Simulation Research of Vehicle Lane-changing Behavior Evolutionary Game Model Based on NetLogo

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Abstract. Based on evolutionary game theory, the rules of lane-changing behavior on two lane roads are analyzed and formulated. Based on the NetLogo simulation platform, the simulation environment of roads and vehicles are built to give the vehicle acceleration, deceleration, speed keeping and lane changing behavior rules. Through simulation operation, the influence of traffic density, game rules, and changes of driving behavior on the evolution of vehicle lane changing behavior is explored. The simulation results show that the cooperative driving behavior of vehicles is directly related to the degree of civilization named r of the area. When the number of initial cooperative drivers is fixed, the higher the value of R, the more drivers tend to cooperate in the process of driving. There is a close relationship between vehicle cooperative driving behavior and traffic density, vehicle speed and traffic flow status.

Introduction

At present, road traffic safety problems and efficiency problems caused by vehicle lane-changing are becoming more and more prominent. The driver of motor vehicle is still a human driver, so it must have been affected by the incompletely rational characteristics of human drivers. Using classic game theory to study driving lane-changing issue can simplify the problem and improve computing efficiency, but the irrational factors of drivers are not considered. The evolutionary game theory is used to study the problem of vehicle lane-changing behavior, taking full consideration of the driver's incompletely rational psychology, making the process of the research more objective and practical, and providing a new perspective for the research of lane-changing.

Game Analysis and Simulation Implementation

Objects

In china, the traffic rules are asymmetrical. Changing the road from right to left is different from changing from left to right. For a single vehicle lane-changing behavior, it can be generally understood as:

(1) A target vehicle N is trying to change the lane from the right lane to the left lane and a vehicle NB in left lane after that target vehicle, who is the game player of N.

This aggregate can be expressed as: I = {lane-changing vehicle N, target lane vehicle LB}

(2) A target vehicle N that is trying to change lane from the left lane to the right lane, and a vehicle RB in right lane after that target vehicle.

This aggregate can be expressed as: I = {lane-changing vehicle N, target lane vehicle RB}

Payoff Matrix

In the evolutionary game model, the driver who chooses the cooperative behavior needs to pay a profit C. At the same time, the driver of the game will get a profit B, and the profit is defined by the speed of
the vehicle. According to the evolutionary game of vehicles, the changing profit of each round of game will increase or decrease 1% for the next round of vehicle cooperation probability.

Under the general rule, vehicle N, in order to improve his speed and pursue higher returns, always gets a profit B, while his game opponent LB or RB always gets a negative profit C. The return matrix is shown in Table 1.

Table 1. Payoff matrix based on general rules.

| player          | Target vehicle |          |          |
|-----------------|----------------|----------|----------|
|                 | cooperate      | defect   |          |
| Active vehicle  | b , c          | b , c    |          |
| defect          | b , c          | b , c    |          |

For the general rule, the profit matrix does not take into account the social characteristics of drivers in the actual driving process. The following improved income matrix is introduced, which is based on kin selection rule.

In different area, phylogenetic relationships R are different. Because of the degree of civilization between area, the driving concept of drivers is different. In a highly cooperative area, drivers are more inclined to identify other drivers as "relatives". Therefore, the higher the degree of civilization of area, the greater of R.

In each round of game, according to the relationship between target turtles and target turtles, there are different kinship coefficients. Payoff matrix based on kin selection is shown in table 2.

Table 2. Payoff matrix based on kin selection.

| player          | Target vehicle |          |          |
|-----------------|----------------|----------|----------|
|                 | cooperate      | defect   |          |
| Active vehicle  | b+(c*r) , c+(b*r) | b+(c*r) , c+(b*r) |          |
| defect          | b+(c*r) , c+(b*r) | b+(c*r) , c+(b*r) |          |

**Simulation Model Realization based on Evolutionary Game**

According to the actual traffic environment and the traffic objects, the simulation environment is set and arranged. On the NetLogo platform, the two lane road environment is built in the form of tile, and the central separation line is set up between the lanes, allowing the vehicle to operate the lane changing under the premise of the rules. The properties of the lane include the direction from left to right, the width of the lane, the mileage and the color of the road. The vehicle is equipped with different built-in parameters. The main parameters are shown in Table 3. The value of the simulation parameter setting is shown in Table 4.

Table 3. Vehicle parameters.

| Parameter          | Value          |          |          |
|--------------------|----------------|----------|----------|
| Vehicle length     |                |          |          |
| vehicle color      |                |          |          |
| Road length        |                |          |          |
| Vehicle shape      |                |          |          |
| Cooperative behavior label |          |          |          |
| Cooperation coefficient |          |          |          |
| Leftward tendency  |                |          |          |
| Rightward tendency |                |          |          |
| payoffs            |                |          |          |
| Max speed          |                |          |          |
| Velocity discretization parameter |          |          |          |

Table 4. Simulation parameter setting.

| Parameter          | Value          |          |          |
|--------------------|----------------|----------|----------|
| vehicle/m          |                |          |          |
| R_d                |                |          |          |
| R_0                |                |          |          |
| R_s                |                |          |          |
| P_cc               |                |          |          |
| P_dc               |                |          |          |
| Road length/m      |                |          |          |

The NetLogo program language is used to simulate the vehicle behavior. The simulation interface is composed of several parts, which are the initial environment of vehicle and road, the initial state of the vehicle, the control of traffic flow density, the control of the defective vehicle number, the control of the vehicle cooperation, the control of the initial cooperation degree of the defective vehicle, the control of the initial cooperation degree of the cooperative vehicle and the move of the vehicle. The row behavior control and the running result output interface are made up. Road and vehicle
simulation is shown in Figure 1. Figure 2 is an evolutionary game simulation interface for lane changing behavior.

![Figure 1. Road and vehicle simulation.](image1)

![Figure 2. Simulation interface.](image2)

The parameters of the simulation results of the game system are set together by the behavior space option in NetLogo, and the single operation is not carried out on the system page. The data is exported in the format of CSV. After the data is exported, the data is selected and processed in the SQL Server, and the target data is introduced into the R software ggplot2 program package for data analysis.

**Results**

Figure 3-8 show the spatiotemporal shapes of the simulation under different traffic flow density when \( q \) is equal to 0.5, and it revealed the three phase of the traffic flow.

![Figure 3. Density=20veh/km, left lane.](image3)

![Figure 4. Density=20veh/km, right lane.](image4)
Figure 5. Density=40veh/km, left lane. Figure 6. Density=40veh/km, right lane.

Figure 7. Density=80veh/km, left lane. Figure 8. Density=80veh/km, right lane.

Figure 9, 10 evaluated the difference evolution outcome under several different traffic density. The outcome of figure 9 contain evolution outcome under different proportion of the initial driver of cooperative driving. Figure 10 contain the evplution outcome under different degree of r.

Figure 9. The evolutionary results of the proportion of the initial driver of cooperative driving under different traffic density conditions. Figure 10. The evolution of different degree of r under different traffic density conditions.
Conclusion and Discussion

The cooperative driving behavior of vehicles is directly related to the degree of civilization of the area. The higher the value of R, the high inclination the vehicle evolves to cooperative driving behavior.

There is a close relationship between vehicle cooperative driving behavior and traffic density. When the vehicle density is about 40veh/km, the cooperation behavior of vehicles reaches a peak.

When the values of R is equal to 0.5 and the traffic density is about 40veh/km, the time-space diagram shows the synchronous flow state. At this time, the traffic flow is at the peak of about 2000veh/h. The speed difference between vehicles is the least. Vehicle speed is close to 60 km/h, and the cooperative driving behavior among vehicles is the most obvious, about 80%.

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