Physica A 391 (2012) 2712–2719

Contents lists available at SciVerse ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Dynamic weight in intelligent transportation systems: A comparison based on two exit scenarios

Chuanfei Dong [a,*], Xu Ma [b]

[a] AOSS Department, College of Engineering, University of Michigan, Ann Arbor, MI 48109, USA

[b] Department of Physics, Syracuse University, Syracuse, NY 13244, USA

ARTICLE INFO

Article history:
Received 8 May 2011
Received in revised form 28 November 2011
Available online 13 December 2011

Keywords:
Dynamic weight
Congestion cluster
Exit scenario
Intelligent traffic systems
Cellular automaton model
Velocity distribution

ABSTRACT

Proposing a good exit scenario can make great contributions to improving road conditions. The influence of two exit scenarios, which depend on the dynamic behavior of the last vehicle (that closest to the exit), on the route flux, vehicle number, and speed by using two feedback strategies with different arrival rates (V_p) was studied. We find that the weight of the route is dynamic instead of static, which depends on the real route conditions. In our case study, we find that the flux threshold value with respect to the necessity of applying information feedback strategy is 0.32 (which corresponds to $V_p \approx 0.65$). Further, we illustrate the velocity distribution plots of each route, which provide us with most of the important information we need, when adopting different feedback strategies and exit scenarios with two arrival rates (V_p).

1. Introduction

In the modern world, traffic congestion problems have become a major issue. Traffic flow and related problems have attracted considerable attention in the past decade [1–5]. Various theories and models have been proposed [6–11] to study the dynamic behavior of vehicular traffic flow, which provide insights that help traffic engineers and other professionals to better manage congestion. Recently, numerous works have been published that report investigations of the dynamic behavior of the traffic flow in scale-free networks [12–19]. Wang and his collaborators [12,13] studied the traffic dynamics based on a local routing protocol in a scale-free network, focusing on both continuous and abrupt phase transitions from a free-flow state to a locally congested state. Besides, they also studied the general dynamics of traffic and routing on a weighted scale-free network [14–16], which is closely related to studies in a weighted traffic system by Dong and his collaborators [20–23]. For example, in the work by Yang et al. [16], they found that there exists an optimal weighting scheme for which cascading failures and traffic congestion can be suppressed significantly; similar results are also shown by Dong et al. [20] in a two-route intelligent traffic system, where they set the weight factor $k = -1.98$ to optimize the road conditions. Further, Barrat, Barthélemy, and Vespignani (BBV) [17] presented an evolutionary model to investigate weighted networks. Inspired by the BBV model, Xie et al. [18] proposed a traffic-driven model to investigate the coevolution of traffic and topology on weighted technological networks by also taking into account the evolution of weight and topology among the old nodes.

Among the large number of research areas, information feedback in intelligent transportation systems (ITSs) has become one of the main streams of research due to its strong capability of improving the road conditions. Recently, some advanced information feedback strategies have been proposed [24–29,22,20,21,23,30,31]. Each feedback strategy has its weakness; for

* Corresponding author. Tel.: +1 4048243966; fax: +1 7346159723.
E-mail address: dcfy@umich.edu (C. Dong).

0378-4371/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.physa.2011.12.010

example, although the Predication Feedback Strategy (PFS) is better than others in terms of improving the road flux [28], the validity of the PFS depends on the length of the route when the transportation system is multi-route, and also the PFS is very time consuming to realize [29]. In order to provide road users with better guidance, a strategy named the Weighted Vehicle Density Feedback Strategy (WVDFS) is presented, which is independent of the length and number of the routes. Further, we investigated the velocity distribution of two routes based on two exit scenarios, depending on the dynamic behavior of the last vehicle, and two different arrival rates V_p, which will be defined in the next section. In the present work, we adopt the two-route model proposed by Wahle et al. [24] with a single route following the Nagel–Schreckenberg mechanism [10] (except for the vehicle closest to the exit).

The structure of the remainder of this paper is as follows. We briefly introduce the NS model, the two-route scenario proposed by Wahle et al. [24], and two feedback strategies, Congestion Coefficient Feedback Strategy [27] and WVDFS, in Section 2. We present and discuss the simulations and analyze the results in Section 3. Finally, we present some conclusions in Section 4.

2. The model and feedback strategies

2.1. NS mechanism and two-route scenario

The rules of the NS mechanism for updating the position x_i of a car are as follows: (i) Acceleration: $v_i(t) \to v_i\left(t+\frac{1}{3}\right) = \min[v_i(t)+1, v_{\max}]$. (ii) Deceleration: $v_i\left(t+\frac{1}{3}\right) \to v_i\left(t+\frac{2}{3}\right) = \min\left[v_i\left(t+\frac{1}{3}\right), g_i(t)\right]$, so as to avoid collisions, where $g_i(t)$ is the spacing in front of the ith vehicle. (iii) Random brake: with a certain probability p, $v_i\left(t+\frac{2}{3}\right) \to v_i(t+1) = \max\left[0, v_i\left(t+\frac{2}{3}\right)-1\right]$. (iv) Movement: $x_i(t+1) = x_i(t) + v_i(t+1)$.

In the NS model, the road is divided into cells (sites) with length $\Delta x = 7.5$ m. The total length of the route is set to be $L = 2000$ cells (corresponding to 15 km). The vehicle density can be defined as $\rho = N/L$, where N denotes the number of vehicles on one route and L is the route length. A time step corresponds to $\Delta t = 1s$, the typical time a driver needs to react. The flux of one route can be defined as $F = V_{avg}\rho = V_{avg}\frac{N}{L}$, where V_{avg} denotes the average velocity of all the vehicles on one route. In the present paper, we set the maximum velocity $v_{\max} = 3$ cells/time step (corresponding to 81 km/h, and thus a reasonable value) for simplicity.

Recently, Wahle et al. [24] investigated a two-route model. In their model, a percentage of drivers (referred to as dynamic drivers) choose one of the two routes according to the real-time information displayed on the roadside. In their model, the two routes A and B are of the same length L. A new vehicle will be generated at the entrance of the traffic system with arrival rate V_p at each time step. If a driver is a so-called static one, he/she enters a route at random, ignoring any advice. The density of dynamic and static travelers is S_{dyn} and $1 - S_{dyn}$, respectively. Once a vehicle enters one of the two routes, the motion of it will follow the dynamics of the NS model (except the vehicle closest to the exit). In our simulations, a vehicle will be removed after it reaches the end point. It is important to note that, if a vehicle cannot enter the preferred route, it will wait till the next time step rather than entering the unpreferred route.

2.2. Exit scenario

Fig. 1 illustrates the "one entrance and one exit" structure of the traffic system. The first exit scenario is as follows.

(a) The special velocity update mechanism for the vehicle nearest to the exit is as follows.
  (i) velocity(t) = Min(velocity$(t)+1, 3)$, (probability: 75%).
  (ii) velocity(t) = Max(velocity$(t)-1, 0)$, (probability: 25%).
(b) The rules at the exit when vehicles are competing for exiting are as follows.
  (i) At the end of two routes, the vehicle nearer to the exit goes first.
  (ii) If the vehicles at the end of two routes have the same distance to the exit, the faster a vehicle is driven, the sooner it leaves.
  (iii) If the vehicles at the end of two routes have the same speed and distance to the exit, the vehicle in the route which has more vehicles leaves first.
  (iv) If rules (i), (ii), and (iii) are satisfied at the same time, then the vehicles go out randomly.
(c) velocity(t) = position(t) − position$(t-1)$, where position$(t) = L = 2000$; (valid only for the vehicles that failed in competing for leaving at the exit).

Here, we want to stress that the vehicle nearest to the exit will not obey the NS mechanism but the special mechanism as shown in rule (a). However, vehicles following the vehicle closest to the exit still obey the NS mechanism. One should also be aware that, if the vehicle nearest to the exit does not compete with the vehicle on the other route for exiting or wins in the competition, the vehicle will ignore rule (c). The special velocity update mechanism (rule (a)) is equivalent to the situation that 75% of drivers exhibit aggressive behavior and 25% of drivers exhibit timid behavior near the exit, which is similar to that in the recent work studied by Laval and Leclercq [32]. However, drivers that exhibit timid behavior at one time step may also exhibit aggressive behavior at another next time step, otherwise timid drivers may stop at the exit forever. Finally, we