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Convolutional neural network-based peak picking method for modal analysis

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ABSTRACT

This paper presents a peak picking approach to automatically extract peaks in the frequency domain representation of structural responses. As the peaks of the frequency domain data can be possibly natural frequencies of a structure, the peak picking is considered as a simple and basic method for structural system identification. In general, the peaks are manually identified; however, this process based on human intervention is inappropriate and difficult to be implemented in long-term monitoring and embedded systems such as wireless sensor networks. Recent advances in convolutional neural networks have proven performance in classifying natural images utilizing their distinctive features of geometric patterns and full color information. This study uses the convolutional neural network to automatically obtain the peaks of the frequency domain data.

1. INTRODUCTION

Peak picking is one of the most traditional and fundamental approaches to select salient peaks, widely used in modal analysis from frequency domain data, including frequency response function, Fourier transform, and power spectrum. An important challenge here is to automatically extract the peaks from data with the noisy peaks. Automated peak picking is particularly required in the cases of long-term monitoring and embedded systems in the civil engineering field, while methods for automation have received little attention. Recent advances in convolutional neural networks have proven performance in identifying natural images based on their characteristic features of geometric patterns and full color information, such as AlexNet (Krizhevsky 2012), VGGNet (Simonyan 2014), ZFNet (Zeiler 2014), GoogLeNet (Szegedy 2015), and ResNet (He 2016). As the peaks in the frequency domain data have distinctive geometric patterns, the convolutional neural network has a strong potential to be used for automated peak detection.

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This paper presents an automated peak picking approach based on the convolutional neural network. A deep learning architecture is introduced to automatically and correctly determine peaks from the frequency domain representation of structural responses. The proposed peak detector is focused on the successful identification of peaks from the noisy data, which is difficult to accurately detect clear peaks by the previous methods. In the training stage, the frequency response function of 2 degrees-of-freedom systems is numerically generated and then utilized to train the peak detector. Subsequently, the peak identification performance is experimentally validated from acceleration responses measured from a simply-supported beam.

2. PEAK DETECTOR

The peak detector is designed based on the convolutional neural network, which has been recognized as a powerful tool for natural image classification. In this study, AlexNet (Krizhevsky 2012), which is one of the widely used convolutional neural network, is used to develop the peak detector. For peak picking, frequency domain data is calculated from the measured structural responses such as acceleration and converted to an image file format. The images are used as the input to the peak detector, going through the convolutional and fully-connected layers as well as the output layer that finally determines the peak locations.

3. EXPERIMENTAL VALIDATION

A simply-supported beam (Fig. 1) is utilized to evaluate the peak identification performance of the proposed peak detector. The experimental beam is made of steel, which has the uniform cross section of 0.08 m by 0.01 m and is 2 m in length. Three accelerometers (PCB 353B33) are installed at an interval of 0.5 m to measure acceleration responses with a sampling rate of 200 Hz. Note that an impact hammer is used to excite the beam.

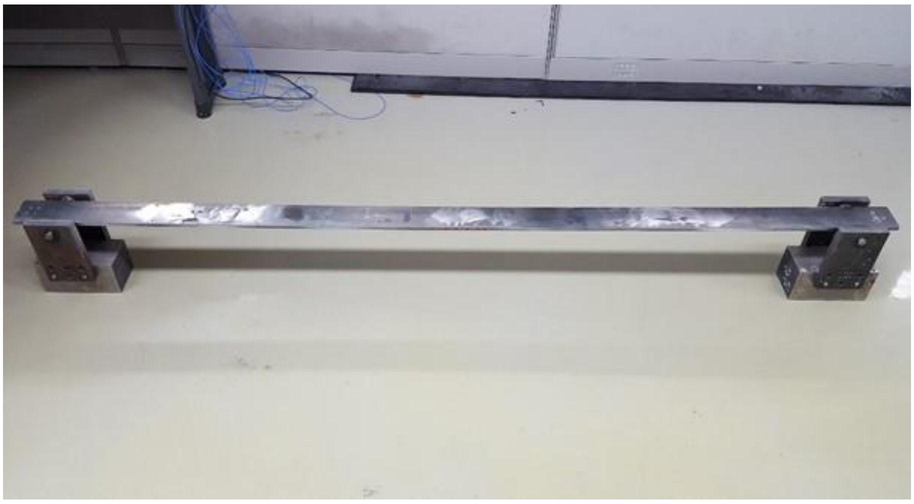

Fig. 1 Simply-supported beam in experimental validation

The structural responses measured by three accelerometers are utilized to calculate the frequency domain representation from Frequency Domain Decomposition (Brincker 2001); subsequently, the result is converted to the JPEG image format to be used as the input of the proposed peak detector. The peak detector is applied to the image to extract peaks of the frequency domain data. Fig. 2 shows typical identification results of the peak detector and the threshold-based method. The natural frequencies of the experimental beam are successfully identified by the peak detector, whereas the false positives are occurred in the case of the threshold-based method.

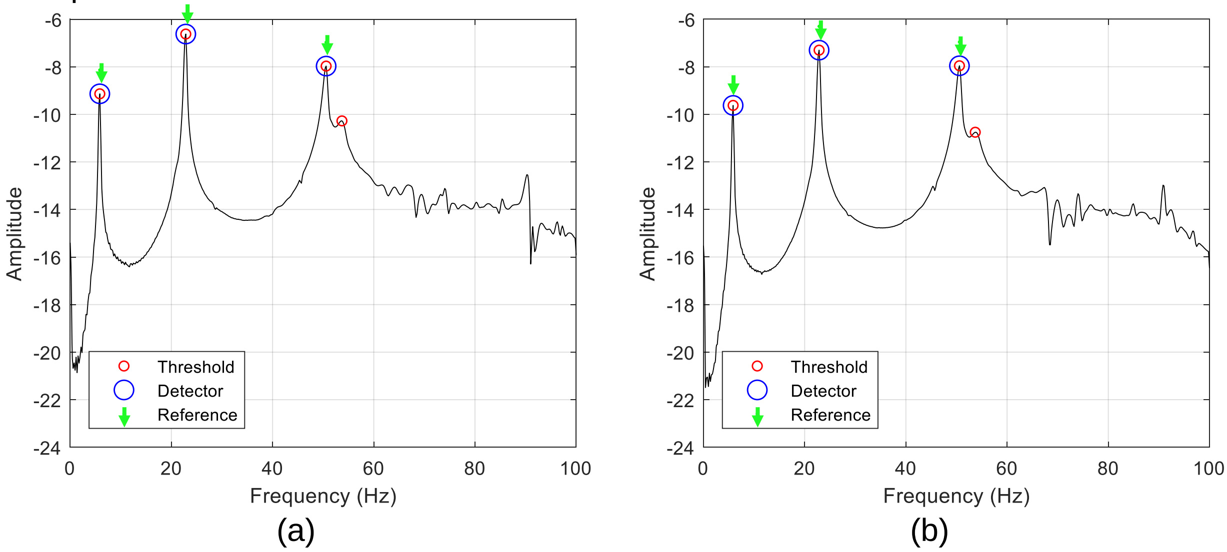

Fig. 2 Peak identification performance comparison of peak detector and threshold-based approaches

4. CONCLUSION

This paper presented a peak picking approach to automatically extract peaks in the frequency domain representation of structural responses. The deep learning architecture of the proposed peak detector was designed based on AlexNet, which was further trained using numerically generated data. In the experimental validation, all the natural frequencies of the experimental beam were correctly extracted by the peak detector, whereas the false positives were occurred in the case of the threshold-based method.

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