Modern trends in Bridge Health Monitoring (BHM)

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Abstract

Bridges are exposed to harsh environmental conditions and require more robust monitoring to ensure their safety. With the current technological advances many new monitoring approaches are considered. Some of them include smart sensors, fiber optics, and computer vision based technologies and machine algorithms. Unmanned aerial vehicles (UAVs) and robotic vehicles have also been employed successfully with the advantage being easy access and fast data acquisition. However it is important to understand the nature and limitations of each technique.

Keywords: Bridge health monitoring (BHM), Smart sensors, Computer vision, Unmanned aerial vehicles (UAVs)

1 Introduction

Bridges are among the most monitored civil engineering structures as they sustain excessive structural degradation caused by several factors, including harsh environment, traffic collisions, and increasing traffic volume and load. Bridge health monitoring (BHM) is a multi-discipline field developed to predict and detect damage at the early stages. Traditional BHM involves onsite evaluation, requires substantial field labour, experience, and operational interruptions. Therefore, developing a cost effective, accurate, and automated noncontact solution for efficient and reliable BHM has been an emerging research topic. This paper presents a brief summary of various techniques and procedures used in the last two decades for BHM.

2 Global and local Health Monitoring of Bridges

Damage at a local level may be considered as changes in the effective material properties or conditions such as crack, spalling, corrosion. Ultrasonic measurement, impact-echo and tap tests are well proven technologies that are used to evaluate local conditions [1]. Global health monitoring methods are centred on finding shifts in resonant frequencies or changes in structural mode shapes. Various techniques are used for global. These include, but not limited to: 1. Observing natural frequency shift 2. Change in mode shape 3. Ritz vectors 4. Matrix update method 5. Statistical pattern recognition approach using Bayes theorem.

3 Modern techniques used in BHM

With the technological advancement many new approaches have been employed for BHM. Some of the most promising techniques are briefly discussed along with their limitations and advantages.

A novel method to monitor cracks is the use of imaging and pattern recognition. The fact that Cracks reflect or absorb light differently from the neighbouring region is used. X-rays and Gamma rays are used to get visual images of the interior of structures such as steel cables and slabs. The size of the equipment makes it difficult to reach locations with difficult access. These techniques require access to both sides of a structure, however use of back-scattered signals has mitigated this problem [1]. Radar technology has recently seen many new innovations in the area of sensing. Major innovations include the development of ground penetrating radar and broadband radar. Infrared thermography is also employed to detect debonding of steel bars[1]. However dependence on the thermal emissivity, effects of the external temperature reduce the accuracy of the measurements and allow for qualitative investigations only [2]. Elastic waves are generated by a material experiencing internal changes. By monitoring the acoustic emission of these elastic waves, it is possible to monitor the structural health of bridges even with a limited coverage of the structure [2]. The recorded data by application of actuators and sensors such as piezoelectric materials for long term monitoring is extensive and requires costly processing. Hence smart sensors are employed which can process the data before the output is recorded. Another class of smart sensors consists of those sensors that can communicate with each other and are capable of communicating among themselves and communicate the sensed data wirelessly by hoping from one sensor to another. Wired sensors need to be installed during construction thus affecting the use of structure and also limiting the number of sensors deployed [1]. Fiber optics have made distributed sensing possible. The chemical coated fiber optics can be used to detect the corrosion in reinforcement [1]. Flexibility, Electromagnetic Interference Immunity, and scalability are among the advantages [2]. However expensive data acquisition equipment, complicated installation process are among disadvantages. These can be avoided by using coaxial cable as sensors. For efficient BHM very large amount of data is collected. ML algorithms and Convolutional Neural Network (CNN) are being developed to process this huge data and provide real-time feedback. The template matching technique, feature matching technique and optical flow are the most common algorithms for obtaining displacement time histories with high accuracy. Modal 3D algorithm is used for Image processing. Mask R-CNN is used for component identification. Examples of CNN include custom CNN, Xception, and AlexNet for detection of concrete deterioration.

4 Vision Based techniques

With the advances in image processing techniques, researchers have employed photogrammetry and computer vision based techniques to overcome the limitations of the number of data collection points, accessibility and interference with the normal functioning of bridge. Digital image correlation (DIC) involves applying camera detectable patterns on the surface to measure displacements. Light detection and ranging (lidar) uses light in the form of a pulsed laser to measure and quantify variable distances. Digital twins (DTs) are used to create a virtual representation or digital counterpart of an entity, which can be an object or a procedure. Computer vision (CV) is another low-cost, long-distance, contactless process. Fig 1 shows a framework for CV based BHM [3].

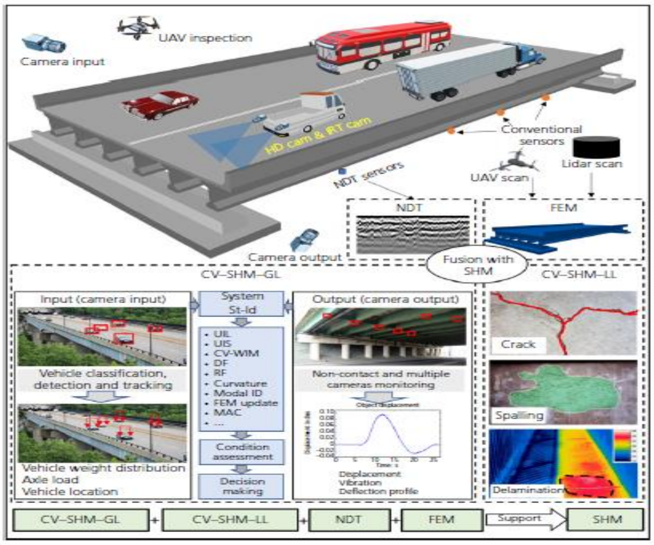

Figure 1: Framework for CV based BHM [3]

5 UAV and robotics sensing systems

Unmanned aerial vehicles (UAVs) and robotic vehicles have the ability to expedite the optical-based measurement process with increased accessibility, and reduced interference. UAVs can fly autonomously, remotely controlled by computers, humans or both. These small-sized aircraft have been used increasingly in a variety of civil applications. These include inspection of pipelines, bridges, roads, capturing images for 2D and 3D DIC analysis, combined area virtual models, 3D orthogonal mapping [2], etc. On the other hand ubiquitous bridge inspection robot systems (U-BIROS) have a robotic arm with a camera installed, used to scan and generate a crack map for bridges. Similarly with the help of a mounted camera and an integrated edge detector software, robotic crack inspection and mapping (ROCIM) was able to autonomously inspect bridge decks. A wall-climbing robot was employed successfully for monitoring and corrosion detection in reinforced concrete. Metric learning support vector and impact-echo techniques were used for the functioning of this robot.

6 Conclusions

None of these technologies offer a solution to solve all problems in bridge engineering. It is essential to define the problem and the desired end goals before considering which technology to use. Understanding the capabilities and limitations of the technologies, some of which are briefly described here, is also a critical step towards achieving the end goal. In addition, some of these technologies can be employed and combined in an integrated manner.

References

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