

# INTELLIGEN HEALTH MONITORING SYSTEM for BRIDGES

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**Abstract:** *A series of bridge collapse take place in recent years, which cause people to pay more attention to bridge health monitoring and early warning. An intelligent health monitoring system for bridges is proposed after analyzing the functions and characteristics of the current bridge health monitoring system. The paper first introduce main functions of system and key technologies, then mainly introduce bridge health monitoring and early warning subsystem based on GIS. The functions of subsystem include bridge spatial data maintenance and management, running bridge health early warning data model to get early warning information, displaying early warning information, querying bridge health data and present the information on electronic maps. To reduce the cost, we select ArcIMS as a means of map issue. We encapsulate the map realization in the module, and it not only separates the service realization and the map realization but also reduces the development difficulty.*

**Key words:** *intelligent; early warning; GIS; spatial database; ArcIMS*

## I INTRODUCTION

Bridges especially long-span bridges cost hundreds of millions or even billions of dollars. It plays important role in traffic, military and social life. In the process of construction and usage, because of the vehicles, wind, earthquake, fatigue, erosion of hazardous substances and the continuous degradation of material properties, different parts of the bridges have some damage and deterioration. These injuries can cause a bridge to reduce the service life, even lead to the destruction and sudden collapse. According to statistics, in the United States nearly 600,000 bridges are in the performance deficiencies and functional defects accounted for 28.6%. Maintenance of the old bridge accounts for 90% sum of U.S. annual investment of the bridge, only 10% is for the new bridge <sup>1</sup>.

There are approximately 5000 Highway bridges in china, 1.3 million km, One third of the bridges are structural defects, varying degrees of damage and functional failure of the hidden danger. In recent years, several major bridge accident have taken place in china: September 24, 1998, when Ningbo Bridge is being close, the fracture occurred; January 4, 1999, caihong bridge in Congqing, china collapse, 40 people were killed; August 13, 2007, bridge was collapsed in Fenghuang County in Hunan, 64 people were killed in the accident <sup>2</sup>. These incidents were related to many factors, but

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1 <http://bbs.pecbbs.com/viewthread.php?tid=20064>

2 <http://www.jgzj.net/bbs/archiver/tid-288409.html>

the lack of effective monitoring and the necessary repairs, conservation measures are important reasons. These startling incidents make people to pay attention to the quality and life of the modern bridges gradually. How to carry on bridge quality inspection and health monitoring has become a new hot spot in academia and engineering area.

The traditional bridge inspection relies heavily on the experience of managers and technical staff, lack of scientific systematic approach. Lacking of a comprehensive grasp of the situation and understanding exists on bridge health monitor because of lacking of timely information feedback. If underestimation of the disease occurred, the bridge is very likely to lose the best opportunity to conserve and process of bridge damage will speed up, that will shorten the service life of the bridge. Meanwhile, overestimation of the disease would result in unnecessary waste of money, the load capacity can not be fully realized.

Bridge health monitoring in China started late comparing with other country, the work began in the late 90s of last century. With the development of china, transport infrastructure and large-scale bridge construction increase rapidly. Many bridges collapse incidents give alarm message, bridge health monitoring has been gradually built. At the same time testing and monitoring tools have been improved and updated. Researchers in china have launched a bridge online health monitoring system. However, being limited by technical and economic conditions, these monitoring systems do not use advanced wireless sensor technology and data processing. Therefore, on test accuracy and stability terms, improvement to these monitoring systems is required.

The paper proposed a bridge health monitoring system based on the intelligent multi-source information fusion. The system help to complete remote and real-time bridge health monitoring, raise early warning, determine the bridge site of injury, assess the remaining life of the bridge, and provide a scientific basis for conservation to ensure the safe operation of the bridge.

The paper is organized as following: In section II, the paper introduces main functions of the system and key technologies. In section III, the logical and physical layers of the platform are introduced and the functions of every layer are described in detail. In section IV, the solution about WebGIS is described. And finally, we conclude this paper in section V.

## II MAIN FUNCTION and KEY TECHNOLOGY

### A. Main Function

Brief functions of the system include maintenance of bridge information, real-time monitor, early warning.

1) *Maintenance*: Through GIS and database management system technology, the attributes of bridge such as surround environment, design drawings, bridge material will be saved into spatial database for information management. The original data will be reorganized by maintenance software as data with geospatial features. The system carry on maintenance on two levels: One is 2D e-map, including road layer, river layer, lake layer, building layer and bridge structure layer etc; another is 3D-map, supervisor of the system should create 3D model for the bridge with supported tool. And basic database have two types: one is attribute database, including hydrological data, climate data, socio-economic statistics etc.; one is geospatial database, include layer information and 3D model.

2) *Real-time monitor*: Bridge health monitoring center is an important spot, including computer networks, databases, there subsystems.

- Field monitoring subsystem, the most important point is sensor layout plan and data transfer;
- Detection and control subsystem;

- Data process and analyze subsystem.

3) *Early warning and warning*: Based on real-time and accumulated historical data, early warning subsystem illustrate early warning and warning. Data mining technology is therefore applied to analyze the information.

4) *Friendly-interface*: implement of visualization of bridge information, users can examine the distribution of health indicator at e-map.

### B. Key technology

For implement of real-time remote monitoring of health status, early warning, determines the damage location, health evaluation, intelligent health monitoring system includes these key technologies: optimization of sensor layout based on the hopfield neural network, bridge health early warning data model based on data mining technology, bridge health monitoring and early warning based on geographic information systems technology.

#### 1) GIS

Geographical information system is any system that captures, stores, analyzes, manages, and presents data that are linked to location. In the simplest terms, GIS is the merging of cartography and database technology. Geographic information system (GIS) allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts<sup>3</sup>. WebGIS is an inevitable trend, help to solve the problems of spatial information integration and sharing in the web environment <sup>[1]</sup>.

The system use WebGIS technology to develop a user-friendly, yet powerful graphical interface, that solve visualization of bridge information, and can display distribute various sensor.

#### 2) OLAP

OLAP provides multidimensional conceptual view of data. "Dimension" is one specific point of observation data. Enterprises are often concerned about the changes of product sales data due to various areas. From the view to observe the geographical distribution of product sales, the geographical distribution is a "dimension." Likewise, time is also a Dimension. A "dimension" often has multiple layers. For example, time dimension has layers of "Date", "month", "quarter", and "year". As to bridges, there are layers such as cross section, section, parts, etc. Multidimensional view of data make user to mine information from huge amounts of data. So in-depth geographical Solution of the information contained in the data and its meaning. Providing the form of multi-dimensional view of the data available to users meet the people's thinking, and reduce the confusion, meanwhile, reducing the possibility of interpretation error.

This paper mainly discusses the implement of geographic information system in the intelligent health monitoring system for bridge.

## III ARCHITECTURE of SYSTEM

The whole monitoring system is composed of three layers:

- data acquisition layer

The layer use VC++ to develop software to collect data from various distributed sensor, and by utilizing Oracle9i technology, the software can implement continuous geospatial storage.

- data processing layer

OLAP is used in the layer to process and analyze data.

- System service layer

The interface base on WebGIS solves visualization of bridge information, and can display distribute various sensors.

Management and maintenance staff in the office can browse web site at any time to carry on the operation of the bridge and real-time monitoring of changes in parameters and can give according to the system decision support information to determine preventive maintenance on the bridge.

#### IV ArcIMS-NCU KITS

WebGIS map publishing system is now an important visualization technique. ESRI provided WebGIS platform ArcIMS, the product just position map for the simple release, product ArcGIS has analytical function, but ARCGIS are expensive. In order to reduce production risk, we carry out secondary development using Java to ArcIMS, extend the analysis performance of ArcIMS. In the system, geospatial interface base on ArcIMS solves visualization of bridge information, and can display distribute various sensors.

ArcIMS is ESRI's second generation of WebGIS platform software, used to meet in the Intranet / Internet to provide geographic data and services. ArcIMS architecture is fit for Internet applications. It can be applied to small Intranet site, meanwhile it can be extended to meet the needs of enterprise-class system or e-commerce site. When the site demand increases, ArcIMS can be configured to meet the telescopic server requirements<sup>3</sup>.

ArcIMS is a distributed systems composed by client component and server-side components. Clients request information on ArcIMS through the Internet or Intranet server, ArcIMS server processes the request, then returns to the client browser. ArcIMS architecture is shown as Figure 1.

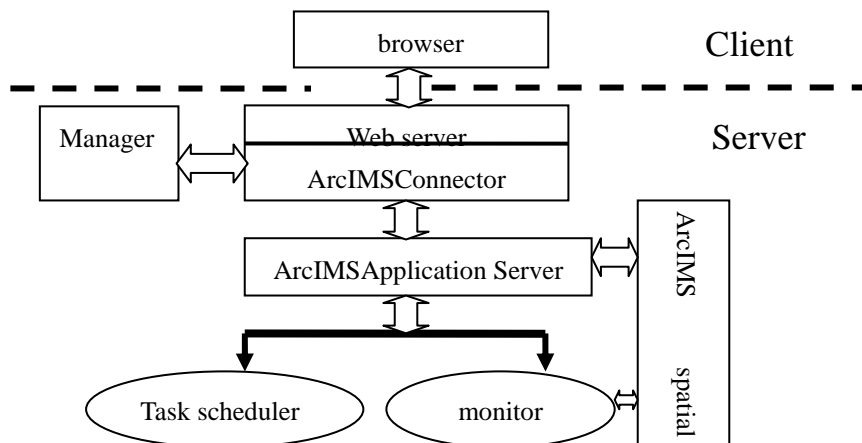


Fig 1. ArcIMS architecture

In implementation process, we need implement some analysis based on geographic information system functions, such as contours. However, after consultation with the ESRI's technical staff, we learned that ArcIMS is difficult to achieve these analysis capabilities, only ArcGIS server have these capabilities. But ArcGIS Server is expensive, that will increase our production costs, meanwhile market competitiveness of our products will be decreased. After technical studies, assessments, we decide to carry out the secondary development on ArcIMS using JAVA.

Using component technology, based on ArcIMS secondary packaging, we encapsulate simple operation and complicated features in our ArcIMS-NCU kits. Using ArcIMS-NCU kits, developer can develop professional applications without understanding of ArcIMS related technologies, thus development efficiency has been greatly improve. ArcIMS-NCU kits need to achieve the following objectives:

- Sharing memory and efficient image compression technology, can fully meet needs of low-speed network access;
- Adapting to multi-user access;
- Map control functions include: zoom in, zoom out, map roam, full image display, layer control;
- Query function: point queries, rectangular inquiry;
- Map annotation features include: single (Smart) tagging, annotation and dynamic labeling compound;

- Contour and ISO-surface of the production function.

Java Development on the ArcIMS has two modes: one is Bean, the other is the label, and these two models generally

### 3 <http://www.esri.com>

use JSP as the display layer<sup>[2]</sup>. We will use Bean's model. ArcIMS provides ArcIMS JSP examples for developer. Our aim is to package the original class, making it easy to use for each function, and add the corresponding map of features, such as contour lines, rendering map.

The following is solutions to technical difficulties:

- Majority of the development depend on ArcIMS Java's API, which is JavaConnector Classes API, the user must install ArcIMS Java Connector (non-default installation) for using ARCIMS-NCU kits.
- Contour and ISO-surface shape file generated using MapObjects Classes API interface.
- To solve the multi-user problem, server create a map object and open up a working directory for each client, the user's operations such as production of contour, renderings in its own directory is not affected each other.

Below is a diagram of class. As can be seen from Figure 2, the map has multiple layers (like layer sets), and layer has multiple elements. In other words, the map is actually the root object, the layers are the sub-object of the map, element of the layer is the sub-object of layer. All operations start from the map.

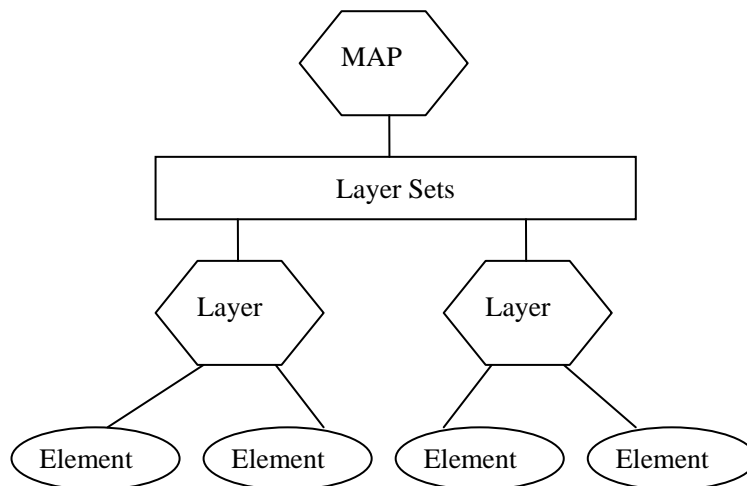


Fig 2. Diagram of class

## V CONCLUSION

The paper presents the research of development of intelligent health monitoring system based on GIS technology, the system can help to monitor status of bridge health based on information of distributed various sensors on a bridge. The paper describes the solution of WebGIS in detail. The ArcIMS-NCU kits are developed to solve visualization of bridge information of B/S mode applicaitons.

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