STRUCTURAL DAMAGE DETECTION USING
SPEAKER RECOGNITION TECHNIQUES

Luciana Balsamo[a,1], Raimondo Betti[b,1], Homayoon Beigi[c,2]

[1]Department of Civil Engineering and Engineering Mechanics, Columbia University, New York,

NY – 10027, USA

[2]Recognition Technologies, Inc., 300 Hamilton Avenue, Suite 411, White Plains, NY 10601

[a]lb2591@columbia.edu, [b]betti@civil.columbia.edu, [c]beigi@recotechnologies.com

Over the past several years, structural vibration response analysis has become a dominant approach in structural health monitoring and damage detection, as evidenced by the vast amount of literature on the subject. Within the wide array of vibration based damage detection techniques, the application of the methods based on statistical pattern recognition schemes are increasingly gaining momentum in the civil engineering community. One of the primary advantages of the statistical pattern recognition framework lies in its ability to distinguish between different states of the structure by representing the structure through a probabilistic model instead of a physical model. This probabilistic representation thus circumvents the inherent uncertainties which are almost always present in a physical model owing to uncertain material parameters, approximations in constitutive relationships, as well as from assumptions in structural geometry (such as those related to connections). Additionally, a pattern recognition based damage detection methodology can also be trained to account for expected "non-damage induced" variations in structural response, such as those resulting from environmental effects. These potential advantages associated with the pattern recognition framework favors its application in structural damage detection purposes.

The fundamental task involved in any statistical pattern recognition based damage detection procedure is to define the probability density functions of damage sensitive features. The primary requirements of a good damage sensitive feature are its ability to detect the presence of damage, i.e. effectively distinguish between the damaged and undamaged states of the structure, followed by its ability to possibly locate and quantify the extent of damage. Additionally, for a robust damage sensitive feature, it should be possible to extract it from the structural response time histories even when the time histories are corrupted by measurement noise. For a given damage sensitive feature, a general pattern recognition framework constitutes training and testing phases. During the training phase, the damage sensitive feature vectors are extracted from the structural response time histories of the healthy system, and their probability densities are then modeled statistically to serve as the reference statistical model. This statistical model will also inherently account for the uncertainty in the feature vectors due noisy measurements, and also possibly take into account other "usual" variations from environmental effects. During the testing phase, the damage sensitive features extracted from the monitored structure under unknown conditions are fitted into the reference statistical model: if the fitting

score is higher than a predetermined threshold the structure is declared healthy, and otherwise damaged.

Since, the robustness and effectiveness of the method, as identified above, is greatly dependent on the features selected, the selection of "good" damage sensitive features forms a crucial part of the whole exercise. In fact, it would be best, if these parameters convey information solely on the structure, irrespective of environmental, loading or recording conditions. For this reason, in this study, we investigate the possible adaptations of the features commonly employed in the field of speaker recognition for structural damage detection purposes. Given a speech signal uttered by a certain individual, the task of speaker recognition is that of identifying the speaker by analyzing the recorded utterance. While the task of speaker recognition is performed within a general pattern recognition framework, its consistent and wide application in real-life situations during the last two decades has led to the development of a methodology with state-of-the-art performance.

In this study, we propose the use of cepstral coefficients, a feature widely used and accepted for speaker recognition purposes, in detecting and locating the presence of structural damage. The proposed damage detection method uses the cepstral coefficients, extracted from structural response time histories, with frequency warped in a way to efficiently summarize the main characteristics of the structural response. The statistical modeling of the cepstral coefficients and the ensuing testing phase are performed exploiting the likelihood ratio techniques, also typical of speaker recognition processes. The effectiveness of the proposed damage detection method in both identifying and locate structural damage is finally validated through numerical simulations representative of real-life situations.