Optimal model of highway road based on GPS

Huaping Li*

Chongqing City Management College, China Chongqing, 401331

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Abstract

Intelligent transportation system (ITS) has gradually become reality with the increasingly wide application of GPS in car navigation system. It is wider and wider applied into traffic management to support short-tern traffic prediction, provide the information for public travel rapidly and effectively and realizes the effective supervision on traffic state. It can also relieve the pressure of highway road in our country. This paper focused on the study of floating car data technology based on GPS in ITS and developed relative procedure based on algorithm theory. It designed out a solution suitable for highway real time road condition system based on GPS floating car data technology after the demand analysis, functional decomposition and concept design on highway real time road condition system and best road and shortest time selection on driving by mathematical modelling so that achieve highway road optimization.

Keywords: GPS floating car data, GPS, ITS, mathematical modelling, driving time

1 Introduction

Developments of modern society bring people highly developed economy and wonderful material lives as well as negative effect such as traffic jam. City traffic infrastructure cannot keep up with traffic demand growth. City planning, land utilization and highway network planning are not reasonable. In addition, urban bus transport lags behind. And growth speed of mini car is too quick and volume of parking lot is not enough [1]. These problems all deteriorate traffic jam, which affects rapid development of social economy to a large extent. Therefore, scholars and experts from different countries begin to devote to this problem and some positive achievements have gained. Precondition for these achievement need improvement and development of advanced technology such as ITS and GPS [2].

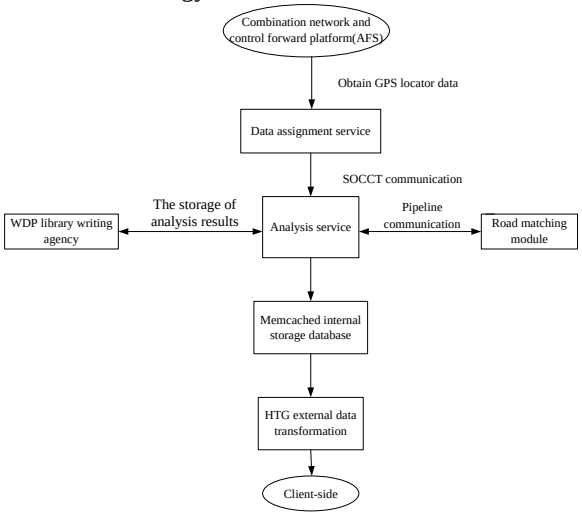

FIGURE 1 System overall flow figure

Although the research on ITS in our country started late, the research result on this aspect of experts is delightful. Zhou Yang from Nanchang Aviation University developed a national highway traffic system-B/S system based on GPS floating car data technology in research of highway real time road condition system based on GPS floating car data [3]. This system realizes 5 min real time refreshing and road condition prediction function. Meanwhile, it provides second development interface for external which is convenient for second development on other map developers. Bai Fengwei [4] made information more efficiency and diversified by improving highway information collection system in Opinion and Suggestion on Information Collection of Highway Monitoring System. Wang Junming [5] from Chang'an University studied topic of digitization of highway simulation monitoring system and laid a strong foundation for networking of highway monitoring system in research of highway monitoring system and relative device. This paper focused on study on principle of floating car data based on GPS and algorithm realization. And a highway real time road condition system was developed. Compared to traditional road condition system, it can collect road condition information flexibly with little cost. It is a good solution for current traffic jam.

2 Current situation overview and research thought of highway

Most road condition system in our country adopts fixed data collection means in view of current real time road condition system. For instance, Shanghai public transport system and Tianjin real time road condition all adopt video collection technology. And these systems are mainly applied in main traffic artery in city centre; however, road

* ***Corresponding author*** e-mail: lhpcqcs@163.com

condition information collection by floating car data technology is still in theoretical research and verification stage in most area. Some cities have gradually applied floating car data technology to obtain real time road condition information.

Author programmed this paper according to development procedure of software system combining with basic requirement of master's thesis. The detailed flow figure is as Figure 1.

3 GPS floating car data technology and algorithm

3.1 GPS FLOATING CAR DATA TECHNOLOGY BASIS

3.1.1 Overall structure principle explanation

Floating car data technology based on GPS is based on GPS combining with geographical information technology, wireless communication technique such as CDMA, GSM, WCDMA, etc. computer communication and data processing technology [5]. It collects information through mobile car terminal installed in driving car and constructs computer model to process and analyse locator data by matching software in information centre. Thus, traffic jam condition information is obtained. The overall structure figure is as Figure 2.

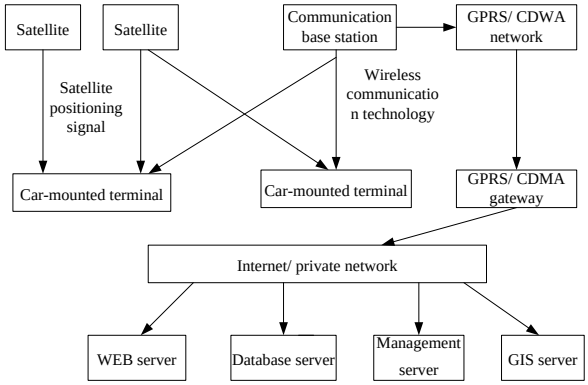

FIGURE 2 Overall structure chart based on GPS floating car data technology

3.1.2 Car-mounted terminal description

GPS car-mounted terminal is also termed as GPD car-mounted monitoring terminal. It monitors car position information and car state and provides software and hardware comprehensive system relying on satellite positioning, geographic information and wireless communication technique means. GPS car-mounted terminal is mainly composed of GPS positioning module, microprocessor unit, wireless communication module, client-side software and other extension unit [6]. The structure is shown in Figure 2.

3.2 MAP MATCHING ALGORITHM DESCRIPTION

Highway road condition system makes analysis on national highway road condition. Speed of matching algorithm largely affects the efficiency of system. Therefore, the critical part of matching algorithm is to match GPS information of floating car data to relative road as soon as possible. The basic flow is shown in Figure 3.

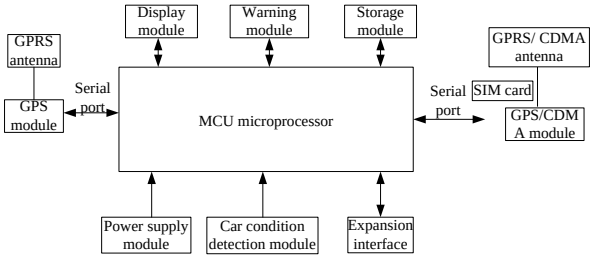

FIGURE 3 Matching algorithm flow chart

3.3 SEARCH AND REALIZATION OF MATCHING DISTANCE

In this system, the realization of matching algorithm is through the analysis from MAPX. And matching of GPS and highway road segment is realized through primitive lookup algorithm of MAPX. The function method is as follows:

OBJECT. Search within Distance (Source, double Distance, short Units, and short Search Type).

This method search surface features within a certain scope with some point or some primitive as standard. First parameter sets a point object or a feature object. Second parameter sets distance. Third parameter set unit. Fourth parameter sets return result and the position relationship between standard and distance [10].

Above function searches highway road segment information with certain scope by importing GPS position information. Then it analyses deeply angular separation according to initial matching road segment information and at last confirms the matching road segment of GPS point information.

3.4 ALGORITHM OF REAL TIME SPEED OBTAINING

Vehicle tracking method estimates average speed: one field in vehicle locator data packet. This speed is obtained by GPS car-mounted terminal. Its speed is also the instant speed of car. For the floating car data that has no continuous locating point in the same road segment, the instant speed of cars driving in that road segment is obtained and weighting for obtaining average speed.

$$w_r = \frac{p_r}{\sum_{r=1}^{n} p_r}, \tag{1}$$

$$u_l = \sum_{r=1}^{n} w_r u_r \ , \tag{2}$$

where w_r is the weight of floating car r, n is the number of floating car data positioning packet that pass road segment 1 and u_r is car speed in positioning packet.

The system is limited in locator data in single road segment. And national data size is too large. Therefore, this system adopts vehicle tracking - direct obtaining method to obtain speed of road segment in view of complexity of calculation.

4 Shortest driving time selection by mathematical modelling

4.1 MODEL BACKGROUND AND ANALYSIS

Road traffic state is nonlinear. And car, speed and road condition have interaction function. Its research is including micro model and macro model [8]. There are four indexed to measure in view of traveling of traveller. First is that expected driving time is shortest; second is the high reliability of route, that is, the possibility of serious block is low; third is that the journey is shortest; four is the lowest cost [9]. Sometimes these indexes are contradictory and balance is needed between two sides. In this paper, we took shortest driving time as design purpose.

4.2 PROBLEM ANALYSIS AND MODELING

We can conclude road condition on road L_i into three conditions: normal, jam and serious jam. The number of relative road segment is n_{i1}, n_{i2}, n_{i3} . Expectation and standard deviation of driving time on every road can be calculated according to the data obtained by sensor. Then the expectation and standard derivation of the whole road is:

$$\mu_{Li} = \sum_{i=1}^{n_{i1}} \mu_i^n + \sum_{i=1}^{n_{i2}} \mu_i^c + \sum_{i=1}^{n_{i3}} \mu_i^h \ , \tag{3}$$

$$\sigma_{Li} = \sqrt{\sum_{i=1}^{n_{i1}} \sigma_i^n + \sum_{i=1}^{n_{i2}} \sigma_i^c + \sum_{i=1}^{n_{i3}} \sigma_i^h} \ , \tag{4}$$

where $\mu_i^n, \mu_i^c, \mu_i^h$ are respectively expressed as the expectation of driving time in the condition of normal, jam and serious jam and $\sigma_i^n, \sigma_i^c, \sigma_i^h$ are respectively expressed as the standard derivation of driving time in the condition of normal, jam and serious jam. And obedience parameter of driving time of road L_i is normal distribution of $\left(\mu_{Li}, \sigma^2{}_{Li}\right)$.

If the material is not sufficient, then there are three estimations on time: the most optimistic estimation, the most possible estimation and the most conservation estimation, which are respectively corresponding to normal, jam and serious jam. The three estimations can be recorded as a, b and c. And suppose that the probability of value as a, b, c are respectively $\frac{1}{6}, \frac{4}{6}, \frac{1}{6}$. Then expectation of finishing the road can be estimated by $ET = \frac{a+4c+b}{6}$. It can be known from Chebyshev in equation $p\{|t_i - ET| \geq \varepsilon\sigma_t\} \leq \frac{1}{\varepsilon^2}$ that when $\varepsilon = 3$, the possibility of deviation between time of finishing this road t_i and expected time ET exceed three times of divide difference of time need in finishing this road will not larger than $\frac{1}{9}$. Suppose the minimum value of t_i is $a = ET - 3\sigma^t$ and the maximum value of t_i is $a = ET + 3\sigma^t$, then $b - a = 6\sigma^t$. Therefore, divide difference of time that need in finishing L_i can be estimated by $\sigma_t = \frac{b-a}{6}$.

Next we consider a road. Suppose that the road can be divided into m segments, then estimation on the expected time μ that needed in finishing this road can be expressed as sum of expected time of m segments. Estimation on time variance σ^2 can be expressed as sum of time variance of m segments road. Progressive obedience normal distribution of time can be known from central-limit theorem of probability theory. Based on it, probability P of finishing this road within a certain period of time can be calculated:

$$P = \int_{-\infty}^{t} \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(\tau-\mu)^2}{2\sigma^2} d\tau} = \varphi\left(\frac{t-\mu}{\sigma}\right). \tag{5}$$

According to above discussion, we can transform original problem into uncertain PERT network problem. Optimal purpose is defined as the shortest time needed in finishing some road in the condition of probability P.

5 Conclusions

This paper introduced ITS and mainly studied floating car data technology based on GPS in order to solve the increasingly serious traffic jam. Although research based on GPS floating car data technology have many theoretical achievement, many experiments focus on the area of urban main road where vehicles are intensive. However, these papers mainly face to national highway and the vehicles density and supporting points do not reach the amount of previous research achievement. Through practical observation and analysis, highway is different with previous research result. Vehicles density of highway is not such large as that of urban traffic road. But the structure of highway is simpler and few cars can reflect traffic condition. In addition, we increase jam feasibility for reference and explore a solution suitable for this system by nearby road detection and mathematical modelling.

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Author

Huaping Li, born in October, 1974, Chongqing Province, China

Current position, grades: associate professor.
University studies: Mathematics education, Chongqing Normal University in 1997.
Scientific interest: higher mathematics, mathematical modelling.