An Early-warning Approach for Monitored Bridges Based on the HLM Indices

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Summary

An early warning method based on the HLM indices for monitored bridges is proposed in this paper. Only three basic values, the highest value, the lowest value and the mean value in each periodicity (daily periodicity, weekly periodicity, lunar periodicity, etc.), are reserved in this method. The values are categorized and added to corresponding sub-tables of the periodical database. Based on these three key values, a series of mathematical models of early warning indices is established to make a statistical analysis of bridge behavior. The indices include the load-carrying capacity index, loading intensity index, volatility index and directional movement index. This method has already been successfully applied to Yufeng bridge health monitoring system in China's Jiangsu Province and achieved fine results.

Keywords: bridge; early warning; assessment; HLM index; health monitoring

1. Introduction

Of all the bridge health monitoring systems that have been put into operation, most only deal with the data collection and storage processes, but seldom they have the ability to automatically give forewarning. The reasons are summarized as follows: (1) Lacking an effective method to process massive monitoring data; (2) The structural damage early warning using existing approaches mostly needs analyzing and processing of data with additional tools and measures artificially at a later stage, and can thereby not realize real-time and automation level; (3) The sensitivity and accuracy of the methods are reduced because of the complexity of the structures and various errors and uncertainties, which result in ineffectiveness.

Aiming at these problems hereinbefore, a new method for monitored bridge early warning systems based on the HLM indices is developed in this paper.

2. The Early-warning Method Based on the HLM Indices

2.1 The HLM Line

The HLM line is composed by three basic values, which are the highest values, the lowest values and the mean values (hereafter referred to as HLM values) of every monitoring parameter in each periodicity (hourly periodicity, daily periodicity, weekly periodicity, lunar periodicity and yearly periodicity). The monitoring parameters mentioned here can be any type, such as strain, deflection, cable force, acceleration, etc.

2.2 Multidimensional Tables of Database

To improve the operating efficiency of databases, and facilitate programming for the early warning indices, a concept called multidimensional tables of database is proposed in this paper. Dimension here refers to the particular perspective in which data are categorized.

Based on the characteristic of monitoring data, three relevant dimensions---time dimension, geographical dimension and category dimension are designated around the theme of HLM values, and each dimension encompasses several different hierarchies. Taking time dimension for example, it can be defined by different rules, such as year, quarter, month, week, day, etc., which compose the hierarchies of time dimension. In the same way, the members, sections and measuring points of a bridge compose the hierarchies of geographical dimension, and strain, deflection, cable force, acceleration, etc. compose the hierarchies of category dimension. According to the different dimensions designated, the HLM values are classified and respectively saved in different sub-tables of the database defined by time dimension, geographical dimension and category dimension. The informations recorded in each sub-table should cover time, sensor number, the HLM values, etc.

2.3 The Design of Bridge Early-warning Indices Based on the HLM Line

The HLM indices include four types: load-carrying capacity index, loading intensity index, volatility index and directional movement index.

2.3.1 Load-carrying Capacity Index

The load-carrying capacity index compares the highest value and the lowest value in current periodicity with the design allowable value, so as to identify the utilization of structural design bearing capacity.

2.3.2 Loading Intensity Index

The loading intensity index compares the rangeability of the extreme value of monitoring data in current periodicity with that in several periodicities in recent time, to identify the extent of change of the extreme values in current periodicity, so as to reflect the increment or decrement of current structural loading intensity.

2.3.3 Volatility Index

The volatility index compares the mean value in current periodicity with the moving average of the mean values in several recent periodicities, to identify the deviation degree between their difference and the extreme value rangeability of the mean values in several periodicities lately. In other words, discover the abnormalities in monitoring data in time by calculating the degree in which the mean value in current periodicity deviates from the moving average of the mean values in recent periodicities.

2.3.4 Directional Movement Index

The directional movement index is an ideal tool to perform holistic tendency analysis of monitoring data. It compares the mean values among multiple periodicities, to find the ascending tendency and descending tendency of monitoring parameters during this period, so as to reflect the changes in direction, strength and trend.

3. Discussion

The advantages of the method are as follows:

1) Solve the massive data problems in HMSs effectively;
2) Reflect the fluctuation of bridge monitoring parameters timely and visually;
3) It is applicable to various types of bridges as well as monitored parameters, which proves to have a good generality and expansibility, and is suitable to be developed into a general early warning and assessment platform for monitored bridges.

Following the concept, researchers could develop further better indices to have a deeper and thorough understanding of bridge performance, which provides a new way for bridge assessment and early warning.