MOBILE DATA COLLECTION METHODS USED IN THE PAVEMENT MANAGEMENT SYSTEM

WANG JIAQI, YANG SHUNXIN, LIU MING and CHENG JIANCHUAN

Transportation College, Southeast University, 2 SiPaiLou, Nanjing,
210096 P.R. China. Tel: 0086 25 83790163, 0086 13 815899143.
E-mail: wjqzcy@hotmail.com and wangjiaqi1981@126.com

ABSTRACT

Over the past 20 years, the development of highway and urban road construction has been extraordinarily fast in China. The Pavement Management System (PMS) has thus been established to maintain, repair and reconstruct the pavement. There are many useful and efficient surveying methods to detect distressed pavement (Wang, 2000). Most methods perform pavement surface distress detection automatically. However, those methods do not manage and integrate the detected results along with the documentation that include geographical components, such as maps indicating the roads and transportation networks. Traditional man-made inspection and documentation methods (Army, 1982) rely on human visual capability which causes this pavement survey work to be cumbersome and inefficient. This paper details the approaches to integrate information technology for mobile devices such as Personal Digital Assistants (PDA) and Global Positioning System (GPS) in pavement management system as an assistant data acquisition component. With the precision location data collection capability of GPS and the spatial processing power of GIS, it provides an accessory system for researchers to collect data with increased efficiency and ease. The research discussed in this paper is aimed at designing and implementing a pavement distress data collection prototype for inspecting pavement condition or spotting accidents and exceptional instances with the aid of mobile GIS.

1. INTRODUCTION

The rapid development of information technology has benefited engineers in many ways. The use of Personal Digital Assistants (PDA), Global Positioning System (GPS) and Geographic Information Systems (GIS) in engineering has become a new trend in high-tech usage that can take the place of traditional methods. If engineers can use these advanced tools in PMS, the efficiency and the reliability of data access work can be improved. In traditional data access methods, engineers carry many paper forms to record various data in the field and input the hand-written scripts into a computer to perform further analysis. This is prone to human error and it is sometimes difficult to trace back to the site and find explanations.

Recent advances in information technology of mobile devices like Personal Digital Assistants (PDA) and Global Positioning System (GPS) receivers have created a whole new area of opportunities for developing systems that allow field workers to tap into this new computing power.

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The ease of use and mobile nature of the PDA provide engineers with an effective and reliable way of recording and organising data in the field. A GPS receiver allows users to immediately find their location, thereby benefiting pavement investigations. A GIS system can help engineers organise the information and spatial data gathered, allowing a pavement management system to be rapidly established. This study introduces the application of PDA, GPS and GIS to improve the effectiveness and reliability of pavement condition investigations.

2. CONCEPTS AND APPLICATIONS OF PDA, GPS AND GIS IN PMS

During the data access process, PDA and GPS technologies can be integrated with PMS. Some disadvantages in using the new method compared to traditional ones cannot be avoided, but if the architecture of the data access system is designed properly, or the modules are integrated into the system in a suitable way, it will definitely enhance efficiency.

2.1 Pavement Management System (PMS)

Pavement management, in its broadest sense, includes all the activities involved in the planning and programming, design, construction, maintenance, and rehabilitation of the pavement portion of a public works programme. A pavement management system (PMS) is a set of tools or methods that assists decision-makers to find optimum strategies for providing and maintaining pavements in a serviceable condition over a given period of time.

The database is a central feature of a PMS. It serves as a repository for the information required to support virtually all decisions, including those concerning maintenance and rehabilitation. Moreover, the quality of the data will dictate the value of the PMS.

The most important component in PMS is the pavement condition survey, which includes distress inspection in the field and the rating procedures for archiving. GIS provides us with a very useful tool to manage the pavement data visually on the map and assist in decision-making regarding the PMS. Figure 1 illustrates the structure of PMS based on GIS.

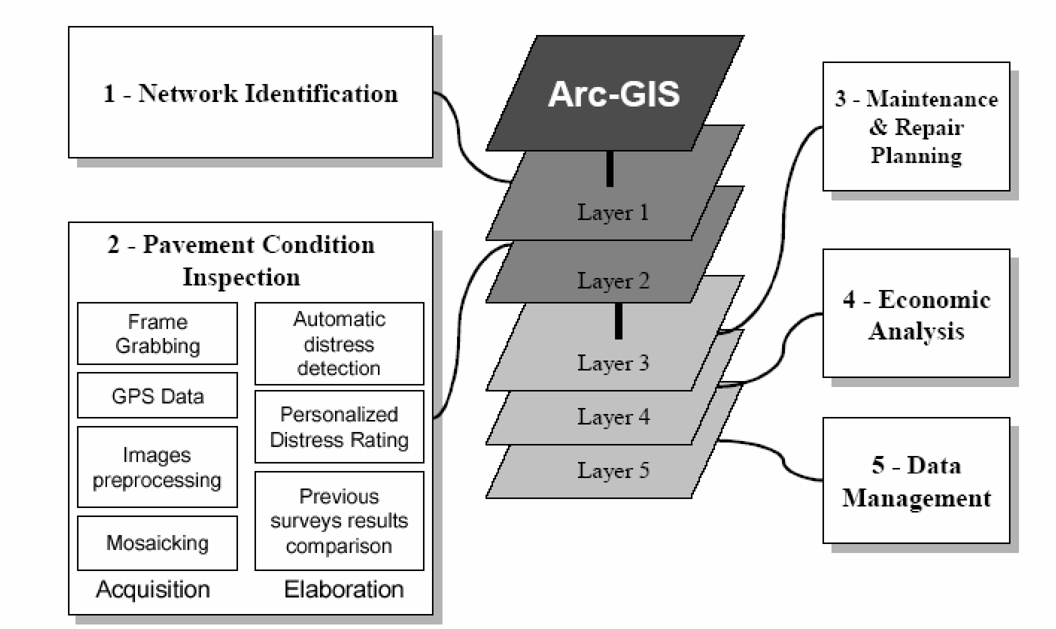

Figure 1. GIS-based pavement management system.

2.2 GPS Devices

The global positioning system (GPS) was developed with the support of the U. S. Department of Defence as an aid to navigation and for military positioning requirements. The current Navistar system operates with 24 satellites that orbit the earth in 6 planes that are inclined 55 degrees from the equatorial plane and transmit signals that can be received only on the ground. There are 6 satellites in each of the planes. Information from these satellites can be used to determine the location of the GPS receiver with a high degree of accuracy. In order to determine the location, the GPS must have information from at least 4 of 24 of the satellites. If more satellites can be simultaneously observed, greater accuracy can be achieved in determining the position of a point.

In comparison with the traditional method of location data collection, the system developed in our project is more convenient for the inspector, as he only needs to stand at the distress location to receive the GPS coordinates. Even if it is not possible to obtain the GPS coordinates of the distress location due to physical obstruction of the signals from the nearby buildings, the inspector can use the offset method where he can stand at a suitable position and determine the offset distance to the actual location. GPS has provided significant improvement in the ability to capture spatial positioning data.

2.3 Geographic Information Systems (GIS)

A geographic information system is a special case of an information system where the database consists of observations of spatially distributed features, activities or events. These are definable as either a raster-based description or a vector-based description that identifies space as points, lines or areas. Generally speaking, GIS can be defined as an organised system composed of computer hardware, software, geographical data and personal data aimed at efficiently capturing, storing, retrieving, updating, manipulating, analysing and displaying all forms of geographically referenced information. It is often considered that four major components should be listed as follows: spatial data input, data management, data analysis and data display. Because GIS can display not only spatial data, but also non-spatial data, it is very suitable for managing databases that combine spatial data and non-spatial data. There are many GIS software programs on the market.

At the initial design stage, the GIS software ArcGIS Desktop was used to produce the basic map. In fact, ArcGIS is a suite of three integrated applications, namely ArcMap, ArcCatalog, and ArcToolbox. Different layers of the map of an area were created using ArcCatalog and assembled using ArcMap. All layers were created in vector format (shapefiles).

2.4 Handheld Computers

A handheld computer is simply a computer small enough to fit in a person’s hand, so it shares its roots with all types of computers, including mainframe, mini and personal computers, and their forerunner, the adding machine. In the 10 years since the debut of Messagepad, a variety of technologies, including wireless connectivity, have been introduced to yield market-specific results. Handheld computing has become a key technology in all kinds for scientific fields.

3. EXPERIMENTAL METHODS AND SYSTEM ARCHITECTURE

The prototype developed in our research aims to harness mobile GIS technology to improve the efficiency of information collection. GIS has been employed for highway and airport pavement management. However, mobile GIS that integrates GPS in GIS running on a mobile handheld device (e.g. PDA) is still a relatively new technology, and it has not been widely recognised by the pavement management community.

The pre-field work preparation varies greatly between the manual and mobile data collection processes. For the manual process, the amount of preparation work is quite limited. Other than printing out the necessary copies of the paper logs, the pre-field tasks of the inspector are quite limited. For the mobile data collection process, the pre-field preparation is not trivial. In order to properly load data into the interface, design drawings and/or aerial photography must be created or downloaded for use as a base map for the correction process when taking GPS points. This process can take from a few hours, in the case of downloading corrected aerials, to several days' worth of work, as in the case of converting large-scale design plans into GIS layers.

After the maps were created and were ready to be transferred to ArcPad for implementation, ArcPad Studio was used to customise the toolbars and forms in ArcPad. The customisation was done in a Windows desktop environment and deployed in the mobile device via a copy of ArcPad.

The principle behind the design of the proposed system is to meet the needs of the end-users, namely the inspectors who are more concerned with the convenience and efficiency of the user interface. As the pavement inspectors may not be skilled in GIS, it is necessary to put more emphasis on creating a user-friendly interface, which integrates with the traditional procedures with which the inspectors are familiar. As a result, many of the design objectives are based on the end-user's ability to reduce the need for re-training.

The proposed prototype, with the aid of a mobile GIS, seeks to provide a user-friendly interface to allow ease of data collection, and speedy recovery of information while performing spatial and attribute searches. We believe that with the full utilisation of the mobile GIS and advanced spatial data searching techniques such as indexing, the efficiency of the data collection system will definitely be increased.

The PDA is a handheld device with a touch screen that has functions such as data recording, simple calculation, and data communication with a desktop computer. However, the PDA has certain limitations such as screen size, storage capacity, CPU speed and less software support. Therefore the development of PDA applications must consider the user's needs.

To exploit the merits of both the PDA and desktop computer, the characteristics and features of the two devices should be integrated. The PDA can be regarded as a "satellite" device of desktop computers. Data acquisition is its primary function. The data obtained should be able to synchronise with the desktop computer or database server through a direct link or via the Internet. Complicated tasks such as data analysis, drafting, file processing, etc. should be carried out by desktop computer. Before considering using a PDA, the characteristics, procedures and requirements of pavement investigation should be understood.

The following applications of the PDA in pavement investigation are suggested:

- Recording of the identification of the type of distress
- Recording the exact location of the distress
- Photo capturing of the distress.

GPS immediately offers information such as WGS84 position, evaluation, direction, etc. Many factors influence the precision of GPS, for instance the receiver itself, the signal quality of satellites, the correction factors of the atmosphere, etc. Therefore the choice of equipment should depend on the requirements and characteristics of the task. According to our research, it is recommended that DGPS be used, which can improve the precision of GPS measurement and is very convenient when using the equipment with a PDA for locating positions. The system architecture is illustrated in Figure 2, which shows the data flow from the server computer to the mobile device while data collection is being carried out.

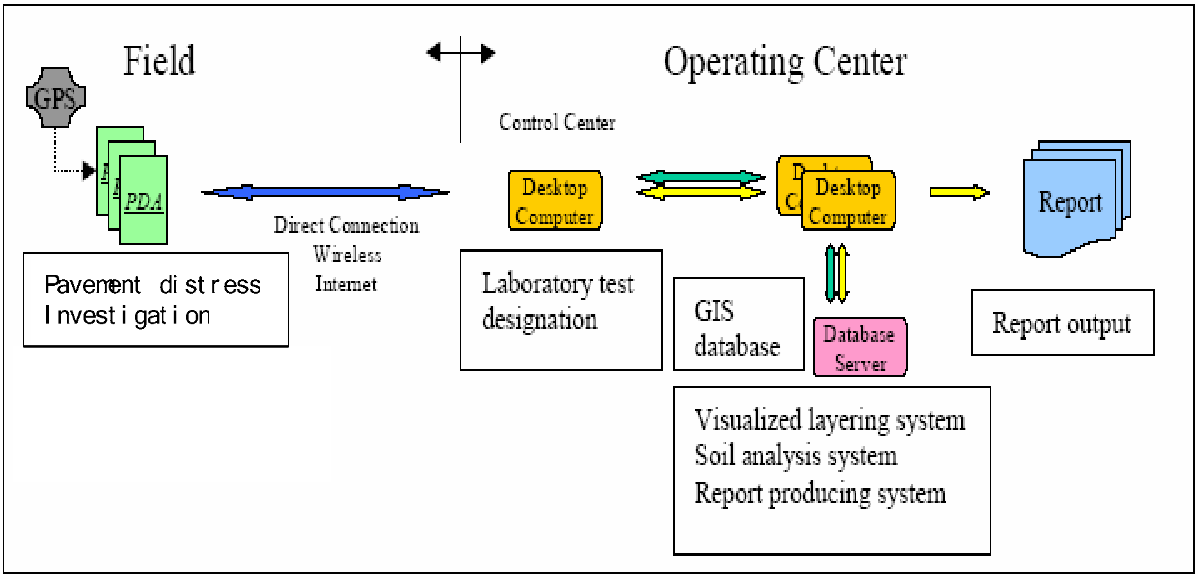

Figure 2. System architecture of data collection.

4. GPS FIELD PAVEMENT DISTRESS DATA COLLECTION

For PMS, how to collect real-time data efficiently is the first consideration and is the foundation of the system. It is a big challenge to collect such a large amount of positional data. To save time, more effort should be put into the process of making the field collection procedures automatically without wasting time training personnel.

There are in actual fact a three different datasets to be recorded for every distress identified in pavement. The first dataset to be recorded is the identification of the type of distress. It is essential to identify the correct type of distress and carry out the relevant geometric measurements, such as length of cracks, width of cracks, depth of cracks and presence of loose particles. These measurements are needed to calculate the severity of the located distress in comparison to the rest of the distresses identified.

The second dataset to be recorded is the exact location of the distress. The efficiency of recording the location of the distress will definitely be increased with the introduction of GPS into the proposed system.

The last piece of data to be recorded is the photo capture of the distress. The reason for capturing photos is ease of future identification and comparison. The camera can be equipped with a PDA.

For ease of data collection, the coordinates of the distress location are collected using a GPS module attached to the PDA. During the data collection process the engineers input investigation results in the field. This design concept of the data collection module is very different from the traditional PC program. It places the most frequently used functions directly on the PDA screen so that the engineers can carry out their operations with as few taps on the touch-screen as possible. Also, switching between screens is quick and reduces the user's waiting time.

Although the PDA offers some ways of inputting Chinese characters, it is not as convenient as a PC. Therefore the system should simplify the character input work into the PDA whenever possible.

To assist engineers to judge pavement distress in the field, the interface of the system is coded using graphical presentation to help them visualise the overall condition of the pavement.

5. DATA SYNCHRONISATION AND COMMUNICATION

There are a few ways of synchronising PDA data to PC, such as direct wired, infrared ray, modem and network, etc. However, how the PDA and the PC exchange data is handled by the data synchronisation module, a dynamic link library (DLL) program, which was developed using C++ language to perform these special operations. It is necessary to devise a certain “synchronisation logic” to judge which data records are new and correct, and then update the database.

For real-time application, the first thing that must be dealt with is the communication interface between the computer and GPS units. In order to receive real-time data from the GPS units, the proper communication interfaces must be established.

Among these are:
- The MSComm control program that provides a standardised format for communication.
- The port and the cable connection for the computer.

6. PC DATA PROCESSING

After the steps mentioned above have been carried out on the GPS data collected and transferred to a PC, the GPS files are ready for processing. Before processing, the positional data has to be converted to be fitted to the GIS software. Most GPS measurement equipment provides this function. The information is generally stored in the data collector used with GPS unit, which means that additional conversion may not be necessary. However, when carrying out real-time data collection and modification in the field simultaneously, it may be necessary to use a desktop PC as a server to store and manipulate data instead of the GPS data collector. The reason for this is that the desktop PC provides convenience of use and the GPS unit cannot store sufficient information or carry out additional calculations using the data. With the GPS unit, desktop PC and the handheld computer, the three systems can be operated simultaneously using hot-synchronisation. The information recorded by the GPS unit and the desktop computer should be related using the feature’s ID. After finishing the measurements, the two datasets can be joined together, stored and converted to a GIS format at a convenient time. Properly designed, the process is very simple.

The PC module receives the data from the data synchronisation module. It manages the following tasks according to field pavement distress data:

- Data presentation and editing synchronized data.
- Input of associated data not input by the PDA.
- Designation of laboratory tests for samples.

- Produces distress report forms.
- Import and export data for special format requirements.

Because most of the distress data are already in the database, more advanced software can be built on top of the system to conduct special pavement analysis effectively.

6.1 Coordinate Systems Conversion

There are many different types of coordinate systems used in mapping and surveying. Examples are geodetic, UTM, etc. The basic information from GPS measurement is usually recorded in a Geodetic Coordinate System referenced to the WGS84 ellipsoid with the ellipsoid as the reference surface. For most applications the WSG84 and NAD83 reference systems can be considered interchangeable. PC-based computer programs are available to permit easy transfer of the data from one coordinate system to another. Measurements made were transformed so that all the results were expressed in the UTM system.

6.2 Map Updating

The GIS map has to be updated to feed back the real-time pavement condition. The way to update the database is to consider the old map as a newly generated GPS map (actually, it is a piece of generated new map compared to the old one). It is called a GPS map just for a certain feature which should be somewhere between the location in coverage A and the location in coverage B. This means that the weighted average of coverage A and coverage B may find the "correct" position for the particular feature. It is the basic idea behind map updating.

The map updating is implemented using ArcGIS scripts. It can utilise the object-oriented programming language named Avenue to accomplish macro operations. Avenue is the programming language and development environment which is an integral part of ArcGIS. The scripts currently written are Avenue scripts. When it is necessary to deal with more complex situations such as real-time communication between computer and GPS unit, we can also use Visual Basic for macro operations. No matter what kind of programming language is chosen, the underlying principle is always the same.

7. GIS INFORMATION INQUIRY SYSTEM

GIS is developing at an extraordinarily rapid pays nowadays, and is a powerful tool for relating attribute and spatial data. A GIS system should include an inquiry function and an analysing function, and provide decision support for the user. Because of the increase of CPU speed and memory capacity, it is very feasible to construct a pavement management system based on the GIS platform. A GIS-based pavement management system will need databases such as environmental, positional and distress databases. With the help of photo survey data, engineers can oversee a large area for long-term monitoring. A GIS pavement management system can help us integrate resources, lower costs and provide effective analysis for decision support.

Therefore we utilised GIS software to superimpose GPS points obtained from a PDA with GPS and hyperlinked the points with the distress photos to make a preliminary distress GIS enquiry system. The waypoints (locations) were collected by GPS and the PDA were transferred to a PC and saved as a GIS database file. Figure 3 shows the main flowchart of the automated GPS data collection procedure.

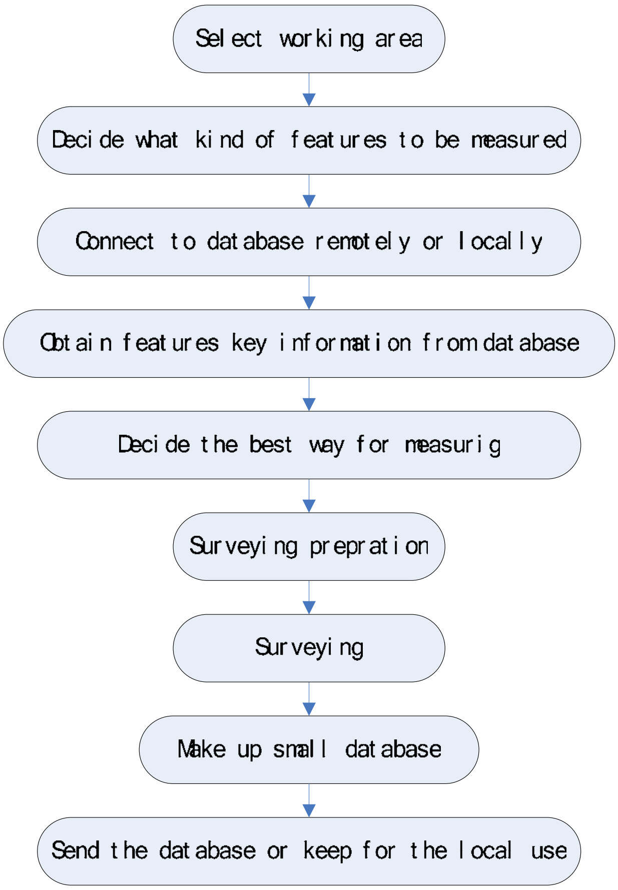

Figure 3. Main flowchart of the automated gps data collection procedure.

8. APPLICATIONS OF NANJING URBAN PAVEMENT MANAGEMENT SYSTEM

The data access system is in the initial stages of application to the Nanjing Urban Pavement Management System (UPMS). To integrate the data access method into the UPMS, there are more problems than there are for freeways. Firstly, the urban pavement situation is more complicated. Not only must pavement distress be taken into consideration, but also many other factors that can affect the data access process, for example traffic, pipelines, junctions and nodes. Secondly, the GPS signal is intermittent due to the buildings along the street. Thirdly, the database is more difficult to establish because of the large amount of data to be processed. However, after solving the problems mentioned above step by step, it is feasible to successfully establish the data access system and put it into the UPMS.

9. CONCLUSIONS

This paper has presented an overview of the methodology of automatically capturing positional data by the use of GPS equipment and using this information to update the GIS mapping database. The data access system has been put on a trial application in the Nanjing UPMS. The data collected with the system are the foundation of the GIS-based PMS. GPS technology is undergoing very rapid development and automatic measurement could be carried out using a wide range of GPS units.

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