A New Generalized Autoencoder for Structural Damage Assessment

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Introduction

- **Background:** Powerful data-driven approaches have been increasingly employed in Structural Health Monitoring (SHM) of civil structures in order to extract Damage Sensitive Features (DSFs) to be used in damage assessment strategies.
- **Purpose:** Using Cepstral Coefficients (CCs) as DSFs, we develop a New Generalized Auto-Encoder (NGAE), integrated with a statistical-pattern-recognition-based approach. This NGAE has the advantage of minimizing the variance of CCs linked to the excitation forces and measurement noise, while at the same time, emphasizing the structural component.

Power cepstral coefficient expression:

$$c_d[q] = \theta[q] + \gamma_d[q]$$

$$\begin{cases} \theta[q] = \dfrac{1}{q}\displaystyle\sum_{l=1}^{N_d} 2e^{-\xi_l \omega_l \Delta t q} \cos\left(\omega_{damp,l} \Delta t q\right) - 1 \\ \gamma_d[q] = -\dfrac{1}{q}\displaystyle\sum_{l=1}^{M} Z_l^{(d)q} \end{cases}$$

Methodology

- Extract cepstral coefficients as the input and output of the NGAE framework.
- Compute normalized root mean squared error (NRMSE) and standard deviation ratio (SDR) to assess the damage.
- Compute a series of damage indices for further damage detection and quantification.

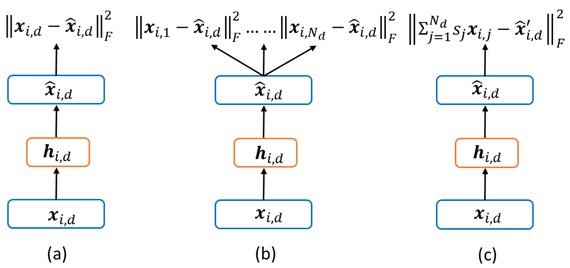

Figure 1. The traditional autoencoder (a), the GAE (b), and the proposed NGAE (c).

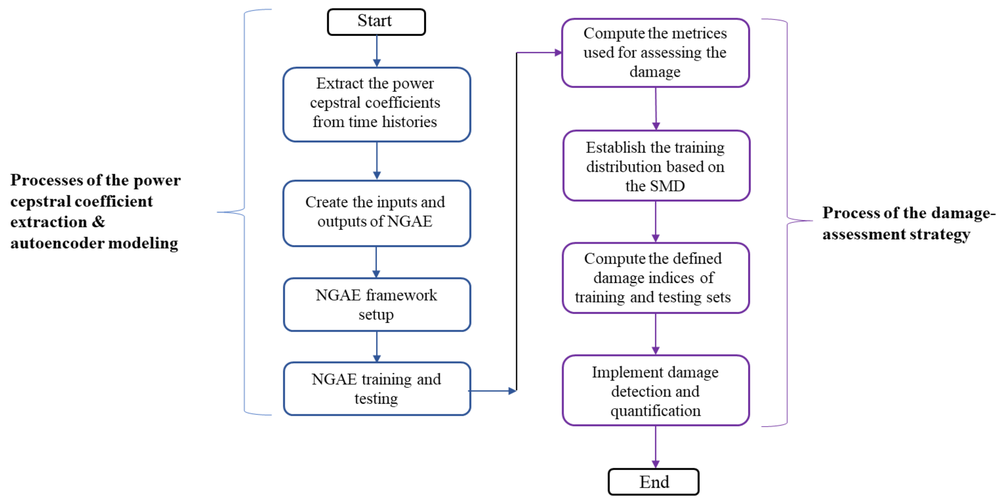

Figure 2. A flowchart of the proposed method for structural damage assessment

Results

Two case studies were conducted to validate the effectiveness of the proposed method for structural damage assessment, using:

- The cepstral coefficients extracted from the simulated time-histories of the structural acceleration from **an 8 DOF discrete structural model**.
- The cepstral coefficients obtained from the time-histories of acceleration response recorded by sensors installed on **the Z24 bridge (a benchmark)**.

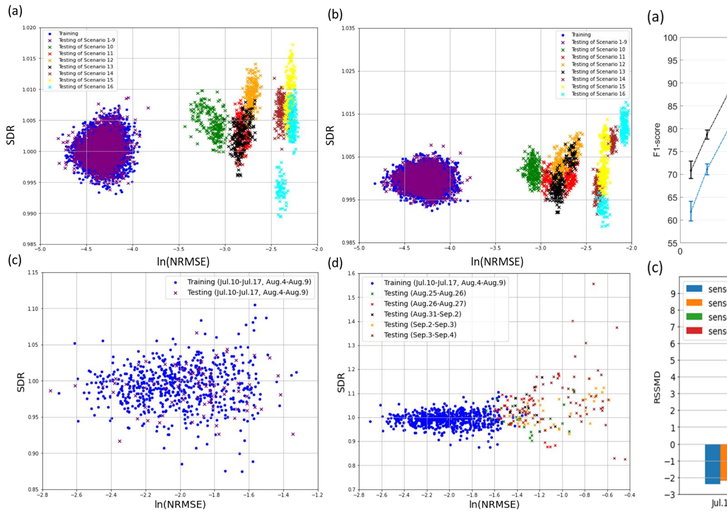

Figure 3. Distributions of the two evaluation metrices obtained from the 8DOF system (a)&(b), and the Z24 bridge (c)&(d).

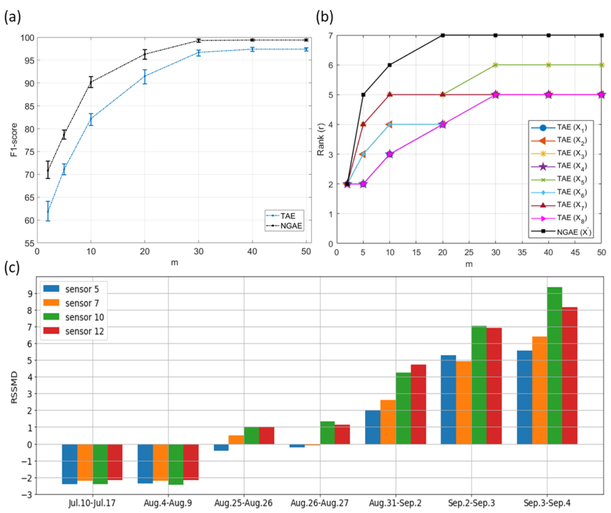

Figure 4. F1 score vs. the number of considered coefficients (a)&(b); Damage quantification for the Z24 bridge structure (c).

Conclusion

The proposed NGAE can better characterize the overall structural properties embedded in the cepstral coefficients by the newly defined input-output mapping, resulting in a much better performance in the structural damage assessment.

Acknowledgments

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