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고유진동수 변화를 활용한 구조물 결함 및 신호 패턴의 분류

Classification of Damage Signal Pattern through Modal Frequency Change

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1. Introduction

This study intends to compare the performance of PCA and Isomap in terms of classifying damage-sensitive features such as patterns of modal frequency variation. Here, damage in a structure is simulated by reducing stiffness of specific location of finite element of cantilevered beam model. Preliminary results using numerical simulation show that Isomap is an effective tool for classifying the pattern of modal frequency shift, which can be exploited to solve practical damage detection problems.

2. Isomap and Simulations

2.1 Isomap Algorithm

Isomap[1] is a nonlinear generalization of classical MDS(Multi-Dimensional Scaling). The main idea is to perform MDS, not in the input space, but in the geodesic space of the nonlinear data sets. The geodesic distances represent the shortest paths along the curved surface of the data sets measured as if the surface were flat. This can be approximated by a sequence of short steps between neighboring sample points. Isomap then applies MDS to the geodesic rather than straight line distances to find a low-dimensional mapping that preserves these pairwise distances[2]. Isomap's global coordinates provide a simple way to analyze and manipulate high-dimensional observations in terms of their intrinsic nonlinear degrees of freedom[1].

2.1 Damage Detection Simulations

A numerical simulation is conducted to validate the damage detection performance using data classification techniques such as PCA(Principal Component Analysis) and Isomap. For simplicity, it is assumed that damage occurs in the form of stiffness reduction at a specific location of finite elements. The schematic drawing of the cantilevered beam is shown in Fig 1.

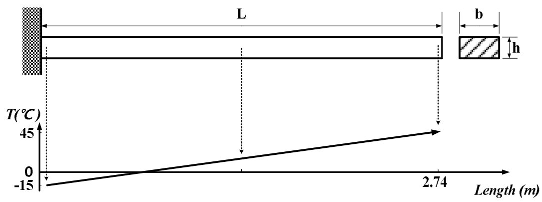

Fig. 1 Schematics of a cantilevered beam applied to temperature gradient in each element.

The variation of the first ten modal frequencies due to local reduction of stiffness value in specific damage locations is visually classified using PCA and Isomap, respectively. This attempt becomes significant as the quality of damage detection result using modal frequency change rapidly deteriorates due to unharmful environmental effects such as temperature gradient. The damage classification

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results using PCA and Isomap are illustrated in Fig. 2 and Fig. 3.

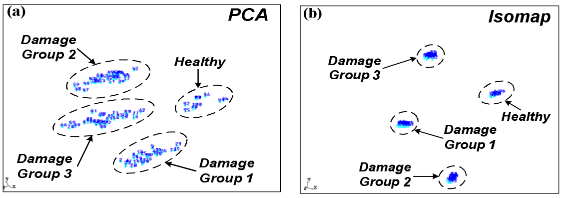

Fig. 2 Classification results for the single damage group: (a) PCA result and (b) Isomap simulation.

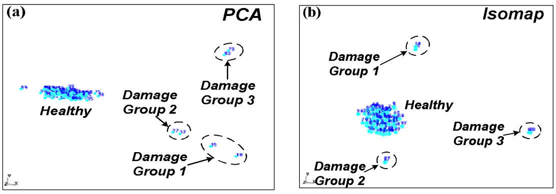

Fig. 3 Classification results for the dual damages group: (a) PCA result and (b) Isomap simulation.

Note that all the classification plots are projected on three-dimensional space. Although both PCA and Isomap successfully classified single-damage scenarios, it is obvious that Isomap outperformed the PCA in terms of level of separation and grouping toward homogenous data. And, the classification results of dual damages in the cantilevered beam are presented in Fig 3. Again, Isomap-based classification provides better separation result when it is compared to that of PCA. Speaking of PCA-based results, damage group 1 and 2 may not be distinctly separable without knowing the true group of damage locations.

3. Conclusions

PCA and Isomap-based data classification technique is applied to a structural damage localization problem using numerical simulations. The preliminary results show that Isomap-based classification can be a powerful candidate for replacing PCA-based damage detection under the influence of environmental effects such as temperature gradient in a structure.

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References

1. J.B. Tenenbaum, V. de Silva, J.C. Langford, A global geometric framework for nonlinear dimensionality reduction, Science Vol. 290, pp. 2319-2323, 2000.
2. Ali Ghodsi, Dimensionality reduction, a short tutorial, University of Waterloo, 2006.