Journal of Information Processing Vol. 19 12–24 (Jan. 2011)

Regular Paper

Reducing the Network Load in CREPEnvironment

Nguyen Thanh Hung,[†1] Hideto Ikeda,[†1]
Kenzi Kuribayasi[†1] and Nikolaos Vogiatzis[†2]

This paper presents a car navigation system for a future integrated transportation system forming a component of an Intelligent Transportation System-ITS. The system focuses on the mechanisms of how to detect the current position of each vehicle and to navigate each vehicle. Individual vehicular data is collected using the Global Positioning System - GPS, for location data and it will then be transmitted to a control center via a mobile phone. For the purpose of this paper, the device will be referred to as "Reporting Equipment for current geographic Position" or REP. It is suspected that if a great number of REP equipped vehicles report their positions to the control center simultaneously, there would be a heavy load on the computational communications network ("network"). This paper proposes an algorithm to reduce the network load associated with large numbers of vehicles reporting their position at the same time; if a car skips some reports then it is not possible for the control center to estimate its correct position therefore we need an algorithm that aims to decrease the frequency of the reporting without sacrificing the proper level of accuracy for the position. Compared to periodical reporting, the load effectiveness shows a 50-66% improvement.

1. Introduction

In present traffic systems, car navigation systems have been effectively put to practical use [1),2)]. Traffic is controlled by recognizing road conditions such as queue lengths at the stop lines of intersections or at toll gates, vehicular headways, geometric and control delay, etc. by means of infra-red sensors, in-road induction loops and cameras located on roads or from satellite imagery. However, some of these systems only detect events such as traffic incidents, and congestion, etc. and some even less and at this stage none can obtain individual vehicle information in real time. To provide enough data for navigation, the system needs to acquire the current position information of all vehicles on the road.

To provide en-route vehicular navigation information to drivers and the appropriate control strategies to control traffic efficiently, a comprehensive environment has been defined in a paper written by Hung, et al. (2006) [7)]. The authors described a new environment in which the real-time information is reported from a new type of device named "Reporting Equipment for current geographic Position" (REP) equipped in each vehicle. At the core of REP is GPS which provides position, speed and direction information, and the mobile phone network which provides device level communications. The REP terminal uses the mobile phone network to provide the facility by which the Control Center can provide information/instructions to the individual drivers. The environment in which all vehicles are equipped with a REP is referred to as a "Comprehensive REP Environment" or CREPE. If a sufficient enough number of REP terminals are in 'the field' then we can consider that a CREPE is in operation, thus the large number of REP terminals will have a significant effect on the data network load; this needs to be considered since the current mobile networks only have a limited number of communication channels.

This paper proposes the development of REP and discusses an optimum algorithm to reduce the expected network load associated with a CREPE. The algorithm aims to decrease the frequency of reporting to ensure that the accurate positioning detail of the vehicles is not affected. To evaluate the algorithm, we conducted experiments to analyze the accuracy of the reports in different cases; such as for periodic reporting and during the change of vehicle characteristics, say, speed or direction through different traffic situations. For the experimental process, each REP terminal equipped vehicle needed to provide the necessary information to the control center. The experiment results show us the optimum algorithm for reporting to reduce the frequency of report, consequently reducing the load of the mobile network.

2. Motivation

The prime purpose of ITS is to improve vehicle safety, and reduce the management costs of the environment by improving vehicle control using IT. A large number of services have been deployed such as safety driving assistance, provi-

†1 Ritsumeikan University
†2 University of South Australia

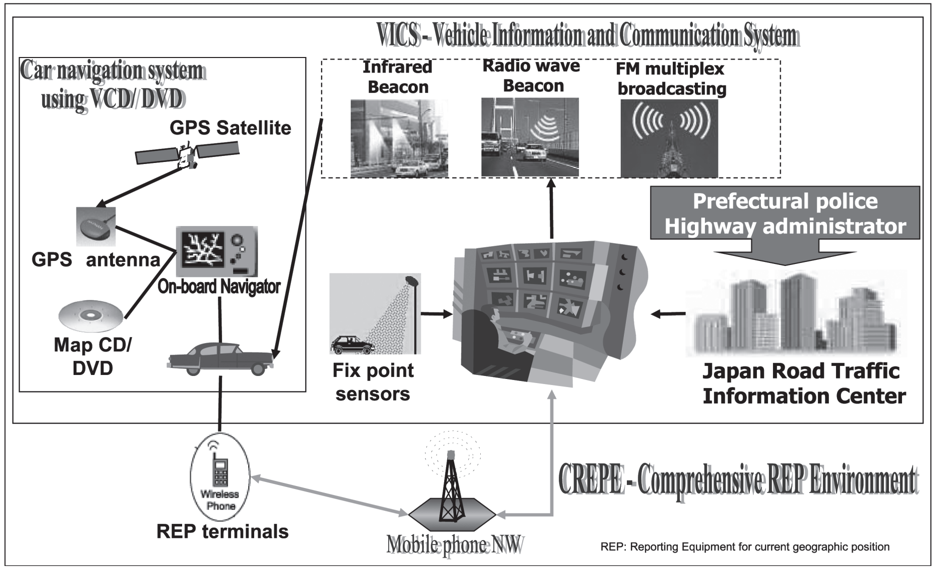

Fig. 1 Comprehensive REP environment.

sion of in-vehicle services and information, vehicle and road management, and distribution systems for traffic data (**Fig. 1**).

The first generation of ITS is an in-car navigation system using VCD/DVD and GPS. Due to the delay in updating road information, this system cannot provide real time information for drivers. Where there is new road construction or a change of traffic regulations, this system cannot provide information about it to drivers. Thus, this system is in-efficient for route searching.

In Japan, a consortium consisting of the Tokyo Metropolitan Police Department, the Ministry of Posts and Telecommunications, and the Ministry of Construction, formed to offer real-time traffic data; the system developed is known as VICS, which stands for Vehicle Information and Communication System [1], and it was launched in 1996 and can be considered as a 2nd generation of ITS. VICS can assist drivers to navigate by providing them with dynamic information such as route guidance, traffic information and so on or can acquire vehicle information such as probe data [3], taxi-probe data [5], etc. The VICS center first obtains information on traffic and road closures in real-time from the Japan Road Traffic Information Center which collects traffic data from others organizations such as local police departments or traffic control centers run by highway administrators. This kind of information is then analyzed and passed to drivers. In this way, VICS only provides traffic information to drivers and this information is collected from the others within the transport network. Thus, the natural latency associated with VICS can be considered significant due to the issue of information process delay and dissemination since drivers are required to download to use VICS's data. Furthermore, the traffic data from VICS is collected from fix-points sensors (stations) and VICS is deployed either in the central city or at critical junctions so VICS cannot process traffic conditions at all network locations. Further more, under the Probe Car System, many kinds of sensor data in vehicles on the road is collected on real time, and used to create traffic information. With this system, if much data is collected from Probe Cars to obtain correct traffic information, the packet telephony cost is raised, because a cellular phone is used to collect data.

3rd generation ITS solutions include pre-crash accident avoiding systems such as AHS (Advanced Cruise-Assist Highway System) [2]. AHS attempts to prevent accidents before they happen by giving drivers real-time information on accidents and traffic congestion ahead. It uses sensors and road-to-vehicle communications to provide this information [6]. Every car using AHS needs to be equipped with an in-vehicle sensor in order to communicate with the control center. However such devices are very expensive, so, AHS is currently only supported on highways, hence limiting its usefulness and coverage.

In order to improve traffic network systems and to co-ordinate the network of moving units, and integrate various kinds of transportation systems, Vogiatzis, et al. proposed an Integrated Transportation System - IMAGINATION [8)–10)] that takes into account all aspects of a transportation management system, using artificial intelligence, data streaming management systems, and GPS. The system is decentralized, stable and highly automated. IMAGINATION is a new type of integrated traffic management/traffic micro-simulation system, in which each vehicle in the network is "connected" to IMAGINATION, thus there is no longer a need for the traffic signalling system to be interested in the movement of vehicles between intersections. In this paper, IMAGINATION is a base for our discussion.

3. CREPE Architecture

3.1 CREPEnvironment and IMAGINATION

The three layer object model which is the basis of IMAGINATION is shown in **Fig. 2**.

The lowest layer manages specific controllers such as intersections and acquires data from those locations and controls the environment. Data is acquired by a local unit consisting of front-end component-fix point sensors; data is then transmitted to the data management system or related to control centers. Some data is used specifically for the control of individual locations whereas other data is locally summarized and then transmitted to the middle layer. Besides information collected from the front-end components, the REP terminal provides the functionality for reporting and receiving information between the vehicles in the network and the control center.

The DBS (Database Management System) in the middle layer also manages data from individual controller and system-wide data for the purpose of resource management, analysis and transport facilities planning. The data in the middle layer is used for establishing new knowledge rules, supporting activities including the management of local transport offices, registration of vehicles, the administrating of roads, etc.

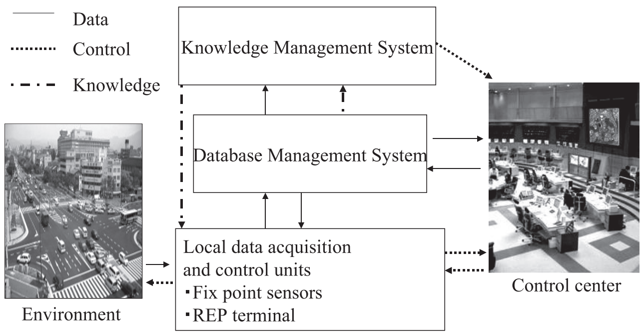

Fig. 2 Three layered model of IMAGINATION.

In the top layer, the KS (Knowledge System) manages the control/behavioural rules associated with the environment such as intersections, facilities and appropriate rules for determining appropriate protocols for accident wardens/investigators, traffic congestion, etc.

Finally, control centers are designated for specific purposes such as a fire control, highway monitoring maintenance centers, road traffic monitoring etc. Each control center connects to the related local units to get the appropriate level of data for its control mechanism. Springing from the notion of an "integrated system" (IMAGINATION), a new environment called CREPE is defined by Hung, et al. (2006) [7]. CREPE, which stands for Comprehensive REP Environment, is an environment in which all vehicles are equipped with a REP terminal and is used to acquire vehicle information and report said data to control centers. Based on the data acquired, control centers can estimate the future location of all vehicles running on road by means of a micro-simulation system [14)–17)] and thus control traffic movements in real time [7]. Since IMAGINATION collects real-time traffic data from each REP terminal to construct and validate traffic control algorithms, it can efficiently control traffic and be used to navigate each vehicle through the network for maximum efficiency.

The CREPE architecture is described in **Fig. 3**. The REP terminals received the current position of a vehicle from GPS satellite then report that data including other vehicle information such as speed, direction, etc. to the control centers through mobile phone networks.

3.2 Reporting Load

In CREPE, it is possible to heavily load to the network since the REP terminals will always be collecting and processing GPS which they will then need to decide whether it should be transferred to the control centers which analyze all received reports and control traffic.

In **Fig. 4**, it is shown that the expected load at the control centers should always be high, especially during peak periods (morning peak, typically between 8am and 9am and afternoon peak between 4pm and 6pm, and during special events such as sporting or cultural events) as the control centers have to acquire the information from a vehicle and then estimate each movement for all vehicles so as to control traffic streams in real time. That problem is solved by

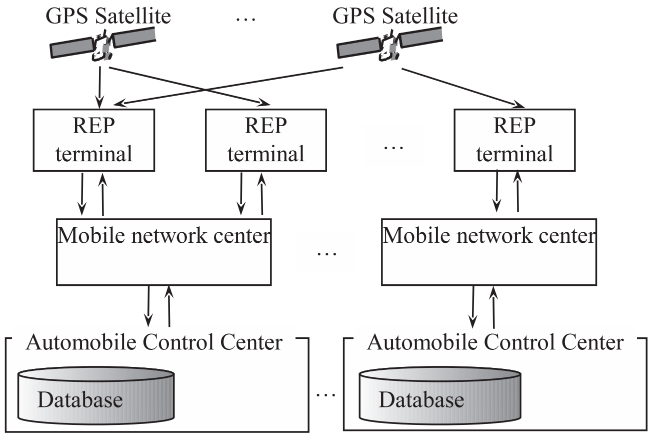

Fig. 3 Architecture of CREPE.

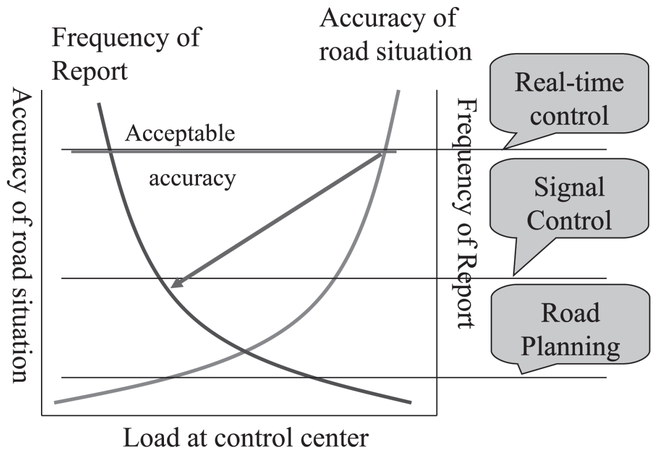

Fig. 4 Reporting load problem.

the deployment of local control centers using distributed computing resources geographically decomposed (Hung, et al., 2006) (**Fig. 5**) [7]. Furthermore the application of a functional decomposition for the Scope central, which manages special accidents, special incidents of traffic congestion on roads, is in the process

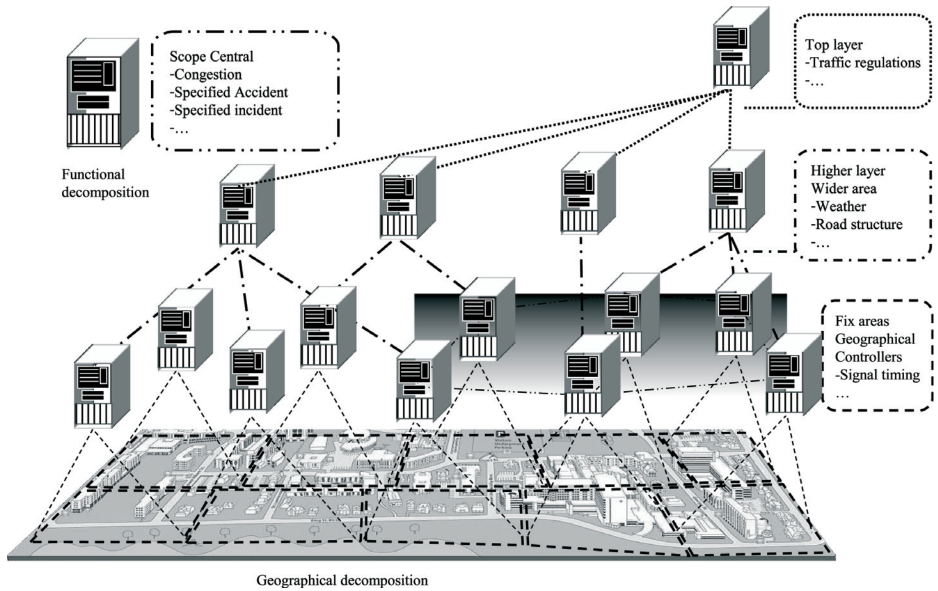

Fig. 5 Deployment a decentralized system of CREPE.

of being designed. Using a hierarchical of composition to share data among local computers, the local computers are divided into three levels; each level deals with local data. Some information should be managed in the top (3LOM) layer, such as weather or environment data. Some information (such as road conditions, etc.) will be managed in the middle layer as they share data items. Finally, some information such as the current position of a car or on road incidents are of importance potentially only in local areas, and so the local subsystems give that information to each vehicle.

Beside the load at the Control Center, the frequency of reporting from REP terminals also affects mobile/cellular telephone network centers' load since their communication channels are limited. Depending on different types of service being provided such as road planning, signal control or real-time control of traffic, the control center requires differing levels of information accuracy associated with the conditions on the road. However, as Fig. 4 shows, each REP terminal may

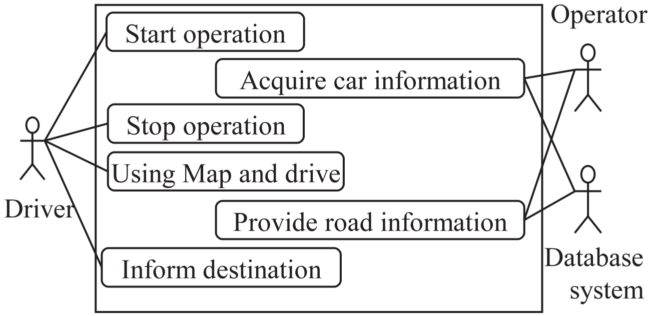

Fig. 6 Use case diagram of REP terminal.

have to decrease the frequency of its reporting to provide enough information to the control center based on the communications network load. If the frequency of report is decreased, the accuracy of the detail as reported to the control center is also affected, especially as the control center cannot estimate the correct position of each vehicle on the road as well as if it had more accurate information and it may not be able to assist in the navigation task for road users or control the traffic network as efficiently. Thus, we need an optimum algorithm for reporting vehicle information from the REP terminal. To achieve the stated requirement, we first discuss the implementation of REP terminals.

4. Implementation of Rep Terminal

4.1 Requirements for Reporting Function

We consider the following requirements:

- The current position of all cars to be acquired.
- The acquired data to have an acceptable level of accuracy.
- Every vehicle moving on road can receive road information and control signals from the control center.
- The frequency of each REP terminal report can be efficiently decreased.

The implementation of a REP terminal is described as follows:

4.2 Functional Architecture of REP

Figure 6 shows the Use case diagram for REP terminals. The driver decides the destination by using the navigation system and keeps driving on road (typically not at the same time for safety reasons!). Information from the vehicle such as speed, direction, and current GPS position is acquired and is reported to an operator at the control center by the REP terminal. The latest road information is acquired from the data base system and is used for the navigation. To achieve that functionality, **Fig. 7** shows the design for the functional architecture of REP terminals and is described as follows: "**GPS receiver**" receives GPS data using RMC (Recommended Minimum Specific GNSS data [NMEA standard]) which includes the angle of deviation, the terrestrial magnetism mode, checksum at the measurement time and status, latitude, longitude, ground speed, direction and time. The data received from GPS is processed and transmitted to the Data reporter. The **Data reporter** reviews the timing of the report after comparing GPS data with the map data and route information from "**Map manager**" and "**Route manager**" respectively. The **Log system** records automatically the operation outputs of the REP. The **Data transmitter** communicates between REP terminals and the control center ⋆1 based on the optimal 'timing' strategy and the content of the report from a given vehicle (discussed in the next section). If the control center recognizes the map information has not been updated, it will transmit the latest map data to the Data transmitter and then pass it to the Map manager. After it has been updated, the Map manager issues a re-detection

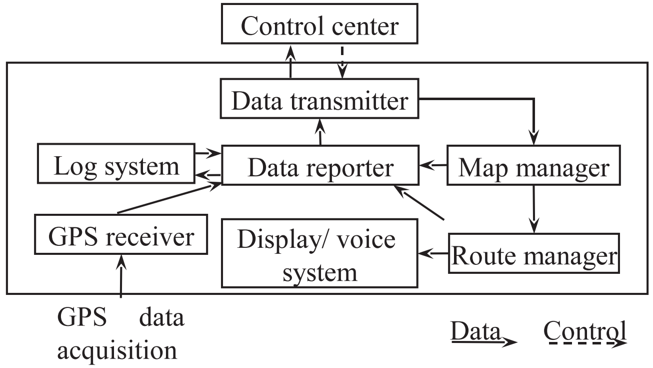

Fig. 7 Functional architecture of REP terminal.

⋆1 see Section 3.1

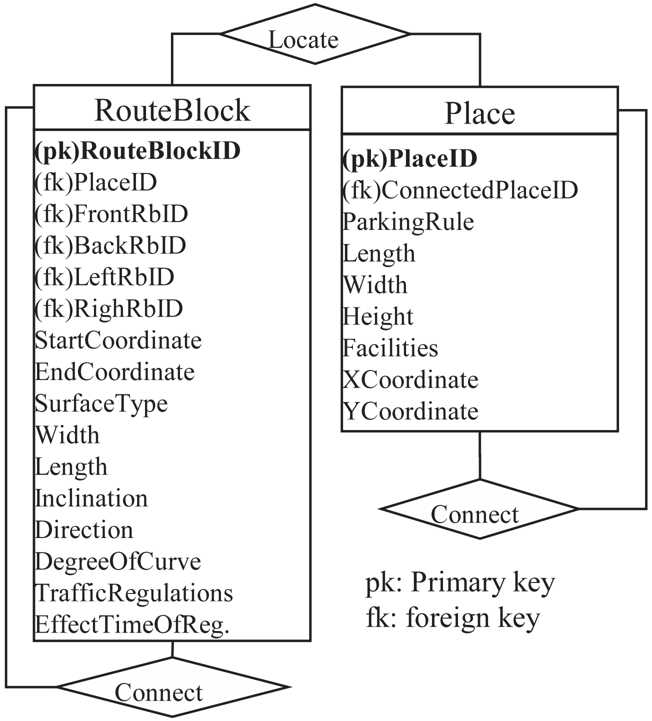

Fig. 8 Data structure of map information.

for the associated route to the Route manager. The **Display/voice system** assists the driver in the navigation process by providing the latest map and route information by visual and audio means.

4.3 Data Structure of Map Information

Due to the limitation of storage, a REP terminal cannot utilize the same level of digital map data as one would find in a typical computer as it will overflow the system, hence **Fig. 8** shows a modified version of the map data structure which takes the memory limitation into account and allows it to be stored on typically sized mobile devices. In which, pk and fk stand for primary key and foreign key respectively.

In this structure, each Route-Block can be connected to one another, thus the

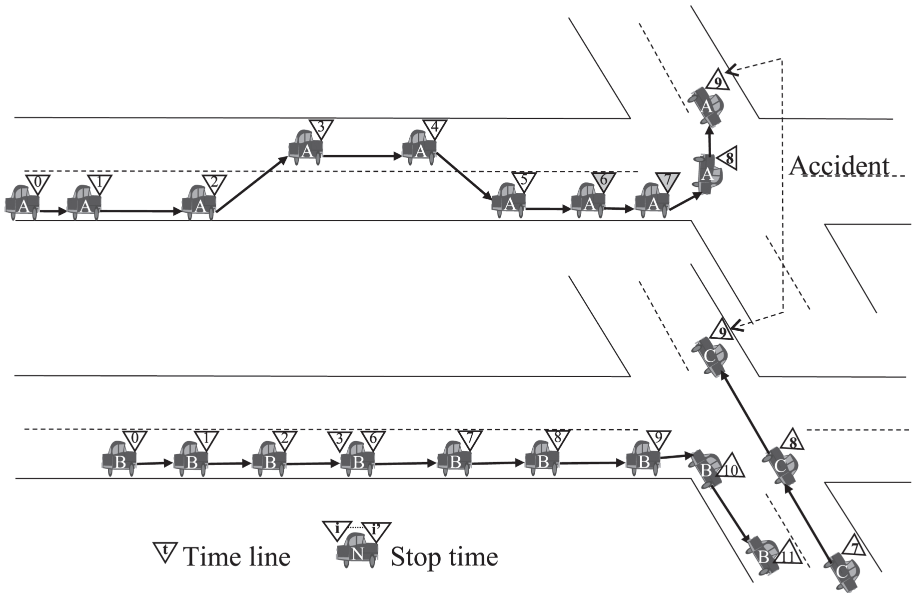

Fig. 9 Vehicle behaviors.

neighbouring Route-Block IDs are recorded. Additional road information is necessary to complete the picture such as coordinates, surface type, etc., traffic regulations and the time during which they are in effect. The Place table provides the information about parking, intersections, etc. Adjoining places can be searched by using the "ConnectedPlaceID" key, and the relationship between each Route-Block and Place can be found by using the "Locate" relationship. Thus, this data structure is sufficient for road and route detection. Based on the detected information, the REP can calculate vehicle OD route (Origin-Destination) by its shortest route finding method.

4.4 Data Format of the REP Report

Potentially we consider that each individual expresses their unique behaviour when on the road. To define the data format of the REP report, it is necessary to analyze initial behaviours of each vehicle on road.

Figure 9 demonstrates various vehicle behaviours on road for three cars A, B and C on a given road section. The number inside the triangle is a time stamp for each vehicle. The arrow indicates the direction and speed of the vehicle, in which, a longer arrow means a higher speed. So, the first noted behaviour is when we observe the speed of vehicle A changing from time step 0 to time step 2, and for car B the speed changing between time steps 6 to 7. The second noted behaviour is the changing of direction exhibited by, for example, car A changing its direction to overtake car B at time step 2, then at time step 7 car A turns left and finally at time step 10 car B turns to the right. Yet another behaviour exists when car B stops between time period 3 to 6, and finally, we note the expression of a road incident when we see car A and C at the same position.

From the discussion about driving behaviours above, the data format of the REP report string for those four types is:

Start information: When driving begins.

Transmission data: vehicle ID, driver ID, position, speed, destination and time.

Receive data: Congestion and regulation of traffic.

Stop information: When driver stops.

Transmission data: vehicle ID, driver ID, position, Consolidating data and time.

Receive data: None.

Update information: When REP updates the road situation.

Transmission data: vehicle ID, driver ID, position, time, consolidating data and destination.

Receive data: Congestion and regulation of traffic.

Incident information: When a vehicle is subject to an incident (including vehicle accidents).

Transmission data: vehicle ID, driver ID, position, time, status of incident (type, injured person, present traffic trouble, etc.).

Receive data: Incident processing method.

The above mentioned information is reported to the control center by the general algorithm shown in **Fig. 10**. In general, when a driver starts driving, the REP terminal acquires data from the GPS receiver and reports "start information". Every time the state of the vehicle changes while driving such as changing direction, changing speed, stop or start the vehicle, passing an intersection, the REP terminal will report the "update information". As a vehicle may keep the same direction for some time, the REP terminal may also report periodically. The REP terminal only reports "stop information" when the vehicle reaches its destination or finishes a journey.

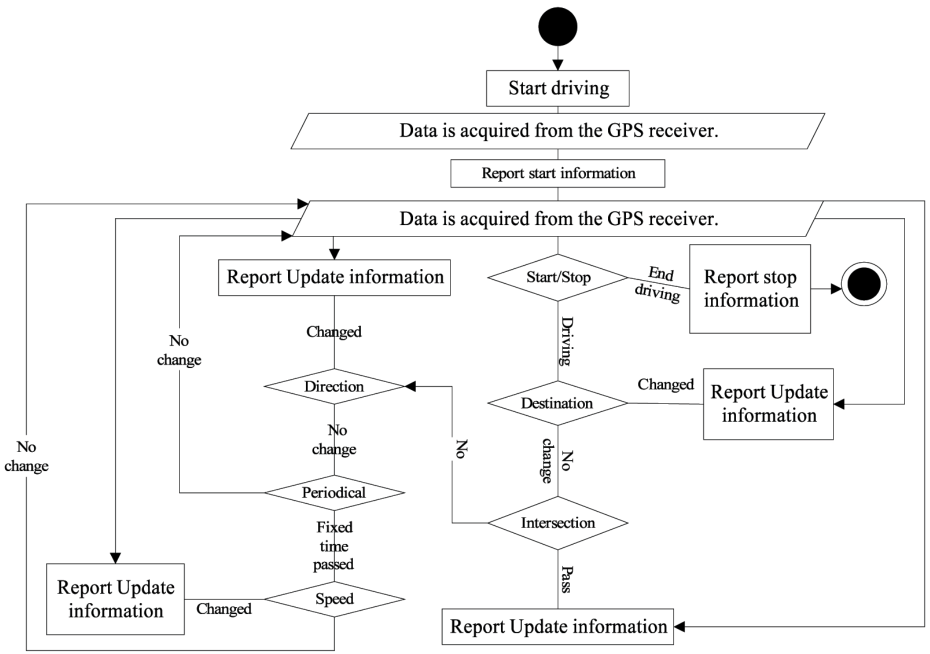

Fig. 10 Activity diagram of reporting algorithms.

5. Reporting Algorithms of Rep Terminal

We consider the following cases to analyze the different timing (or report frequency) schemes during which a REP may report to the control center.

- Periodical timing.
- Different route detected.
- The event when the parameters of car changed such as speed, direction and destination.

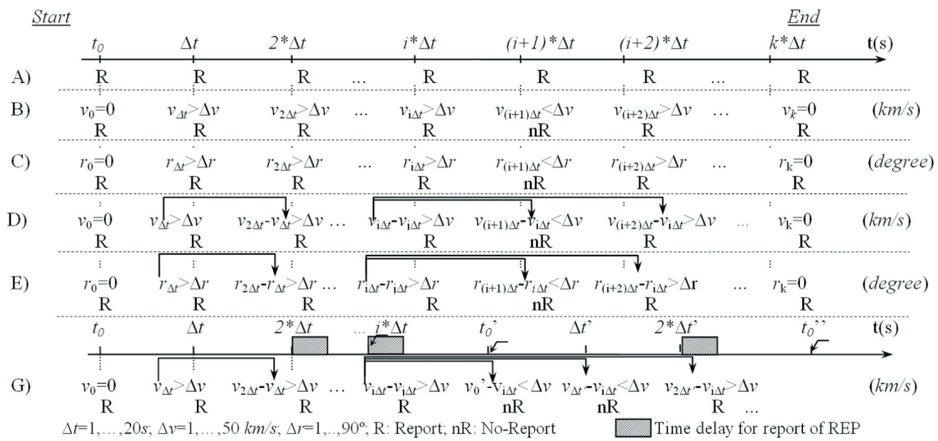
Fig. 11 Report timing algorithms of REP terminal.

- The event when a vehicle is travelling through an intersection.
- Assumption: When moving, the vehicle is assumed to carry a vector. If the direction of the vehicle has changed, the new vector will have a different angle to that of the previous vector which we call the "angle of vehicle" or r.
- The report frequency is assumed to be the number of seconds between two report times.

The REP terminal always acquires data from the vehicle and decides when to report according to the data content from the GPS receiver (Fig. 10). From those cases, we analyze the following algorithms.

5.1 Reporting Algorithms

Algorithm A Periodical reporting.

The REP terminal will report at fixed interval of time (**Fig. 11** A). In this paper, the given time interval between reports is denoted by Δt (s). The shorter the interval the higher the accuracy that can be achieved; however the heavier the network load we will have. This algorithm is used as the base comparison with relation to assessing our algorithms for reducing the reporting frequency.

Algorithm B Periodical reporting base on vehicle speed.

The report frequency is defined as follows:

Definition 1 Assume Δt (s) is the given time interval between reports, Δv (km/s) is the constant of variance speed, v (km/s) is vehicle speed.

For each Δt and Δv: at each time $t_i = i \times t$, If $(v_{t_i} - v_{t_{i-1}} > v)$ then [*Report*] else [$No-$ *Report*].

This definition means that the REP recognizes vehicle speed periodically and it will report if the vehicle speed is greater than a constant speed variance (Fig. 11 B).

Algorithm C Periodical reporting base on vehicle direction.

The report frequency is defined as follows:

Definition 2 Assume Δr (^{o}) is the constant angle, Δt (s) is the given interval between reports.

For each Δt and Δr: at each time $t_i = i \times \Delta t | i \in N$, If $(r_{t_i} - r_{t_{i-1}} > r)$ then [*Report*] else [$No-$ *Report*].

This definition means the REP recognizes the angle of the vehicle periodically and will report if the angle is greater than a constant angle (Fig. 11 C).

Algorithm D Report on speed changed compared to the last report.

The report frequency is defined as follows:

Definition 3 Using the same Δt (s) and Δv (km/s) as Algorithm B, and assuming that the last time of the report is t_i, we have:

If $(v_{t_{i+1}} - v_{t_i} < v)$ then [$No-$ *Report*] else if $(v_{t_{i+2}} - v_{t_i} > v)$ then [*Report*].

This definition means that: The speed of vehicle is calculated periodically. The REP only reports if it sees the difference between the last reported and the current speed exceeds a constant value (Fig. 11 D).

Algorithm E Report on direction changed compared to the last report.

It is similar to algorithm D, but in this case, the angle of the vehicle is recognized periodically and compared to the last report of the vehicle. The report frequency is defined as follows.

Definition 4 Assume that the last time of report is t_i (s), we have:

If $(r_{t_{i+1}} - r_{t_i} < \Delta r)$ then [$No-$ *Report*] else if $(r_{t_{i+2}} - r_{t_i} > \Delta r)$ then [*Report*].

The definition means that the REP only reports if the difference between the angle of the car at the last reported time and the current calculated angle is greater than a constant value (Fig. 11 E).

Algorithm F Combination D & E.

Combine two algorithms D and E, the speed and the direction of the vehicle are both calculated periodically. The algorithm F is defined as:

Definition 5 If $[AlgorithmD = true]$ or $[AlgorithmE = true]$ then $[Report]$ else $[No - Report]$.
This definition means the REP reports if the speed changed more than a constant speed value or the angle of the car changed more than a constant value of angle.

Algorithm G Add the time delay of report to the time interval.

In this algorithm, we add the reporting time latency of the REP terminal. Using the same interval time Δt (s) and constant of speed Δv (km/s) as previous algorithms, the report frequency is defined as follows:

Definition 6 Let the last time of report be t_j, If $(v_{t_i} - v_{t_j} > v)$ then $[Report]$ and $[Reset - timer - to - 0]$ else $[No - Report]$.
The definition means (similar to algorithm D) that the REP terminal only reports if the difference between the last reported and current speed is greater than a constant value. After each report, the REP will reset its timer (Fig. 11 G).

Algorithm H Periodical estimation and report.

Definition 7 Let the last time of report be t_j (s), v (km/s) be vehicle speed, p_i be the vehicle position at time i, p_e be periodically estimation of the vehicle position at Δt (s), Δp be constant value 1% to 10% and Δv be a constant speed 1 to 50 km/s. If $(\sum |p_e - p_i| > \Delta p)$ or $(v_i - v_j > \Delta v)$ then $[Report]$ else $[No - Report]$.
This means that: there is a constant value 1% of error equal to 35 m. Algorithm H is to report current information of the vehicle when the sum of errors of longitude and altitude estimated periodically ($\Delta t = 1$ to 20 seconds) is greater than a specified constant value 1% to 10% or the speed is changed Δv (1 to 50 km/h) compared to the last report. We name this algorithm "estimation based algorithm".

5.2 Related Works

There are several researches on uplink control to reduce the cost of communications in ITS.

In Ref. 11), the authors proposed Positionics mechanism by using of Quasi-zenith satellite for downlink and cellular network for uplink, which broadcasts position- based- information with area tag from the satellite center and collects data from the vehicles returned to the center's requests by own position. Vehicles with a PAS-based GPS receiver, driving in a specific area and below a constant speed, return their position and vehicle speed. The communication capacity is large in some cases. In the traffic congestion road, the number of uplinks is more than 40,000, even when the system filters the reporting vehicle as having a speed below 20 km/s. We can consider algorithm D as a comparable method with this method, but D has some advantages because it can reduce more the number of uplinks, as in congestion the vehicle speed may only have a minor change. In an application for traffic accident prevention, the domain of the position tag is set to about 500 m. It is corresponding with an interval report time of 1.5 seconds and it would be considered as algorithm B.

Ishizaka, et al.[12] discuss the feasibility of a system that collects traffic information using probe vehicles in a developing city in terms of cost efficiency. The probe data includes latitude, longitude, time and other signals which are received by a GPS antenna. They conclude that a 5 seconds interval is enough to record travel time with high reliability. It is a kind of periodical report (comparable with algorithm A in this paper).

Amin, et al.[13] have demonstrated that GPS-enabled cell phones can be used as sensors for traffic monitoring purposes, while preserving individuals' privacy when collecting data. Each cell phone was reporting its position and velocity every 3 seconds. This data is used to evaluate the quality and accuracy of traffic data. This research focuses on the proportion of equipped vehicles to obtain accurate results.

6. Experiment And Performance Evaluations

6.1 Experimental Environment

To evaluate the algorithms relating to the various report frequencies, we devised an experiment as follows: The REP terminal is assumed to be a cellular phone pocket PC Mio168RS including GPS, and Bluetooth communication. The mobile phone can receive GPS data using the NMEA-0183 standard and it was programmed to report using the different algorithms posited in various traffic situations such as speed changed ($\Delta v = 1 \sim 50$ km/s), vehicle angle changed ($\Delta r = 1, \cdots, 90^o$). The map data, which included road network information for Yawata City, in the Kyoto prefecture, is stored locally in the terminal by the

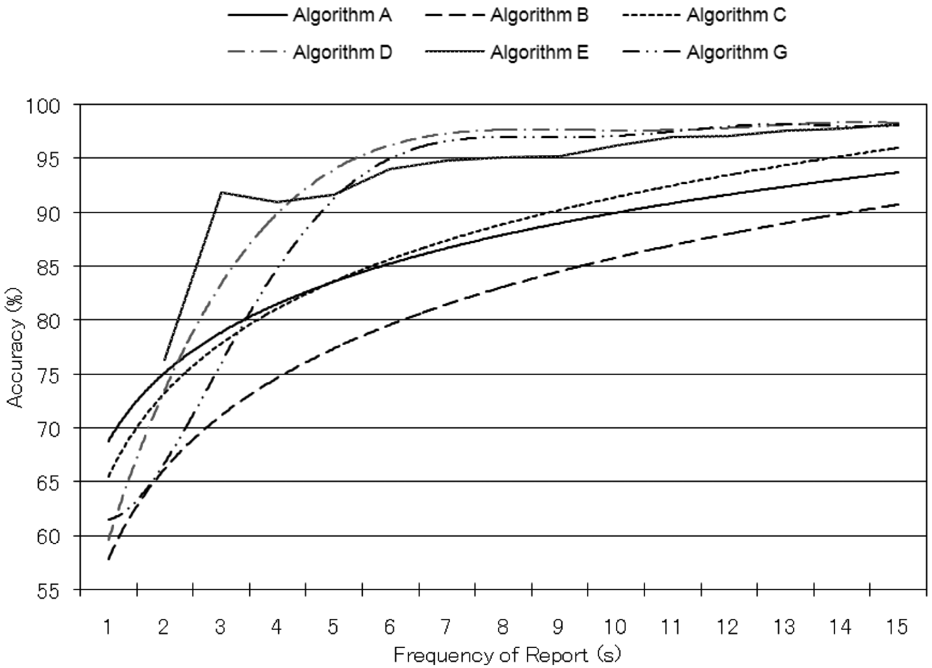

Fig. 12 Approximation curve: Report Frequency vs Accuracy of algorithm A, B, C, D, E, G.

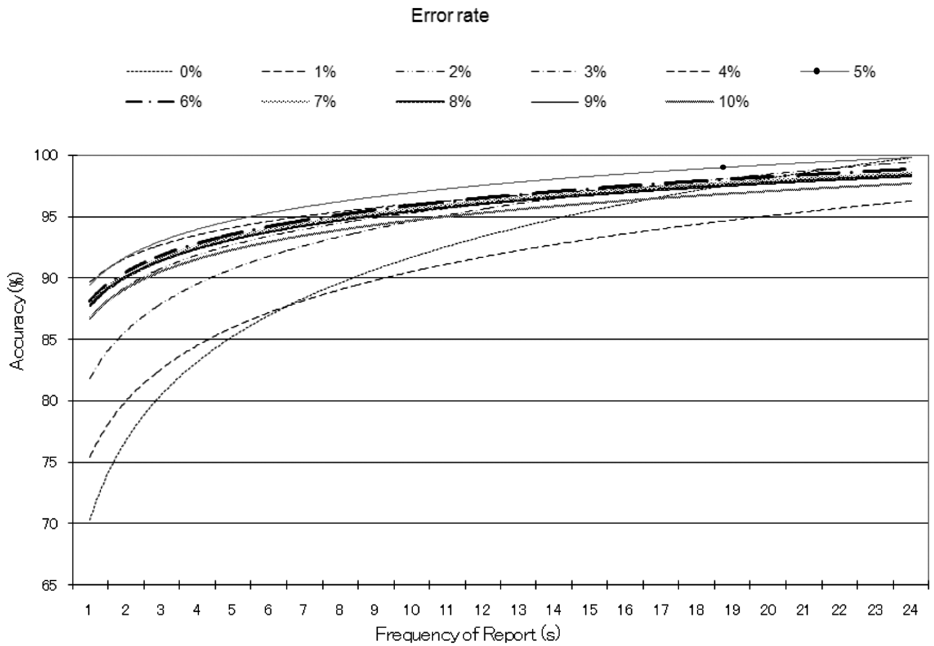

Fig. 13 Approximation curve based on different error rate of algorithm H.

proposed data structure (see Section 4.3). The REP terminal is located in a vehicle running on 3 different routes at different times and the evaluation data was obtained by collecting GPS data 5 times for the 3 routes during 10 minutes.

We consider that the accuracy is related to the level of confidence related to the difference between the estimated mean samples and the collected data (position, speed, and angle). In our experiment, a relative error represents the difference between estimated data and the data that is periodically collected. We consider the estimation is reliable if the error is less than a pre-set permitted value (e.g., $\varepsilon = 5\%$). Assume that each time the control center received a report, it will examine the relative error and then use the collected data for the next cycle of estimation.

6.2 Performance Comparisons

In order to compare reporting frequencies for the periodical reporting algorithms, each algorithm collected data and evaluated the accuracy Ac (%) by using the below formula:

$$Ac = \frac{d(p_i, t) - d(p_0, t)}{d(p_0, t)} \times 100(\%) \quad (1)$$

In which, p_i is the step of reporting interval with $\Delta t = 1$ to 20 s, p_0 is periodical reporting, and $d(p, t)$ is data acquired including speed, position and vehicle angle. Thus, in our experimental settings, the unit of controllable parameters is as follow; Δt in second, Δv in km/s, Δr in degree, and Δp in percentage.

6.3 Discussions of Experimental Results

The following discussions show the results of calculating the accuracy of the control center estimations based on the various criteria.

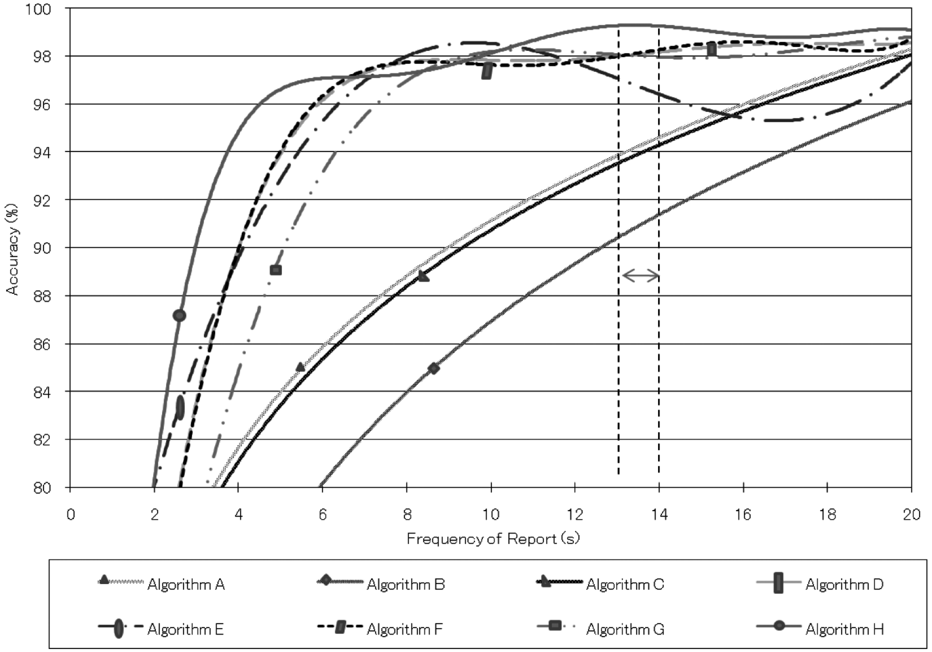

Fig. 14 Frequency of report and accuracy.

Figures 12 and **13** are approximation curves based on the accuracy of the report for the discussed algorithms. In Fig. 12, we note that the REP report strategy is best when one accepts a 5% error rate.

Figure 14 shows the result of the experiment when comparing between the frequency of reports and accuracy, in which algorithm H is selected with an error rate of 5% gives the best result.

Finally we identified the following points:

(1) To report every time the speed and the direction of a vehicle, algorithms B and C were the most 'chatty' in terms of frequency and decreasing the frequency also decreased the accuracy of the report.

(2) Using algorithms D and E it is possible to reduce the frequency of report compared with algorithms A, B and C whilst maintaining the same accuracy.

(3) Algorithm F analyzed the speed and the direction with the constant angle of 0, 45 and 90 degree. The accuracy is similar between each of the cases. However, when changing direction, e.g., such as a vehicle going round a curve or changing lanes, the speed is decreased but the direction angle is still less than the constant angle, thus the algorithm timing becomes dependent on the speed.

(4) The algorithms D and G have a similar accuracy regardless of the frequency. However, algorithm D is simpler than G.

(5) Algorithm H is able to decrease the report frequency and keep the accuracy higher than algorithm D. The experiment result shows that the frequency of report can be optimum if we accept an error rate of 5% for the sum of errors of longitude and altitude estimated periodically of $\Delta t = 13 \sim 14$ s, and the speed is changed $\Delta v = 38$ km/s. The frequency of report Δt is selected to be 14 s. The accuracy is fixed at 98 to 99%. By the algorithm H, the network load is able to reduce efficiently.

7. Conclusions

An optimum data structure, and various algorithms for determination of an optimum reporting frequency for REP terminals is discussed and an experiment is undertaken to resolve the network load problem. After the experiments, we found an optimum algorithm which focuses on measuring vehicle speed and its location in each route block, and named the "estimation based algorithm" which is the best for reducing the expected communications load at control centers as well as mobile phone centers. Thus the algorithm is simple and the frequency of reporting is optimized.

The paper revealed the possibility of deploying REP terminals widely as the first step in achieving the implementation of the CREPE for future traffic control.

References

1) Matsuda and Roymatsu: *What is VICS? The New World of Car Navigation*, Nikkan Kogyo Shimbun (1996).
2) Advanced Cruise-Assist Highway System Research Association. http://www.ahsra.or.jp
3) Wada, K.: Probe Car Information System Project, *Journal of Information Pro-*

cessing Society of Japan, Vol.43, No.4, pp.363–368 (2002).
4) Traveller Route Guidance Systems. http://www.wirelesscommunication.nl/reference/chaptr01/roadtrin/ivhsrout.htm
5) Liu, K., Yamamoto, T. and Morikawa, T.: Feasibility of Using Taxi Dispatch System as Probes for Collecting Traffic Information, *Journal of Intelligent Transportation Systems*, Vol.13, No.1, pp.16–27 (Jan. 2009).
6) Hatakenaka, H., Kanoshima, H., Yaegashi, Y., Inoue, H., Oshima, T. and Takenaka, K.: Study of the Practical Application of an Advanced Cruise-Assist Highway System Utilizing Probe Data, *15th World Congress and Exhibition on Intelligent Transport Systems and Services*, ITS America (Nov. 2008).
7) Hung, N.T., Ikeda, H., Vogiatzis, N. and Lin, Z.: New Environment CREPE for transportation control and its effectiveness, *IAENG International Journal of Computer Science*, International Association of Engineers, pp.790–795 (2006).
8) Vogiatzis, N., Ikeda, H., Woolley, J. and He, Y.: Integrated Multi-nodal traffic Network systems, *Journal of the Eastern Asia Society for Transportation Studies*, Vol.5 (Oct. 2003).
9) Ikeda, H., Vogiatzis, N., Wibisono, W., Mojarrabi, B. and Woolley, J.: Three Layer Object Model for Integrated Transportation System, *1st International Workshop on Object Systems and Systems Architecture*, Victor Habor, Australia (2004).
10) Vogiatzis, N., Ikeda, H. and Wibisono, W.: On the locality-scope model for improving the performance of transportation management systems, *27th Acstralasian Transport Research Forum*, Adelaide (2004).
11) Iwahashi, T., Higuchi, H., Goto, Y. and Watanabe, T.: Positionics: A solultion to position-based ITS info-communication services, *Proc. 11th World Congress on ITS*, Japan (2004).
12) Shizaka, T., Fukuda, A. and Narupiti, S: Evaluation of Probe Vehicle System by using Micro Simulation Model and Cost Analysis, *Journal of the Eastern Asia Society for Transportation Studies*, Vol.6, pp.2502–2514 (2005).
13) Amin, S., et al.: Mobile Century Using GPS Mobile Phones as Traffic Sensors: A Field Experiment, *15th World Congress on Intelligent Transportation Systems*, New York, NY (Nov. 2008).
14) Kitamura, R., Chen, C., Pendyala, R.M. and Narayanan, R.: Micro-simulation of daily activity-travel patterns for travel demand forecasting, *Transportation*, Vol.27, pp.25–51 (2000).
15) Rindt, C.R., Marca, J.E. and McNally, M.G.: Toward dynamic, longitudinal, agent-based microsimulation models of human activity in urban settings, Working Paper (July 2002).
16) Oh, C. and Ritchie, S.G.: Anonymous Vehicle Tracking for Real-Time Traffic Surveillance, Center for Traffic Simulation Studies, Paper UCI-ITS-TS-WP-02-16 (2002).
17) Hu, W.: Traffic accident prediction using 3-D model-based vehicle tracking, *IEEE Trans. Vehicular Technology*, Vol.53, No.3 (May 2004).

(Received March 31, 2010)
(Accepted October 4, 2010)
(Released January 12, 2011)

Nguyen Thanh Hung was born in 1976. He received his Masters Degree at the Computer Science Department, Ritsumeikan University, Japan in 2004. He has been working in Ritsumeikan University since 2008 and is now a research associate of the Department of Computer Science. He is currently pursuing his Ph.D. degree in Computer Science in Cyberspace Technology Laboratory, the Department of Computer Science, Ritsumeikan University. His supervisor is Professor Hideto Ikeda. His current research interests include CyberSpace technology, database, algorithms design and analysis, Intelligent Transportation systems and Natural Language Processing. He is a member of IPSJ, IEICE and IAENG.

Hideto Ikeda is the director of the Cyberspace Technology Laboratory. His extensive career in Database Research commenced whilst a post graduate in Mathematics at Hiroshima University. He has held several high level management positions including Vice-Director of the Computer Science, Hiroshima University, Project Manager of the Library Automation Project, Tsukuba University, and Director of the Computer Science Center, Ritsumeikan University.

Kenzi Kuribayasi graduated from the Department of Computer Science, Ritsumeikan University. He is continuing his Masters Degree in Computer Science, Ritsumeikan University. His research subject is mobile computer design.

Nikolaos Vogiatzis received his Ph.D. Degree at the Transport Systems Center, the University of South Australia. A graduate of Applied Mathematics and Political Science from the University of Adelaide, he has been a professional Software Engineer/Analyst Programmer for 10 years. Nik has expertise in developing soft real-time systems in the Railway Engineering field, and has developed a number of systems including financial systems, web-based surveys and implemented VLDBs.