Development of an Internet-Based Mobile Equipment Management System

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Key words: mobile equipment management, wireless communication, Global Positioning System (GPS), Geospatial Information System (GIS)

ABSTRACT

Positioning technology such as Global Positioning System (GPS) has been integrated with different types of information systems as a core data source for recent years. Especially, GPS and data management system integration technology has been widely used and has shown its capabilities as a powerful tool in information industry area. Also, mobile telecommunication technology is changing not only people's daily lives but also the phase of information technology development. Wireless communication devices are no longer the special hi-tech scheme and the Internet and its services are available in small wireless devices nowadays. Internet-based Mobile Equipment Management System (IMEMS) is trying to overcome the existing problems of current Mobile Equipment Management System (MEMS) by using the benefits of Internet communication technology. To demonstrate the concepts, a prototype system has been developed and continuing research efforts are put into development towards operational system.

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1. INTRODUCTION

Extraordinary achievements have been made in the innovative use of satellite navigation technology such as Global Positioning System (GPS). GPS, with its ability to generate accurate positional data, is uniquely suited to integration with Geo-spatial Information System (GIS) [1]. Whether the object of our concern is moving or not, whether our concern is for a certain place at a certain time, a series of places over time, or a place with no regard to time, GPS can measure it, locate it, track it – all that's missing is a context for that data. As the Internet rapidly changes our notions of what kinds of information are available and to whom, at what price the usefulness of a GIS as a means for organizing, analyzing and exploring data becomes quite striking [2].

Recently, Location-Based Service (LBS) system has received great attentions from industries for its practical purposes. Numerous LBS applications are introduced and known as being developed for a variety of practical purposes. It has led to a wide range of applications including Intelligent Transportation System (ITS) and Mobile Asset Management (MAN). However, most of implementations still are in the stage of tracking or location data acquisition. To provide the total solution for the end users to make decisions, there are some problems, which still remain to be solved. As already stated in [1], major reasons for the problems include:

- Real-time management with operational decision-making, different from transit systems, involves the management of a variety of mobile entities which differ in type and functionality. Since different types of equipment perform different designed job tasks and therefore they are often managed by different divisions/departments within an organization.

- The primary value of information extracted from the mobile entities for operational decisions is usually not the position/location information of itself but other relevant information, such as the performance and operational conditions of the assets. This fact doesn't contradict with the importance of the location data which is critical for dispatching and, coupled with the time data from satellite navigation system, makes sense of the rest of the incoming real-time information.

- Operation decisions in real-time management are often made at various levels and require real-time mobile entity information from a variety of databases. Every decision within the system must be an informed decision, transparent to other operational decisions.

Considering the problems and striking benefits of Internet, this paper describes the concepts of system architecture for Internet-based mobile equipment management system toward operational decision-making. It was based on an integration of satellite navigation, data management, wireless communication system and Internet. From studying existing Mobile Equipment Management System (MEMS), Internet has a big potential to enhance and improve the capabilities of existing MEMS. More practically, GPS for acquiring location information, GIS for managing and processing data, and wireless Internet for wireless communication are used in this project. Internet publishing is added for dissemination to more users. It means that IMEMS avoids physical Local Area Network (LAN) and enables unlimited access possible from anywhere Internet connected. Based on new architecture design, IMEMS not only includes basic processing procedures such as retrieval, manipulation, analyzing but also offers much more flexible services to potential users over the Internet.

2. DEVELOPMENT OF A PROTOTYPE

Figure 1 shows the conceptual diagram of major technologies of IMEMS proposed here.

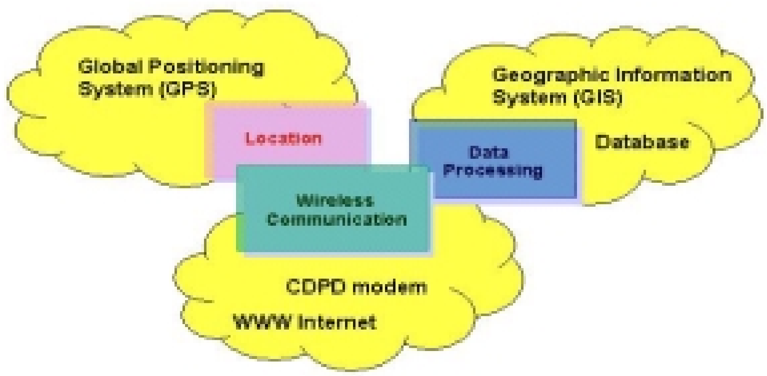

Figure 1. Concept of IMEMS

Main point of IMEMS is to integrate these different technologies and well organize them to fit the real situation. In order to do that, following four major components have to be considered:

- Mobile Component
- Wireless Communication Component
- Data Management Component
- Decision Making Component

Before going into more details in each component, it would be helpful to see how each component works together. First, mobile component is working independently in the field and connected with wireless communication. Acquired data in the field is then transmitted to the main server in data management component. In office, raw data including location information are processed and managed with different functions such as retrieving, mapping and etc. As long as appropriate processing is done in the server, well-processed information is disseminated to end-users. In this stage, IMEMS proposes Internet publishing for presenting information to end users letting them make their own decisions on their own usages (decision-making component). More details in each component will be discussed in the following section with some practical situations.

To demonstrate the described concepts, a prototype system has been developed with an application to the management of mobile lightplant equipment for open-pit mining applications. The aim of this prototype is to discover and learn how such a system can increase productivity while reducing revenue loss in a mining environment [1]. Based on discussion of the system architecture in the previous section, Figure 2 shows the system configuration in a mining environment.

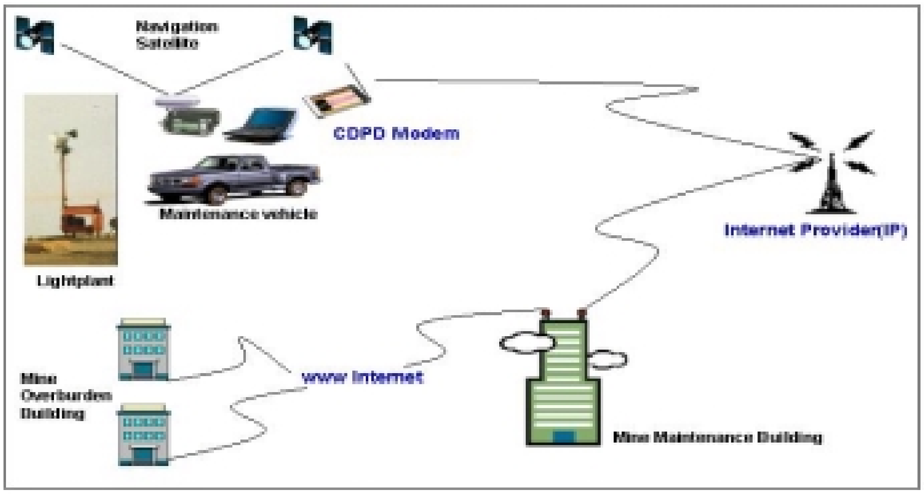

Figure 2. System Configuration

The prototype is comprised of four main subsystems.

2.1 Mobile Component

There are two major steps to develop the mobile component. Considering real fieldwork, the information (or attributes) dataset should be created first. What kind of information is needed? How are they represented in the form? These questions are necessary for creating database. Second step is the data acquisition. In data acquisition step, program is developed based on Java language, which is independent to different platforms. Data acquisition program provides functions of

- Mobile equipment positioning or location using satellite navigation system such as GPS, GPS+GLONASS or Galileo in the future dependent on the required accuracy. This information coupled with time tags will be the basis for the development of a mobile database.
- Collection of data, spatial and non-spatial, relevant to the mobile equipment. Depending on the application and the amount of data, the mobile component could be equipped with a laptop computer, Palmtop, or a PDA, etc.

- Transmission of data back to office computers via a wireless communication network. Many communication options exist nowadays including radio tower, cellular network, and satellite, Internet etc.
- Data compressing and encryption function to improve reliability and transmission speed.

As shown in Figure 3, data collector has choices of different receivers and different wireless communication devices. In the testing, Ashtech GG24 receiver and Novatel Merlin CDPD modem for communication were used. Also, appropriate datum should be selected according to the area we collect the data from. It is very critical for location information to be presented in the digital maps correctly in the data management component.

Figure 3. Mobile Component

Figure 4 shows the interface for the data collection in the mobile component. There are two parts in the interface. First part is to design for entering attributes (information) about the specific equipment. As we consider mobile lightplant equipment in the testing, there are Unit ID, Engine Oil, Meter Reading, Lights, Condition, and so on. Second part is to get current positioning information from the equipped navigation device (Ashtech GG24 in the testing).

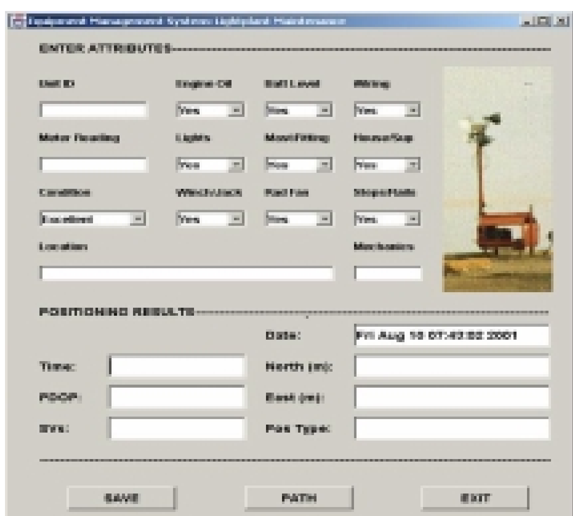

Figure 4. Mobile Component

2.2 Wireless Communication Component

Along with the fast advances in wireless communication technology and fixed Internet, the Wireless Internet has become one of the most important communication methods today. The Wireless Internet has many advantages over conventional radio data transmission methods for Mobile Equipment Management System.

First, the Wireless Internet has a wide coverage. The Internet is a global network and its transmission range is not constrained by physical factors. The wireless telephone systems, AMPS/CDPD (Advance Mobile Phone Service/Cellular Digital Packet Data) and GSM (Global System for Mobile), two most common and dominant systems applied for the Wireless Internet in Europe and North America, keep expanding everyday and also are evolving into global networks. CDPD technology is adopted in the prototype because the coverage of CDPD is larger than that of GSM.

Second, the data transmission via the Wireless Internet is much more reliable than that via the wireless radio modem. For example, CDPD is a packet-switched data service that uses the existing AMPS network to transmit data at a rate of 19.2 kbps. Dense transmission tower network is built to keep a constant signal power and cellular technology is used to assign the neighbor transmission towers different frequencies in AMPS to avoid frequency collision. Moreover, the channel separation is set to 30KMz which is much larger than the channel separation in UHP commercial band to minimize the corss-channel interferences.

IMEMS provides Wireless Internet access for mobile users such as exploration and survey companies to manage and monitor their operations and activities in the field or on the spot. Thus the overall efficiency will be increased. In the testing, Novatel Merlin CDPD modem was being used. As shown in Figure 2, CDPD modem is coupled with GPS receiver in the mobile platform (laptop in the testing) and is transmitting text form data to the server through the IP provider (Telus in the testing).

2.3 Data Management Component

Data management component consists of programming environments, database structure and GIS operations. Defining data structures and choosing the right data access technology have optimized the system architecture for efficient database management.

First, the current management component of IMEMS is using MS Access for the database structure but using ESRI's MapObjects instead of ArcView software which was used in previous development. MapObjects software is a set of mapping software components that lets programmers add dynamic mapping and geo-spatial information capabilities to existing Windows applications or to build custom mappings and GIS solutions. With MapObjects, IMEMS have unprecedented flexibility for creating customized interfaces for maps. Developers can use one of several industry-standard programming environments (in this case, Visual Basic) to create applications with a small memory footprint, and also can combine MapObjects with other software components to realize synergistic relationships between maps and the information which end users want to manage.

In addition, MapObjects is considerably cheaper than ArcView software. Therefore, the choices for programming software were Visual Basic 6.0, MS Access 7.0 for database structure, and MapObjects 2.0 for map viewing component. The management system being built currently looks like Figure 5. Data management component is considered as a part of the entire distributed database system used for mobile equipment management system and it can conduct a number of database functions as shown in Figure 5. These functions allow the database management process to directly combine spatial and non-spatial data in the relational or object-oriented DBMS. All of these operations can be facilitated by the interface.

Direct manipulations allow natural geometrical transformation and overlay operations from the interface. The non-spatial objects used in the database are modeled using types such as integers, character strings, numbers and Boolean. However, the spatial data is more appropriate since it is stored as point information on the display screen [1]. In Figure 5, currently, 1991 town zone layer and Calgary street map layer (in shape file format) are embedded in the data management component for the testing.

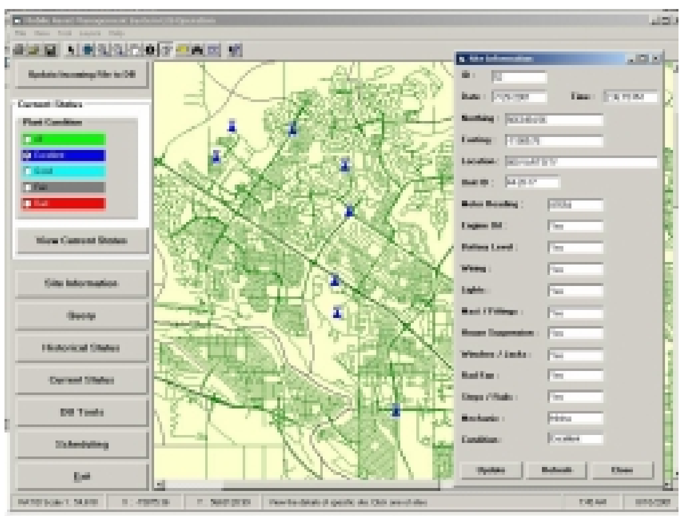

Figure 5. Data Management Component

The current data management component is linked dynamically. The main frame has functions to control database records such as updating, retrieving, and refreshing, etc. As long as raw data is stored in specified database structure, the user can see the most updated record and also the past records if she/he wants. The attributes in the record are UnitID, date, condition, engine oil, meter reading, mechanic and so forth. All of the lightplants or some of them can be displayed in different colors according to current equipment condition. Considering the mapping component, it includes several map viewing functions such as zoom in, zoom out, pan, full extent, etc. Furthermore, the user can retrieve or find map layer information using specific functions.

Data management component allows automatic database updating and also if the wireless interface encounters problems in transmitting information, it allows the database administrator to manually update the incoming information from the field. Figure 6 shows the editing function in current record window. The database administrator can also verify the numbers of records in the database for maintenance and administrative purposes as a good indication which the information has been uploaded into the database. When new information for equipment is obtained, it automatically replaces the old equipment information. Therefore, the current record table never grows or shrinks: it always provides current mobile equipment information. Once clicked, the software retrieves the information form the database via open database connectivity (ODBC) onto a new form. This form interface is in the format of a spreadsheet and it provides the user with direct access to the database for manipulation, querying and editing features.

In query function, the user can retrieve the current records or historical records according to Unit ID, Beginning Date and Ending Date. This gives users the flexibility to track movement of specific equipment during a specific period time. In doing that, utilization studies on efficiencies of equipment can be carried out. Over a period of time the historical status table could become over populated with information for equipment, especially if a piece of particular equipment is being actively moved on a daily basis. In addition, the user can query according to Mechanic or Meter Reading or Equipment Condition which are mostly concerned.

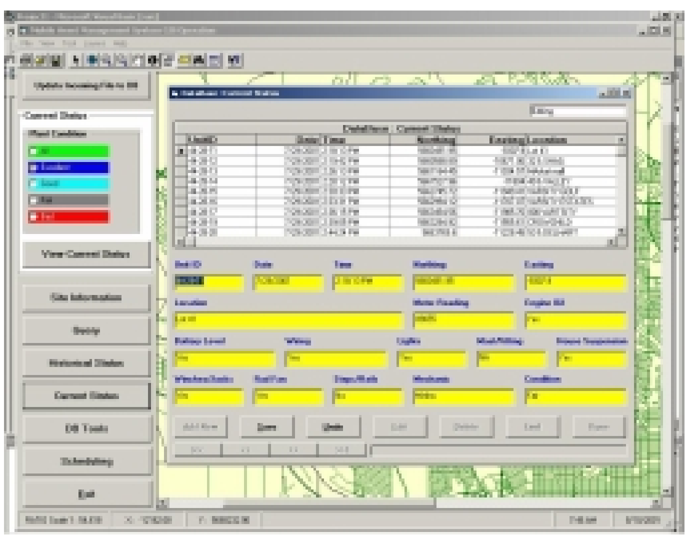

Figure 6. Data Management Component

2.4 Decision Making Component

Once the data management component has processed data correctly, next step is to present those data to the users who need them. On previous research, Local Area Network (LAN) was proposed to disseminate the information. However, IMEMS proposed Internet publishing for letting the end users to access the processed information they want. That means, anyone who is accessible to the Internet, not just physically connected office users, is able to access and get the information she/he wants. That is main advantage of Internet–based MEMS over previous research on MEMS. The IMEMS decision-making component (in Web) provides a global interface to the equipment management system. This interface allows users to access the different databases containing information such as condition and location of equipment.

This component is implemented using client-server architecture. The server stores all the various databases and manages user requests for data. The client is used to build queries and present the results to the user. The IMEMS web component is implemented using client-server technology. Such architecture requires a web server to host the data and software to process requests sent by the client. The client software provides an interface for users to perform queries on the data stored on the server and present the results from these queries. The IMEMS client side provides users with an interface to perform queries on the data stored on the server. IMEMS is implemented with a thin-client architecture for easy global access. To use the system, the user requires a connection to the Internet and a web browser such as MS Internet Explorer.

The client interface in Figure 7 is available on the IMEMS home page (http://136.159.122.39/Imems). To ensure only authorized user access the system, a user login is required. This login is authenticated against a database containing user information and available privileges. Once a user is logged onto the system, the main menu provides a list of functions available to the user. The functions are categorized as either fuel or maintenance related. Fuel scheduling activities allow the user to view status and schedule fueling of equipment. Maintenance scheduling activities provide similar functionality, with a focus on maintenance activities.

Upon selection of a particular function, the IMEMS client sends the appropriate request to the server in the form of a Uniform Resource Locator. For example, a user may request to view the current location of all the equipment for fuel scheduling purposes.

Selecting this option from the list of fuel scheduling activities (visible by clicking the arrow next to the fuel scheduling button located on the menu panel on the left) will result in a request for a table of the locations. The request is sent to the server where it is processed as described below. The server returns the results in the form of an html page in Figure 8.

IMEMS uses Microsoft Internet Information Server (IIS) as its web-server running on a Windows NT Server operating system. To maintain a cross-platform architecture, the server-side functionality is implemented using Java. Java is used to handle requests from the client through the web server, process the request using Java Server Pages (JSP) and return the results in the form of a web page. JSP is a form of server-side scripting and is useful because of its ability to dynamically generate and format content to be sent to the client. To support JSP, the web server requires a Java Server engine, IMEMS implements Allaire's Jrun 3.1.

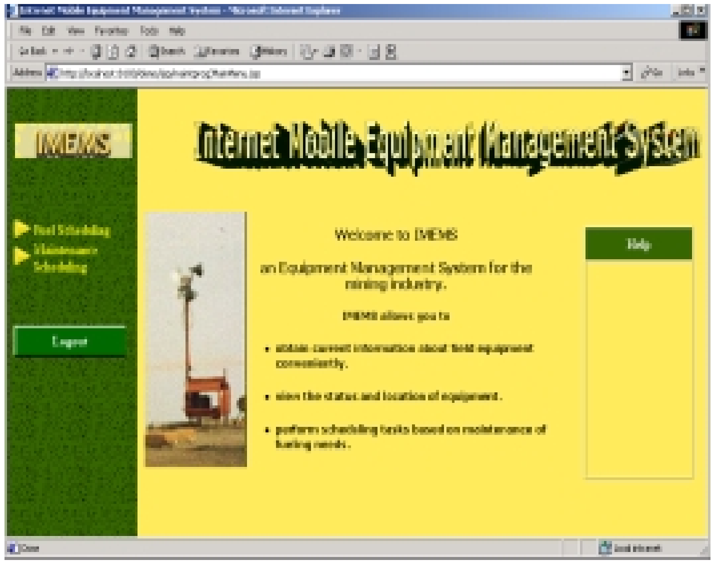

Figure 7. IMEMS Home Page

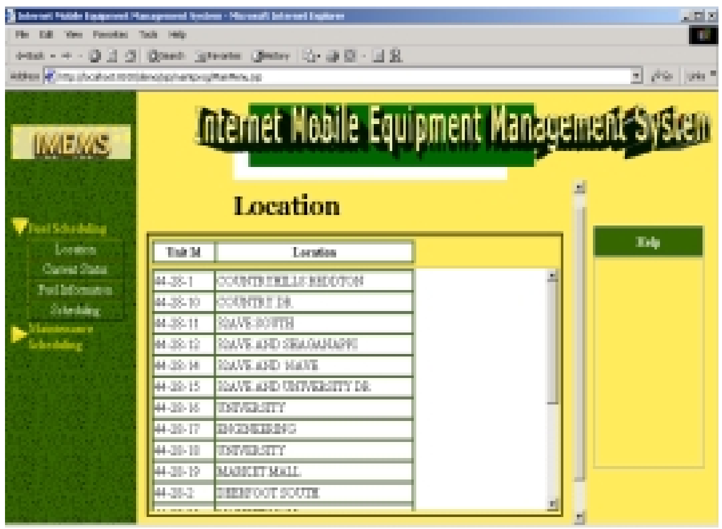

Figure 8. Sample Response of a Query

When the client sends a request to the server, for example a user may request to view the current location of all the equipment, it is accepted by IIS. A typical client request is sent in the form of a Uniform Resource Locator (URL), for example http://136.159.122.39.8100/demo/jsp/maintprog/LocationOfEquipment.jsp. This URL contains the web-server to be contacted and which port to send the request to. As illustrated in Figure 9, IIS accepts the request and sends it to Jrun for processing. A JSP is called up to process the request and render the results in HTML format. The JSP uses a Java Database Connectivity (JDBC) object to establish a connection to the database and perform the appropriate queries. The result is then sent back to IIS and displayed in the client's browser.

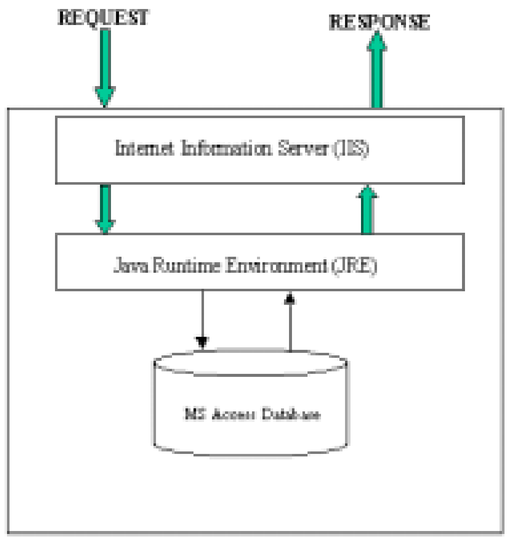

Figure 9. IMEMS Server Architecture

The current version of IMEMS provides basic functionality of an equipment management system over the World Wide Web. The system allows users to view information available in a database stored in a central location. The system is implemented using Java and Java based technologies such as JSP allowing the system to be implemented on any platform. IMEMS has currently been tested on a Windows platform but can be easily ported onto any system running a web server with support for JSP.

Although Jrun supports multiple concurrent requests, IMEMS has been implemented with an evaluation copy that only supports 3 concurrent users. The system has been tested successfully over a local network and is currently being test for global Internet access.

3. CONCLUSION

The system architecture of Internet-based Mobile Equipment Management System (IMEMS) which has been presented enhances both reliability and accessibility of existing MEMS. It shows that using Internet connection is giving more benefits to real operational applications upon the availability of the Internet. A prototype system only includes minimum operational functionality for testing. In the future, the research would be more focused on the operational system development of Internet-based Mobile Equipment Management System (IMEMS).

ACKNOWLEDGEMENTS

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REFERENCES

[1] Gao, Y. and Ramsaran, R. (2000). **"***Mobile Asset Management toward Operational Decision-Making"***,** Proceedings of ION GPS'2000

[2] Environmental Systems Research Institute, Inc. *Integrated GIS and Global Positioning System.*

BIOGRAPHICAL NOTES

Dr. Yang Gao is an Associate Professor in the Department of Geomatics Engineering at the University of Calgary. He currently leads a project to develop an integrated technology of satellite navigation, geo-spatial information management and wireless communication. **M. Park** is an Msc student in the same department.