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An extended car following approach using agent based model on evacuation system of micro traffic

Tri Harsono[1,2], Achmad Basuki[1,2], Kohei Arai[1]
[1] Information Science Department Saga University, Saga Japan
[2] Electronic Engineering Polytechnic Institute of Surabaya Indonesia
triharsono69@yahoo.com; basukieepis2008@yahoo.com; arai@is.saga-u.ac.jp

Abstract

We proposed an extended car-following approach on evacuation system of micro traffic. It is based on the agent model. Parameter which is owned by the agent is the velocity. We added one driving behavior in the car-following a smart driver. Characteristics of smart driver he has a concern for the distance between his vehicle with the vehicle in front of him so that he will change the speed based on aforementioned conditions. Smart driver is determined randomly, and he can become an agent. In the simulation, we observed the evacuation time toward the smart driver and the mean speed respectively based on the number of agents.

Keyword: car-following, micro traffic, smart driver, agent based model, evacuation time

1. Introduction

The traffic flow studies using microscopic simulations had been leap occurring with the advancement of computer technology in the last one and half decade [1][2]. The evacuation system in the micro traffic simulation has been studied and reported a couple of years ago. In the early stage, some examples of micro traffic simulation regarding to emergency evacuation are provided by [3][4]. The modeling system of emergency evacuation in the traffic [5][6][7] has chosen to estimate evacuation time from an affected area using static analysis tools at the macroscopic or microscopic level. Two basic components of agent-based modeling are (1) a model of the agents and (2) a model of their environment provided by Deadmann P.J. [8]. Individual agents make decisions based on interactions with other agents and localized knowledge [9].

How evacuation time can be affected under different evacuation scenarios, such as opening an alternative exit, invoking traffic control, changing the number of vehicles leaving a household was observed based on agent-based simulation techniques[10]. Neighborhood evacuation plans in an urbanized wild land interface described by Cova T.J. [11] using agent-based simulation. They were able to assess the spatial effects of a proposed second access road on household evacuation time in a very detailed way. Studies [3]-[7], [10] and [11] enhanced the great benefits of agent-based modeling and simulation in studying emergency evacuation. Study of investigation of the effectiveness of simultaneous and staged evacuation strategies using agent-based simulation was presented [12] with three different road network structures. They measured the effectiveness based on total time of evacuation in affected area.

One important part of the micro traffic is car-following (CF). Studies of car-following models have been proposed to describe the interaction between drivers and vehicles. Car-following model is an important evaluation tool for intelligent transportation system strategies since 1990. CF theories based on the assumption that each driver reacts in some specific way to a stimulus from the vehicle in front of him. A very attractive microscopic traffic model called the optimal velocity model (OVM) proposed by Bando [14]. It was based on the idea that each vehicle has an optimal velocity, which depends on the following distance of the preceding vehicle. Despite its simplicity and its few parameters, the OVM can describe many properties of real traffic flows, such as the instability of traffic flow, the evolution of traffic congestion, and the formation of stop-and-go waves.

OVM has been calibrated using empirical data by Helbing and Tilch [15]. They stated that when using empirical data OVM has the weaknesses, it has a too high acceleration and unrealistic deceleration. Helbing and Tilch have completed these problems by using a generalized force model (GFM) [15]. Jiang and Wu [16] investigated and stated that GFM cannot describe the delay time δt and the kinematic wave speed at jam density c_j properly. They put forward the full velocity difference model (FVDM) [16]. FVDM has too high deceleration since empirical deceleration and acceleration are limited between the certain regions [-3m/s^2,4m/s^2] [15][17].

In order to improve the OVM and considering the Intelligent Transportation System (ITS) application, H.X. Ge et al. put forward a new model taking into account the velocity difference Δv_n and Δv_{n+1}, where $\Delta v_n \equiv v_{n+1} - v_n$ [17]. They obtain a more useful model called the two velocity difference model (TVDM). TVDM has shown that unrealistically high deceleration does not appear when they simulate the deceleration progress of two cars. Car-following models [14]-[17] known as time-continuous models. They have in common that they are defined by ordinary differential equations describing the complete dynamics of the vehicle's positions x and velocity v. In this study car-following proposed based on stochastic traffic cellular automaton (STCA) [1][13].

Aforementioned studies above about evacuation simulation described how to evacuate all residents in affected area [3]-[7], [10]-[12]. Our study evacuates vehicles in affected road using agent-based modeling. We conduct micro traffic agent-based modeling and simulation for assessment of evacuation time from the suffered area. In the micro traffic agent-based modeling and simulation, road traffic (probability of vehicle density), driving behavior such as probability of lane changing, car-following are taken into account. In this study has proposed one parameter for the car-following. This parameter is a smart driver. The number of smart drivers will be determined by probability. A smart driver can be an agent. For the next, the term smart drivers written by diligent drivers. Although the proposed simulation is based on the Nagel-Schreckenberg proposed traffic cellular automata [1][13], lane changing and car-following parameters are specific to the proposed simulation.

Following section describes the model used in the proposed micro traffic agent-based modeling and simulation together with the parameter setting for the simulation. Then simulation results are followed by together with some discussions and conclusions.

2. Model

Parameter proposed in the car-following is smart drivers (diligent drivers). A diligent driver can be an agent. Either the diligent driver or the agent is a parameter in the car-following. Traffic flow rules used in this study is based on the Nagel-Schreckenberg traffic cellular automaton (TCA) [1][13]. Lane of traffic used in this study using 2 lanes (multi-lane traffic). Accordance our expression above that driving behavior such as probability of lane changing and car-following is taken into account.

The basic implementation of driving behavior a lane-changing model in a TCA setting, leads to two sub steps that are consecutively executed at each time step of the cellular automata (CA):

- first, the lane-changing model is executed, exchanging vehicles between *laterally* adjacent lanes,
- then, all vehicles are moved forward (i.e., *longitudinal*) by applying the car-following part of the TCA model's rules.

Our proposed driving behaviour has rule and steps:

- *lane changing*

$$x_{(i=2,\,j)}(t)=0 \Rightarrow x_{(i=2,\,j)}(t) \leftarrow x_{(i=1,\,j)}(t\text{-}1) \quad (1)$$

or

$$x_{(i=1,\,j)}(t)=0 \Rightarrow x_{(i=1,\,j)}(t) \leftarrow x_{(i=2,\,j)}(t\text{-}1) \quad (2)$$

i = 1, 2; with probability of lane changing PL.

- *car-following*

$$x_{(i,\,j)}(t) \leftarrow x_{(i,\,j)}(t - 1) + v(t) \quad (3)$$

if $x_{(i,\,j)}(t - 1)$ non smart driver (diligent driver)
$v(t) = v$ (v mean speed)
if $x_{(i,\,j)}(t - 1)$ smart driver (diligent driver)
$v(t) = v + c$ which $c = [0{:}v]$
if $x_{(i,\,j)}(t - 1)$ agent
$v(t) = v + \lambda c$ which $\lambda = 1, 2, \dots$

Thus the full rules proposed for the driving behavior is

i. acceleration

$$v_{(i,\,j)}(t) < v \Rightarrow v_{(i,\,j)}(t) \leftarrow v_{(i,\,j)}(t\text{-}1) + 1 \quad (4)$$

ii. braking

$$gs_{(i,j)}(t\text{-}1) \le v_{(i,\,j)}(t) \Rightarrow v_{(i,\,j)}(t) \leftarrow gs_{(i,j)}(t\text{-}1) - 1 \quad (5)$$

($gs_{(i,j)}(t)$ space gap at each time step t)

iii. randomization

$$\xi(t) < p \Rightarrow v_{(i,\,j)}(t) \leftarrow \max[0,\, v_{(i,\,j)}(t) - 1] \quad (6)$$

iv. car-following

$$x_{(i,\,j)}(t) \leftarrow x_{(i,\,j)}(t - 1) + v(t) \quad (7)$$

if $x_{(i,\,j)}(t - 1)$ non smart driver (non diligent driver)
$v(t) = v$ (v mean speed)
if $x_{(i,\,j)}(t - 1)$ smart driver (diligent driver)
$v(t) = v + c$ which $c = [0{:}v]$
if $x_{(i,\,j)}(t - 1)$ agent
$v(t) = v + \lambda c$ which $\lambda = 1, 2, \dots$

v. lane changing

$$x_{(i=2,\,j)}(t)=0 \Rightarrow x_{(i=2,\,j)}(t) \leftarrow x_{(i=1,\,j)}(t\text{-}1) \quad (8)$$

or

$$x_{(i=1,\,j)}(t)=0 \Rightarrow x_{(i=1,\,j)}(t) \leftarrow x_{(i=2,\,j)}(t\text{-}1) \quad (9)$$

i = 1, 2; with probability of lane changing PL.

vi. car following

$$x_{(i,\,j)}(t) \leftarrow x_{(i,\,j)}(t - 1) + v(t) \quad (10)$$

if $x_{(i,\,j)}(t - 1)$ non smart driver (diligent driver)
$v(t) = v$ (v mean speed)
if $x_{(i,\,j)}(t - 1)$ smart driver (diligent driver)
$v(t) = v + c$ which $c = [0{:}v]$
if $x_{(i,\,j)}(t - 1)$ agent
$v(t) = v + \lambda c$ which $\lambda = 1, 2, \dots$

The rule above for increasing the speed of a vehicle and braking to avoid collision, i.e., rule Eq. (4) as well as rule Eq. (7) for the actual vehicle movement. There is an additional rule Eq. (6), which introduces stochasticity in the system. At each time step t, a random number $\xi(t) \in [0,1]$ is drawn from a uniform distribution. This number is then compared with a stochastic noise parameter p

∈ [0,1] called the slowdown probability, as a result there is a probability of p that a vehicle will slow down to $v_{(i,j)}(t) - 1$ cells/time step. Sven Maerivoet and Bart De Moor [13] presented that the STCA model is called a minimal model, in the sense that all these rules are a necessity for mimicking the basis features of real-life traffic flows. According

Nagel and Schreckenberg [1], the randomisation of rule Eq. (6) captures natural speed fluctuations due to human behaviour or varying external conditions. The rule introduces overreactions of driver when braking, providing the key to the formation of spontaneously emerging jams.

3. Time-space diagram and k-q diagram

To get an intuitive feeling for our system dynamics, we have provided two time–space diagrams in Fig. 1. Both diagrams show the evolution for a global density of k = 0.2 vehicles/cell., but with diligent driver *(dd)* set to 0.25 for the diagram (a), and *dd* = 0.5 for the diagram (b). As can be seen in both diagrams, the randomization in the model gives rise to many unstable artificial phantom mini-jams. The downstream fronts of these jams smear out, forming unstable interfaces. This is a direct result of the fact that the intrinsic noise (as embodied by *p*) in the STCA model is too strong: a jam can always form at any density, meaning that breakdown can (and will) occur, even in the free-flow traffic regime [13].

For low enough densities however, these jams can vanish as they are absorbed by vehicles with sufficient space headways or by new jams in the system [13]. It has been experimentally shown that below the critical density, these jams have finite life times with a cut-off that is about 5×105 time steps and independent of the lattice size. When the critical density is crossed, these long-lived jams evolve into jams with an infinite life time, i.e., they will survive for an infinitely long time [18].

Being stated by [19] that when vehicles are not impeded by other traffic they travel at a maximum speed (*free speed*) then at free speed, flow rate *q* and density *k* will be close to zero. It also occurred in our simulation results in our model shown in Fig.2. On saturated roads (large density), Fig.2 show the flow rate *q* is down to smaller one (the vehicles are queuing). This state is appropriate with phenomena of traffic flow stated by [19][13].

4. Simulations

We apply our proposed car-following approach on traffic with the specification: road shape straight road, road length 200 cells, 2 traffic lanes, mean speed of vehicle 3 cells/time steps, and deviation of vehicle speed 2 cells/time steps. Evacuation time is measured by the total time needed for evacuation. We evaluate evacuation time toward diligent driver and mean speed respectively based on the number of agents.

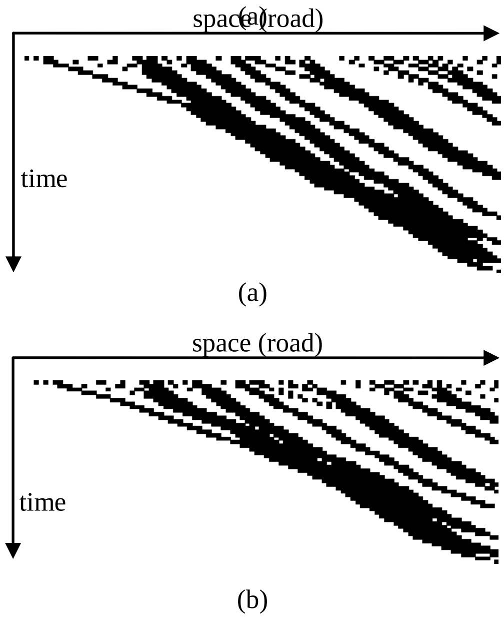


Fig. 1. Simulated traffic (a). at a density 0.2 (20%) and diligent driver 0.25 (25%) (b). at a density 0.2 (20%) and diligent driver 0.5 (50%). Each new line shows the traffic lane after one further complete velocity-update and just before the car motion. It is only on a single lane (space-time diagram).

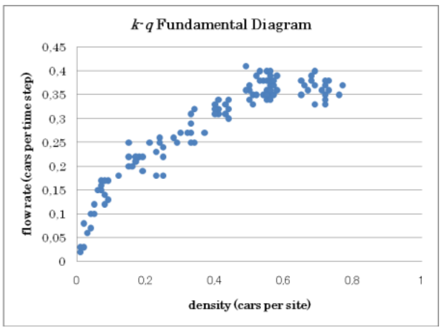
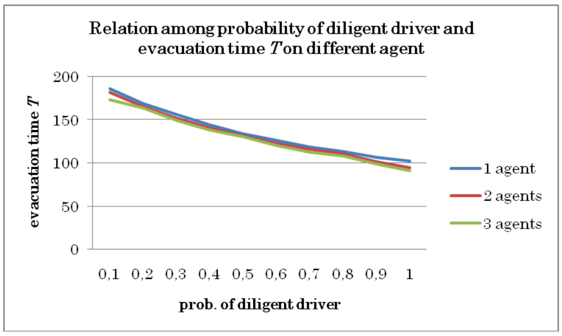


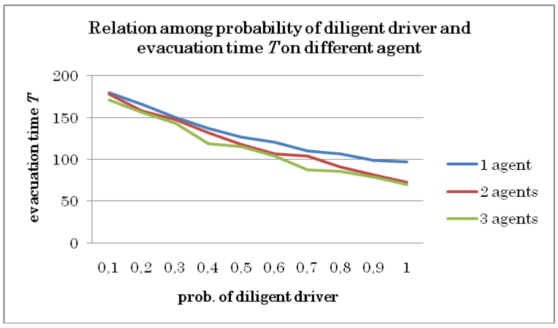
Fig.2. Flow rate *q* (cars per time step) *vs* density *k* (cars per site) from simulation results (*k-q* diagram).

Fig.3. show relation among probability of diligent driver and evacuation time *T* on different number of agents. The number of agents used in this simulation 1, 2, and 3 agents. Fig. 3(a) relation between both of them using density 0.6 and probability of lane changing *PL* = 0.2, and Fig. 3(b) their relation using density 0.6 and probability of lane changing *PL* = 0.6. Either graph of 3(a) or 3(b) with different *PL* has the same pattern, when the probability of smart driver or probability of diligent

driver increases causes evacuation time decrease. It occurs in all different number of agents. For instance Fig. 3(b) using density 0.6 and *PL* = 0.6, we can see that evacuation time decrease when the probability of diligent driver increase, it was found either on the number of agents 1, 2 or 3. We see also in these graphs (e.g. Fig. 3 (b)), using the number of agents 2 has evacuation time is shorter than using the number of agents 1, on the same probability of diligent driver. This condition also occurs for the number of agent 3 toward the number of agent 2, using the number of agents 3 has evacuation time is less than using the number of agents 2, on the same probability of diligent driver.



(a)



(b)

Fig.3. Relation among probability of diligent driver and evacuation time *T* on different number of agents. (a) using density 0.6 and probability of lane changing *PL* = 0.2, (b) using density 0.6 and probability of lane changing *PL* = 0.6.

We also observed the relationship between evacuation time *T* with the mean speed *v*, mean speed is one of the parameter in the car-following. In this simulation we use density 0.6, probability of lane changing 0.4, and probability of diligent driver (smart driver) 0.8. The experiment results show that evacuation time *T* decrease when the mean speed *v* increase. This situation occurs for all specification of agent, either the number of agent 1, 2 or 3 all condition show the same pattern (Fig. 4). From Fig. 4 also can be seen that by using the 2 agents in the evacuation simulation, resulting the evacuation time is shorter than the evacuation time produced by using 1 agent (on the same mean speed). Further evacuation system using 3 agents produces evacuation time is shorter than using 2 agents, at the same mean speed.

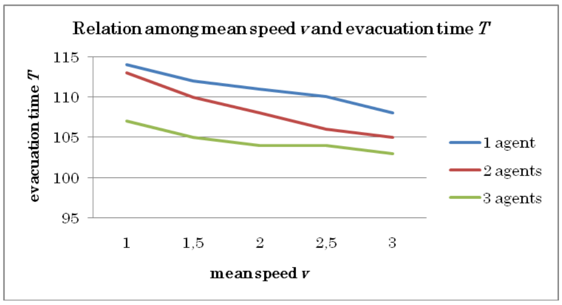
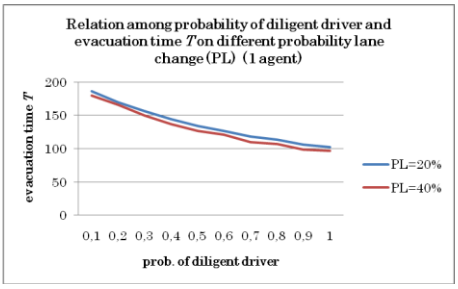
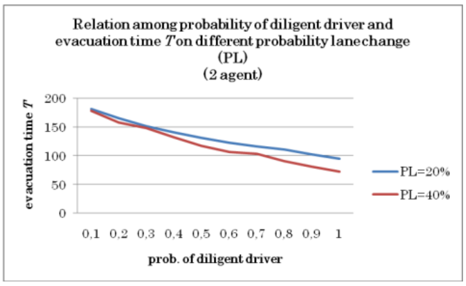


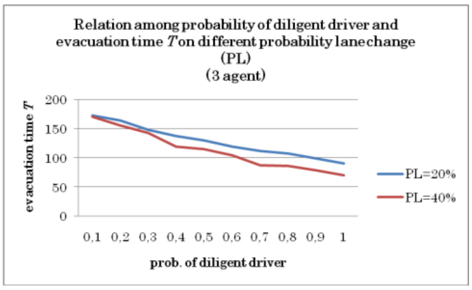
Fig.4. Relation among mean speed *v* and evacuation time *T* using density 0.6, probability of lane changing 0.4, and probability of diligent driver 0.8.



(a)



(b)



(c)

Fig.5. Relation between probability of diligent driver and evacuation time *T* on different probability lane changing *PL*, (a) using 1agent, (b) using 2 agents, (3) using 3 agents.

In this study, the evacuation time was also observed when viewed from the probability of lane changing *PL*. For the simulation we use density 0.6, and *PL* = 0.2, and 04. Fig.5. show simulation results of evacuation system using 1, 2, and 3 agents. Either using the number of agents 1, 2, or 3 agents produces evacuation time with the same pattern. From the graph can be seen that using the value of *PL* = 0.4 in the evacuation system produces evacuation time is shorter than using the value of *PL* = 0.2.This condition occurs either evacuation system using the number of agent 1, 2, or 3 agents.

5. Conclusions

This evacuation simulation studies have observed the evacuation time *T* in terms of one of the driving behaviour parameters (smart driver or diligent driver) and also in terms of one of car-following parameters (the mean speed). This study has proved based on simulation results of evacuation system that evacuation time decreased with the increasing of smart drivers (diligent drivers). This condition occurs in all specification of agent (the number of agents 1, 2, or 3 agents). While observing the evacuation time *T* based on the mean speed *v* have also been proved that evacuation time decreased with the increasing mean speed *v*. This situation occurs in the evacuation system by using the number of agents 1, 2 or 3 agents.

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