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Bridge monitoring and management system using GIS

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Abstract. In this modern world, the use of computer technology in most of the parts of life are necessary especially in engineering scopes. With an advanced technology system, engineers are able to solve the problems encountered from the unexpected situations with an effective ways. Bridge monitoring and management system encompasses the important aspects to be taken in its lifecycle and life span of the bridge. Effective and practicability of system developed allow bridge practitioners to collect, process, analyses, visualize and presented the database information through a moderate medium of delivery among the users. GIS acts as a tools for a bridge practitioners to provide spatial solutions for a problems encountered in spatial data handling for a bridge. This paper discussed about the GIS approach in the monitoring and management system for a bridge structure.

1. Introduction

Bridges are large and expensive structures which have a great impact toward the development of economy and society of developing countries. With the development of the economy, more and more long span and flexible bridges are built to meet the demands of daily increasing traffic in transportations field. Bridge safety will become an even more serious problem faced by the bridge authorities [13]. Delays in delivering spatial information to support the decisions about maintenance and inspection of bridges may cause risks and stoppages into the bridge management process and flow. However, this structures are often exposed to hard environmental and weather conditions [11]. Throughout the service life, bridges are subjected to various kinds of weakening agents such as winds, loads, temperature variation, erosion, structural aging and earthquakes. Due to these, bridges may lose its ability upon to its purpose of constructed for as well as being unsafe for public usage [1]. Therefore, bridge monitoring and management can ensure the capacity of the bridge to resist these conditions [12].

It is necessary for bridge authorities to introduce the health monitoring of the bridge structures as to satisfy the service and safety of the bridges [11, 7]. Health monitoring of bridges shall be performed by simultaneous measurement of loads on the bridge and effects on these loads which typically includes monitoring of traffic flow, weather, wind, prestressing of cable-stayed, deck, and pylons. This knowledge can be used by engineers as well as bridge authorities in order to estimate the loads and their effects. Besides that, engineers also are able to estimate the state of fatigue or other limit state and forecast the probable evolution of the bridge's health [11]. According to [1], structural health monitoring task has to be conducted in order to ensure the bridges is operating safely and efficiently. Bridge's safety status and condition can be known by monitoring the displacement and recording the fatigue history [12].



Traditionally, among of the methods used in bridge health monitoring includes visual inspection, sampling and laboratory testing are very complicated and tedious, costly and most important to be highlight is time consuming. Nowadays, the technological advances in monitoring systems such as sensors, cameras and remote sensing are advances in data collection, transfer, storage, analysis, interpretation and presentation can be implemented in the scope of bridge health monitoring. As a result, real-time monitoring and better decision making can be achieved. Besides that, early warning systems can also be built by using these advanced technologies [13].

Therefore, bridge authorities or engineers are responsible for the make sure the road transportation network and bridge infrastructure are well maintained and managed efficiently in order to meet the increasing demand of social and economic development of the nation of their country. Regular inspection, maintenance and monitoring work has to be done in a strategic ways as it will affect the huge amount of financial and life cycle of the structure itself. Despite of these important elements to be highlight in bridge health structure systems, managing all those the data are also necessary. Bridge maintenance management system which developed on the fundamental of the bridge structural engineering, mechanism of disease detection and geographic information systems which offers effectively economic and technical convenience for the inspection and maintenance of the bridge [5].

On the other hand, according to [9], limitation in resources especially financial part are available to maintain the nation's stock of bridges in a safe condition thus make it highly essential for an optimal bridge maintenance and rehabilitation program through the development and use of a computerized bridge management system. Bridge authorities responsible for the management and maintenance of bridges by considering the use of computer-based database as data management and analysis tools to aid them in performing many important bridge management functions and decisions [4]. With the advanced technology approach in computer-based data management, data redundancy, miscommunication and costly conversion when moving through planning, design, construction and operation of infrastructure data can be eliminated. Besides that, according to large volume of data needed in the structure database system, many of the limitation has arrived in implementation of bridge management system for a road transportation network [4, 10].

According to [6], the arrangement and management of such huge network fundamentally done at the level of national and local stages. The national level arrangement is a broad based and is done using some macro level data while local level arrangement is problem specific and confined to a vicinity of a few metropolitan cities. In addition, the significant planning in various aspects of road network can be attributed to the absence of availability of large volume data required. Regardless of whether this information is made accessible, problems on how to manage and access the data are still emerge. The valuables information related to existing transport infrastructure is scattered at different organizations. Besides that, [4] has discussed about the problem arise in developing bridge management systems. The first problem in dealing with bridge management as a network level is the difficulty of identifying the geographic relationships involved in bridge management activities while the second critical problem is the difficulty to quickly make an appropriate decision at each lifecycle stage of a bridge as well as problems regarding on the superior spatial data handling capabilities.

Geographic information system (GIS) technology is progressively being considered for the execution in most of the infrastructure planning and management systems, including bridge management systems. GIS also provide spatial solutions to many fields in civil engineering such as transportation, water resources, facilities management, urban planning, construction and other fields [10]. Thus, the adoption of newly emerging technologies such as geographic information system (GIS) can be used in encountered with those problems discussed earlier. GIS in bridge management system can help to improve the decision making process for a better use of the available limited funds [4, 5, 6, 9]. This paper covers the application of GIS in bridge monitoring and management data system.

2. Bridge monitoring and management data system

Bridge management consists of all activities carried out to ensure that every bridge in a highway road network remain fit for its extended purposes throughout its service and life span. Bridge management

activities includes bridge inspection and assessment, bridge reconstruction, bridge maintenance and rehabilitation [16]. A number of bridge management system (BMS) are now being developed and applied in various countries such as Pontis and Bridgit system which has been developed in the USA in 1991 and assessment code called Operation Bridge Guard under the UK Department of Transport. Pontis and Bridgit are two very well-known BMS's. Database development and the detection of the classification, rating, Sorting and the service life prediction of the maintenance operations are developed in the Pontis [3].

Pontis supports the complete bridge management cycle, including bridge inspection and inventory data collection and analysis, recommending an optimal preservation policy, predicting needs and performance measures for bridges. Pontis applications also has been customized by developing the additional applications for its system such as providing additional data entry reports and forms. On the other hand, Bridgit is a system which uses a project level-based optimization strategy to provide networking within a state agency recommendations and guidance for the purpose of funds allocations on a bridge network and optimize network performance strategy [3].

Database management system can execute the basic information about the bridge, inspection record, maintenance history, input of the image information, provide a variety of information queries, and the recorded data automatically generates the documentations needed by the bridge evaluation and assessment [5]. Large structures of bridges are very flexible and vulnerable to various types of loads. Bridge monitoring can help to reveal the real performance under severe loading, which can provide useful information in understanding structure performance. Data gathered and collected from monitoring process will form the most essential part in BMS [13].

Other than that, the data in bridge management system are based almost entirely on the visual inspection of bridge's condition. A bridge is given a rating according to indications of its elements through the rating. According to [11], bridge monitoring can ensure the capacity of the bridge itself to resist conditions and thus negative impacts on country's economy and society can be prevented. This shall be performed by simultaneous measurement of loads on the bridge and effects of these loads which include extreme weather, traffic loads and structural aging.

3. GIS application

Nowadays, the development of internet and technology has bring the data communication to be widen customized and multi-user among the users. Information can be shared and transfer easily around the world and being access by different users in making decision and choices. The integration of GIS and internet technology has prolonged the flexibility functionalities of geospatial information at any time and everywhere [3].

GIS technology provides the tools for creating, managing, analysing and visualizing the data associated with developing and managing infrastructure [15]. GIS operations similar to other information technologies which requires several components such as hardware, software, people who refers to the GIS professionals and infrastructure itself. GIS offers powerful tools to manage high volume of spatial data in vector and raster forms, a number of spatial analysis functionalities and ability to display and visualization of the data in various ways [14].

GIS have been perceived as an important device and tools for geospatial data application decision support and planning analysis. GIS technology has been broadly executed in most of the public and private organizations since GIS has special features for the storage, retrieval, manipulation, analysis, and display of geographically referenced data. Since map can improve understanding than verbal sentence, GIS provides great capacity for applications about geospatial data [3].

Traditionally, maps have been used as an analogue storage device for spatial data. However, GIS is more than just an electronic map. Besides providing a means for spatial display, it provides supports for analysing the interrelationships among the various spatial data elements. GIS seen as a natural way to model and represent the spatial objects that human deal with in their daily activities [9].

According to [10], GIS has the potential to merge a person's process and field knowledge with a powerful computer system that documents activity and builds a fundamental for further streamlining. It

can remove some of the tedious tasks of daily operations by easing the burden of the worker, resulting in the potential for productivity increases. Meanwhile, new data documentation requirements are added that form the foundation for future GIS analyses.

GIS is ideally suited as a tool for the presentation of data derived from distributed measurement stations [2]. The rapid development of GIS has provided a great opportunity for developing a new type of bridge management system including bridge planning, design, construction, monitoring, maintenance and even inspection. In addition, GIS application also has help the bridge engineers to make a quick and appropriate decision making at each lifecycle stage of a bridge [4]. Besides that, GIS allow project managers and different people involved in project with different backgrounds to get the information about the progress of the project and provide common basis of understanding and communication among these people [10].

4. GIS application in bridge monitoring and management system

Requirements for the implementation of bridge monitoring and management systems consists of data collecting components, data transferring components, data storage components, data processing, data analysis and presentation, data visualization and power supply components. ArcGIS software is used to plan and design the overall system of the bridge monitoring and management system. This software is used to process, analyse, present and visualize the collected data. ArcGIS system are able to processed and analysed with variety of filters and attribute analysis tools. Then the result will be visualizing and presented on a bridge map models.

For the implementation of GIS in bridge monitoring and management system, adequate amount of data and information are required so that the database is able to perform. Bridge monitoring and management system is a general technical system that integrate bridge monitoring and information management. The main functions of GIS in bridge monitoring include the monitoring of data collection, management, analysis and processing, visualization and monitoring information distribution. Bridge monitoring and management system range includes three main databases which are bridge working environment monitoring database, geomatics displacement monitoring database and bridge mechanical properties monitoring database [7].

Research conducted by [7] discussed on how GIS develop a system framework for bridge management system. The information system of bridge structural system based on GIS need to access, process and manage various types of data, including static and dynamic data, graphics and non-graphics data, conventional and massive data. Large database management system for bridge are used to manage massive data from sensor, all kinds of document of bridge as well as all kind of analysis results. The whole system development and operation should be based on the thought of client or server architecture in order to realize the networking information processing and management.

Moreover, visualization is a strong mean for people to intuitively research and analysis massive data [8]. Visualization can clearly reflect the dynamic change situation of the structure of the bridge. Therefore, the visualization of monitoring data is one of the essential functions of monitoring system for the bridge as shown in Figure 1 and 2 [18]. One of the previous researcher has conducted a study application of GIS into the bridge health monitoring by using 3D modelling as a design approach [17]. Some kinds of information, such as, bridge location map, bridge drawing, sensor position in the bridge, structure monitoring data coming from sensors and the analysed result, attribute (health) about the bridge bodies, should be managed efficiently. These data have different features, such as graphic, non-graphic, static, dynamic, as well as large data required.

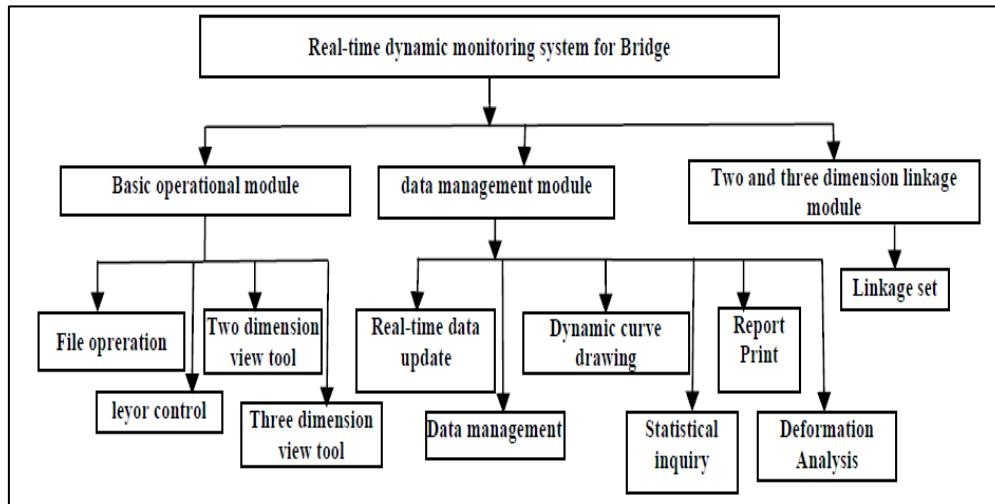


Figure 1. The interface of realization of bridge monitoring system.

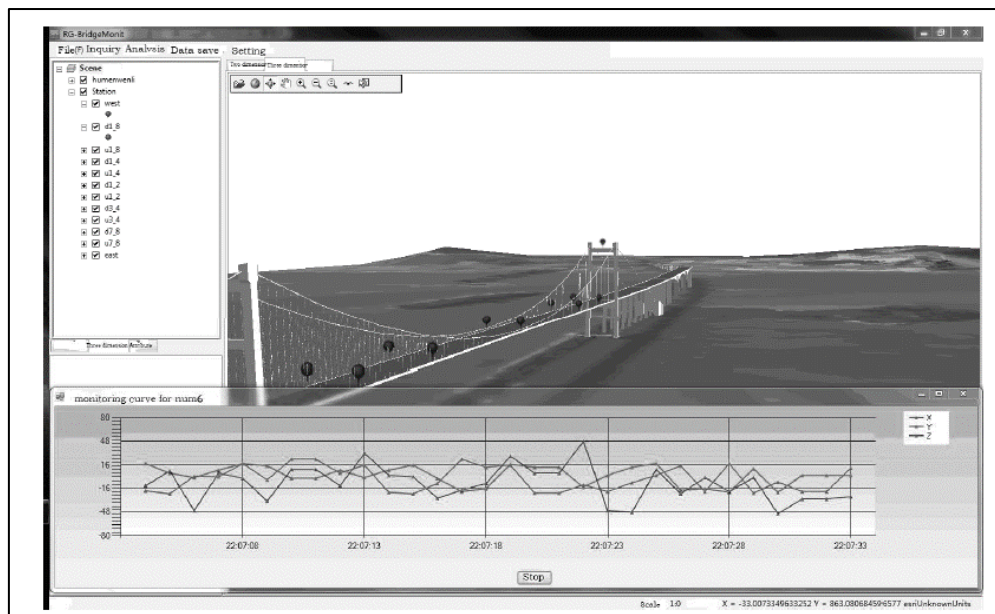


Figure 2. The interface of visualization of bridge monitoring system.

On the other hand, GIS is adopted to manage graphic information such as the map (bridge location), bridge (body) drawing, and locations of sensors, visualize the bridge structures health in special method such as colour and texture. In 2D GIS, some information could not be represented, because all the spatial information is projected into horizontal level or profile. For example, it is impossible if users want to see the bridge bodies, bridge structures, and sensors in different direction, or to view the scene of the bridge location. 3D GIS have the ability to manage 3D spatial information and can overcome the above problems. It is necessary to establish bridge monitoring system based on 3D GIS model [17].

Graphic data that the system need to manage mainly include bridge site topography, bridge model, and sensor location. Graphic data directly use the spatial data management function of GIS software layer manage. To the topography, we can accord to the national basic geographic information code to layer or accord to the demand to highlight the bridge, road, water, and buildings, each of them consists of a layer, other elements as the background layer. The location of bridge model and sensor are placed in the same graph. according to the bridge monitoring requirements, after the bridge CAD model or

designed graph are generalized, they are divided into different bridge structures objects, such as bridge surface, pier and cross beam and converted to graphic pattern that GIS can manage [7].

5. Conclusion

Bridge act as an important infrastructure in road network of developing countries. As the infrastructure of the bridge become complex from time to time, the need for a monitoring and management system for a bridge is highlight as an important elements in order to ensure the life cycle cost and life span of the bridge itself. It is concluded that GIS are effective tools for plenty activities which include various types of data and format. It can improve the discipline of bridge monitoring and management system by combining the management, capturing, analysis, storing, visualizing and presenting the large volume of data in one complex system.

GIS technology provides the core framework for the development of advanced computer-based database system for bridge experts. The use of GIS for BMS allows users to geographically retrieve bridge information and perform spatial queries and analyses on the bridge inventory and condition ratings. Besides that, this tools also are able to help bridge experts in making decision quickly as well as visualize the health conditions of the bridge. Integration of the database management allows different backgrounds among bridge authorities and experts to access the common basis data of the bridge at the same time.

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