Application of GIS/GPS in Shanghai Airport Pavement Management System

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Abstract

Shanghai airport pavement management system (SHAPMS) has been developed and updated for the Hongqiao and Pudong international airports that utilize the power of GIS and GPS for data collection, data storage, geospatial analysis of pavement evaluation and optimization of maintenance planning. This paper discusses the function design and the application effort of using GIS and GPS in the system. The practice shows that the pavement inspection time is reduced greatly, the geospatial tools are available for maintenance and rehabilitation, and the reliable data can be provided to solve future problems and optimize pavement maintenance decisions.

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1. Introduction

Shanghai airport pavement management system (SHAPMS) was developed for the Hongqiao and Pudong International Airports in 2005 [1]. The purpose of developing this system is aiding airport authorities to determine the most effective application of maintenance and reconstruction (M&R) work for a given airport pavement. SHAPMS has been updated to integrate the geographic information system (GIS) and global positioning system (GPS) technologies to expand the capabilities and usefulness of the original system.

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Incorporating GIS into pavement management systems has been occurring rapidly for the last ten years and is greatly expanding their capability. GIS can provide the airport management staff with visual pavement information and powerful analysis tool. Meanwhile, the spatial information managed by GIS can ensure the accumulation of valid attribute data of airport pavement. A study of US airport executives in 1999 showed that over 60% were using (or had planned implementation) GIS to support their pavement management activities [2]. However, the use of GIS with APMS in China just starts, only some large busy airports have developed APMSs. The use of GPS technology integrated in APMS is now being researched as part of a state-of-the-art system [3]. According to the requirements of airport pavement meticulous management, detailed information of pavement should be collected and recorded, such as distress location. The Denver international airport in US uses GPS receivers with wide area augmentation system (WAAS) for pavement data collection, which is a project only available in north America funded by the federal aviation administration (FAA) designed to improve the overall accuracy and integrity of the GPS signal. Some airports in other countries use differential GPS technology for spatial position. Overall, GPS applications in airport pavement management are not widely.

2. Establishment of spatial database

The establishment of spatial database is the premise of GIS application. The spatial entities in SHAPMS not only include polygon features such as pavement management units, but also include polyline and point features such as pavement surface roughness test lines and falling weight deflectometer (FWD) measure points.

2.1. Pavement division

Airport pavement is a large area, wide distribution structure. Dividing the pavement up into smaller, more controllable units is an important component in the APMS process [4]. The purpose of pavement division is to provide spatial reference position and assure the comparability of pavement evaluation. As specified in CAAC MH/T5024-2009 [5], the definition of network is comprised of three main divisions: branch, section, and survey unit.

Airport pavement is divided up into several branches. A branch is comprised of an entire segment of infrastructure such as a runway or taxiway. In SHAPMS, the airside pavement was subdivided into three types of branches based on functional classification: runways, taxiways and aprons.

The next stage of division is critical to the proper functioning of SHAPMS. Using the existing pavement inventory and engineering drawings, each branch is broken into smaller components called “sections”. A section must have uniform design, construction history, traffic, and condition.

The final step in the pavement division process is to split each section up into survey units for inspection and evaluation purposes. As stated by the CAAC MH/T5024-2009, the sample unit size for airfield pavements are 20 ± 8 slabs for each Portland cement concrete (PCC) pavement unit and 450m² ± 180m² of area for each Asphalt concrete (AC) pavement unit.

After the completion of pavement division, each branch, section, and survey unit should be identified by a unique ID. The ID is a unique code used to help store and retrieve data from the spatial database.

2.2. Map generation

In addition of the pavement division, airport pavement contains many other spatial entities. Because of the different topology relationship and attribute, these entities should be organized as layers according to the data requirements of spatial database. Through field measurements, the results of the pavement
division are drawn in an AUTOCAD document as a base map. Once the base map is created, layers can be generated that use the base map to show the location of any desired feature such as lighting, underground pipelines, and drainage structures. The spatial database can be established by map file conversion using the ArcMap 9.3 software which is developed by American ESRI Company. ArcGIS Engine components are integrated to realize pavement visual management in SHAPMS. Figure 1 shows the GIS module in this system.

3. Data collection using GPS

The data in SHAPMS includes not only the pavement entities information, but also the property information, which are comprised of distress condition, traffic data, roughness and friction etc. The property information can be collected in numerous ways, from pen and paper to electronic equipment. One challenge faced at the airport was locating the selected survey units or slabs in the field. However, airfields are open spaces without enough distinct features to assist in location. As could be seen in Figure 1, most airfield branches contain several sections and many survey units and therefore present a challenge for locating the objective in the field. Traditional layout method is paining the survey unit ID on the pavement to assist the investigators for location. But the biggest problem with this method is labor and time consuming and lack of productivity.

Using GPS technology can solve the problem effectively. The purpose of using GPS for data collection in SHAPMS is to get GIS data such as locations of slabs, lengths or areas of observed distresses. In order to realize this function, a Trimble Real-time sub meter GPS receiver along with a field computer is acquired. Figure 2 shows the purchased units. The GPS unit is mapping quality (sub meter real time and 50 cm accuracy after post processing) and communicates with the field computer using Bluetooth.

A data collection software program suited field survey workflows is developed and run on the field computer. Traditional paper survey form is eliminated. For example, the pavement distress survey is completed in this manner, GPS determines the location and the quantity (length or area) of the pavement distresses simultaneously, and the data are collected directly into digital format and are never transcribed from field notes. All the useful information of the distresses is collected which may be discarded in the paper inspection sheets. This method decreased the time necessary to complete each unit inspection. After the investigation, the raw survey data is downloaded from the field computer to the office computer. Combined with base station data, differential correction is then applied to the data to improve its accuracy.
4. Geospatial technologies for pavement management

The complexity in geospatial technologies makes SHAPMS one of the most unique, challenging and comprehensive pavement management systems. Some of the innovations of SHAPMS implementation for pavement management include the following:

4.1. Cartography of thematic maps for reporting pavement condition

One advantage of using GIS programs is that thematic maps and spatial queries can be created from the survey data. The civil aviation agencies in China usually use the pavement condition index (PCI) methodology for pavement evaluation. Pavement evaluation involves determining the current condition of the pavement network in terms of overall condition, cause of deterioration, and rate of deterioration. Shanghai Hongqiao international airport completed the pavement condition index survey rating for a 100 percent sample annually, with over 5500 unit inspections being carried out across the airfield. A computer program is embodied in SHAPMS to calculate the PCI in accordance with the procedures of ASTM D5340, which uses the distress data collected in GIS format as the data source. SHAPMS offers users the thematic maps rendered by ArcGIS Engine cartography components to report the PCI on unit and section levels.

4.2. Distress mapping for deciding remedial action

The time saving benefits of the GPS data collection procedure were introduced in section 3. Additional benefits of this procedure can also be realized during the data analysis and reporting stages. The thematic maps of pavement PCI can only help engineers grasp the overall situation of pavement, but cannot guide the actual maintenance actions. PCI values are reported on the unit and section levels only, where repairs are generally done on a slab-by-slab basis. In order to make informed decisions regarding maintenance and rehabilitation work, the engineer must know the types of distresses present in a given location and their quantities. Since all the distress information was recorded using the GPS device, it was easily imported directly into the GIS map. Viewing each section on the GIS map gives an indication of what distresses are present, their severity and quantity all at once.

In the example of the taxiway section named TP4 at Hongqiao, the survey units were divided along the full width of the taxiway. As shown in Figure 3, the PCI of each unit reached a trigger level that means the section cannot adapt to the requirements of aircraft operations and requires remedial action. However, Figure 4 shows that only the slabs in the center of the section TP4 need immediate replacement because of lots of structural distresses.

Fig. 3. PCI results of section TP4 on unit level
4.3. Feedback mechanism of pavement maintenance effect

For a detailed project level analysis, every unit in the section can be surveyed with the GPS equipment providing an accurate account of the distresses present. All of the bad slabs can be detected and repaired. After implementation of maintenance the repair data is recorded in SHAPMS. By spatial analysis and comparison of the distress data and the repair data in GIS, two type parameters can be acquired. One type parameter is used to estimate work quantity for next year from distress quantity in annual maintenance planning. Another kind is the maintenance effect denoted by the service life of treatment measure which is computed from the implementation time to the end time when the repaired distress appears new damage. This two type parameters reflect the cost effectiveness of various repair techniques. With the accumulation of data, the estimated parameters will be consonant with the actual, and distresses will be repaired economically by the optimal results.

5. Conclusion

This paper has documented the function design and the application effort of using GIS and GPS in SHAPMS. The system utilizes GPS receivers for data collected. Time required to complete pavement surveys has been reduced, minimizing the impact on airport operations of conducting airfield inspection. Using GIS leads to a multitude of new analysis techniques that allow for optimum management of the pavement maintenance. Furthermore, using this system allows the engineers to have a much higher degree of confidence in the data reliability.

References


