Battlefield Object Control via Internet Architecture

Network-centric Application

Dr. Meng-chyi Harn
Shih-ping Hsu

Graduate School of Defense Information
National Defense Management College
National University

P.O. Box 90046-15, Chung-Ho, Taipei
Taiwan 235, Republic of China

+886-933-823-473 (Tel)
+886-2-8221-3421 (Fax)

harn@rs590.ndmc.edu.tw
goldenmouse.tw@yahoo.com.tw

Dr. V. Berzins and Luqi

Computer Science Department
Naval Postgraduate School
Monterey, CA 93943 USA

{+1-831-656-2610, +1-831-656-2735} (Tel)

{berzins, luqi}@cs.nps.navy.mil

Battlefield Object Control via Internet Architecture*

Dr. Meng-chyi Harn
Shih-ping Hsu

Graduate School of Defense Information
National Defense Management College
National University

P.O. Box 90046-15, Chung-Ho, Taipei
Taiwan 235, Republic of China

+886-933-823-473 (Tel)
+886-2-8221-3421 (Fax)

{harn@rs590.ndmc.edu.tw, goldenmouse.tw@yahoo.com.tw }

Dr. V. Berzins and Luqi

Computer Science Department
Naval Postgraduate School
Monterey, CA 93943 USA

{+1-831-656-2610, +1-831-656-2735} (Tel)

{berzins, luqi}@cs.nps.navy.mil

Abstract

The motivation of this study is to reach the goal of information and competition superiority for the future battlefield. We develop an adaptive C4ISR system, called Real-time Object Control System (ROCS), for military needs by integrating the following information transformation technologies: Global Positioning System (GPS), Geographic Information System (GIS), Battlefield Information Transmission System (BITS), and Intelligent Transportation System (ITS). The basic architecture of the ROCS includs three parts: the front-end position system, the GPRS (General Packet Radio Server) (2.5) & 3G telecommunication system, and the rear-end control center. Users can command and control battlefield objects via this transformation architecture. Finally, we describe an application of the ROCS to the vehicle object control that has been designed and executes well in the IP-based operational environment.

Keywords: C4ISR Systems, Information Superiority, Battlefield Objects, Computer-Aided Prototyping System (CAPS), IP-based Operational Environment.

*This research was supported in part of the R.O.C. National Science Council under the grant number 90-2213-E-123-001.

1. Introduction

The purpose of this study is to build an adaptive C4ISR system, called Real-time Object Control System (ROCS), for military needs by integrating the following information transformation technologies: Global Positioning System (GPS), Geographic Information System (GIS), Battlefield Information Transmission System (BITS), and Intelligent Transportation System (ITS). Completely automatic control of objects in a battlefield is very difficult today, but the real-time battlefield object control of ROCS in a Command and Control (C2) center via Internet is feasible. We have explored the digitizing processes and functions of the ROCS, and built the information transferring architecture for the future battlefield.

In our study for the future battlefield, there are two consideration phases of a man-machine system, information superiority and competition superiority, for a decision maker to deal with defense businesses shown as Figure 1.

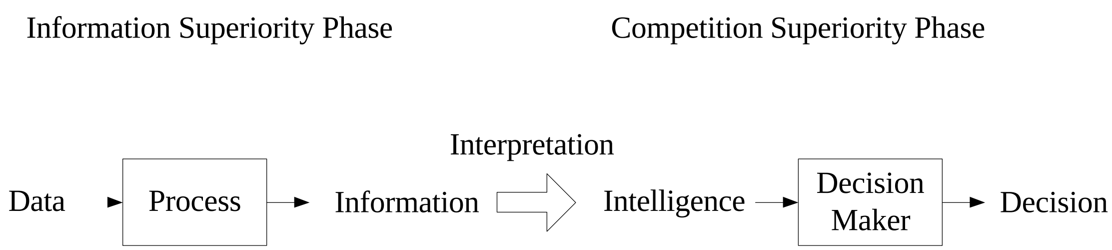

Figure 1: Two Phases of a Man-machine System

The information superiority phase can be defined as the data collection activity of domain-specific knowledge through a process that inputs many related data items and outputs useful information. The competition superiority phase can be defined as the decision-making activity of a commander for conquering the battlefield through a decision process that inputs much related intelligence and outputs many qualified decisions. Generally, the relationship between these two phases is that the mechanism of information superiority is the best way to reach the goal of competition superiority. Using information technology (IT) in data processing, including computer hardware and software, databases and the Internet, can effectively integrate the data of weapon systems and military people, obtain battlefield transparency and create information superiority. That is, battlefield data coming from any sensor platforms can be processed and produced into specific and necessary information for decision maker’s needs by using information technology. The decision maker makes certain command and control decisions based on the battlefield intelligence that is collected from many types of domain-specific information for creating competition superiority.

To obtain the information and competition superiority a decision maker, such as a commander of the battlefield, should control all of battlefield objects via the C4ISR system that integrates military people, weapon systems, platform sensors, navigation systems and communication links. Therefore, integrating battlefield objects by C4ISR workstations for winning a war is an essential technology that has been studied for years in Taiwan, R.O.C.

1.1 The Problem

We attempt to manage, control, monitor and integrate moving objects of battlefield by the software of C4ISR systems. Our idea is to embed the GPS system into moving objects of the battlefield and direct them from a workstation of the command and control center via the Internet. The vehicle road guidance with command and control mechanism has been used well in many countries [Maeda, 1999] and is a typical application of C4ISR systems in the Army. The core technology of this application is the integration of GPS, GIS, BITS, and ITS.

We have succeeded in extending the application area of vehicle objects to other moving objects, such as military people, tanks and so forth. We studied the numerous commercial technologies about the vehicle road guidance and found there are several crucial problems of the vehicle road guidance that should be overcome while we developed ROCS at the beginning. Most of the vehicle road guidance products created by traditional and known technologies have several limitations as follows:

- No real-time report,
- No web site support,
- Lack of interoperability,
- Lack of standardized information exchange format, and
- Only providing unidirectional transmission capability.

To simplify and resolve these problems encountered, we explored the following research directions:

- Using Web Automatic Vehicle Location (Web-AVL) and Web GIS for command and control.
- Building the interoperability mechanism of battlefield objects in IP-based communication environments.
- Enhancing the capacity of information exchange and signal transmission among different battlefield objects.
- Creating the data transmission software for transferring the satellite data into the standard transmission format.
- Specifying user requirements about the transmission technology of bi-directional interoperations.

1.2 Background

Our study focuses on the battlefield object control and real-time data transmission technologies of C4ISR systems. The ROCS proposed is a kind of Command and Control (C2) system, actually, C2 architecture has been extended into C3, C3I, C4I, and C4ISR [Harn *et al*., 1999a]. Center for Army Lessons Learned (CALL) Dictionary and Thesaurus defines C2 as the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the mission. Arranging, personnel, equipment, communications, and procedures perform the function of C2 employed by a commander in planning, coordinating, and controlling forces and operations in the accomplishment of a mission.

In [Malerud *et al.*, 1998], Malerud defines C2 concept, C2 structure and C2 system as follows:

> *C2 concept: A set of characteristics of a C2 system describing how it reaches its objective.*
>
> *C2 structure: An assembly of personnel, organization, procedures, equipment and facilities arranged to meet a given objective, and within fixed economical limits.*
>
> *C2 system: An assembly of personnel, organization, procedures, equipment and facilities organized to accomplish C2 related functions. A C2 system comprises three main components: C2 tasks, C2 functions and a C2 structure.*

A formal model is developed by applying an object-oriented modeling technique to measure C2 systems. The formalization procedures are described in the following steps [Malerud *et al.*, 1998]:

> *An object model is developed capturing the static structure of the C2 system which include the objects of the system, relationships between the objects and attributes and operations that characterize each class of objects.*
>
> *A dynamic model is constructed consisting of state diagrams specifying when functions/processes in the system are executed.*
>
> *A functional model is developed specifying the functions/processes carried out in the system. The function model consists of flow diagrams which describe the flow of information between functions and objects.*

These steps show that C2 systems can be formalized and measured by using an object-oriented modeling technique.

Therefore, we formalize the battlefield objects of a generic single-user C4ISR system and classify them into five types: users, weapon systems, platform sensors, navigation systems, and communication links. In our study, spots and tracks of battlefield objects received from GPS systems can be shown in the single-user ROCS workstation and their related data/information can be retrieved from the ROCS database.

1.3 Relative Technologies

As mentioned earlier, the main relative technologies of the ROCS involve GPS, GIS, BITS, and ITS. The applications of GPS and GIS are very popular in civilian and military contexts. We briefly describe the BITS and ITS technologies for our needs.

1. ***BITS***

The BITS is one of the infrastructures of the C4ISR system and is the communication basis of the future battlefield. The generic plan of the BITS includes the adaptive hardware and software acquisition for building command and control platforms, the common text and data format for sharing to other people, the common operation environments for controlling battlefield objects, and the integration of current communication systems and tactical Internet for the needs of the next generation battlefield. The content of data transmission of the BITS is not only voices and data, but also texts, pictures, and video that have been planned in the Warfighter Information Network-Tactical (WIN-T) instead of the Tactical Information (TI) network system for enhancing the capacity of the battlefield data communication.

2. ***ITS***

ITS technology has been used in many cities to solve the horrible traffic problems, for example the Traffic Light System for the Future (TL2000) that is created by the students of Naval Postgraduate School, U.S. using the software automation tool, CAPS (Computer-Aided Prototyping System) [Harn *et al.*, 1999b]. In Japan, at the Miyagi Prefectural Police HQ developed and installed its own internet server at its traffic control center with a view to secure safe and smooth traffic within the prefecture by providing various types of traffic-related information [Maeda, 1999]. Our idea of providing battlefield information via the Internet originated from the awareness of the fact that the Internet is a very significant communication media of the ITS. In this way, we think the battlefield object control can be considered as traffic control and conducted in the internet-based environment.

2. Design of ROCS

2.1 Assumptions of designing ROCS

This paper addresses the need to integrate battlefield objects with the ROCS. It describes the effective use of GIS, GPS, BITS, and ITS techniques for battlefield object control to develop the architecture of the ROCS. When we utilized the current information infrastructure of defense and commerce for developing ROCS, some assumptions related to the command and control mechanism of the ROCS were concluded as follows:

- The operational environment of designing the ROCS, including the IP-based and internet architectures, has been built and the applications of TCP/IP, such as file transferring and e-mail, can be executed in the BITS.
- The issues of information security in communication, such as encoding and decoding, have been considered and handled well.

The battlefield object position derived from GPS system is sufficiently accurate so there are no precision issues of GPS, and the tiny variations can be accepted.
The problem of the distributed database and the optimization of database models have been considered well.
The installation of GPS system into battlefield objects have finished and the relative techniques have been solved.
There are no missing data problems in the message transmission process.

2.2 Architecture of ROCS

The basic architecture of the ROCS can be decomposed into three parts: the front-end position system, the GPRS (General Packet Radio Server) (2.5) & 3G telecommunication system, and the rear-end control center, shown as the Figure 2.

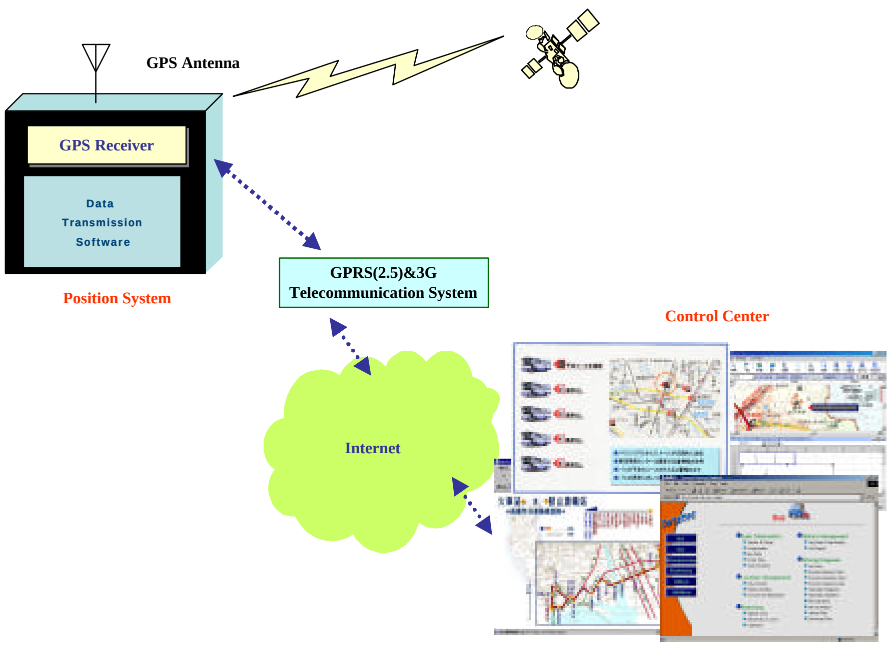

Figure 2: The Basic Architecture of the ROCS

The position system is an assembly of equipment that includes the GPS receiver and a portable PC with the data transmission software. The receiver module of the position system outputs the data with GPGGA or GPRMC format. The data transmission software transfers the real-time position data from the GPS antenna and GPS receiver to the GPRS (2.5) & 3G telecommunication system, that is a communication module providing the functionality similar to a cell phone, by e-mail or *http* format. Once the data by e-mail or *http* format is delivered to the control center, the users can monitor battlefield objects on the Web GIS system at a portal web site. The control center has the following main functions for controlling battlefield objects: current position and history track query, advanced path planning, battlefield object management, and message transmission.

The supporting software in the control center is as follows:

Operating system: Linux or IBM AIX 3.12,
Database: Oracle or IBM DB2,
Language: Perl and JAVA,
Graphic interface software tool: Autodesk Mapguide, and
WWW and e-mail server software: supported by Linux or IBM AIX 3.12.

The control center has a IBM data collection server and incorporates the following hardware with network environments:

Position system,
GPRS (2.5) & 3G telecommunication system facilities, and
Internet and LAN.

The control center has three databases: real-time position database, history track database and job assignment database. An operational environment of web pages for military people has been designed to browse and query the related information from the above database via the Internet. We also specify the received rate of the e-mail server to 15 seconds for collecting battlefield object data, whose items include real-time position, timing, battlefield object types and numbers, and recording them into the real-time position database. Some of the collected data are transformed into the related history track data that are recorded into the history track database. The job assignment database stores system message exchange data and job assignment data.

The control module of the position system is implemented by data transmission software in the potable PC that can automatically generate system parameters by two ways.
The first way is described as follows:

Getting the data with GPGGA format and embedding them into the e-mail text by means of the data transmission software.

Delivering the assembled e-mail text to the e-mail server of the ROCS workstation for transmission within 15 seconds.

The portion of the e-mail text with GPGGA format is shown as follows:

To: harn@mis.ndmc.edu.tw // our command and control center
Subject: 2002/04/10-10:10:10 //time
*From: ***@***.*** // mail sender*
$GPGGA,122240,2111.1111,N,12511.1111,E,1,06,03.55,000031.1,M,0040.3,M,

The second way is described as follows:

Getting the data with GPRMC format from the COM PORT and appending them to a web site URL with *http* format by means of the data transmission control software.

Transferring the assembled web site URL to a WWW server database for transmission within 15 seconds.

The portion of web site URL with GPRMC format is as follows:

http://140.119.73.167/ GPRMC_http.p1?to=”database_name”&from=”battlefield_object_id”&datatime=”current_time”&data=”sattlelite_position_data”,

The ROCS uses TCP/IP applications including e-mail and WWW. The position system, considered as a kind of the front-end facility of the ROCS, has a potable personal computer terminal that provides bi-directional data transmission and integrates GPS and communication modules. The position system sends the real-time position data of a battlefield object to the real-time position database in the control center via communication module, the GPRS 2.5 & 3G. The database of ROCS provides the basic data query functions. Military people authorized can query relative data about battlefield objects from a portal web site and command and control them by the browser.

The graphic user interface is a map created by the Web GIS that has been well designed in the ROCS. Users can check the position of a battlefield object and retrieve related information from this graphic user interface. Users also can send command and control messages to any battlefield objects through the communication modules. The command and messages shown in the front-end facility can be texts, pictures, video, or voices.

3. An Example of ROCS

In our study the ROCS has been successfully applied to the vehicle control in the battlefield and we take it for example. The user requirements and specifications of the ROCS can be represented by the PSDL language of the CAPS system [Luqi, 1992]. Actually, we have conducted the specification of the vehicle control system using CAPS and designed the whole system.

The functions of ROCS include basic data management, location management, vehicle searching, mission assignment of vehicles, emergent situation monitor, and command and control. These functions are integrated in an operational environment that can be manipulated by any levels of commanders. The main functions of ROCS are described in details as follows:

3.1 Basic Data Management

1. ***User Login***
   Users login by ID and passwords.
   The authority of users are classified into system managers and general users.
2. ***Unit Organization Architecture***
   According to the unit organization architecture the vehicle data in the vehicle database are constructed in different levels shown in the Figure 3.
3. ***Appending a New Driver***
   The related data of a new driver are added and modified in this function.
4. ***Grouping Management***

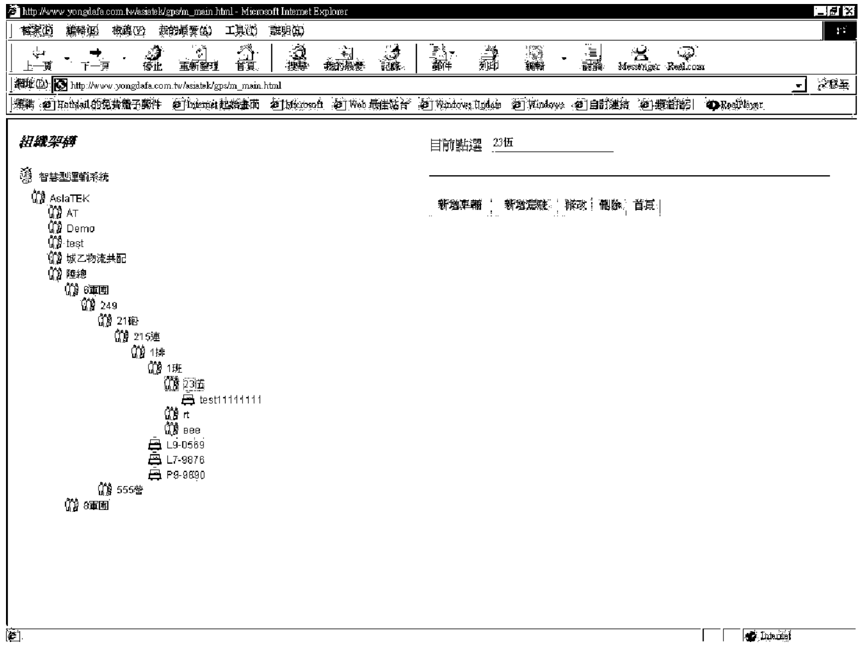

Figure 3: The Vehicle Data Classified by the Unit Organization Architecture

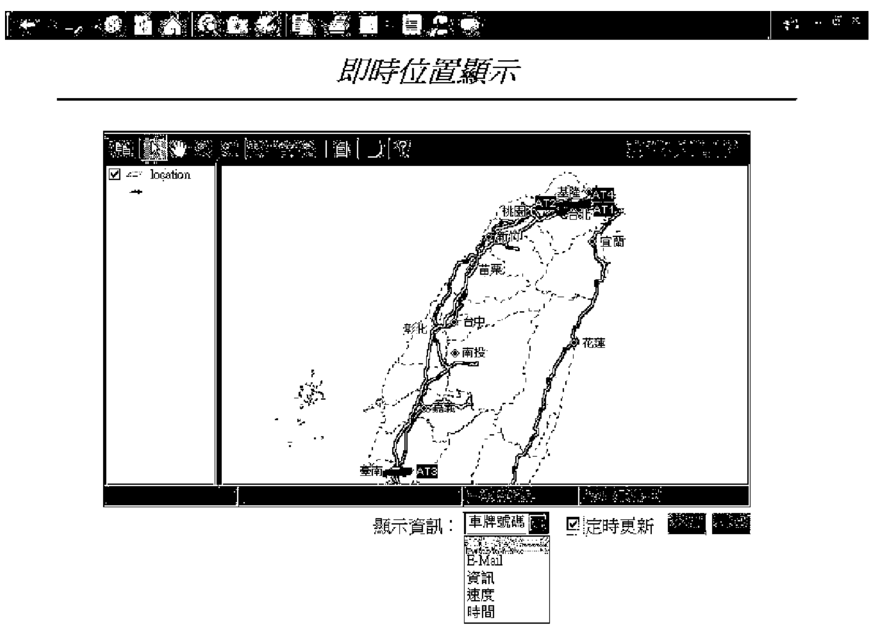

Figure 4: The Vehicle Positions on the Web GIS Electronic Map

Vehicles are classified into different groups.
The grouping management subsystem sends the same commands to all of the vehicles in the group.
A vehicle can belong to several groups.
The grouping principle is based on the need of a specific task for vehicles.

5. ***Passwords Modification***

Users can modify their passwords any time for protecting the ROCS system.

3.2 Location Management

1. ***Real-time Location***

Users select vehicle objects of their unit organization architecture based on user's authority, and then the GUI of the ROCS shows the vehicle positions on the Web GIS electronic map shown as the Figure 4.
The vehicle position data, downloaded via the telecommunication system, GPRS 2.5 & 3G, to the WWW server database, modify the vehicle position on the screen per 15 seconds.
This function provides two options: modifying the vehicle position and keeping the vehicle track on the screen.
This function also can show the information about vehicle identifier, e-mail address, time, and vehicle speed while a user selects a vehicle object.

2. ***History Track Query***

Users select vehicle objects of their unit organization architecture based on user's authority, enter the initial time and ending time, and then the GUI of the ROCS shows the vehicle tracks on the Web GIS electronic map as in Figure 5 and 6.

3.3 Vehicle Searching

Users query the vehicle positions on the electronic map based on the vehicle identifiers.

3.4 Mission Assignment of Vehicles

Mission assignment of vehicles provides the bi-directional transmission between the front-end vehicle facilities and rear-end WWW server in the_command and control center.
Users receive the information of the front-end vehicle facilities and dispatch missions on the rear-end WWW server in the command and control center.
The driver in the front-end vehicle read the missions by using the e-mail function of his portable PC.

3.5 Emergent Situation Monitor

Drivers press the emergent button on the vehicle while they meet a emergent situation.

¾ ¥ ɏ y ñ ḑ ß

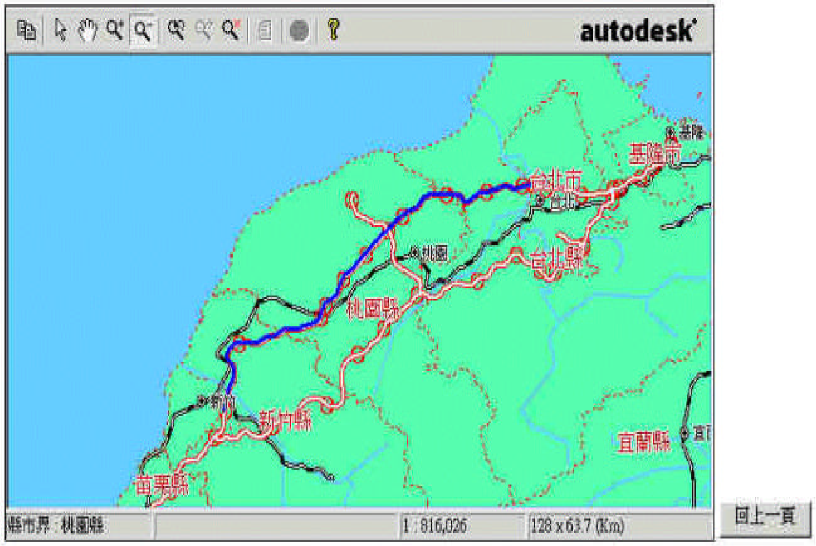

Figure 5: The Vehicle Tracks on the Web GIS Electronic Map (I)

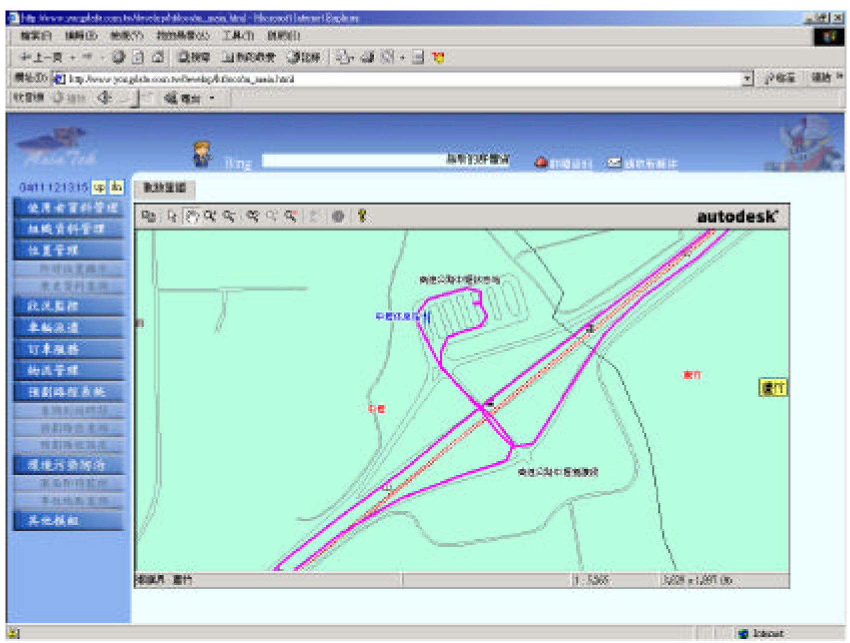

Figure 6: The Vehicle Tracks on the Web GIS Electronic Map (II)

The emergent messages are sent to the rear-end control center and the alarm system is triggered and shows the vehicle position on the Web GIS electronic map.

Users send the response messages to the driver by texts, pictures, video, or voice to the front-end PC.

3.6 Command and Control

The ROCS provides message exchange and file transfer by the following functions: message input, sending and receive an e-mail, and uploading and downloading a file.

4. Conclusion

The architecture of the ROCS was developed in the environment that has been built by civilians and military for years. We save the building cost of the ROCS and obtain high command and control performance because some common operation environments have been built such as communication platforms and Internet operation architecture. The transmission delay, from the front-end personal computer to the rear-end database, by using e-mail for sending messages is about 30-40 seconds but the transmission delay by using *http* is about 2 seconds. There are no time limitations for transmitting position data of GPS to the command and control center. For information comprehension of battlefield the information is represented by multi-medium such as texts, pictures, video, or voice on the web-based environments.

In the future, we try to dispatch the missions by the real-time message, e-mail, and telecommunication conference that are based on the IP-based network system, and short messages and voice that are based on the cell phone system to reach the goal of information superiority.

References

[Harn *et al*., 1999a] M. Harn, V. Berzins, Luqi, and W. Kemple, "Evolution of C4I Systems," *Proceedings of 1999 Command and Control Research and Technology Symposium*, United States Naval War College, Newport, Rhode Island, June 29 - July 1, 1999, pp.1361-1380.

[Harn *et al*., 1999b] M. Harn, V. Berzins, and Luqi, "Software Evolution Process via a Relational Hypergraph Model," *Proceedings of IEEE/IEEJ/JSAI International Conference on Intelligent Transportation Systems*, Tokyo, Japan, October 5-8, 1999, pp. 599-604.

[Luqi and Ketabchi, 1988] Luqi and M. Ketabchi, "A Computer-Aided Prototyping System," *IEEE Software*, March 1988. pp. 66-72.

[Luqi, 1992] Luqi, "Computer-Aided Prototyping for a Command-And-Control System Using CAPS," *IEEE Software*, January 1992, pp. 56-67.

[Malerud *et al.*, 1998] S. Malerud, E. H. Feet, and U. Thorsen, "A Method for Analyzing Command and Control Systems," *Command and Control Research and Technology Symposium*, Naval Postgraduate School, California, June 29 - July 1, 1998, pp. 231-240.

[Maeda, 1999] H. Maeda, "About the Internet as ITS," *Proceedings of IEEE/IEEJ/JSAI International Conference on Intelligent Transportation Systems*, Tokyo, Japan, October 5-8, 1999, pp. 478-483.