to other vehicles etc. The most striking characteristic of CA models is that they are capable of representing both single lane and multi lane traffic which is important for traffic modelling of highways.

A. Single-Lane Models

Many models have been proposed for single lane traffic, for example NaSch [1], VDR [2], CD [3], MCD [4] and FMCD [5] models. These models represent different characteristics of single lane traffic flow system like minimal features of a traffic flow system, slow to start notion, brake-light influence, synchronized flow, sensitive driving and randomization in update rules.

B. Two-Lane Models

In big cities the traffic system incorporates two lanes or multi lanes so modelling two lane traffic flow system is dire need of the day. There are some parameters that should be considered while modelling two-lane traffic: movement in one-lane and behaviour of vehicles during lane change. During lane change, two points are important, incentive for lane change and safety rules. These lane changing rules were first introduced by Rickert [6] and Knospet [7].

II. RELATED WORK

The basic CA model [8] for one dimensional flow of traffic is Rule 184 given by Wolfram. Many other models are based on this model. According to this rule there are 23=8 possible configurations for a cell and its two immediate neighbors. The rule defining the Cellular Automata must specify the resulting state for each of these possibilities so there are 28=256 possible elementary cellular automata. Stephen wolfram assigned each rule a no from 0 to 255 which has become a standard. Each possible current configuration is written in order: 111,110,…,001,000 and the resulting state for each of these configurations is written in same order and interpreted as binary representation of an integer. This number is taken to be the rule no of the automata. For example 184 is written in binary as 10111000.

NaSch model [1] is a variation of Rule 184. This model is capable of anticipating the realistic behavior of vehicles by taking into account acceleration and deceleration phenomena. According to this model speed of car can be determined as a function of lambda which can be adjusted. Based on one dimensional NaSch model a two-lane traffic model was also investigated, but the update rules were not defined in the same manner as in Nasch model so it could not satisfy the two lane traffic conditions.Another model named VDR [2] was proposed by Barlovic which introduced meta-stable states missing in NaSch model. According to VDR model the randomization probability is dependent on velocity which supports slow to start notion. Knospe and Santen proposed CD [3] model incorporating synchronized flow to some extent .It is an enhancement of

VDR model. This model not only enhances the effect of brake light but also takes into account the phenomena of anticipation which allows the driver to anticipate the behavior of the predecessor vehicle. MCD [4] and FMCD [5] models were then proposed which incorporated all the features of synchronized flow. These models were enhancement of CD model. FMCD model is considered to be the best model depicting the synchronized flow of single-lane traffic. Another one dimensional model FI [9] was proposed by Fukui and Ishibashi which generalizes the cellular automata rule 184.according to this model a car can move by at most sites if there are no cars ahead of it or cars ahead do not block it. The basic difference between NS and FI model is that in NS model a vehicle can move only with the speed of one site at a time but according to FI model it can move many sites at a time. A two dimensional version of the above Fukui-Ishibashi model was presented and elaborated by Wang et al. [12] it considered single-lane traffic by taking into account the exchange of vehicles between the first and the second lane. A new model was proposed by B. Jia, R. Jiang, Q. S. Wu, and M. B. Hu which introduced the Honk effect into the basic symmetric two-lane CA model [10].

III. PROPOSED MODEL

The proposed model is enhanced form of model proposed by Yang-Jie Chu, Xin-wei Chen [11]. But their model does not incorporate behaviour of vehicles in the presence of traffic signal lights which are now essential part of every traffic control system. So the proposed model has the ability to represent all the parameters of an efficient traffic control system. There are two cases of the proposed system, single lane model and two lane model.

A. Single-lane Model

For single lane model following suppositions are made. Vehicle (n+1) represents predecessors of n[th] vehicle. $b_n(t)$ represents brake light of n[th] vehicle at time t. the condition $b_n(t)=0$ if brake light off and $b_n(t)=1$ if light is on. The gap between the predecessor and the nth vehicle is denoted by($d_n=x_{n+1}-x_n-l$) where l is the length of the vehicle, x_n is the position of the nth vehicle. ($t_{r,n}$) denotes the time taken to reach the position of the predecessor. ($t_{s,n}$) denotes the time the nth vehicle will stop. (L_g) represents green signal light. (L_y) represents yellow signal light. (L_r) represents red signal light. (d_{seff}) represents effective distance from signal lights. d_{peff} represents effective distance from the predecessor. ($v_{anti,n+1}$) is the anticipated velocity of (n+1)[th] vehicle in next time step. ($t_{f,n}$) denotes the time that vehicle n moves a velocity larger than(v_c) (speed in synchronized flow). (Pdr) represents predecessor then, the detail of update rules regarding acceleration and braking are expressed in Eqs. (1 to 5).

$$\begin{cases} \textbf{if } (b_{n+1}(t)=0)\,\textbf{OR}\,(t_{r,n}>t_{s,n}) & \textbf{AND}\,(L_g=1)\textbf{, then} \\ v_n(t+1)=v_n(t)+2 & \textbf{if } v_n(t)>0 \\ v_n(t+1)=v_n(t)+1 & \textbf{if } v_n(t)=0 \end{cases} \quad (1)$$

$$\begin{cases} \textbf{if } L_r=1\textbf{, then} \\ V_n(t)=V_n(t)-d_{seff} & \textbf{if } pdr=0 \\ V_n(t)=V_n(t)-d_{peff} & \textbf{if } pdr=1 \end{cases} \quad (2)$$

$$\begin{cases} \textbf{if } L_Y=1 & & \textbf{then} \\ V_n(t)=V_n(t)+1 & & \textbf{if } V_n(t)=0 \\ & & \textbf{if } V_n(t)>0 \\ \begin{cases} V_n(t)=V_n(t)-2 & \textbf{if } pdr=0 \\ V_n(t)=V_n(t)-d_{peff} & \textbf{if } pdr=1 \end{cases} \end{cases} \quad (3)$$

$$d_{seff}=d_n+(v_{anti,n+1}-\textit{safety gap from signal lights}) \quad (4)$$

$$d_{peff}=d_n+(v_{anti,n+1}-\textit{safety gap from predecessor}) \quad (5)$$

1) Green light ON, Eq.(1): If brake light of (n+1)[th] vehicle is off OR time taken by n[th] vehicle to reach the position of predecessor is greater than the time it will take to stop AND n[th] vehicle is moving then in next interval of time speed of n[th] vehicle will be increased by two units and If brake light of (n+1)[th] vehicle is off OR time taken to reach the position of predecessor is greater than the time it will take to stop AND n[th] vehicle is stationary then in next interval of time speed of vehicle n will be increased by one unit because standing vehicles take time to accelerate.

2) Red light ON, Eq(2): If there is no predecessor, then velocity is reduced by the effective distance from signal light. If there is a predecessor, then speed of vehicle will be decreased based on the effective distance from the predecessor.

3) Yellow Light ON, Eq(3): If vehicle is standing at the signal due to red light and it turns yellow, then velocity of vehicle will be increased by one unit. If vehicle is moving and it encounters a traffic signal and signal light is yellow and there is no predecessor, then its velocity will be decreased by 2 units. If vehicle is moving and it encounters yellow light and there is a predecessor, then its velocity will be decreased based on effective distance from the predecessor.

According to Eq. (6), the velocity of the vehicle can be reduced by one unit due to any reason if required.

Normally the randomization is applied before braking phenomena. If vehicle is moving in synchronized flow for a long time and it encounters green light, then it will keep on moving with the same speed. Else. if it does not encounter green light then it will have to stop. Eq. (7) shows the calculation of synchronized folw. Position of car is updated by the speed it is moving, which is equal to $x_n(t+1) = x_n + v_n(t+1)$

$$Randomization: \begin{cases} if\ rand() & < & P_n(t+1) \\ V_n(t+1) & = & V_n(t+1)-1 \end{cases} \quad (6)$$

$$Synchronized: \begin{cases} if\ V_n(t+1) \geq V_c \quad AND\ L_g = 1 \\ t_{f,n} = t_{f,n} + 1 \\ else \\ t_{f,n} = 0 \end{cases} \quad (7)$$

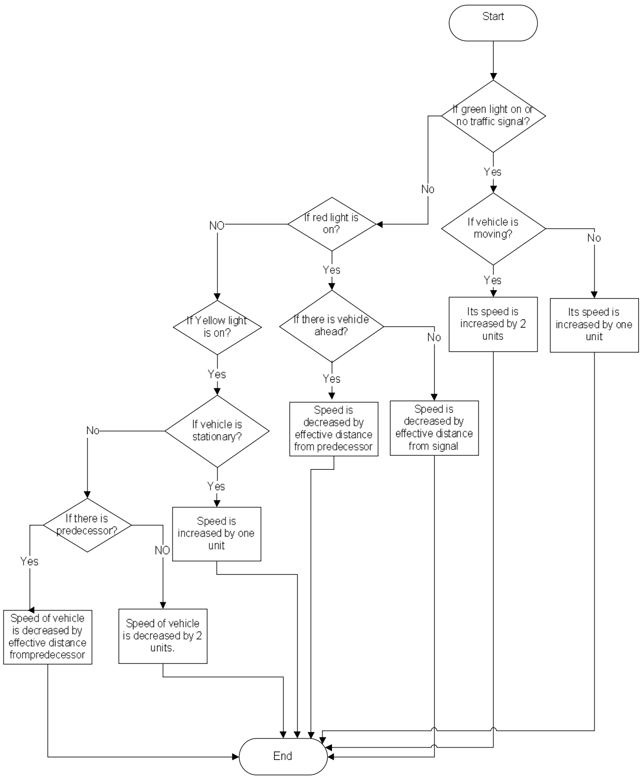

Fig. 1 Flow chart of cellular automata lane model rules.

B. Two-lane Model

Incentive and safety criteria are the two prerequisites of lane changing. Eq. (8) shows the incentive for lane change. It means, brakes are not applied by n^{th} vehicle and its velocity is greater than (d_n) and if traffic lights are encountered and green light is on then it will decide to change the lane. Eqs. (9, 10) shows the safety criteria, where (d_{npeff}) is the effective distance between the n^{th} vehicle and its new predecessor if it changes lane. (d_{succ}) denotes the gap between the n^{th} vehicle and its successor in the new lane. ($V_{succ}(t)$) denotes the speed of the new successor. So if criteria in Eq. (8) & Eq. (9) are fulfilled then n^{th} vehicle will turn on its lane changing lamp. Now whether it change lane or not depends on Eq. (10) means it will depend on the behavior of its successor in the target lane that whether it change its speed or not. So if the successor in new lane slow down its velocity then the lane change will be performed otherwise the n^{th} vehicle will turn off its lane changing lamp. Flow chart of cellular automata model rules is shwon in Fig 1.

$$Incentive: \begin{cases} b_n(t) & = & 0 \\ V_n(t) & > & d_n \\ L_g & = & 1 \end{cases} \quad (8)$$

$$Safety\ Criteria_1 : \{ d_{npeff} \quad \geq \quad V_n(t) \quad (9)$$

$$Safety\ Criteria_2 : \{ d_{succ} \quad > \quad V_{succ}(t) \quad (10)$$

IV. CONCLUSION

Traffic jams and accidents are issues of serious concern these days. To anticipate the flow of trafffic many strategies are used in past but CA is the most popular one. The ability of its simple rules to model the complex behaviour of vehicles in critical situations is the main reason of its popularity in modelling traffic systems. Many one lane and two lane models have been proposed which address different issues of traffic system but uptill now traffic system with traffic lights was not given a serious consideration. In these days traffic system cannot be made safe without traffic lights so behaviour of vehichles needs to be studied and modeled in their presence. So in this paper a new model for two lane traffic system is proposed which not only take into account the parameters of sensitive driving but also incorporates the behavior of vehicles in the presence of traffic lights. In this way the proposed model covers all the aspects of a two lane traffic system in big cities and it will help in regulating the traffic system, avoiding traffic jams and accidents.

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