The main objective of this research is to explore, investigate and develop the new data analysis techniques along with novel sensing technologies for structural health monitoring applications. The study has three main parts. First, a systematic comparative evaluation of some of the most common and promising methods is carried out along with a combined method proposed in this study for mitigating drawbacks of some of the techniques. Secondly, non-parametric methods are evaluated on a real life movable bridge. Finally, a hybrid approach for non-parametric and parametric method is proposed and demonstrated for more in depth understanding of the structural performance.

In view of that, it is shown in the literature that four efficient non-parametric algorithms including, Cross Correlation Analysis (CCA), Robust Regression Analysis (RRA), Moving Cross Correlation Analysis (MCCA) and Moving Principal Component Analysis (MPCA) have shown promise with respect to the conducted numerical studies. As a result, these methods are selected for further systematic and comparative evaluation using experimental data. A comprehensive experimental test is designed utilizing Fiber Bragg Grating (FBG) sensors simulating some of the most critical and common damage scenarios on a unique experimental structure in the laboratory. Subsequently the SHM data, that is generated and collected under different damage scenarios, are employed for comparative study of the selected techniques based on critical criteria such as detectability, time to detection, effect of noise, computational time and size of the window. The observations indicate that while MPCA has the best detectability, it does not perform very reliable results in terms of time to detection. As a result, a machine-learning based algorithm is explored that not only reduces the associated delay with MPCA but further improves the detectability performance. Accordingly, the MPCA and MCCA are combined to introduce an improved algorithm named MPCA-CCA. The new algorithm is evaluated through both experimental and real-life studies. It is realized that while the methods identified above have failed to detect the simulated damage on a movable bridge, the MPCA-CCA algorithm successfully identified the induced damage.

An investigative study for automated data processing method is developed using non-parametric data analysis methods for real-time condition maintenance monitoring of critical mechanical components of a movable bridge. A maintenance condition index is defined for identifying and tracking the critical maintenance issues. The efficiency of the maintenance condition index is then investigated and demonstrated against some of the corresponding maintenance problems that have been visually and independently identified for the bridge.

Finally, a hybrid data interpretation framework is designed taking advantage of the benefits of both parametric and non-parametric approaches and mitigating their shortcomings. The proposed approach can then be employed not only to detect the damage but also to assess the identified abnormal behavior. This approach is also employed for optimized sensor number and locations on the structure.
Approved for distribution by Necati Catbas, Committee Chair, on March 11, 2014.

The public is welcome to attend.