Structural Damage Detection Using Machine Learning Techniques

Project Background

In order to ensure the integrity of the structure, timely and accurate detection and identification of structural damage during and after an extreme event or over the lifetime of a structure is a very important for safety and economic reasons. Structural damage detection and identification techniques can be generally classified into two main categories based on whether they use dynamic or static test data.

Structural damage detection and identification can be conducted using non-destructive vibrational experiments that identifying changes in structural dynamic characteristics, such as frequency response functions (FRFs) and modal properties. At present, the common measure is to install a sufficient number and type of multiple sensors inside the structure during construction, and continuously obtain the dynamic response data of the structure during operation. One method of feature extraction is to calculate the dynamic features of the structure and then to detect damage by monitoring the changes of these features. Structural detection methods focus on whether a change has occurred or not and structural identification methods also focus on the type of damage and extent of damage based on the changes in response detected.

Structural damage detection and identification can also be performed using deep learning methods and collected image sets, which can be static or collected by a drone real time to optimize structural damage detection and recognition are presented. The first example is the design of a CNN topology to classify simulated damage and normal conditions and to locate damage when it is present. The performance of the proposed technique is evaluated by finite element simulation of undamaged and damaged structural connections. Samples are trained using images of strain distributions as a result of different loads with several different crack conditions. In a second example, the post-disaster detection of reinforced concrete bridges was carried out based on the three-level image method that used images of the structural members, and a new training strategy was adopted for deep learning. A CNN for image classification, a CNN for object detection and a CNN for semantic segmentation were proposed. These were used to perform system-level fault classification, component-level bridge pillar detection and local damage level damage location, respectively.

Description of Methods and Tools

This research project will use convolutional neural networks, which will focus on leveraging the capabilities of several models and toolkits, including AlexNET, TensorFlow and Pytorch. In deep learning, a convolutional neural network is a class of deep neural network, most commonly applied to analyze visual imagery. AlexNet is the name of a convolutional neural network (CNN). AlexNet contained eight layers; the first five were convolutional layers, some of them by max-pooling layers, and the last three were fully connected layers. It sued the non-saturating ReLU activation function, which showed improved training performance cover tanh and sigmold. TensorFlow has a reputation for being a production-grade deep learning library. It has a large and active user base and a proliferation of official and third-party tools and platforms for training, deploying, and serving models. TensorFlow has a large and well-established user base and a plethora of tools to help productionize machine learning. Many machine learning algorithms and datasets are built into TensorFlow and are ready to use. PyTorch was created to offer production optimizations similar to TensorFlow while making models easier to write. The difference between the PyTorch and TensorFlow is the framework used to define the computational graphs. While TensorFlow creates a static graph, PyTorch believes in a dynamic graph.

Project objective

Improve the accuracy and broaden the applicability of a CNN-based structural damage identification method

Project tasks

1. Establish baseline performance metrics for an existing CNN-based program using a static image set of classified bolt, corrosion and crack damages.
2. Investigate the application of machine learning methods to improve the performance of the CNN-based program on identifying damage.
3. Investigate the performance of the modified CNN-program on new image data sets that are collected real-time using a drone.

References

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