VIBRATION MONITORING OF CIVIL ENGINEERING STRUCTURES USING ARTIFICIAL NEURAL NETWORKS

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INTRODUCTION

In our day to day life we usually come across many structures constructed long years ago and that may have expired their life span. We are forced to use these old structures in the absence of new ones. The main hurdles in the replacement of such structures are shortage of funds, shortage of land, administrative delay, disputes etc. These structures include bridges, dams, aqueducts, viaducts etc. and are made either in steel or concrete. If it is a steel structure, it may be a road or rail bridges, an offshore platform, towers etc. constructed 100 to 200 years back. On the other hand the examples of old concrete structures are dams, bridges, aqueducts etc.

These structures still serve the needs of the public even after all the adverse condition of static and dynamic loading during the entire period since their construction. The nature of loading may be even higher and complex than that might have anticipated by the designers during construction. Damage is assumed to be equivalent to stiffness deterioration, i.e. to a reduction of the Young modulus in one or more regions inside the structure. The concrete is supposed to behave as an isotropic elastic material, whereas Poisson ratio is regarded as known a priori and unaltered by the deterioration process. Reduction of elastic modulus and tensile strength may be due to past extreme loadings such as earthquakes; and/or it can occur slowly in time in the presence of alcali–silica reaction (ASR), also denominated alcali-aggregate reaction (AAR). For example, studies show that along decades of service life, physico–chemical process determines a correlated deterioration of both strength and stiffness in dam concrete particularly in the presence of diffused cracking at the micro-scale, due to concrete ageing.

STRUCTURAL INTEGRITY MONITORING

The importance of structural integrity monitoring of civil engineering structures such as long span bridges, tall towers, dams and offshore platforms is increasing due to safety considerations. Offshore platforms are susceptible to failures due to corrosion, fatigue or short term damages caused by accidental collision of supply vessels, falling objects and severe cyclones. Long span bridges may be subjected to increased load and heavy traffic. Dams may get its stiffness deteriorated due to extreme earthquake loading or due to alkali-silica or alkali-aggregate reaction. It is not possible to strengthen all the existing structures rapidly due to economic reasons, especially in developing nations like India. Structural integrity monitoring can be conveniently used for continuing use of these structures which may be judged to be under strength based on theoretical calculations. This enables the detection of

serious damages much before the failure occurs. Vibration monitoring which monitors the vibration parameters of the structure is reported to be one of the best methods for assessing the integrity of these structures.

Recently, Artificial Neural Networks (ANN), which are artificial intelligence, based on information processing systems working on principle analogous to the working of human brain, were found to be useful for the detection and diagnosis of structural damages. ANN provides a fast and efficient method for automatically interpreting vibration data thereby reducing human assistance to a minimum. Vibration parameters usually used for monitoring are natural frequencies, mode shapes and response signatures. For determination of natural frequencies and mode shapes, the structure has to be vibrated at various frequencies and the response has to be recorded. This cannot be easily adopted for heavy structures like long span bridges, dams and offshore platforms. Hence alternate methods like impulse and relaxation, which can be easily applied, are used. The application of impulse causes the structure to undergo damped free vibrations, which can be used to determine the dynamic parameters necessary for assessing the integrity of the structures.

Vibration monitoring is based on the fact that any structure has certain dynamic parameters such as natural frequencies of vibration and corresponding mode shapes. These inherent characteristics of the structure do not change unless there is a change in stiffness or mass distribution. The responses at several points of the structure due to the impact load can be measured using sensitive accelerometers and recorded. The frequency plot of the response can be obtained from the time series of displacement by performing a discrete fourier transform. The peaks in this plot represent the different natural frequencies of the structure. The displacement vectors corresponding to these peaks (for all nodes) for the first and second modes are normalized to get the corresponding response signatures. These response signatures are similar to mode shapes but do not contain any negative values. The changes in these impulse response signatures are used for diagnosing the damages.

ARTIFICIAL NEURAL NETWORKS

Man has always wondered about the immense capabilities of human brain. Development of a system which is capable of performing like human brain has been the main objectives of scientists in the field of artificial intelligence research. Recently, there has been a lot of advancement both in the hardware and software of computers resulting in considerable reduction in the computation time. But the time involved for processing the information the human brain handles is very high making the system useless for such applications. This prompted the researchers to try parallel architecture on which the ANN is based. This approach captures the guiding principles underlying brain's working and applies it to computer systems. The ANN's are parallel systems consisting of interconnected simple processing

units called artificial neurons. These systems have robustness, fault tolerance and are capable of leaning from “experience”. ANN’s are capable of performing tasks such as classification, pattern matching, optimization and functional approximation. The artificial neuron was designed to mimic the basic characteristics of the biological neuron. A feed forward ANN consists of several layers of artificial neurons. The first layer is the input layer and last layer is the output layer. The layers in between the input and output layers are hidden layers. The different layers are interconnected by weighted pathways. The weights are applied to the values in the input layer to get the input to the hidden layer neurons. An ANN should be trained so that the application of a set of inputs produces the desired set of outputs. Training means adjusting the connection weights such that the above condition is satisfied. Adaptive Resonance Theory (ART-2) and Radial Basis Function Network (RBFNN) can be effectively used for the monitoring of structures.

CONCLUSION

Online structural integrity monitoring of our old civil engineering structures using the Artificial Neural Networks is an innovative idea. The ANNs are once trained using the theoretical or experimental data of the structure or its model for all the possible damage cases, we will get online data showing the nature of the damages occurred. This will indeed help us to avoid the huge losses that might have been occurring due to the catastrophic failure of such structures.