Simulation of Traffic Flow at a Signalised Intersection

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Abstract. We have developed a Nagel-Schreckenberg cellular automata model for describing of vehicular traffic flow at a single intersection. A set of traffic lights operating either in fixed-time or traffic adaptive scheme controls the traffic flow. Closed boundary condition is applied to the streets each of which conduct a uni-directional flow. Extensive Monte Carlo simulations are carried out to find the model characteristics. In particular, we investigate the dependence of the flows on the signalisation parameters.

1 Introduction

Modelling the dynamics of vehicular traffic flow by cellular automata has constituted the subject of intensive research by statistical physics during the past years [1,2,3]. *City traffic* was an early simulation target for statistical physicists [4,5]. Evidently the optimisation of traffic flow at a single intersection is a preliminary but crucial step to achieve the ultimate task of global optimisation in city networks [6]. In principle, the vehicular flow at the intersection of two roads can be controlled via two distinctive schemes. In the first scheme, the traffic is controlled without traffic lights [7]. In the second scheme, signalised traffic lights control the flow. Our objective in this paper is to study in some depth, the characteristics of traffic flow and its optimisation in a single intersection with closed boundary condition.

2 Description of the Problem

Imagine two perpendicular one dimensional closed chains each having L sites and unidirectional vehicular traffic flows. They intersect each other at the middle sites $i_1 = i_2 = \frac{L}{2}$ on the first and the second chain. With no loss of generality we take the flow direction in the first chain from south to north and in the second chain from east to west. (see Fig.1 for illustration). Cars are not allowed to turn. Each car occupies an integer number of cells denoted by L_{car}. Time elapses in discrete steps of Δt and velocities take discrete values $0, 1, 2, \cdots, v_{max}$ in which v_{max} is the maximum velocity. To be more specific, at each step of time, the system evolves under the Nagel-Schreckenberg (NS) dynamics [8]. The length of each car is taken 4.5 metres. Therefore, the spatial grid Δx (cell length) equals to $\frac{4.5}{L_{car}}$ m. We take the time step $\Delta t = 1$ s. Furthermore, we adopt a speed-limit

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of 75 km/h. In addition, each discrete increments of velocity signifies a value of $\Delta v = \frac{4.5}{L_{car}} m/s$ which is also equivalent to the acceleration. Moreover, we take the value of random breaking parameter at $p = 0.1$.

3 Fixed Time Signalisation of Lights

In this scheme the period T,*cycle time*, is divided into two phases. In the first phase with duration T_g, the lights are green for the northward street and red for the westward one. In the second phase which lasts for $T - T_g$ timsteps the lights change their colour. The gap of all cars are update with their leader vehicle except those two which are the nearest approaching cars to the intersection. For these approaching cars gap should be adjusted with the signal in its red phase. The streets sizes are $L_1 = L_2 = 1350\ m$ and we take $L_{car} = 5$. The system is update and after transients, two streets maintain steady-state currents denoted by J_1 and J_2 which are defined as the number of vehicles passing from a fixed location per time step. In general, the dependence of total current on ρ_1 depends on the value of T_g. Except for small values of T_g, total current increases with ρ_1 then it becomes saturated at a lengthy plateau before it starts its linear decrease. We have also examined the behaviour of J_{tot} for other values of ρ_2. Figures (2) exhibits the result for $\rho_2 = 0.05$. Our simulations confirm that for small ρ_2 up to 0.1 total current shows a distinguishable dependence on T_g in the entire range of ρ_1 especially in intermediate values. In contrast, for $\rho_2 > 0.1$, we observe no significant dependence on T_g in the intermediate ρ_1 but we observe notable dependence for large ρ_1.

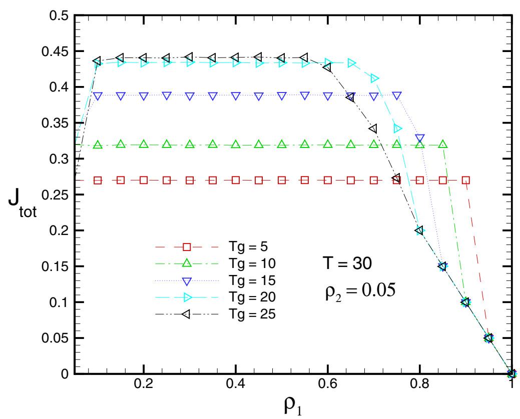

Fig. 1. Total current J_{tot} vs ρ_1 for various values of T_g at $T = 30$

4 Traffic Responsive Signalisation

In this section we present our simulations results for the *so-called* intelligent controlling scheme in which the traffic light cycle is no longer fixed [9,10], the

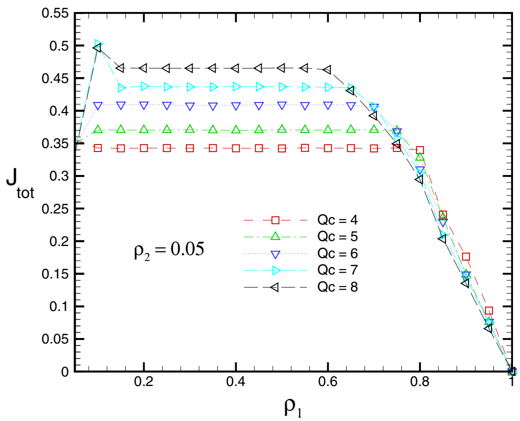

Fig. 2. Total current vs ρ_1 at $\rho_2 = 0.05$ for various values of cut-off lengths Q_c and ρ_2

signalisation of traffic lights is simultaneously adapted to traffic status in the vicinity of intersection. This scheme has been implemented in simulation of traffic flow at intersections with open-boundary conditions [11]. To be precise, we define a cut-off queue length Q_c. The signal remain red for a street until the length of the corresponding queue formed behind the red light exceeds the cut-off length Q_c. At this moment the lights change colour. Apparently due to stochastic nature of cars movement, the cycle time will be subjected to variations and will no longer remain constant. In figure (3) we exhibit J_{tot} versus ρ_1. Analogous to fixed-time scheme, for given ρ_2 a lengthy plateau in J_{tot} forms. The plateau height as well as its length show a significant dependence on Q_c. higher Q_c are associated with smaller length and higher current. We have also examined larger values of ρ_2. The results are qualitatively analogous the above graphs. The notable point is that for ρ_2 larger than 0.1, J_{tot} do not show a significant dependence on ρ_2.

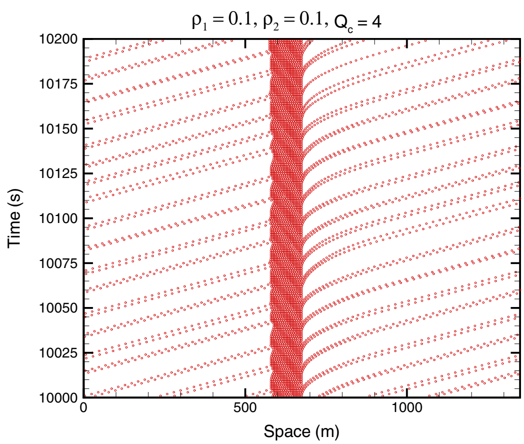

Fig. 3. Space-time plot of vehicles for traffic responsive schemes

To shed some light onto the problem, we sketch space-time plots of vehicles. It is seen that in traffic responsive scheme, the cars spatial distribution is more homogeneous which is due to randomness in cycle times. Lastly, we compare our results to those obtained in simulation of a nonsignalised intersection [7]. It can be concluded that signalisation strategies are apparently more efficient in comparison to non-signalisation scheme.

5 Summary and Concluding Remarks

By extensive Monte Carlo simulations, we have investigated the flow characteristics in a signalised intersection via developing a Nagel-Schreckenberg cellular automata model. We have considered two types of schemes: fixed-time and traffic responsive. In particular, we have obtained the fundamental diagrams in both streets and the dependence of total current on street densities. Our findings show hindrance of cars upon reaching the red light gives rise to formation of plateau regions in the fundamental diagrams. This is reminiscent of the conventional role of a single impurity in the one dimensional out of equilibrium systems. The existence of wide plateau region in the total system current shows the robustness of the controlling scheme to the density fluctuations.

References

1. Chowdhury, D., Santen, L., Schadschneider, A.: Physics Reports 329, 199 (2000)
2. Helbing, D.: Rev. Mod. Phys. 73, 1067 (2001)
3. Kerner, B.: Physics of traffic flow. Springer, Heidelberg (2004)
4. Biham, O., Middleton, A., Levine, D.: Phys. Rev. A 46, R6124 (1992)
5. Nagatani, T.: J. Phys. Soc. Japan 63, 1228 (1994); J. Phys. Soc. Japan 64, 1421 (1995)
6. Chitur, Y., Piccoli, B.: Discrete and Continuous Dynamical Systems B 5, 599 (2005)
7. Foulaadvand, M.E., Belbasi, S.: J. Phys. A: Math, Theor. 40, 8289 (2007)
8. Nagel, K., Schreckenberg, M.: J. Phys. I France 2, 2221 (1992)
9. Webster, F., Cobb, B.: Traffic Signal Setting. H.M.S Office, London (1966)
10. Bell, M.G.: Transp. Res. A 26(4), 303 (1992)
11. Fouladvand, M.E., Sadjadi, Z., Shaebani, M.R.: J. Phys. A: Math. Gen. 37, 561 (2004)