A Situation-Aware Road Emergency Navigation Mechanism Based on GPS and WSNs

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Abstract. Traffic congestion happens when emergencies occur. Traditional congestion algorithms evaluate traffic congestion only according to real-time vehicle speed, instead of comprehensive aspects. To address this shortcoming, we provide a new algorithm for congestion evaluation based on WSNs and GPS, which provide many sensor nodes to monitor and transmit traffic message in time. This paper takes more aspects for traffic into consideration, including congestion situation, danger condition and sudden road peak flow, and turns them into weights, which help to measure congestion intensity. According to congestion intensity, congestion field is established to navigate for the vehicles. Furthermore, we propose future prediction mechanism for vehicles. Finally, we do simulation with Matlab to evaluate the performance of the prediction mechanism, and results show that the performance of prediction mechanism is better than greedy algorithm. Moreover, a route will be recommended after a comprehensive evaluation about the distance, time, congestion and traffic lights number. In a word, the prediction mechanism for traffic can not only ensure the effectiveness of the navigation, but also protect drivers from the sudden peak flow, which brings convenience and comfortableness to drivers.

Keywords: Road congestion · Emergency navigation · Situation-aware

1 Introduction

Wireless Sensor Networks (WSNs) [5,7,12,16] has been got extensively applied currently because of its capability of providing a stable and reliable data prediction relatively [3,9,10,15,22,23,25]. But that is not enough, a stable navigation

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device between WSNs and vehicles is what we need. Global Position System (GPS) [2,11,14] plays an important role in our life and is widely applied in road traffic navigation. GPS navigators appear as the medium between WSNs and vehicles. In [2,11,15], great improvements have been made in the aspects of network stability for road navigation and real-time monitor for surrounding environment. However, it cannot play well in solving congestion situation, with the more and more complex road traffic situation, as a result of which, it is urgent to propose a new road navigation prediction mechanism. In this study, we build a communication network with WSNs and GPS. Traditional algorithms measure road congestion and navigate vehicles only with real-time driving speed, which fail to evaluate the road comprehensively. Multi-view aspects for road congestion are concerned in this paper to ensure the road measurement accurate. Besides, Traditional navigation mechanism cannot predict the future traffic condition, which can influence the final evacuation effect definitively, especially in sudden peak flow. This paper proposes the Future Prediction Mechanism for Road (FPMR). FPMR gets future traffic condition and total travel time by predicting the future arrival moment of the vehicles and recording it in the corresponding nodes list.

Many alternative roads can be offered by GPS. We calculate the total driving time, distance, congestion, and traffic number, instead of only road congestion condition, to choose the final road with smallest calculated result, which ensure the comprehensive measurement for emergency navigation.

The main contribution of this paper are as follows:

(1) Providing a new algorithm based on WSNs, which can measure the road congestion degree comprehensively.
(2) Proposing a prediction mechanism of FCRM, which predict future traffic condition to avoid future emergency congestion.
(3) Based on the driving time and traffic lights number that predicted by FCRM, this paper combines driving distance and road congestion to evaluate alternative roads and choose the final road, which is more humanize for drivers.

The remainder of this paper is organized as follows. We describe the theoretical foundation in Sect. 2 and introduce the algorithm detailed in Sect. 3, we present the experiment results in Sect. 4. Conclusion is given in Sect. 5.

2 Related Work

2.1 Background

Many articles mentioned the application of distributed sensor networks or GPS, and exploited one of them as basic network interactive platform for road traffic detection. Many of the traffic evacuation model that based on WSNs are proposed. In [1], it combined WSNs with smartphone, and built a new network model for vehicle navigation. This new model can realize real-time navigation, further, the thought of real-time was inspired by this model. [20] proposed the

Free-Oscillation navigation of OPEN based on WSNs, Eliminating reciprocating phenomenon on the maximum extent is the main contribution, we can call that reciprocating with circle phenomenon as random walk in road. It is common that random walk in road occurs. OPEN consider the dangerous situation for roads, this is instructive for us to avoid the random walk of road when navigation. Oscillation phenomenon that before and after moving driving mode [4] is legitimate sometimes. The feeling of experience is getting worse.

There were a great use of Optical flow on application areas to solve road traffic problems also. In [6], collecting road information based on the image information of road traffic, then getting the road vehicle traffic stream, measuring the road congestion condition final. [13] put forward the OF- MCMC method basing MCMC (Markov chain Monte Carlo) and improve the prediction accuracy of the optical flow. SURE [21] optimize predicted accuracy and distribution performance of optical flow vectors. In detail, SURE model obtain the road load condition for the current traffic through technical, after that, SURE analyze this load data to adjust vehicles. But they did not consider the future traffic condition else.

2.2 Problem Statement

(1) The effect of evacuation
Road traffic condition deteriorating more and more, low overall regulatory capacity and high time delay of the traffic network, inefficient travel phenomena occur, such as random walk in road. As shown in Fig. 1, random walk in road tends to cause greater congestion. Navigation system needs to be able to identify road congestion condition for all roads, and provides solution to avoid these congested road sections.

(2) The impact of local navigation failure
In WSNs, there may be temporary or permanent local node/link failures due to battery outage and node destroy. Once the connectivity destructed

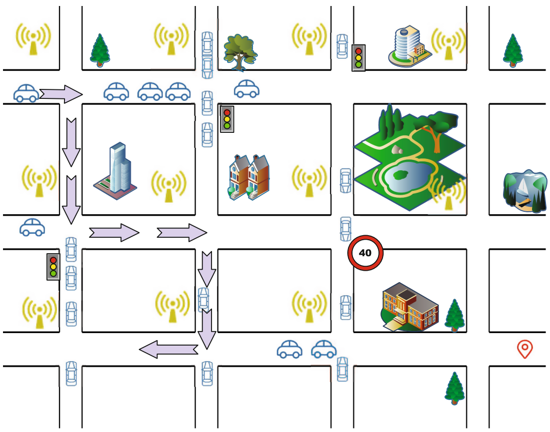


Fig. 1. The scene of the road random walk

between nodes, navigation failure. For this situation, we need to make timely treatment, and strive to minimize the impact of this situation. In this paper, the average node degree is above 6, which pledges the connectivity when the node battery outage or node damaged, ensure the data transmission and navigation affect.

3 Algorithm

In the network model, sensor nodes are placed at each intersection [8,17,24,26] sensor node identify the dangerous road section through this two respects: (1) If one sensor node can not communicate with the other sensors node any more due to damaged or the other cause, WSNs set it to be a dangerous road section; (2) If sensors communication is normal, when a vehicle is traveling on the road, its running speed dropped to zero suddenly and continual for a long time, then signing to be dangerous. there are m junctions this model. Indexes can be represented as follows:

$$W_c = \left\{W_c^j | j = 1, 2, ..., m\right\} \tag{1}$$

$$W_e = \left\{W_e^j | j = 1, 2, ..., m\right\} \tag{2}$$

$$W_h = \left\{W_h^j | j = 1, 2, ..., m\right\} \tag{3}$$

the concept of congestion can make use of the thought of congestion degree, Japanese uses, to calculate. By formula (4), wherein v represent the true speed, V stands for the standard road speed, we can call that speed limit.

$$W_c = \frac{v}{V} \tag{4}$$

The model of the 2D space that mentioned above mentioned has the ability to describe road conditions in manifold. Because the degree of each node is above 6 in our model setting. In this chapter, we focus on the deep description for the algorithm. Based on the above theories that have been told above, we introduce more detailed algorithm and specific steps next.

3.1 Network Model

The basic network model is shown in Fig. 2, in which WSNs and GPS are combined with. GPS sending all the possible and complete traffic routes to WSNs, WSNs finally choose.

3.2 Congestion Field

According to the current research situation at home and abroad. Europe is INRIX Index, United States is RCI and Japan DC is. This paper consider various road traffic conditions into parameters, and applied into algorithm. The

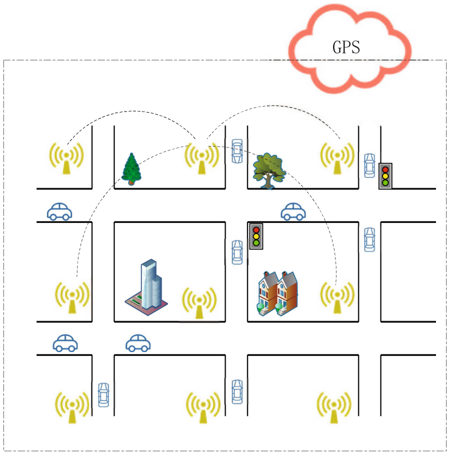


Fig. 2. Basic scene show

Table 1. Parameters in algorithm 1 and algorithm 2

Symbol	Description
R	The road
P_c	Sensor Network
$\lvert PP_j \rvert$	Euclidean distance
W_c	Parameter of road congestion
W_e	Parameter of road evacuation capacity
W_h	Parameter of traffic peak
W_d	Whether danger or not
I	Congestion Intensity
F_v	Congestion Potential

main idea of measurement road congestion algorithm is inspired by [18, 19]. The main parameters are shown in the Table 1. Congestion Intensity (CI): Algorithm is based on the superposition principle. In detail, the using of Euclidean distance can reflect the character clearly that if further away from the congestion location, weaker of the user feelings for the congestion.

$$I = \sum_{j=1}^{m} (W_c^j + W_h^j - W_e^j) \frac{\overrightarrow{pp_j}}{|pp_j|^3} \tag{5}$$

As described as formula (5), this is a kind expression form of instantaneous congestion. But it is not enough that just use the instantaneous strength as the specific road congestion. Further, introducing the concept of Congestion Potential (CP). Congestion Potential: Congestion Potential (CP) is represented by Fv(p) in the formula, and it is based on the build-up of CI. Algorithm using infinite as a measure indicator when accumulated strength, infinite means safety to driver.

$$F_v(p) = \int_p^\infty \mathbf{I} dl \tag{6}$$

In order to avoid congestion, navigation mechanism need to select the smallest congestion value of the road as the re-road scheme, and this congestion value is viewed as an important measurement index to determine whether one alternative road to be chosen. As shown in the formula (7), we chosen the maximum Fv(p) after comparing all the sensor nodes of one road as the road congestion, specifically described as follows:

$$C_s(r) = max\left\{p \in r | F_v(p)\right\} \tag{7}$$

Table 2. Sensor data list

Name	Description
ID	Character a sensor or road uniquely
x	Definition the location with x
y	Definition the location with y
$Neighbors$	The adjacent intersection that connect with one road
$Readings$	The sensor reading
W_d	Whether danger or not
TL	Whether exist traffic light
$Type$	Road type, such as school factory
$Vnumber$	The vehicle number of the node

3.3 FCRM

If the current traffic condition of the driving road is not suitable to move forward any more, driver need to reconsider a new road. For the new road, this paper adds the time prediction mechanism of FPMR, which uses user's request time as the benchmark for the prediction time t_{start}. The start time of FPMR is the moment that vehicle requests, as a result, vehicle can avoid danger and reduce road random walk phenomenon so that repeated congestion can be avoided. Therefore, FPMR makes beneficial solutions for drivers to travel in traffic better. Firstly, according to the congestion situation to predict the driving speed, the driving speed is expressed as formula (8) to calculate,

$$v = V_{normal} * (1 - W_c) \tag{8}$$

V_{normal} represents the maximum speed that road allowed, the setting range of in (0, 1). Greater congestion index display, lower velocity, which turns that the reasonable of formula (8).

$$t_p = t_{start} + \sum_{j=1}^{|p|} \frac{s_p}{v_p} \tag{9}$$

In formula (9), p represents the predict node, $|p|$ is the section number of each alternative road. FPMR uses the superposition thought to predict the arriving moment and total driving time for every alternative roads. With regard to the peak flow, the arriving time t_p need to be judged by sensor node whether locate at the range that peak flow happen, thus reaching the purposes that forecast driving time and avoiding peak flow.

3.4 Overall Merit Method

After measuring the road congestion condition and the arrive moment of vehicles above, in the final evaluation for each alternative roads, we consider the following four aspects: total driving time, distance, congestion and traffic lights number. From the above formula of (8), (9), The total travel time T of every alternative roads can be described in the following:

$$T_r = t_{destination} - t_{start} \tag{10}$$

and total distance S_r:

$$S_r = \sum_{j=1}^{n} S_j \tag{11}$$

Traffic lights has influence on driving time and speed, but this index is often ignored. So this paper think about the influence caused by traffic lights into navigating program when evaluate re-road. The influences are reflected on vehicle velocity mainly, which reflects the comprehensive and humanized for road emergency navigation this paper. 60 s setting as a stage for the traffic lights. In the final road evaluation, all these road indicators are normalized, in order to control the difference influence that indicators bring on assessment. For each of the road, getting the comprehensive analysis and comparison, and choosing the most suitable way for users.

4 Simulation

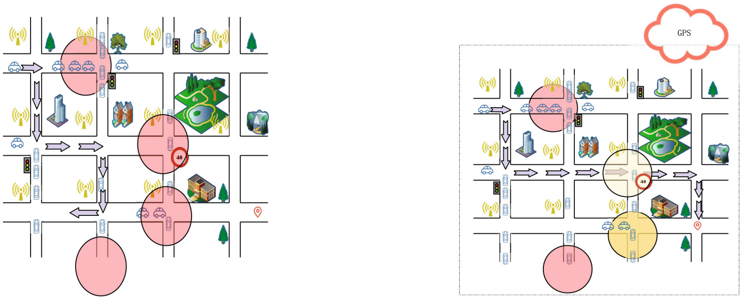
According to introduced above, this paper simulated the specific program. The main process includes data initialization, congestion field establishing, the emergency evacuation road determining.

4.1 Simulation Initialization

In the simulation experiment, road condition is perceived by sensor nodes, which initialize the data entry for WSNs. When model working, sensor node detects the road data continually and receive drivers request when congestion occurs. WSNs establish congestion field, congestion field can make overall observation for traffic network more clear and the sensor list in the Table 2.

4.2 Results and Comparison

We add greedy algorithm navigation scheme to compare with our program called RENS. In this article, the selective method for alternative roads are based on the congestion field that established by WSNs. As shown in Fig. 3(a) is the greedy algorithm mechanism when navigating for drivers, it may cause the random road walk phenomenon in different degree. Random road walk may be caused time delay and bad satisfaction for drivers, so we consider that effect, which is one of the significant innovation of this paper. As shown in (b), it avoid the not ideal navigation condition that caused by the signal message of route after getting reasonable road indexes. In the experiment, we carried out holistic navigation for all the vehicles that running on the traffic network, reaching the balance for traffic network on whole level when evacuation for vehicles.



(a) (b)

Fig. 3. There is the 2D space model that about the road traffic conditions for road navigation, (a) is based on the real time driving speed to measure road congestion, (b) is using RENS algorithm to establish congestion domain for the and select re-road

(1) Road damaged: Road quality should be pay attention. It is worrying that when driving on the damaged road, not only property damage for driver, seriously, a threat to the safety. In this paper, the basis network that combining WSNs with GPS as can perceives dangerous sections timely, and notifies basis network model to avoid damage to user. In Fig. 4, sensor node discover damaged road send this message to GPS, GPS formulate alternative road programs after removing damaged road, that is one of the superiority this paper.
(2) Peak flow In the experiment, we use various scene to simulate. It turn out the efficient that our program performed in different applied range.

As shown in Fig. 5, there are many difference scenes setting for this experiment comparison, RENS and GD use difference indexes of road to measure road condition. As the picture shows to us, GD did not navigate for road congestion very well. In the respect of time, distance and traffic light, our program has advantage after considering more influence factors.

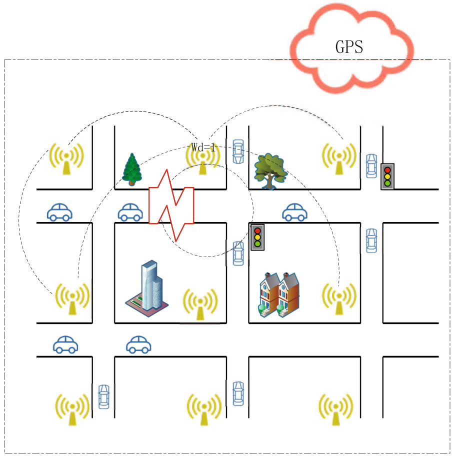


Fig. 4. A damage has exist in this model experiment

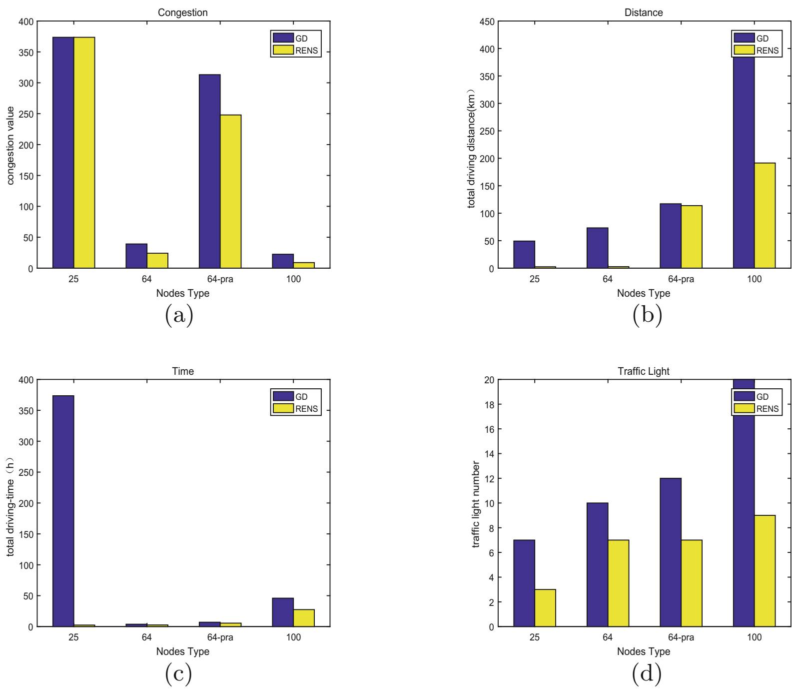


Fig. 5. In different comparison result, from the (a) (b) (c), we can see that more nodes number of the traffic network model, more stable of the RENS performance, and from (c), there are a better performance when RENS applied in the bigger scene.

5 Conclusion

It is an urgent problem needing to be solved that navigating emergency road congestion effectively. This paper proposed a navigation mechanism and consider variety of road indicators in our algorithm. FPMR plays an important role in predicting the future road traffic conditions, which can avoid two times congestion and random walk in road, it is the other innovation and breakthrough in our navigation mechanism. In the subsequent work, we devote to practical application in real life and combine with mechanical learning technology to analysis traffic data deeply. Putting forward to found the internal links on traffic, and solving the problem of the emergency road congestion better.

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