The Keep-Right-Except-To-Pass Rule

Summary

As for the first question, it provides a traffic rule of keep right except to pass, requiring us to verify its effectiveness. Firstly, we define one kind of traffic rule different from the rule of the keep right in order to solve the problem clearly; then, we build a Cellular automaton model and a Nasch model by collecting massive data; next, we make full use of the numerical simulation according to several influence factors of traffic flow; At last, by lots of analysis of graph we obtain, we indicate a conclusion as follow: when vehicle density is lower than 0.15, the rule of lane speed control is more effective in terms of the factor of safe in the light traffic; when vehicle density is greater than 0.15, so the rule of keep right except passing is more effective In the heavy traffic.

As for the second question, it requires us to testify that whether the conclusion we obtain in the first question is the same apply to the keep left rule. First of all, we build a stochastic multi-lane traffic model; from the view of the vehicle flow stress, we propose that the probability of moving to the right is 0.7and to the left otherwise by making full use of the Bernoulli process from the view of the ping-pong effect, the conclusion is that the choice of the changing lane is random. On the whole, the fundamental reason is the formation of the driving habit, so the conclusion is effective under the rule of keep left.

As for the third question, it requires us to demonstrate the effectiveness of the result advised in the first question under the intelligent vehicle control system. Firstly, taking the speed limits into consideration, we build a microscopic traffic simulator model for traffic simulation purposes. Then, we implement a METANET model for prediction state with the use of the MPC traffic controller. Afterwards, we certify that the dynamic speed control measure can improve the traffic flow .

Lastly neglecting the safe factor, combining the rule of keep right with the rule of dynamical speed control is the best solution to accelerate the traffic flow overall.

: Cellular automaton model Bernoulli process Microscopic traffic simulator model The MPC traffic control

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1. Introduction

As is known to all, it's essential for us to drive automobiles, thus the driving rules is crucial important. In many countries like USA, China, drivers obey the rules which called "The Keep-Right-Except-To-Pass (that is, when driving automobiles, the rule requires drivers to drive in the right-most unless they are passing another vehicle)".

As for the whole world, the traffic problem has yet to be resolved since it is more closely to our daily life. Traffic problem is increasingly significant. Next, we will address the following issues.

First, we need to build and analyze a mathematical model to analyze the performance of this rule in light and heavy traffic. Then judge the validity of the rule and whether it is effective in promoting traffic flow.

Second, we also should argue whether or not our solution can be carrier over in some countries where driving automobiles on the left.

Lastly, the rule mainly depends on human judgment, so if vehicle on the transportation was under the control of an intelligent system, our earlier analysis would be changed, what extent would it changed?

2. Analysis of the problem

For the first question, we decide to use the Cellular automaton to build models, then analyze the performance of this rule in light and heavy traffic. Firstly, we mainly use the vehicle density to distinguish the light and heavy traffic; secondly, we consider the traffic flow and safe as the represent variable which denotes the light or heavy traffic; thirdly, we build and analyze a Cellular automaton model; finally, we judge the rule through two different driving rules, and then draw conclusions.

For the second, we address the problem of the Cellular automaton model whether can be used in the countries where drive vehicles in the left through Bernoulli process.

For the last, because vehicle transportation on the same roadway was fully under the control of an intelligent system, we integrate the feature of the intelligent vehicle control system with the conventional traffic control system. With the application of the intelligent system, we try to verify the effectiveness for improving the traffic flow. The following, in terms of the analysis result proposed in the problem one, we try to make it effective by adjusting flexibly.

3. Assumption

In order to streamline our model we have made several key assumptions

- The highway of double row three lanes that we study can represent multi-lane freeways.
- The data that we refer to has certain representativeness and descriptive

- Operation condition of the highway not be influenced by blizzard or accidental factors
- Ignore the driver's own abnormal factors, such as drunk driving and fatigue driving
- The operation form of highway intelligent system that our analysis can reflect intelligent system
- In the intelligent vehicle system, the result of the sampling data has high accuracy.

4. Symbol Definition

i	The number of vehicles
t	The time
$x_i(t)$	The position of vehicle i at time t
$v_i(t)$	The speed of vehicle i at time t
p	The random slowing down probability
R	The proportion of trucks and buses
gap_i	The distance between any two cars
$gap_i^f(t)$	The distance between the vehicle and the nearest front vehicle
$gap_i^b(t)$	The distance between the vehicle and the nearest following vehicle
gap_{safe}	The minimum safe distance
$v_{control}$	The minimum speed of the corresponding lane
P_d	A parameter that can be the lane changing probability
N_{CAR}	The number of small vehicles on the driveway
N_{truck}	The number of trucks and buses on the driveway
L	The total length of the road
Q	The number of vehicles passing a fixed point per unit time
P_f	The evaluation indicator of the safety of traffic flow
P_{f1}	The overtaking ratio of small vehicles over large vehicles
P_{f2}	The overtaking ratio of small vehicles over small vehicles

P_{f3}	The overtaking ratio of large vehicles over small vehicles
P_{f4}	The overtaking ratio of large vehicles over large vehicles
X_a	The average speed of all the vehicles
X_{a1}	The average speed of all the small vehicle
X_{a2}	The average speed of all the buses and trucks
$d_i(t)$	The desire for lane-changing
$s_i(t)$	The stress parameter
$s_i(t+1)$	The accumulated stress
$P_R(x)$	The probability functions of lane-changing to the right lane
$P_L(x)$	The probability functions of lane-changing to the left lane
$J_{perf}(k)$	The corresponding performance function
T_{ctrl}	The controller time step
$N(0)$	The number of vehicles
K	The number of time steps
q_{dem}	The constant demand used for the simulation
q_{out}	The outflow measured at the $20th$ segment

5. Models

By analyzing the problem, we decided to propose a solution with building a cellular automaton model.

5.1 Building of the Cellular automaton model

Thanks to its simple rules and convenience for computer simulation, cellular automaton model has been widely used in the study of traffic flow in recent years.

We study the three lanes in one direction of a two- way six-lane highway in this paper. Considering the road as three one-dimensional discrete grid point chains in parallel, we define

the length of each chain is L, and each grid point will be occupied or empty at each moment. The first lane is the far left one, the second lane is the middle one, and the third lane is the far right one. Vehicles traveling on the highway are concluded as small vehicles (including cars, mini-buses, etc.), trucks and buses in this paper. And the three types of vehicles are randomly distributed in three lanes according to certain density and mixing ratio. Each small vehicle accounts for 1cell space, and each truck accounts for 3 cell space. The speed of small vehicles is 0–120km/h on highway, corresponding to 0–6cell space/s of the model and that of trucks and buses on highway is 0–100km/h, corresponding to 0–5 cell spaces.

Let $x_i(t)$ be the position of vehicle i at time t, $v_i(t)$ be the speed of vehicle i at time t, p be the random slowing down probability, and R be the proportion of trucks and buses, the distance between vehicle i and the front vehicle at time t is:

$gap_i = x_{i-1}(t) - x_i(t) - 1$, if the front vehicle is a small vehicle.

$gap_i = x_{i-1}(t) - x_i(t) - 3$, if the front vehicle is a truck or bus.

5.1.1 Verify the effectiveness of the keep right except to pass rule

In addition, according to the keep right except to pass rule, we define a new rule called: Control rules based on lane speed. The concrete explanation of the new rule as follow:

There is no special passing lane under this rule. The speed of the first lane (the far left lane) is 120–100km/h (including 100 km/h)；the speed of the second lane (the middle lane) is 100–80km8/h (including80km/h)；the speed of the third lane (the far right lane) is below 80km/h. The speeds of lanes decrease from left to right.

- **Lane changing rules based lane speed control**

If vehicle on the high-speed lane meets $v < v_{control}$, $gap_i^f(t) \ddagger \min(v_i(t)+1, v_{\max})$, $gap_i^b(t) \ddagger gap_{safe}$, the vehicle will turn into the adjacent right lane, and the speed of the vehicle after lane changing remains unchanged, where $v_{control}$ is the minimum speed of the corresponding lane.

If vehicle on the low-speed lane meets $v < v_{control}$, $gap(t) \pounds \min(v_i(t)+1, v_{\max})$ and $gap_i^f(t) \ddagger gap(t)$ and $gap_i^b(t) \ddagger gap_{safe}$, the vehicle will turn into the adjacent left lane with probability p_d, and the speed of the vehicle after lane changing will remain unchanged.

- **The application of the Nasch model evolution**

Rickert et al. examine d a two-lane cellular automaton based on the NaSch model [1].Nagel

et al. summarized different approaches to lane changing and classified the multitude of possible lane-changing rules for freeway traffic [2]. They used a cellular automaton model for two-lane traffic to generate the density inversion, and found in many European countries, the densities somewhat below the maximum flow density. Let al. proposed a symmetric two-lane cellular automata model to investigate the aggressive lane-changing behavior of fast vehicle and the effect of different lane-changing probability [3].

(1) Accelerating: $v_i(t+1/3) = \min(v_i(t)+1, v_{\max})$;

(2) Decelerating: $v_i(t+2/3) = \min(v_i(t+1/3), gap_i)$;

(3) Randomly slowing down with probability: m

(4) Location renewal: $x(t+1) = x(t)+1$.

Let P_d be the lane changing probability (taking into account the actual situation that some drivers like driving in a certain lane, and will not take the initiative to change lanes), $gap_i^f(t)$ indicates the distance between the vehicle and the nearest front vehicle, $gap_i^b(t)$ indicates the distance between the vehicle and the nearest following vehicle. In this article, we assume that the minimum safe distance gap safe of lane changing equals to the maximum speed of the following vehicle in the adjacent lanes.

- **Lane changing rules based on keeping right except to pass**

In general, traffic flow going through a passing zone (**Fig.** 5.1.1) involves three processes: the diverging process (one traffic flow diverging into two flows), interacting process (interacting between the two flows), and merging process (the two flows merging into one) [4].

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