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Prediction of Traffic State Based on Fuzzy Logic in Vanet

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Abstract: The prediction and identification of traffic state is a basic and important subject in the field of Intelligent Traffic System (ITS). In the previous researches, traffic information is usually gathered through pre-deployed sensors as well as other infrastructures, in which ways large costs are needed. The existing ways for estimating the traffic state mostly show the drawbacks of large computation and hard implementations. In this study, we propose a new way for estimating the traffic flow phase based on VANET communications. Firstly, we collect traffic information through VANET communications to reduce the costs effectively. Then, we present a prediction method based on fuzzy logic and its membership functions. This method shows the advantages of easier implementations and less computation and it can adapt dynamically to take more factors into considerations if needed. The simulation results based on NS2 and MOVE show that our proposed method gains satisfactory accuracy which can be used for further research based on the real-time traffic state.

Key words: VANET, traffic flow, fuzzy logic, state identification

INTRODUCTION

In the prediction of traffic flow, three-phase traffic flow model is commonly used. From 1996 to 2002, Kerner (2009) proposed a three-phase traffic flow model which focuses mainly on method to interpret the nature of the physical principles of traffic jams on the highway and the characteristics of traffic congestion. Furthermore, Kerner divided traditionally congested traffic flow in to synchronized flow and wide movement congestion flow. Therefore, realistic traffic conditions can be classified into three different states: Free-flow (F), Synchronized flow (S) and wide movement congestion flow (J). This three-phase traffic flow model can accurately reflect path different characteristics in different states and the division of the three states agrees with realistic sensory characteristics, as well as a complete theoretical support. Therefore it is widely used.

For decades, experts and scholars around the world have developed a variety of prediction models and methods for forecasting short-term traffic flow by using methods in various disciplines. The measurement data is obtained through sensors, coils and other infrastructures to transmit in traditional traffic forecasting method (Liu and Guan, 2004) which has higher requirements for the early cost. Vaqar and Basir (2009) proposed a new way to get the data in traffic state prediction, in which data is transmitted and processed through the car self-organizing network (VANET). The vehicle equipped with communication capabilities can add acceleration, ID, direction and other information to the transmission message. Facing mainly to intelligent transportation systems applications, VANET is a new type of mobile Ad Hoc networks which is based on communication among moving vehicles or vehicle and roadside nodes. Recently, VANET has been widely attention for the advantage of its transmission of traffic information. In this study, to avoid the waste of coil deployment, VANET network is used to collect data which is related to the vehicle. Meanwhile, inspired by Ref. Weng *et al.* (2006), we put forward a traffic state prediction method based on fuzzy logic theory. And the method has simple principle and a small amount of calculation. What's more, the method can be dynamically adjusted based on needed to take into account more factors which is very suitable for this lightweight computing of in-vehicle network. The simulation results based on NS2 and MOVE show that our proposed prediction method has higher accuracy, based on which related applications in real-time traffic state can be developed further, such as adjusting broadcast message according to traffic flow to improve network performance.

The remainder of this study is organized as follows: In section 2, fuzzy logic subordinate function gives the principle of traffic condition prediction; In section 3, the simulation method is introduced and results are analyzed; Finally, the conclusion is concluded.

THE PREDICTION OF THE TRAFFIC STATE BASED ON MEMBERSHIP FUNCTIONS OF FUZZY LOGIC

Considering the accuracy, complexity and other factors, this study proposes a method of a membership function based on fuzzy logic method(Zadeh, 1965) which

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can be used to predict the traffic state and traffic flow is divided into three states which are free flow, synchronous movement of flow and width blocking flow. Through considering the vehicular speed, the density within the scope of the wireless and other factors, the method makes weighted summation of the membership degree of various factors under each state and then selects the biggest one of the output value of the three states as a predictable result. Before using the method, we need to obtain the membership function of each factor in advance, because different membership functions largely affect the accuracy of the prediction.

Firstly, classifying each factor (such as speed, average speed, speed variance, vehicular density, headway), in order to correspond to the actual traffic conditions, every factor is divided into three categories which, respectively correspond to the free flow, synchronous movement of flow and width blocking flow. Then through the application of the fuzzy logic theory knowledge and test data, the membership function corresponding to each category of each factor can be obtained, this process is called the training process. Thus, after measuring the actual data of a factor (recorded as j, j = 1,... , m) as x, the state i which the data corresponds to can be obtained (i values □□ 1, 2, 3, respectively corresponding to the free flow, synchronous movement of flow and width blocking flow). When considering the m factors analyzing the traffic state, for the i states, the m factors consist of a data set:

$$\{\mu_{\underline{A}_{i,1}}(x), \mu_{\underline{A}_{i,2}}(x), \mu_{\underline{A}_{i,3}}(x) \ldots \mu_{\underline{A}_{i,j}}(x) \ldots \mu_{\underline{A}_{i,m}}(x)\} \quad (1)$$

In the predicting, certain factors are more important than others, we introduce the normalized weighting factor w_i and w_i satisfy the relation:

$$\sum_{j=1}^{m} w_j = 1 \quad (2)$$

Thus, the calculating formula of the predicted value for the state i is set as:

$$\mu_{\underline{A}_i}(x) = \sum_{j=1}^{m} w_j \bullet \mu_{\underline{A}_{i,j}}(x) \ (i=1,2,3 \quad (3)$$

Then we select the state which the maximum value corresponds to as the final predicted state in the values of the last three states:

$$\text{index} = \text{indexof}(\max_{1 \le i \le 3}(\mu_{\underline{A}_i}(x))) \quad (4)$$

where, index donated as 1, 2, 3, respectively corresponding to the free flow, synchronous movement of flow and width blocking flow.

In consideration of all the factors, the velocity calculation needs a special instruction. In reality, the vast majority of drivers want to reach their destinations as quickly as possible while not drive intentionally with a lower speed. Therefore, the speed becomes the most important and the most intuitive factor in the prediction of the traffic state. Because we need to specify a vehicle to predict the state in a certain range, in order to reduce the randomness, the average method is taken to calculate the speed and considering the impact of the speed of all vehicles within the scope, the formula is set as follows:

$$v = (1-\alpha) \bullet v_s + \alpha \bullet \bar{v}_r \quad (5)$$

where v_s is selected as the speed of the representative and v^{-}_{r} is a mean value of the vehicular velocity in the wireless coverage of the representative vehicle and α is a weighting factor which means the different degrees of importance.

SIMULATION AND RESULTS

In this research, We used simulation software included SUMO, MOVE, NS2. In which, SUMO and MOVE used to build the vehicle motion model with the urban environment, access to vehicle speed and location data. NS2 uses to simulate the operation of the network and analyze network performance.

Parameter settings and scene achieve: In this simulation, we consider each traffic state assorted, that were set free flow, synchronized flow and wide movement blocking flow and evolution model of traffic flow under these three states. Then judged by representatives of each state's vehicle made □□ to verify the representative vehicles made to determine whether the state meets the state assumed in advance, so that you can reflect simple and intuitive method presented in this study whether there is a higher accuracy.

In each state of the simulation, Assuming vehicles are equipped with GPS positioning system and communications equipment and have VANET -based data processing functions. In this study, the simulation time is set to 500s, Simulation scenarios is the two-way four-lane urban road, Besides, In the middle section of the road adds a crossroad, to consider the impact of traffic lights. In this simulation, Optional two car (Designated as numbered flow0_7 and flow0_30) as research subjects,

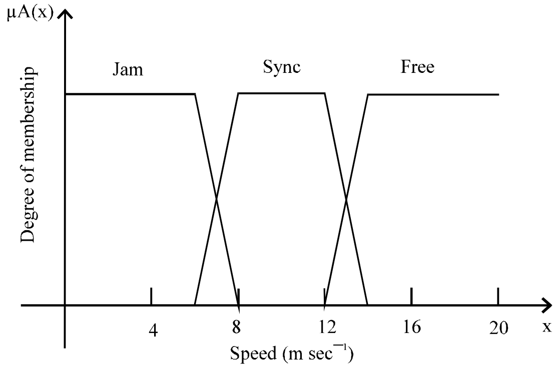

Fig. 1: Speed membership function

Table 1: Simulation parameters

Scene parameter	Value
Topology map	1752×1502 m
No. of lanes	Two-way four-lane
Vehicles node	100
α factor	0.1
J and w_j	j = 1, w_j = 1
Simulation time	500
\traffic lights yes or no	Yes

We can get the appropriate conclusions by analyzing the variation of the vehicle speed in the time range from the starting point to the destination and corresponding predicted output. Specific simulation parameters are in Table 1.

Figure 1 provides membership functions which state estimation speed required. Of course, if necessary, you can also consider additional factors (such as car density) to calculate the membership function in order to improve recognition accuracy.

The simulation results analysis: (1) The velocity and predicted status analysis under the Wide Movement Blocking Flow.

Under the circumstances of WMBF, the car velocity is usually low, however there are still a few cars of relatively high speed. The velocity difference can possibly incur other traffic status in local traffic flow. As Kernel once pointed out, there is a so-called phase change between WMBF and Synchronous Flow, or SF which is very well exhibited by the simulated curve.

The blue curve in Fig. 2 shows the relationship between car velocity and simulation time under the status of Block Flow while the red one shows the corresponding output from the predicted data provided by our method under diverse velocity, in which the red circle at the bottom stands for the WMBF and the other red circles the SF. According to our observation, the difference between the car flow 0_7 and flow 0_30 is it never meets the red light so that it never stops.

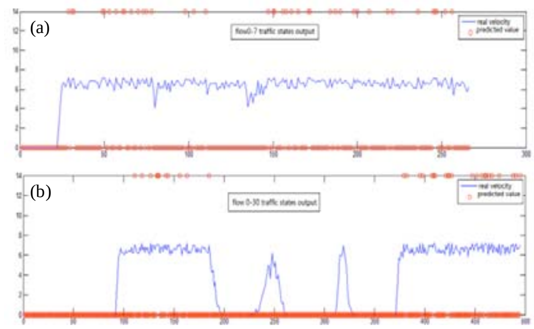

Fig. 2(a-b): Curve of the predicted state and the vehicle speed

According to the observation in Fig. 2, in most of the case our method can precisely work out the status of our current car is WMBF rather than treat the current state as SF. Even when our method mis-treated the current state as SF, there do exist some reasonable judgments. That is because according to Kernel's tri-phase traffic flow theory, when the car in the downstream of the blockage leaves from the congesting area it will become a member of the synchronous stream. Therefore, even if the system is in the Blocking State it can also have the local synchronous behavior. Nevertheless, Kernel also pointed out that in the state of blocking it is not possible to generate a Local Freedom Flow which is proved in our simulation where there is no mis-judgment from Blocking Flow to Freedom Flow. All those in turn show that our method has great utility and accuracy.

The velocity and predicted status analysis under the synchronous flow: In SF, as opposed to Blocking Flow, the car has relatively higher velocity. Similarly, due to the interaction and the changing of headway, the velocity of car will vibrate to some extent. That is to say, the car in the status of SF can possibly maintain in the status of BF as well as Freedom Flow. Moreover, as is already stated by former researchers, the SF is between BF and FF, the status can has some characteristics of both WMBF and FF, therefore the prediction of SF will be more difficult. Kernel's Theory of Tri-phase Traffic Flow also provides explanation to the very phenomenon. In his theory, the transform of 2 traffic status is pointed out and each transform comprises the SF as mid-status. In SF, the traffic status will not only transmit into Freedom Flow due to the car's setting off from congested areas caused by acceleration but also into WMBF due to the car's velocity decreasing by self squeezing which is well exhibited in our figures.

The blue curve in Fig. 3 depicts the velocity curves of the vehicle, while the red part shows the judgment of

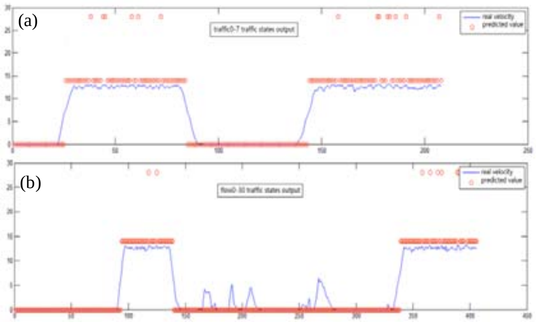

Fig. 3(a-b): Predicted condition and vehicle speed changing curve

the synchronized flow state according to our proposed method. It should be noted that the red circle at the bottom indicates the wide movement blocking flow, the second layer of red circle indicates the synchronized flow, the red circle at the top indicates the free flow. The two vehicles selected have experienced the effects of traffic lights, making the velocity get a larger change.

As can be seen from the figure, our approach has higher accuracy. For two cars at different speeds, basically we can correctly determine the current state. As stated earlier, the synchronized flow is between the wide movement blocking flow and the free flow, so in this case there will be three predictions in our forecast output while in the case of blocking flow our forecast output only has two predictions. For flow0_30 from the time of 90s to 140s, the vehicle is traveling on the road from the starting point to the traffic lights, the impact has not yet received signal at this moment, thus its speed gradually increases, finally because of the vehicle density, to maintain a safe headway, the speed of the car can only be maintained at about 14 m sec^{-1}. And all vehicles maintain on this road a synchronized state. The speed of those vehicles will not be much of ups and downs, although there may be a individual vehicle which has a higher speed, thus the car gets into the partial free-flow state, as predicted at the time of 120s and 130s. At the time of 140, the front vehicle is forced to stop due to the traffic lights, this causes the accumulation and deceleration of the vehicle behind. This process is called self- extrusion process. In the extrusion area of the synchronized flow, the narrow movement blocking will occur. With the growth of the narrow movement blocking, wide movement blocking will form and gradually spread to the upstream and finally affect flow0_30. Before the vehicle leaves the blocked area completely it will take a long time to keep in low speed condition and the vehicle stops and goes until all vehicles in front leave the downstream area from the blocked area. At last the vehicle leaves the downstream area of the blocked area at around 340s, enters another state of synchronized flow, in the new state of synchronized flow, this vehicle may also get into the state of free flow.

Speed and forecast the state of the free flow state analysis: Unlike the previously discussed two states, The free flow state vehicle speed can reach very high values and maintain this state until it encounters traffic lights or other accidents. In this state, Even if the vehicle can be quickly blocked by a blocking state to restore synchronized state transition to a free state. Because after encountering lights or accident and there is a reducing the vehicle speed and maintain a low speed process, Therefore, there will be a free flow state wide movement synchronized flow state and blocking the flow state. However, due to the flexibility of the vehicle speed is strong, Both the relative congestion status may only last for a short period of time, This time depends on the cycle period or accident signal processing.

The blue curve in Fig. 4 shows t he speed of the two cars are affected traffic lights, The red part shows our approach to traffic state projections. Similarly, the bottom of the red circle indicates the broad movement blocking flow, the red circle represents the second layer synchronization stream, the topmost red circle indicates the free stream.

First, overall, we see that free flow conversion wide movement blocking flow streams must be synchronized this “intermediate” state. This is consistent with the phase transformation of the three-phase traffic flow theory Kernel pointed. The change can’t occur directly flowing wide freedom of movement blocking flow. This change can then flow through the free flow synchronization wide movement blocking flow the gradual phase-change process to complete. Because of the flexibility of the vehicle speed and a great choice, the vehicle is always synchronized flow is often very short. This gives us inspiration: in the free flow state, the real impact of the factors is the overall health of cycle traffic accident handling, When the timely processing of accident causing obstruction, traffic can quickly get counseling and will not result in greater traffic congestion, This is on our highways is very important. In flow0_7 graph, the synchronized flow to maintain a very short time and as much in front of the vehicle (or an accident to get timely treatment), so the car can be quickly converted from a blocking state to the synchronized state and then enter the free flow state, high-speed traveling to the finish. In contrast, flow0_30 backlog of vehicles in front of a lot of (the accident did not receive timely treatment), so that the car has a long stay in congested areas which

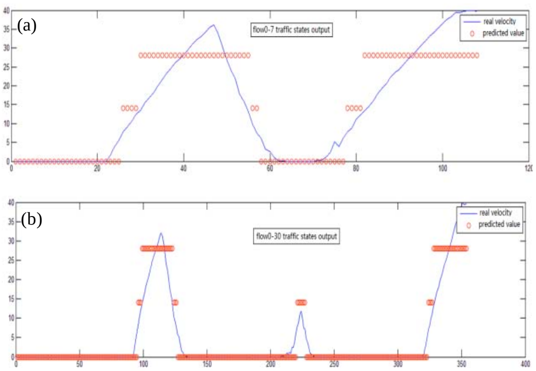

Fig. 4(a-b): Predicted state curve and the vehicle speed

seriously affected the overall operating performance of traffic. Although the car at about 225s into synchronous flow state but due to the vehicle ahead is still affected by the new round of traffic lights, the car can't slow down into a broad movement is no longer blocked, last until about 320s was able to really drive the car from the downstream blocked from traveling to the area and gradually accelerate the end.

By classification analysis above, we find that the proposed method a good predictor of the traffic state and the combination of the three-phase traffic flow theory Kernel us a reasonable explanation of the graph appears traffic state transition phenomenon.

CONCLUSION

Traffic state prediction and recognition is a fundamental and important topic in the field of intelligent transportation. In previous studies, traffic data is obtained through infrastructures such as the pre-deployment coil mostly, the disadvantage of which is the huge cost spend. What's more, there are some shortcomings such as implement complex and large computation in the mostly existing traffic state forecasting methods. In this study, we present a method for traffic flow phase estimation which is based on vehicular communication. In other words, the data is obtained through the communication between vehicles in VANET which can effectively reduce deployment costs. Three types of traffic state are predicted respectively with the consideration of the speed factor. With the compare between forecasting results and the traffic state it is found that the method has high accuracy after deducting invalid data. Furthermore, the prediction results are consistent with the interpretations for phenomenon of traffic state mutual conversion in Kernel's three-phase traffic flow theory. This study also points out that more factors and the corresponding membership functions are needed to achieve higher accuracy.

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