International Journal of Innovative Computing, Information and Control
Volume **9**, Number **3**, March **2013**
ICIC International ©2013 ISSN 1349-4198
pp. 1031–1044

USING THE MIMO MECHANISM TO INTEGRATE VEHICLE INFORMATION PROCESS SYSTEMS IN VEHICULAR NETWORKS

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Received December 2011; revised April 2012

Abstract. *This paper presents dynamic vehicle information for wireless communication and safe systems by integrating radio frequency identification (RFID) technology. These systems are able to derive advantages from integrating RFID with other recognition technologies. The car black box is the best and the most innovative choice for this specific application. This black box can not only protect car, but is also able to recognize events that cause car accidents. The contents of the black box include the RFID, the general packet radio service (GPRS), Bluetooth services, a personal digital assistant (PDA) and a global positioning system (GPS). The proposed system has become increasingly popular with the advent of digitization in terms of merging multiple databases together, therefore, creating a tremendous amount of commercial opportunities. The car black box also possesses the ability to connect multiple users to a singular real-time navigation information system. This navigation information system integrates the independent real-time traffic information database and Geographical Information System (GIS) through the data fusion method. We adopted a traffic information system offering advanced personalized route planning, including added services for alerting motorists to traffic jams by means of the Short Message Service (SMS) through Global System for Mobile (GSM) communication networks. We have used small and low-cost GSM modules for data processing via the Multiple Input Multiple Output (MIMO) ant colony optimization (ACO) algorithm, which have since been developed into a real-time software solution to help users and evaluate their preferences when making use of the car traffic information system.*
Keywords: Vehicle, RFID, GPRS, MIMO, ACO

1. **Introduction.** The U.S. National Transportation Safety Board (NTSB) recommends the inclusion of black boxes, also known as data recorders, for all newly manufactured passenger vehicles. These black boxes are similar to those used in airplanes today. The Institute of Electrical and Electronic Engineers (IEEE) announced that one of its committees had created the world's first technical standard for these devices. The IEEE aims to make it possible to successfully obtain information regarding car accidents. These recorders can be stored and have to be constructed to be tamper-proof and crash-proof. The accuracy of the data gathered aids the development of solutions to reduce the devastating effects of these accidents. Therefore, if the car black box recorder comprises integrated systems that make decisions for the data acquisition information, it would be easy to retrieve significant information for investigating car accidents. A car black box that combines digitized integrated targets would be suitable for developing avenues for commercial opportunities by integrating the broadband network with RFID, Bluetooth, PDA and GPS. These integrated systems can be adopted for purchasing gas, going through tolls, paying for parking, security checks or providing diagnostics for troubleshooting engine problems [1,2].

Recent developments in mobile communication and Internet computing have paved the way for a wide variety of applications. In comparison with the traditional loop detector and GPS-based methods, this newly emerging approach confers benefits such as low device installation and maintenance costs, convenient data collection, particularly of a relatively large peak hour sample size [3]. The real-time operation of GIS is said to be one of the main solutions used currently to alleviate traffic jams and guide traffic flow [4].

Together with the development of GPS and navigation systems for cars, these services can improve route planning and present up-to-date information for motorists throughout the entire journey [5]. The GSM network utilizes Time Division Multiple Access (TDMA) technology, which allows one frequency to be shared between several users simultaneously. Handover signals in the GSM network are applied to balance out cost and efficiency with speed estimation. Mobile information services play important roles in our work and private lives. Increasing the mobility of motorists in urban areas, on the freeway and in densely populated areas requires the use of innovative tools and novel techniques for traffic planning that can be customized for different individuals. Although there are already navigation systems featuring route planning in place, they are difficult to use because neither current traffic information nor personal user preferences are incorporated.

2. System Integration.

2.1. Car information system.

The multiple-recognition system of the car black box is a major configuration that uses RFID. It uses a serial port to transmit data from the user's IC card to the system, and the data are transmitted from the system to the server via a GPRS connection. The driver's identity is verified at the server end, and the relevant information can then be sent back to the system upon verification of the driver's identity. The car black box can synchronously transmit the data to the IC card and the server end, and the data can be backed up by the server every five minutes. The GPS receiver is embedded and communicates via Bluetooth. The PDA mobile phone transmits the data to the server via GPRS. Figure 1 presents the multiple-recognition system integration model of the car black box using the sensors, wireless communication, recognition system, and mobile device for the car's transmitted information.

Figure 2 shows what can be seen at the server end and also displays relevant information about the car. It is synchronized to send GPS data, RFID user information and messages. The driver at the client end can receive messages using a PDA mobile device, as shown in Figure 3.

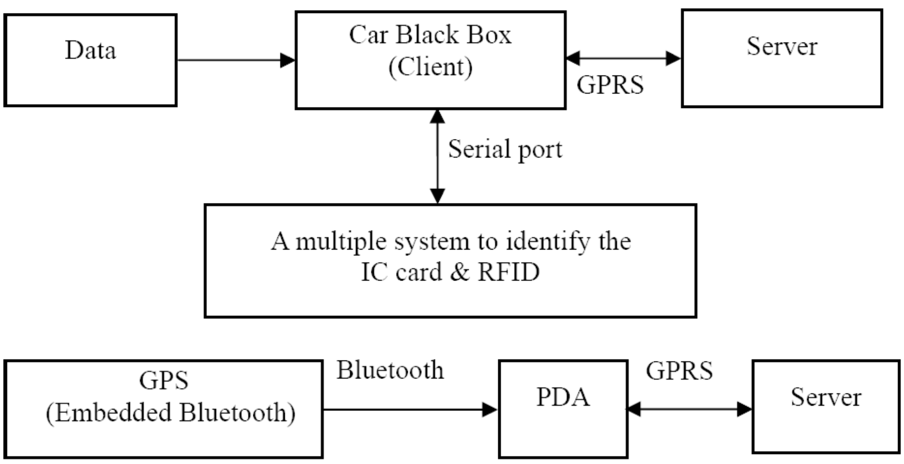

FIGURE 1. The system integration model of the car black box

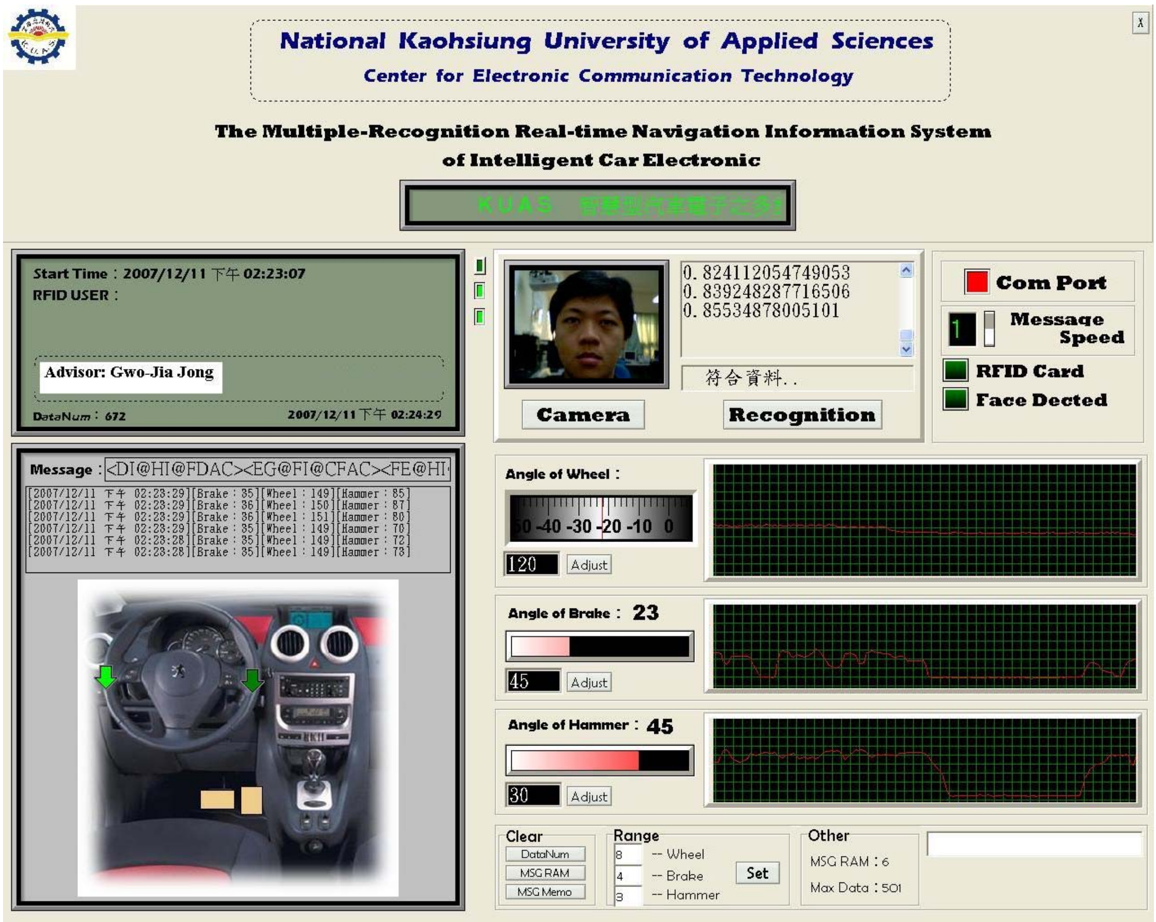

FIGURE 2. The server end of the multiple-recognition system within the car black box

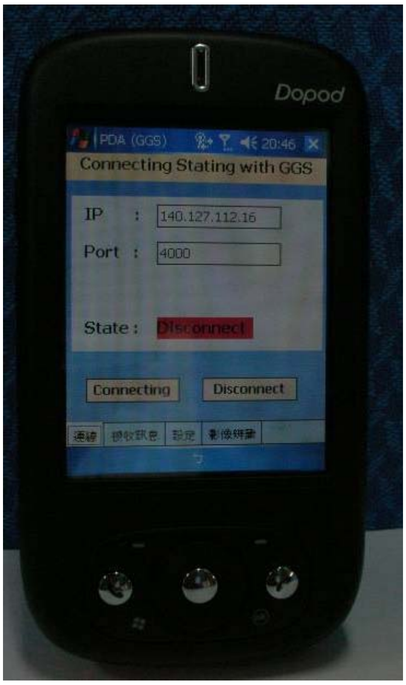

FIGURE 3. The mobile phone end device

2.2. **Traffic information navigation system.** With the current development of flexible devices using cell phones or PDAs, mobile services are expected to play an important role in information technology in the future. Information on the best route is obtained from the users using a mobile phone or from the Internet through the wireless network system. The navigation system will be responsive to the different requests submitted by different users. The route affects the real-time positions of the cars. SMS is used to verify the real-time current positions of the cars using the navigation system. Figure 4 shows the automatic real-time SMS reading service message for the integration model and navigation traffic information system.

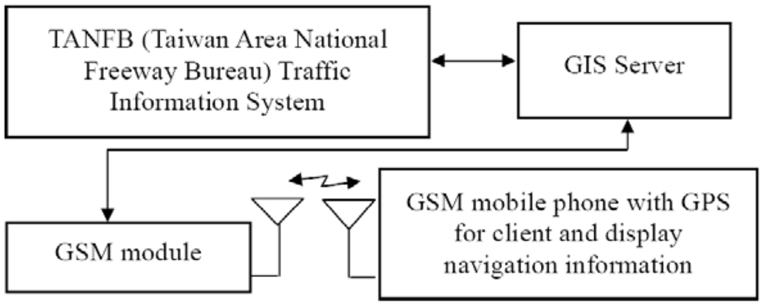

FIGURE 4. The integration model of the real-time traffic information navigation system

In the navigation system of the Taiwan Area National Freeway Bureau Traffic Information System (TANFB), the best route (which includes the parameters of the shortest distance or the shortest time), critical route, and traffic flow analyses are all based on spatial GIS analyses, which are often related to topological networks of the traffic flow control algorithm developed using the MIMO approach as shown in Figure 5. The most suitable rerouting of the user is sent to the user in a flow chart as shown in Figure 6. Figure 7 shows the real-time navigation information and MIMO system flow chart for finding the best route using the MIMO algorithm.

3. The Multiple-User MIMO.

Multiple-input multiple-output (MIMO) communication techniques can be an important area for next-generation wireless systems because of their potential for high capacity, increased diversity, and interference suppression. For applications such as traffic information systems and GSM modules, MIMO systems can be deployed in environments where a single base station (BS) communicates with many users simultaneously [6].

3.1. **Multiple-user MIMO downlink model.** The downlink channel, used by the base station for simultaneously transmitting messages to a group of users, is illustrated in Figure 8. In the situation depicted, the base station attempts to transmit messages over the same channel to users, but there is some inter-user interference for user 1 generated by the signal transmitted to user 2 and vice versa. With the aid of multi-user detection, it may be possible for a given user to overcome the problem of multiple-access interference, but such techniques may be too costly for use at the receiver end [7].

Consider the downlink to K users as represented in Equation (1) by subscript $k = 1, \ldots, K$ where multiple antennas are set up at the base station for transmission to the K receivers at the user end. The received vector signal of user k can be written as

$$\mathbf{y}_k = \mathbf{H}_k \left(\mathbf{x}_k + \sum_{\mu=1,\mu\neq k}^{K} \mathbf{x}_\mu \right) + \mathbf{n}_k$$

$$= \mathbf{H}_k\mathbf{x}_k + \left(\sum_{\mu=1,\mu\neq k}^{K} \mathbf{H}_k\mathbf{x}_\mu + \mathbf{n}_k\right), \quad \text{for } k = 1, 2, \ldots, K \tag{1}$$
$$= \mathbf{H}_k\mathbf{x}_k + \mathbf{z}_k$$

The $M_k \times M_{BS}$ matrix channel between the M_{BS} base-station array elements and the M_k array elements of user k is represented by H_k. The received additive noise combined with inter-cell interference is characterized by the covariance matrix $\mathrm{R}_{\mathrm{n}_k\mathrm{n}_k} = E\left\{\mathrm{n}_k\mathrm{n}_k^H\right\}$. The received vector $\mathbf{y}_k$ at antenna array k can be written as a superposition of the desired signal $\mathrm{H}_k\mathrm{x}_k$ and noise combined with the inter-cell interference z_k, resulting in the end matrix shown in Figure 9, where z_k may not follow a Gaussian distribution. However, it has been shown that the capacity can be closely approximated by the Shannon formula $\log_2(1+SINR)$. The noise with interference z_k component has a mean of zero, is additive, and is also statistically independent from user signal x_k.

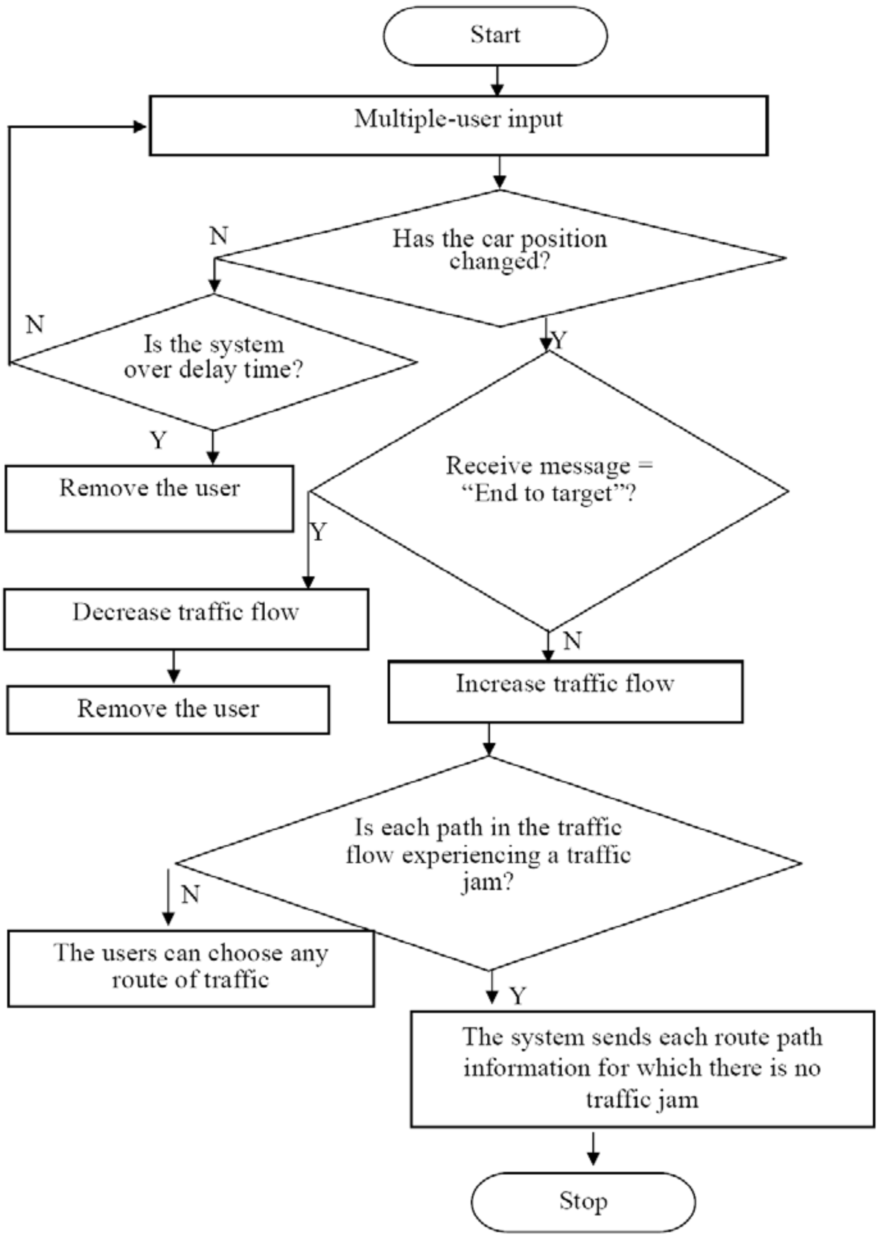

FIGURE 5. The traffic flow control MIMO algorithm

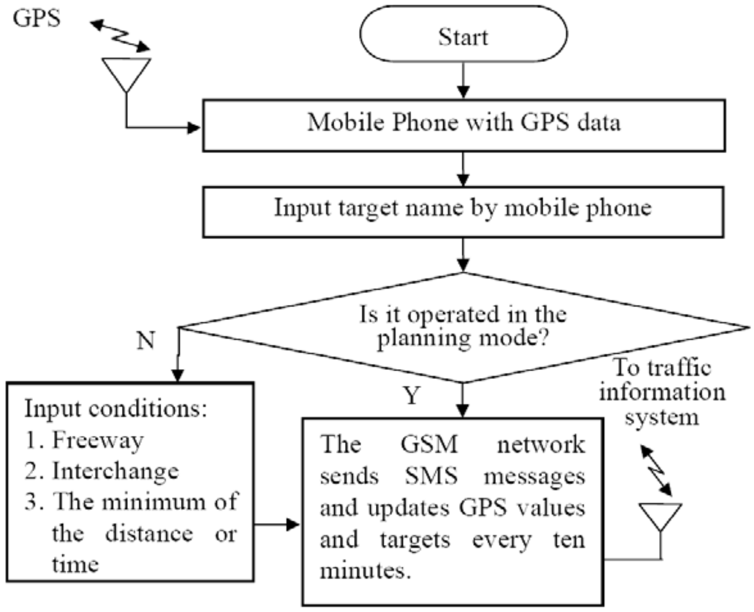

Figure 6. Client user end flow chart

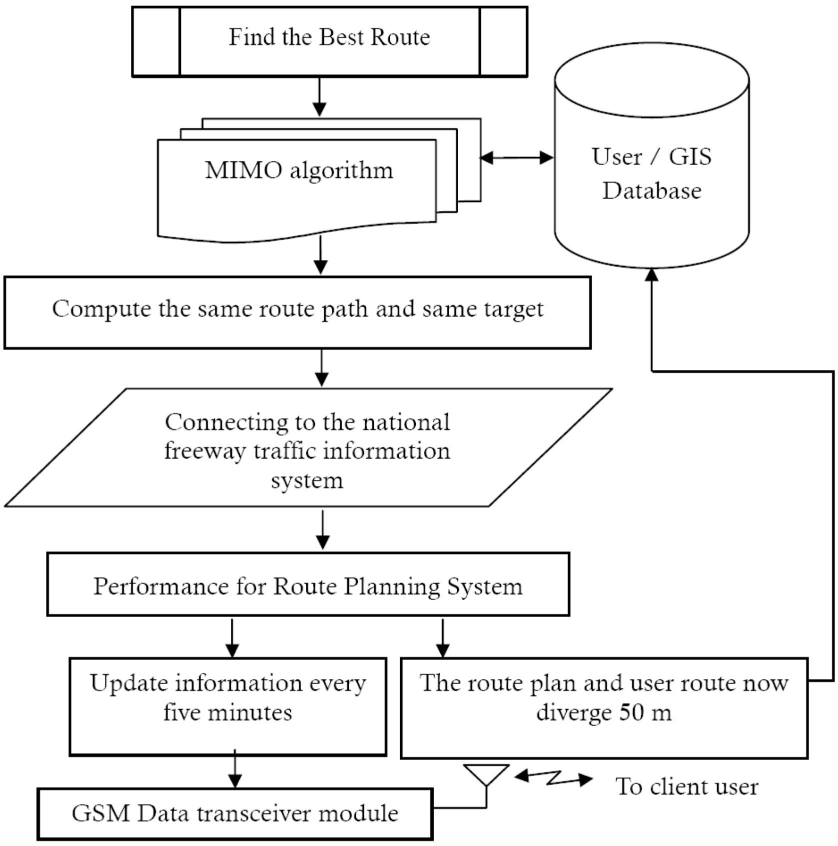

Figure 7. Real-time navigation information and MIMO system flow chart

3.2. **Multiple-user MIMO uplink model.** In contrast to the multiple-user MIMO downlink, where each received vector signal only depends on a single MIMO matrix, the received signal in the uplink is influenced by a total of K MIMO channels. The dimensions of the matrix channel H_k sent from each user to the receiving base station are $M_{BS} \times M_k$

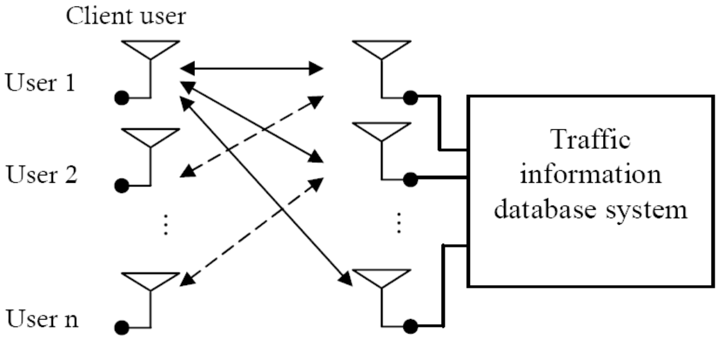

FIGURE 8. The traffic information system model for MIMO

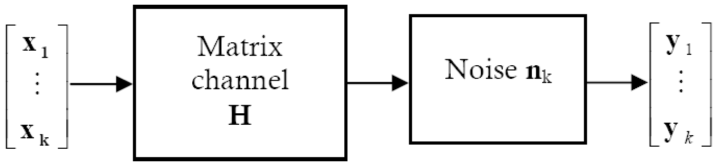

FIGURE 9. Multiple-user MIMO communication block

[8]. The received signals at the base station can be written as

$$\begin{aligned} \mathbf{y}_k &= \sum_{k=1}^{K} \mathrm{H}_k \mathrm{x}_k + \mathrm{n}_k = \mathrm{Hx} + \mathrm{n}_k \\ &= [\mathrm{H}_1\ \mathrm{H}_2\ \ldots\ \mathrm{H}_K] \begin{bmatrix} \mathrm{x}_1 \\ \mathrm{x}_2 \\ \vdots \\ \mathrm{x}_K \end{bmatrix} + \mathrm{n}_k \end{aligned} \tag{2}$$

The $M_{BS} \times 1$ vector n also includes input from noise and inter-cell interference. The multiple-user MIMO uplink may be viewed as a large MIMO system represented by the MIMO channel matrix H of dimensions $M_{BS} \times \sum M_k$. Fast feedback from the base station to each user terminal enables joint optimization of the antenna weight vectors, powers, modulation and coding schemes (MCS) for parallel data streams supporting all users, at least at low terminal speed, which results in quasi-static channels. It cannot be assumed that there is any correlation between user data. Therefore, the joint signal covariance matrix $\mathrm{R}_{xx} = E\left\{\mathrm{xx}^H\right\}$ is block diagonal, i.e.,

$$\mathbf{R}_{xx} = blockdiag(\mathbf{R}_{x_1x_1}, \mathbf{R}_{x_2x_2}, \ldots, \mathbf{R}_{x_kx_k}) \tag{3}$$

In a cellular network, there are two communications problems to consider: the uplink, where a group of users all transmit data to the same base station, and the downlink, where the base station attempts to transmit signals to multiple users. MIMO processing is beneficial in single-user MIMO channels, where there is a coordination of processing among all the transmitters or receivers. In the multiple-user channel, it is usually assumed that there is no coordination between users and that there is a difference between the uplink and downlink channels.

4. **The GSM/GPRS Dimensioning for Traffic.** With the evolution of mobile technologies and increased user demands, the market of mobile communications has grown rapidly in recent years, making it apparent that traditional voice services alone are unable

to satisfy mobile users anymore. Similar to other packet data services, the incentive of GPRS is to dynamically share physical resources among users and efficiently accommodate burst data sources. The physical layer of the GSM system uses the frame structure of TDMA. The basic resource unit is a time slot (TS) without sharing to multiple voice sources, unlike voice transmissions in GSM, although the GPRS system shares the same TDMA frame structure [9].

4.1. **Networking dimensioning for traffic.** Air Interface Dimensioning: To determine the required GPRS, an interface capacity is enabled to estimate the amount of data traffic that a given call will be required to handle in a busy hour because voice transmission is conducted in real time, but data transmission is not. As GPRS is overlaid on the GSM network, the voice and data transmissions share the same RF resource. The system operator has to adjust the distribution of the traffic load between voice and data according to the total revenue received if resources are limited. The RF capacity of a given GPRS system based on the number of GPRS users in a cell can then be calculated.

The advantage of GPRS is the use of packet-switching technology. It enables multiple users to share air interface resources for the GSM/GPRS model of the car black box, as shown in Figure 10. This is a request-allocation procedure where the users feel that their services are “always on” [11].

FIGURE 10. The GSM/GPRS model of the car black box

4.2. **The GSM/GPRS model.** A GSM/GPRS cell can be modeled as a loss system with a total capacity of C, offering a finite number k of traffic streams, each describing a different service. Depending on the partitioning strategy, C is divided into at most three partitions: C_{GSM} refers to the capacity exclusively used for traditional GSM voice calls, C_{GPRS} refers to the capacity exclusively used for GPRS, and C_{Common} refers to the capacity shared by all services. The total cell capacity of the system C depends on the actual number of frequencies used in the cell. Assuming that there is only one voice service in the GSM partition, it can be denoted by $i = 1$, and the GPRS services are denoted by $i = 2, \ldots, k$. To use the whole system capacity, the following conditions must hold [10]:

1) Complete Partitioning (CP) divides the total cell capacity into two parts, one for GSM and one for GPRS traffic.

$$C_{GSM} = C_1^{(ho)} \text{ and } C_{GPRS} = \max\left(C_2^{(ho)}, \ldots, C_k^{(ho)}\right) \tag{4}$$

2) Complete Sharing (CS) does not exclusively assign capacity GSM or GPRS traffic. Handover capacity is only reserved for incoming traffic.

$$C_{GPRS} = \max\left(C_1^{(ho)}, \ldots, C_k^{(ho)}\right) \tag{5}$$

3) Partial Sharing (PS) divides the total cell capacity into three parts: one for GSM, one for GPRS traffic and a common partition.

$$\begin{aligned} C_{GSM} + C_{Common} &= C_1^{(ho)} \\ C_{GPRS} + C_{Common} &= \max\left(C_2^{(ho)}, \ldots, C_k^{(ho)}\right) \end{aligned} \tag{6}$$

5. **The Shortest Path Problem.** The shortest path problem is interesting because it can be adopted to solve a broad amount of everyday problems, such as transport and telecommunication issues, turning the shortest path problem into one of the most important problems in the study of network flow models [12]. The ant algorithm has been applied successfully to various combinatorial optimization problems involving the Traveling Salesman Problem routing in networks.

The graph is transformed into a tree as shown in Figure 11. The search process starts from the left. If a leaf marked by '$*$' is found, this point can be reached, but at another layer situated on the right side of the search point. The system builds a list with different routings, and when the traffic parameters are not modified, a stock solution is taken from the list when a request is submitted to get from one point to another. During the simulation, information on the traffic on the list of routes is modified for blocked streets or freeways; a new algorithm is then started to find a different solution.

Consider a typical interaction of Figure 11 where a driver wants to go from city A to city C, where there is a variety of routes to take. Such routes may differ in length, congestion, speed, road works, and route planning. For efficiency reasons, it is advisable to avoid poor traffic or road works that may be present on some routes. The selection of the optimal route is based on the method of ant colony optimization (ACO) with Genetic Program (GP) in this paper, named KUAS EE and shown in Figures 12 and 13. The freeway and urban map is divided into several zones, and for each zone, an algorithm for finding the best route is applied [13]. The map is transformed into a graph and solved using Equation (7). The intersections are represented by nodes and arcs connecting roads

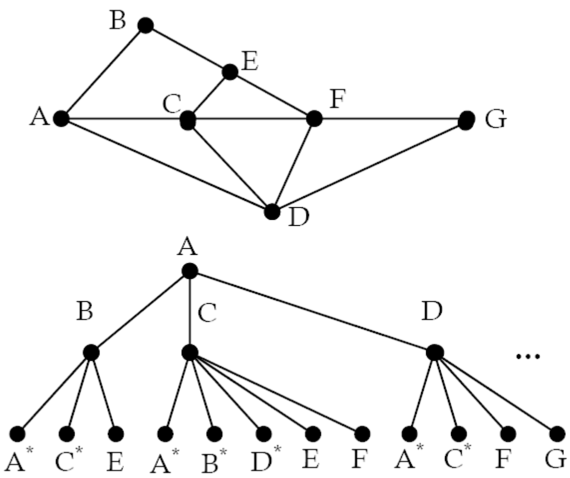

FIGURE 11. The urban map and transformed graph

to each other. The freeway and urban map is a weighted digraph as follows:

$$G = (N, A) \tag{7}$$

where N is a set of nodes, representing the short segments and the long segments. A is a set of directed edges representing the length of the segments.

5.1. **ACO algorithm.** ACO is a graph representation method based on an evolutionary meta-heuristic algorithm. ACO has been successfully employed to solve many different combinatorial optimization problems. The main idea of ACO is to model the problem as a minimum-cost path searching problem in a graph. ACO consists of many artificial "ants" walking through the graph to find the shortest path within the graph. Better paths are found by global cooperation among all artificial ants in the colony as they move from node to node. Their moves are usually associated with their previous actions that are stored in the memory using a specific data structure [14,15].

The artificial ant is the searching agent in the ant colony system. The probability of it choosing a town to go to is based on a specified probability, where that probability is a function of the town distance and the amount of trails present on the connecting edge. We assume that number of cities, n, is the same as the number of ants and that all ants start from the same city. Each ant at time t chooses the next town to visit and will be at that town at time $t+1$ according to the formula. Only when the ant has completed a tour will it traverse a substance, known as the "trail", on each edge (i, j) visited.

$$\tau_{ij}(t+n) = \rho \cdot \tau_{ij}(t) + \Delta\tau_{ij} \tag{8}$$

Here, $\tau_{ij}(t)$ is the intensity of the trail on edge (i, j) at time t and ρ is a coefficient such that $(1-\rho)$ represents the evaporation of trail between time t and $t+n$.

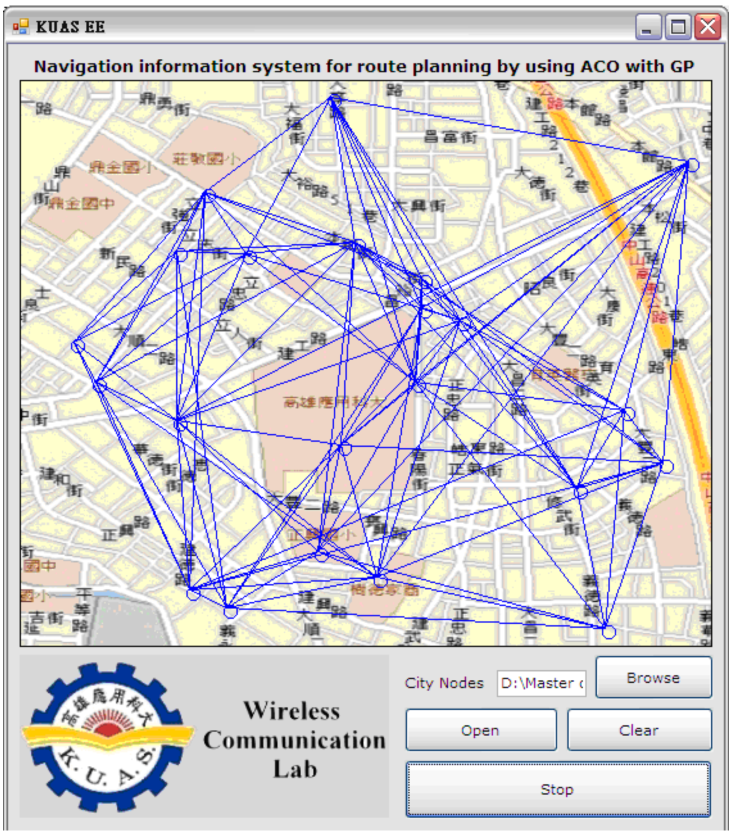

FIGURE 12. The ACO with GP showing all the city map nodes

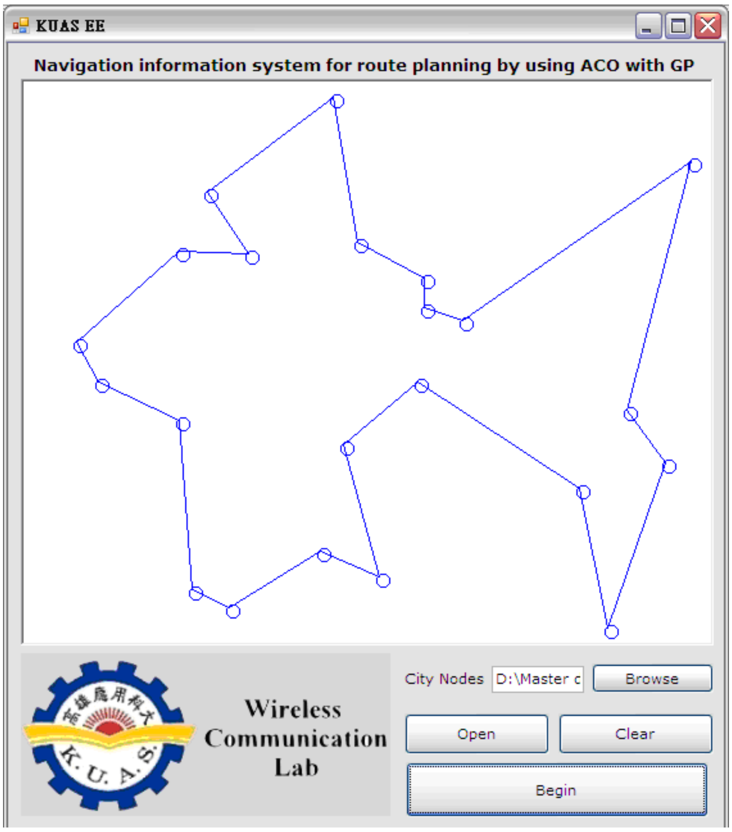

FIGURE 13. The ACO with GP showing all the city map nodes for route planning

The quantity per unit length of trail substance is represented by $\Delta\tau_{ij}^k(t)$ and laid on the edge(i,j) by the k^{th} ant between time t and $t+n$ and is described below:

$$\Delta\tau_{ij} = \sum_{k=1}^{m} \Delta\tau_{ij}^k \tag{9}$$

$$\Delta\tau_{ij}^k(t) = \begin{cases} \dfrac{Q}{L_k} & \text{if edge}(i,j) \in L_k \\ 0 & \text{if edge}(i,j) \notin L_k \end{cases} \tag{10}$$

where Q is a constant and L_k is the tour length of the k^{th} ant. Each ant will move from a current city, i, to a neighbouring city, j, provided that the city, j, does not belong to the tabulated list that is linked to the current ant, as stated in (10). When faced with many neighbouring cities to move to, an ant will choose the most probabilistically likely one. The selection likelihood of each neighbouring city is a function that is proportional to the length of the trail and the proximity to the current city. The probability for an ant k to move from city i to city j is defined as shown below (11).

$$P_{ij}^k(t) = \begin{cases} \dfrac{\left[\tau_{ij}^k\right]^{\alpha}\left[\eta_{ij}\right]^{\beta}}{\sum\limits_{l\in Allowed_k}\left[\tau_{ij}^k\right]^{\alpha}\left[\eta_{ij}\right]^{\beta}} & \text{if } j \in d_k \\ 0 & \text{if } j \notin d_k \end{cases} \tag{11}$$

where the visibility η_{ij} is the quantity $\frac{1}{d_{ij}}$. As stated in (11), this quantity is not modified during the run of the ant system, as opposed to the length of the trail, which changes according to (8).

5.2. **The ant genetic program.** The ant program is created by the genetic program as binary trees. The genetic program can be started with a completely random set of ant programs, a set of ant programs from a previous run, or a combination of both. When a combination of programs is used, the old ant programs and the new ant programs do not need to share the same instruction set.

Genetic Programming is simply an example of a Genetic Algorithm (GA) where the solution strings are replaced with variable-length programs. The goal is to find a program that can solve a desired problem. The program is evaluated for fitness based on the performance results. Because the population in a Genetic Program is a variable-length solution, it is best to store the solutions in a tree format. A tree structure also works well with storing and executing programs, especially those with conditions.

6. **Conclusions.** In recent years, the government has managed traffic issues by using scientifically accurate data to investigate and handle car incidents. Therefore, the car black box will play a very important role in obtaining these data. The car black box system is also integrated with RFID technology, and therefore, the system can confirm the driver's identity and connect with the safety system. The embedded GPS device in the black box system is adapted to monitor the car's speed, direction, static state and dynamic state at any time. The embedding of the GPS device prevents it from being stolen. The car black box uses the management system of transport service.

The system organizes modernization through using the slogan "machine replaces manpower" as its basis. It promotes traffic safety and management operations for systematized rationalization. The car black box can also be set up with a camera on the rearview mirror, which can photograph images and capture sounds within the car.

The real-time mobile traffic information systems using mobile client devices are shown in Figure 14 for cell phones or PDAs. The user is informed about the optimal traveling routes, which have been optimized with respect to personal preferences and system performance. Traffic information, such as traffic flow status, number of cars on the road, traffic accidents, traffic issues, average car speeds, and traffic conditions on national freeways, are shown in Figure 15, and it will be useful to mobile users.

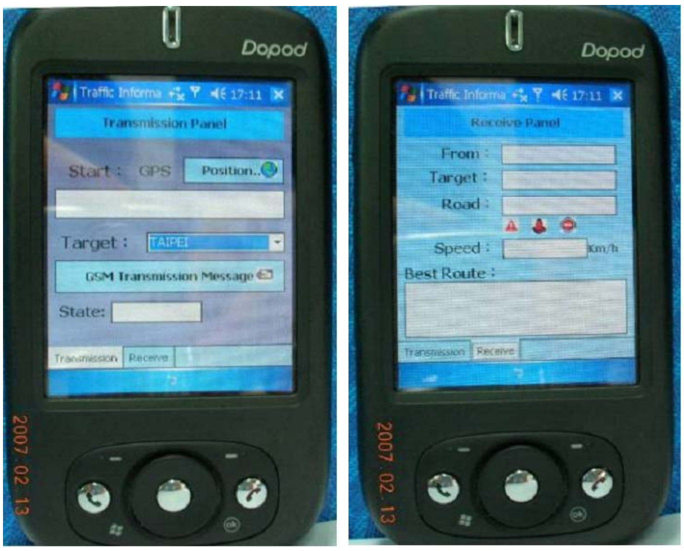

Figure 14. The mobile phone end of the traffic information navigation system

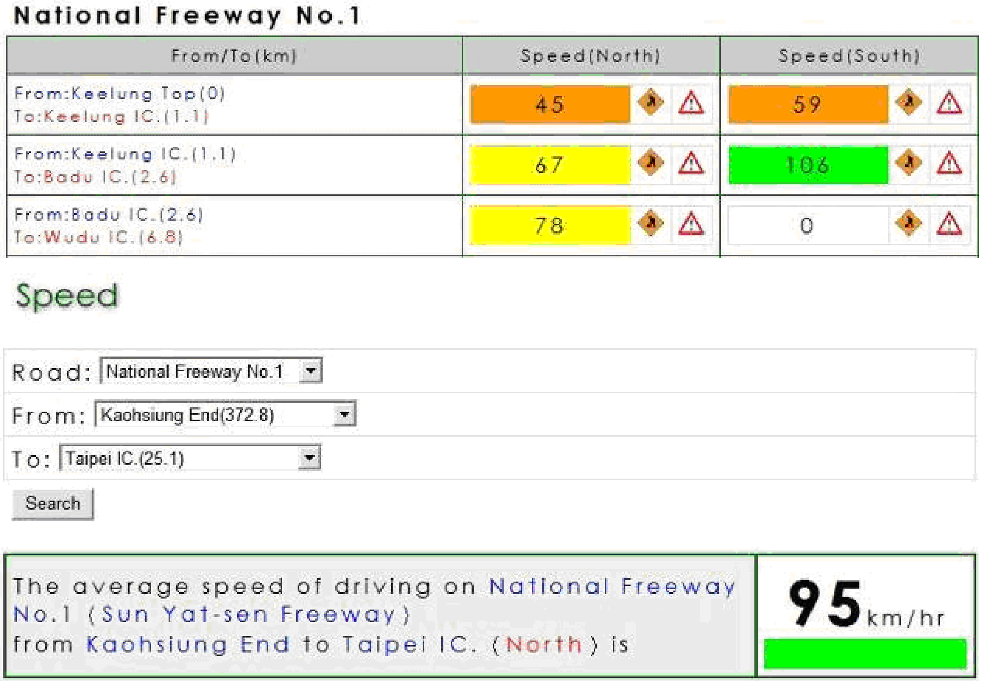

FIGURE 15. Database of traffic conditions on the national freeways

To decrease traffic congestion, a navigation system with route information sharing based on user support is proposed. A real-time multiple-user and high-performance model combined with MIMO and the ant algorithm system modeling is developed.

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