ABSTRACT

The University of Science and Technologou of China (USTC) GPS Intelligent Vehicular Monitoring System (IVMS) is introduced. We master three advanced techniques used in the IVMS: Cities numerical map GIS, Full speed of monitoring all moving objects and Real-time Correction of the Deviation.

1. INTRODUCTION

The GPS Lab, belonging to the Automation Department of USTC, has successfully developed several GPS-based application systems since GPS technology surfaced years ago. Particularly, GPS Vehicular Monitoring System (IVMS) is the newest fully integrated system devised by the GPS Lab. Via approaching solutions to three key technologies: the special digital movable multi-communication and control card, the city's traffic database producing CAD software and the IVMS Monitoring center software station, our IVMS has gone forward on the way towards commodity and products and commodities.

The IVMS developed by the GPS Lab of USTC is an integrated system combining several technologies such as global positioning satellite (GPS), digital movable multi-communication, geographic information system (GIS), and an artificial intelligence database and multimedia system. There are three key technique problems should be solved in advice of an IVMS being applied and spread in cities of China. They are:

* Automatic generation of vector-map. An special intelligent CAD software is needed to develop or generate the vector traffic map even from the city's printed (bitmap form) tourist traffic map and adjusts the vector map database automatically based on some real track records.
* The speed for the Monitoring the vehicles. There is within 30 seconds to receive, display and record the information of up to 100 mobile targets and within 3 seconds to get the emergency alarm if any one pilot press an alarm button in his car.
* Real-time adjustment to the errors of vehicle tracing in the intelligent monitoring platform on the Monitor and Control Center.

The IVMS can be widely used in many fields especially applicable to the bank vehicles, the car theft-proof system, police dispatching and the safe guard of senior officer. The system also provide immediate report to police on the 110 security center in an accident case. After arranging a car with remote shutdown equipment, it can stop a car remotely if the car is stolen. The USTC GPS IVMS has utilized in the 110 Alarm Center of Xamen Public Security Bureau with capability of monitoring 255 moving cars with only
one radio channel.
We are ready for providing every interested customer with the superior IVMS engineering project, the most advanced technologies and first-class all-around service. Meanwhile, aimed at accelerating the wider application of the high-technology products, and bringing out more social and economic profits, the GPS Lab is sincerely seeking co-operation opportunities with institutes and any eligible company both domestic and aboard.

2. THE MONITORING AND CONTROL CENTER

The IVMS is composed of the moving parts in the individual cars and the fixed part on the monitor and control center in an Command Center Office, and whole system is linked with a radio channel, see Figure 1. The Monitor and Control Center (MCC) is the core of the whole system which includes an intelligent monitoring platform, a control and modem card for digital data transfer, a broadcast station in the base, and an antenna for the main control station.

![Diagram of IVMS components](image)

**Fig.1 The IVMS is composed of the moving parts and the fixed part**

The Intelligent Monitoring Platform (IMP) consists of at least three computers connected to a network based on the Window95 WinSock. One computer is used as the NetWare server, and also to communicate using the Control and Modem Card (CMC) for issue orders to and receive signals from the moving cars, and even deliver a command to close the motor of any out-of-control car (thieved, robbed, etc.). We call the computer as the Server and Communication Platform (SerCom). The other computers, being clients for the Microsoft Networks are used as the management platform (ManPlat) and the monitor platform (MonPlat) respectively.
The IMP is equipped with the powerful and user-friendly intelligent monitor software (IMS). The IMS is developed under the environment of Microsoft Window's 95 (Chinese version) by using the Borland Delphi 2.0 language which makes it a complete 32-bit Chinese-version application program. Because it is designed according to the custom of Windows 95, a great amount of time and cost for training the operator is saved. Adapting the advanced vector map technology makes the display of the map clearer, the amount of graphic information greater and the modification or adding of information more convenient and faster. The attached database software (is also a potent GIS) can be used to record various information including conditions of roads, city buildings, each unit's communication address and telephone numbers, etc.

The ManPlat as well as the MonPlat can show all the moving parts' real-time position on big screen with the city's GIS vector map as the background. An example shown screen is in Figure 2. One can Monitor positions of all its moving unites at any time. when an emergency case happens, the police in the Monitor Center may make a central dispatch to organize the police force for quick response to the case(Figure 3).

Fig.2 One can monitor positions of all its moving unites at any time at the ManPlat
There is a few differences between the ManPlat and the MonPlat. In our design, the tracks of the path driven by monitored cars are recorded and projected back by the ManPlat. Whereas on the MonPlat there stored not only the general GIS map, but also some special vector maps (called the Alarm Map) for the purpose of displaying and assistant division making in the emergency case. As the SerCom gets an alarm signal, the enlarged area of the Alarm Map with the position of the emergency event just on its center will be immediately projected on the screen of the MonPlat. There the GIS Maps and information can be modified, stored individually on both the ManPlat and the MonPlat, however the Alarm Map can only be modified and stored on the MonPlat.

An important feature in our IMP is the Real-time Correction of the Deviation (RCD) of vehicle tracks displayed on MCC. The GPS locating accuracy on the standard USA service is around 100 meters. Moreover, in big city due to the obstacle and reflection of high buildings, the locating error may even reach up to 200 meters. Under such hard conditions, the real location of inspected vehicle showed on the monitor display might probably be off the road. Without the RCD, the supervisor has to judge by oneself that which road the monitored vehicles are really on. Such complex situation, especially with many moving objects may cause the operator great mental burdens or misinterpretation. Now, the problem above have been solved to a certain extent by implementing the intelligent RCD software advanced and compiled by our GPS Laboratory in the IMP. The software adjusts the positions errors with a real-time data filtering technique developed by us effectively and automatically. The range of re-adjusting can be given by the operator. Any
deviation to the road within the range can be corrected as the car has been really moving on the road. With the RCD the target is always showed on the road as it is really on. the intelligent RCD effectively increases the operating efficiency and reduces the mismanagement.

3. SPECIAL SYNCHRONIZED TIME-BASED PROTOCOL FOR DIGITAL MOVING MULTI-COMMUNICATION

The USTC IVMS have effectively advanced the speed of monitoring the vehicles. There is within 30 seconds to receive, display and record the information of up to 100 mobile targets and within 3 seconds to get the emergency alarm if any one pilot press an alarm button in his car. The achievement of the highest speed in the IVMS within China should thank to the utilizing of the control and modem card.

The control and modem card (CMC) for digital data transfer is designed and developed by our GPS Laboratory. It works for modulation and demodulation, data compression and encoding, and time synchronization using a sequential data transfer mode in connecting to the computer. It can control many types of radio stations using a wide-area movable network, different frequencies, half double working (emission and reception) broadcast stations, and minimum frequency-shift key control (MSK) modulations. The capability is 255 movable objects on each frequency point, and that covers a range of tens of kilometers.

The CMCs with connecting base station and the mobile radios make up a special mobile communicating network. It utilizes so-called time-based synchronized protocol innovated by the GPS Lab. To satisfy the character request of the net, especially the real-time and the alarm response ability, it is quite necessary to come up with a set of reasonable, standard communication protocol. After referring to the level module of the OSI open system, we brought up and successfully realized the time-based synchronized protocol (TSP) for the digital communication in our IVMS. The protocol is divided into four levels: physical, data link, network and high application, every level of which has definite content and functions. Under the control of the protocol, for Monitoring 100 vehicles in our IVMS, the Circuit Inspecting Period (CIP) is reduced to only 30 seconds. Here the CIP refers to the period of time necessary for the Monitor Center consults with and receives from all the 100 vehicles in turn, detecting, receiving, displaying and recording the signals about the positions, speeds and other necessary messages.

Moreover, suppose a pilot press an alarm button at any one car managed in IVMS, whether it is monitored in time or not, the MCC can detect the alarm signal within 3 seconds. We define the time as the Emergency Alarm Period (EAP). Here we would like to compare the CIP and EAP with that realized in the Vehicular Monitoring System of the 110 Alarm Center of Nanjing Public Security Bureau. Up to now on their VMS the CIP, as well as the EAP, is more than 480 seconds\[1\], slower than ours even more than ten and hundred times respectively.

The CMC hardware is realized on 80C31 single chip. The CMC software is programmed with the MCS-51 assemble language. Compiled under direction of the software project methods, the program has an excellent style. Moreover, we set the system variables such as the cars' serious number and the group members with flexibility which gives the convenience for real-time monitor cars arrangement and the prompt augmentation of the monitor system capability. It is the USTC GPS IVMS, employing the TSP, a protocol newly innovated by the GPS Lab, that ensures so quick response on the whole engineering system.
4. RELIABLE MOVABLE UNIT

The Reliable Movable Unit (RMU) is composed of a car-carrying GPS receiver, an object-used monitor and control card (MCC), a car-carrying radio station and antenna. This single-body takes up little space, so it is quite convenient to install in a car. All instruments share a common power supply in vehicle. Extra electric power is not needed.

The GPS receiver, Micro Tracer, is purchased from the U.S. Rockwell Company. The size of the GPS receiver is smaller than a business card, and one centimeter thick. It has parallel 5 channels, high performance of tracing 9 GPS satellites simultaneously. The time for first fixing the position of the GPS is less than 20 seconds, and is less than 10 second for the next fixing. The differential GPS (DGPS) function is also supported with the position accuracy within 10 meters. The GPS antenna, bought from aboard takes up minimal space (palm sized) and is easy with its magnetic bottom to be attached on the top of a vehicle. With as long as a 5-meter wire, it is very suitable for all kinds of vehicles. A GPS antenna designed specially for ships with a 15-meter wire is also available.

5. AUTOMATIC GENERATION OF CITY VECTOR-MAP

Without the city GIS vector map as the background, the ManPlat, as well as the MonPlat can not show all the moving parts' real-time position. However it is almost impossible in China to find the recent city numerical map or city vector-map for the use in VMS. Thus we should develop a Computer Aided Generation(CAG) of City Vector-Map (CVM) software to develop or reproduce the CVM even from only the city's printed tourist traffic map with the bitmap form.

A map, when saved in database in the format of bitmap, is not convenient for further use and process. Vector format is far more efficient in time and memory space. If we can generate the vector map from the bitmap data by extracting the key information and erasing the other features by adopting a pattern recognition method, the generation of the vector map will be easier and faster. Because the bitmap data can be gotten from the printed map or photograph by scanner, it is very useful where the electronic geographical data is not available.

Based on our research, a relatively successfully implemented system, the CAG-CVM software has been established. After trained by several model maps, the CAG-CVM performs well on the other city traffic maps in the same set. The irrelevant features are filtered and only the roads are kept. After some further processes such as pre-dealing, thinning, piecing together, vectorization, semi-automatic modification of main road position, etc., the final vector map comes out. Now the CAG-CVM can be used for producing CVM from the city's printed tourist traffic map rapidly and conveniently. The CVM or GIS database can be adjusted upon the spot in the MCC via adopting some position numbers (longitude, latitude) abstracted from the real track records of the RMU.

The process of using our CAG-CVM includes some steps. First of all we must select and scan of the city's printed tourist traffic map for getting several Image files with bitmap form stored in computer. Then the file data are processing by the CAG-CVM software. The CVM within IMP provides users a series of functions for using conveniently, which concern increases or modify of the information of points (units), lines (roads) and areas (districts) with any shape. You can input much more relative information such as
the color, name, character of the points, areas and roads in to the vector-map database. Even the multimedia such as sound and graphic can be easy accessed into the CVM database. When the CVM has been developed, all such works can be remained to the users. Users make themselves the operations of the database through an interface dialogs and at the same time monitor and control the whole vehicles in the MCC.

6. WIDE APPLICATION OF THE IVMS

* **Taxi Central Dispatch and Theft Protection.** Arranging the IVMS in the taxi company, one can monitor position of all its taxi cars at any time, and can provide fast and proper dispatch for serve of customers in phone call. The system can also provide immediate report to police, and report to the center in an accident case. After arranging a car with remote shutdown equipment, one can stop a car remotely if the car is stolen.

* **Monitor Center of the Security-Defense System.** With IVMS in the patrolling and alarming vehicles of the Security Defense System, the supervisor can obtain everyone's precise location at any time. In case of any emergency, a quick solution is easily at hand in the Monitor Center to contact a police force to handle the situation, to make a central dispatch to organize the police force for a quick response to the case.

* **Ensure the Security of the Cash-transporting Vehicles.** IVMS is being considered world-widely for companies that physically move large amounts of money. Its installment greatly assures the security of cash and valuable employees.

* **Ship Administrating and Rescue Center.** Installing IVMS system onto the ships, fishing vessels in the fishing area or touring ships in a touring area, one can monitor the positions of each ship and dispatch them easily, so that production can be increased and accidents can be avoided. The IVMS is not affected by weather, it greatly helps in rescuing ships in hurricanes.

* **Administration and Security of Railroad Transportation.** Arranging the IVMS in railroad systems, one can monitor the whole situations in transportation at any time. It is a convenient way to check the management of railroad traffic whenever necessary. Any possible danger will be ahead reported by IVMS to prevent impending accidents. And the railroad transportation capacity can be properly managed and enhanced with the aid of the IVMS.

* **Military Command and Artificial Performance.** Once IVMS is installed in military vehicles and ships, the accuracy and rapidity of battle deployment will be improved to a large degree. Employed in military artificial performance, IVMS will record the whole process for the purpose of a convenient analyses afterwards.

REFERENCES