Structural Health Diagnostics of Dynamic Vehicles Under Uncertainty

Israel Lopez[1]

[1] *Department of Mechanical and Aerospace Engineering*
University of California, Davis, One Shields Ave., Davis, CA 95616, USA

soylopez@ucdavis.edu

ABSTRACT

Uncertainty arises in feature extraction and classification problems when the input feature vector contains noise or imprecision. As the complexity and performance of structures are increased, the quantification of uncertainty becomes more complicated. In structural health monitoring, the sources of uncertainty extend from the structural complexity to the damage feature extraction and analysis. Assessment of impact damage in time-varying structures is an issue of significant importance due to its potential benefits in safety and performance. In addition, because of its significant effects on the measurable dynamics, system and environmental uncertainties erode the damage diagnostics and prognostics in many applications. I propose a robust damage assessment method that will increase the diagnosis reliability of damage in time-varying structures under uncertainties. The objectives of my dissertation research are as follows: (i) Develop a robust damage diagnosis approach with minimum number of measurement inputs; (ii) Uncertainty management and analysis to minimize false diagnosis; and (iii) Aapplication of proposed diagnosis approach to experiments with uncertainties. The broader impact of such research can be summarized as follows: (1) Improve the safety of transportation systems by developing techniques which can be used by a continuous monitoring system in order to prevent catastrophic structural failures; (2) Minimize operational costs by better understanding of structural health, e.g. potentially reduce excessive maintenance costs.

1. PROGRESS

To date, we have developed a damage detection and localization method based on a distance similarity matrix of dimensionally reduced data wherein redundancy therein is removed [Lopez *et al*]. The matrix similarity approach is generic in nature and has the capability of multiscale representation of datasets. To extract damage sensitive features, dimensional reduction techniques are applied and compared. Individual feature extraction methods inevitably have its own strengths and weaknesses. In this work, a mean and product rule are applied to construct an ensemble of dimensional reduction methods to improve the detection and localization of structural damage. The results supports why ensembles can often perform better than any single feature extraction method. Two different experimental datasets have been used to validate the latter damage diagnostic method. For the first case study, aeroacoustic datasets are collected from controlled scaled experimental tests of controlled known damaged subscale wing structure. For the second case study, a vibration experiment study is used for abrupt change detection, localization and tracking. The results of the two case studies demonstrate that the proposed method is very effective in detecting abrupt changes and the ensemble method developed here can be used for deterioration tracking. Figures below show experimental setups and sample results.

2. RESEARCH PLAN

Damage diagnosis and prognosis follows the simplified process of feature extraction, feature selection, classification and decision-making, i.e. diagnostic and prognostic evaluations. To date, current research has properly addressed the feature extraction and classification of the latter process. Significant work remain to achieve the overall objective of damage assessment for dynamic vehicles under uncertainty. To successfully achieve the overall research objective and have significant contribution to the area of diagnostics research, we plan to address the following research objectives:

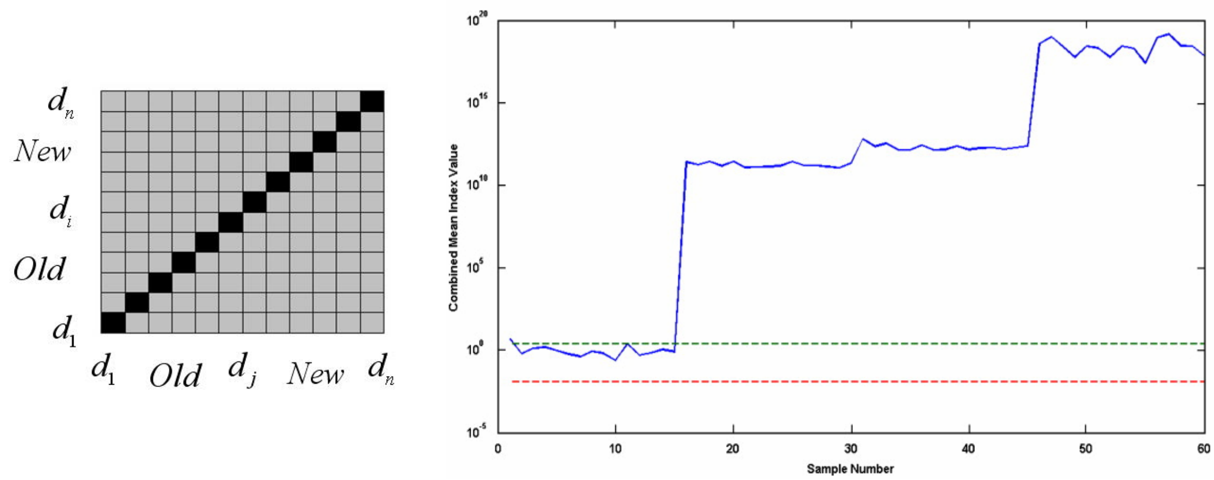
1. *Uncertainty in diagnostics*: Under imprecise or partially known information, effective data fusion techniques need be applied to maximize the diagnostic effectiveness. Varying types of uncertainty, i.e. aleatory and epistemic, to be incorporated to evaluate robustness of damage diagnostics. Current work is being conducted to evaluate the use of Dempster-Shafer Evidence theory for data fusion.
2. *Decision-Making*: Evidential reasoning to be applied given data fusion results. Decision theory must be integrated to properly handle diagnostic cases with multiple sources of uncertainty.
3. *Experimentation*: Experiments need to be conducted with structures to validate damage diagnostic approach under multiple levels of uncertainty, such as temperature variations and sensor noise.
4. *Comparative study*: Comparison to other diagnostic approaches must be performed to evaluate effectiveness of proposed approach.
5. *Integration of vehicular dynamics and damage diagnostics*: Simulation to be carried out to simulate damage in a dynamic environment.

REFERENCES

I. Lopez, N. Sarigul-Klijn (2009). Distance similarity matrix using ensemble of dimensional data reduction techniques: Vibration and aerocoustic case studies, *Mechanical Systems and Signal Processing*, vol. 23, Issue 7, October 2009, pp. 2287-2300.

(a) (b)

Figure 1. (a) Scaled Anechoic Wind Tunnel (SAWT) for noise experiments, (b) Cantilever beam experimental setup.



(a) (b)

Figure 2. (a) Distance similarity matrix of dimensionally reduced data. (b) Sample ensemble dimensional reduction method applied to vibration experiment. No-Mass: 1-15, Mass-1: 16-30, Mass-2: 31-45, Mass-3: 46-60. Damage index for damage detection and tracking.