The Research on the Key Technologies for Improving Efficiency of Parking Guidance System

Zhaosheng Yang, Honghong Liu, Xinyue Wang

Abstract—**An important part of today's traffic is parking and most especially in the congested urban areas. This often leads to additional traffic. As part of ITS deployment in China, Parking Guidance System is drawing attention for alleviating congestion. Considering the existing traffic management measures, the Schematic of integrating advanced parking guidance and information system into urban traffic flow guidance system is put forward in the first part of this paper. The rest of this paper deals with the key technologies for improving the efficiency of Parking Guidance System such as information, routing, toll collection by using Dedicated Short Range Communications, communication technology in the mobile environment, prediction method of available parking spaces, etc. The last section provides some suggestions that future study needs.**

Index Terms—**Artificial Intelligence Tools, Dedicated Short Range Communications, Parking Guidance System, Parking Information**

I. SUMMARY

AS part of ITS deployment in China, Parking Guidance and Information System is drawing attention toward the alleviation of traffic congestion which is made worse by parking search in large urban areas. Advanced Parking Guidance and Information System can inform drivers of parking location and availability of parking space so that they make informed decisions about where they wish to park, and thus find parking conveniently and efficiently. It will reduce traffic congestion and pollution by lessening the amount of traffic circulating in search of open spaces, or attempting to park at a specific facility that is full. It will also enable more complete use of the total number of parking spaces. Advanced Parking Guidance and Information System is regarded as one of the most effective traffic management strategies that can control and influence the use of vehicle especially in urban downtown [1]. The paper describes the background and the technical solutions for Advanced Parking Guidance and Information System.

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II. BACKGROUND

Beijing has won the right to host 2008 the Olympic Games. The Chinese government promises that it will be the most splendid game in Olympic history. One of the factors which affect Olympic Games is traffic system, and Beijing government is determined to provide an on-time, safe and comfortable traffic system. Although today many indexes such as density of road network, registered cars and the number of commuters per day have ranked in the first line of the world, Beijing's fundamental facilities in the field of traffic management fall behind the world.

The characteristics of Olympic traffic is described as the following:

1) Short-term event
2) Hard intensity
3) Severe demand

One of the measures adopted by the Beijing city government's Olympic traffic management is traffic planning and control of Olympic Park. Since 1997, National Natural Science Foundation of China has funded two large projects called "Urban Traffic Flow Guidance System"[2], Jilin University get one of the funds. Because of these reasons, Our group plan to design and build a technically upgraded system (be called advanced parking guidance and information system) for urban parking management by our research group.

III. OBJECTIVES OF THE PROJECT

1) Creat an advanced parking system that would communicate real-time parking information to users.
2) Creat an advanced parking system that would serve as a "wayfinder" system to those users unfamiliar with urban road.
3) Develop an advanced parking system that both architecturally and aesthetically fit with the scheme of urban
3) Integrate parking guidance and information system into urban traffic flow guidance system

4) Develop an advanced parking system capable of expanding post-operational test to accommodate urban everyday traffic need.

5) Creat an advanced parking system that would have a positive impact on the surface transportation system.

IV.SCHEMATIC OF THE INTEGRATED SYSTEM

An advanced Parking Guidance and Information system is a component of Intelligent Transportation System. To combine it with ITS, the schematic of integrating advanced parking guidance and information system into urban traffic flow guidance system is described as in fig 1.

All communication will be brought back to the traffic control and parking control center. A typical central computer includes a central processing unit, graphics terminal, communication board, printer, and software that allow for central control and management of the system.

The in-vehicle navigation system includes GPS receiver, in-vehicle computer, touch screen, and communication unit. Electric map software and route guidance software were loaded in in-vehicle computer.

Equipment at parking lot includes vehicle counting equipment and a controller interface unit. Existing counting equipment was used wherever possible.

Additionally, the information of each garage (include occupancy, fee, operation time, etc) and real-time traffic information could also be provided as output to the public phone network.

V .AN ADVANCED PARKING GUIDANCE AND INFORMATION SYSTEM

The city of Beijing installed the first dynamic parking guidance system in China in 2001. It can inform drivers the number of real-time available vacant spaces. The system links fourteen parking garages (two thousand nine hundred and ninety five spaces) by using dynamic and static signs. Since then, some studies have been performed to reveal both the traffic-related effect and economic effect of the system. The results of these studies showed that the annual saving is about 1.2 million USD.

Parking Guidance System (PGS) is being developed in China for reducing parking difficulty and solving traffic congestion. The content of study presented in this paper are parking information items that are needed, and the key technologies for improving the effectiveness of PGS.

VI PARKING INFORMATION

Basically, the parking information items can be classified into static information and dynamic information[3]. The static information includes (1) Facility's name, address, and phone number, (2) Location on a map, (3) Direction to the facility, (4) Capacity of the parking facility, (5) Fee structure, (6) Hours of operation, (7) Self park or attendant park. The dynamic information includes (1) Number of spaces available at the time of inquiring, (2) Possibility of a space being available when you get there, (3) the best route and the estimated travel time for you to get to the parking location, (4) the traffic conditions in the area of facility, (5) whether or not to reserve a parking space before you start your trip.

As a survey result, considering the limited space available, the most needed parking information to be shown on roadside display is the number of parking spaces available and direction to the facility. So parking facility in garages must include vehicle counting equipment and a controller interface unit. Vehicle counting is accomplished with loop detectors, ticket spitters or cash registers. The controller interface unit contains the computer processing equipment that is necessary to calculate the number of available parking spaces and transmit this information to the central computer.

ITS can potentially enhance the operation of the surface transportation system through accurate, real-time information dissemination. Several technologies which are currently used in distributing traveler information to commuters have been identified as possible mediums for disseminating parking guidance information. These technologies include (1) variable message signs, (2) static signs, (3) advisory radio, (4) Internet service, (5) telephone information service, (6) commercial radio, (7) in-vehicle navigation system and (8) commercial television broadcasts.

VII.KEY TECHNOLOGIES OF THE PROJECT

A. ROUTE GUIDANCE FOR PARKING PURPOSE USING ARTIFICIAL INTELLIGENCE TOOLS

Not only the current information about the available parking space is important, but also the inquiry of the best route to the car park is important too.

Dependent on the destination request of the customer, the parking space situation in the targeted area, the current situation (weather, meeting, building sites, accidents, events, etc) on the route and possible alternatives in the means of transport choice, an optimal can be determined in connection with a suitable parking possibility which can be offered to the user. This dynamic information is delivered by the Traffic and Parking Control Center.

Route guidance is the core of the advanced parking guidance and information system. Although there are many kinds of route optimization methods, they are limited to be used in road network. Traditional algorithm can't meet real-time requirement. Heuristic methods satisfy real-time request, but it is hard to make sure the precision of outcomes [4]. At present, parallel computation is only be used in the aspect of large-size computation [5]. The paper adopted Fluid Neural Network (FNN) that is a type of continuous Hopfield neural network used for route optimization for parking purpose. It is the first time that the best route problem was solved by neural network, which has been a powerfully artificial intelligence tool in many fields. Road network consists of nodes and segments corresponds to a fluid neural network, nodes correspond to nerve units, reciprocal resistance on road segments (it may be distance, travel time, degree of congestion, road quality or other comprehensive index) correspond to weight between two neural units. So we obtain a fluid neural network model suited to traffic network.

$$\begin{cases} du_i/dt = \sum_{j \neq i} T_{ij}(S_j - S_i) + I_i & i,j = 1,2,\cdots N \\ S_i = \alpha\left(\dfrac{1}{1+e^{-bu_i - 0.5}}\right) \end{cases}$$

$$I = \begin{cases} I & \text{when } I \text{ is origination node} \\ -I & \text{when } I \text{ is destination node} \\ 0 & \text{when } I \text{ is other node} \end{cases}$$

Where T_{ij} represents resistance on road segments, because the fluid obey the rules of fast descending and I is a constant, du_i/dt equals to zero when iterative numbers is enough. At this moment, the system attains stable status. The road on which rate of flow is largest is the most possible road among all roads linking these nodes. According to this theory the system search the best route from origination to destination. The following is the step of the algorithm:

Step one: set initial status of FNN, let t equal to zero, $S_1(0)$, $S_2(0),\cdots S_N(0)$ equal to S_0, $U_1(0),U_2(0),\cdots U_N(0)$ equal to u_0, compare the input Origination node with the Destination node determined by position system, if O is not equal to D, turn to step two. Otherwise, process ends.

Step two: when $U_i(t+1)-U_i(t)$ is equal to zero, the system attain stable status and turn to step three. Otherwise let t+1 replace t and turn to step two.

Step three: mark $T_{ij}(S_j - S_i)$ equal to X_{ij} and mark M is the first node between O and D from origination node, M_1 is equal to the maximum of X_{ij}, then search M_2 from M_1 node beginning according to the same method until M is equal to D.

Step four: mark the best route $O-M_1-M_2-\cdots-D$.

B. ELECTRONIC TOLL COLLECTION FOR PARKING UTILIZING DSRC

Usually there occurs traffic congestion around the parking lots in the center of city because it takes time to enter and leave garages or to pay tolls. So the national authorities concerned for the DSRC (Dedicated Short Range Communications) experiment. In order to alleviate the concentration of parking at some dedicated parking lots, which leads to traffic congestion around them, and to improve using efficiency of parking lot, the authorities are planning to build a model of the parking system utilizing DSRC based on the results of the experiment.

DSRC is a communication system that applies Dedicated Short Range Communication technology. It consists of On-Board Unit (OBU), Road-Side Unit, DSRC Protocol, computer network and background process unit. When a vehicle enters or leaves the garage, Road-Side Unit reads vehicle ID in OBU and records the vehicle entering or leaving time, and transmit this information to background process unit which is located in a bank, thus system finish toll collection process which is efficient, safe and exact.

DSRC used in this experiment is a radio communication technology utilizing a frequency of 5.8GHz, which makes the ETC technology become general-purpose. The frequency is adopted as the international standard for DSRC.

Fig 2 shows the structure and the image of information communication in the system utilizing DSRC and ETC.

Because of the high-speed DSRC, parking lot users can be relieved from impatience of looking for vacant parking spaces by smooth guide. Parking lot managers can reduce the operating costs because of saving from labor costs.

C MOBILE COMMUNICATION TECHNOLOGY FOR GUIDANCE INFORMATION TRANSMISSION

Navigation for parking purpose is usually divided into locally determined navigation system and centrally determined navigation system.

The integration of DSRC and wireless communication can accomplish the function of vehicle locating and real-time guidance and information transmission.

For centrally determined navigation system, before leaving homes or offices, the travelers can submit their origination and destination to traffic and parking control center through private terminals such as private computer or mobile telephone or onboard equipment, and the center can provide the optimal traveling route and the selected available garage nearby the destination for travelers based on the real-time road traffic information by transmitting the information to Road-Side Unit through wire or wireless communication network. When the vehicle equipped with OBU passes through the key road antenna, Road-Side Units obtain the vehicle's information (such as vehicle identity, the point identity, the time when the vehicle is passing through the point, etc) to locate it and then the center update the database and provide navigation information by Road-Side Units.

For locally determined navigation system, the system adopted mobile communication technology. GSM, CDPD, GPRS and CDMA are data communication technologies that have been developed recently. The CDPD can only be used to transmit digital data and can't be used widely all over the world because of it has some limitations. The function of GSM is limited in the aspect of data communication and can't meet the requirement of data transmission in ITS.

GPRS (General Packet Radio System) has solved some problems which GSM can't solve and has the following technical characteristics [6]:

1) It can use existing resource and have the characteristic of high efficient due to General Packet Exchange.

2) High speed data transmission between 9.05～171.2kb/s.

3) The connection speed of GPRS is rapid (less than one second) and GPRS can provide seamless connection with current data network.

4) Fee is based on the amount of data flow, the type of service and the level of service, so counting fare is more reasonable.

With the various advantages mentioned above, GPRS was applied to the route guidance for parking and other purposes.

Connected with World Wide Web easily, GPRS can submit real-time traffic and parking information to travelers. At the same time travelers can submit their questions and

requirements to the decision-making center and query the parking information.

D. FORECAST OF OCCUPANCY OF PARKING SPACES IN THE FUTURE TIME

Before a trip, travelers sometimes want to reserve a parking space in the proximity of the destination by Internet. But if an unexpected event (for example, the planned appointment was shifted or canceled) happens during the journey, the situation should be reported to the center immediately.

For the above reasons an advanced parking guidance and information system should develop a service to meet booking demand of travelers. With different terminals, travelers can reserve a space, cancel a reserved planning or change the existing reservation.

A comprehensive system must incorporate a predictive element which can provide future information (when the driver arrives at the garage, whether or not the garage which he is leaving for have some spaces, etc.). So it is necessary to predict the occupancy of parking space in the future time.

The capacity of garage depends on road traffic flow, weather, events, road condition, etc. It follows that the best prediction of available spaces is a combination of short time and historical information [7].

Prediction of available spaces, which shows dynamic change owing to all kinds of factors, is a complex non-linear process. Based on neural network of time series and historical data characteristics, prediction model was made and practised in our experiment system. The calculation results indicate the model is not only reasonable but also simpler than time series statistical model and more useful in function.

Why the selected method of prediction is the neural network model of time series? The reasons are described as the followings:

1) Neural network is a non-linear kinetics system with some peculiarities that include high dimension, extensive linkage among neural units, auto-adaptability and auto-organization, etc.

2) Neural network is suited to deal with some non-precise and fuzzy process affected by many factors and conditions at the same time.

3) Neural network possess self-learning ability.

We must consider the following when using the neural network for prediction:

1) how to select independent variables

As mentioned above, the capacity of garage depends on road traffic flow, weather, events, road condition, etc. So the network input adopted multi-variables input. It was considered separately to select one yea data, two years data, three years data.

2) network structure

Models consist of three layers: input layer, implied layer and output layer. Fig 3 is the neural network structure of time series

3) sample train and weight decision

The learning rate is automatically regulated. If the revised weight can really reduce error function, the situation indicates the selected rate is too small and the system must increase the learning rate. Otherwise, reduce the learning rate.

4) result analysis

The prediction result shows that when sample size is larger, error is smaller. But large sample size will cost much time and so affects real-time requirement. In addition, the appropriate number of implied neural units, which affects the learning time, precision and converge, is hard to select. Historical data is also necessary for such a system and it requires car parks have counting systems.

There are several ITS technologies which can be utilized as a means of effectively managing parking lots. These methods include the use of detection equipment such as loop detectors, automatic vehicle identification, automatic vehicle location to collect parking availability and duration information. In addition to parking guidance and automatic fee calculation and collection, ITS technologies can be effective in detecting illegally parked vehicles, increasing parking lot security, and reducing traffic flow inside the parking lot during congested periods.

VIII. EXPERIENCE OF THE SYSTEM

The system has been in full operation for more than one year. Generally, the system has worked as planned and positive results can be seen. However, some problems occurred during both installation and running of the system. These problems include (1)parking fees are not uniform so that drivers do not move to parking lots with vacant spaces as directed by guide signs; (2)the meaning of parking information on the variable message board installed by the roadside is not be well understood by users; (3)20 percent of the respondents were aware of the system, but had not used it.

IX. MEASURES SUGGESTED FOR IMPROVING PGS

1) Increase the function of information and guidance algorithm

To increase the system's benefits, it is necessary to improve the information and guidance algorithm [9]. When the total parking demand in blocks is small the system should be reinforced as a variable message display system, that is, the system can provide information that maximizes its usefulness to the motorists. Specifically, guidance control should be achieved by consideration of such events as road accidents, construction and traffic control.

2) Fusion of PGS with other system

To increase the utilization of PGS by users, it is necessary to combine the system with other systems such as Park and Ride facilities system, Pre-trip and on-trip information about parking facilities as well as possibilities for reservation and electronic payment, urban traffic control system, commercial information, and other systems[8]. These will improve the benefits of PGS to users.

3) Scientific prediction methods of occupancy of parking spaces is key to an accurate system

It follows that a comprehensive system must incorporate a

predictive element. Scientific prediction method of occupancy of parking space is key to an accurate system. The best prediction of available spaces is a combination of short-term and historic information.

Given an adequate source of both short-term and long-term data, and with more careful design of information signs, Car Park guidance systems would be much more effective. Combining on-Street parking availability with PGS which uses some of the techniques now being implemented would increase its impact considerably.

4) Modern parking management needs not only technical solutions.

A comprehensive approach also takes into account fiscal and legal measures. The parking fees have been harmonized after the introduction of the parking guidance system. The harmonization took place among garages operated both by the city and by private companies as well as with respect to the distance to the city center (parking fees is more expensive when the distance to the city center is closer).

X. CONCLUSION

An advanced Parking Guidance and Information System have many benefits for all travelers in downtown Beijing. Well-designed and comprehensive parking guidance can make a major impact [9], producing 50% reductions on circulating traffic and the consequent reduction in pollution. Parking Guidance can assist us in reaching our goal, with less need for restraint. As Beijing's traffic continues to grow, real-time parking management and ITS elements are needed to manage the increased demand on transportation and parking systems. With the Beijing city's government committed to solve parking and traffic issues affecting downtown workers, residents, and visitors, the PGIS program will become a leading example of how real-time parking management can be integrated with ITS planning.

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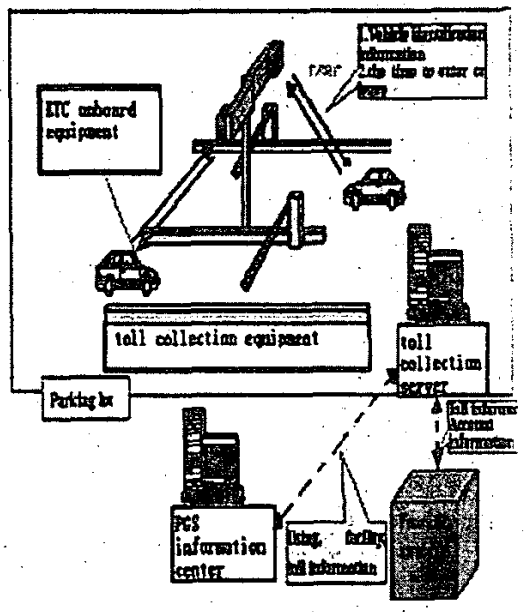

Fig 2 The structure and the image of information communication in the system utilizing DSRC and ETC

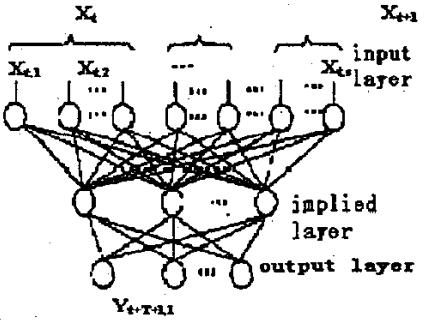

Fig 3 The neural network structure of time series

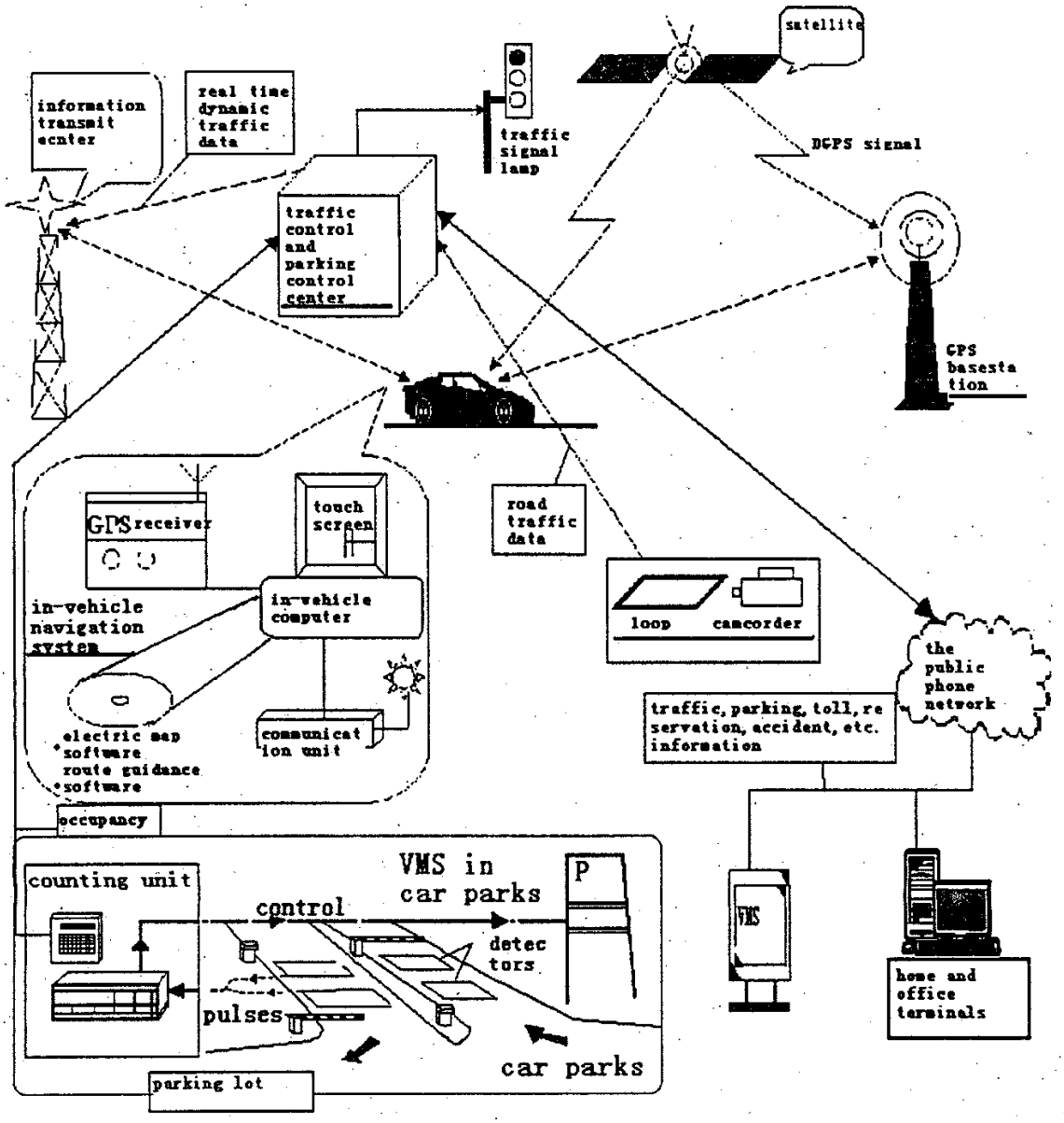

Fig 1 The schematic of integrating parking guidance into urban traffic flow guidance system in ITS