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Artificial immune pattern recognition for structure damage classification

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ABSTRACT

Damage detection in structures is one of the research topics that have received growing interest in research communities. While a number of damage detection and localization methods have been proposed, very few attempts have been made to explore the structure damage classification problem. This paper presents an Artificial Immune Pattern Recognition (AIPR) approach for the damage classification in structures. An AIPR-based structure damage classifier has been developed, which incorporates several novel characteristics of the natural immune system. The structure damage pattern recognition is achieved through mimicking immune recognition mechanisms that possess features such as adaptation, evolution, and immune learning. The damage patterns are represented by feature vectors that are extracted from the structure's dynamic response measurements. The training process is designed based on the clonal selection principle in the immune system. The selective and adaptive features of the clonal selection algorithm allow the classifier to evolve its pattern recognition antibodies towards the goal of matching the training data. In addition, the immune learning algorithm can learn and remember different data patterns by generating a set of memory cells that contains representative feature vectors for each class (pattern). The performance of the presented structure damage classifier has been validated using a benchmark structure proposed by the IASC–ASCE (International Association for Structural Control–American Society of Civil Engineers) Structural Health Monitoring (SHM) Task Group and a three-story frame provided by Los Alamos National Laboratory. The validation results show that the AIPR-based pattern recognition is suitable for structure damage classification. The presented research establishes a fundamental basis for the application of the AIPR concepts in the structure damage classification.

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1. Introduction

The civil structures, such as bridges and buildings, play an important role in people's daily life. Maintaining safe and reliable civil structures is important to the well being of all of us [1]. The sudden failure and collapse of the I-35W Interstate system bridge in Minneapolis has raised policy concerns in US Congress regarding the condition of the nation's transportation infrastructure [2]. Based on the CRS (Congressional Research Service) Report for Congress [2], in 2006, about 26% of bridges were classified as either structurally deficient, functionally obsolete, or both. About 12% of bridges in that year, approximately 74,000, were classified as structurally deficient. To ensure civil structures meeting life-safety standards over their operational lives, early identification and assessment of structural damage are necessary [3].

Structural Health Monitoring (SHM) holds promise for monitoring structure performance with an excellent cost/benefit ratio. The SHM process involves the observation of a structure's dynamic response measurements from a group of sensors, the extraction of damage-sensitive features from these measurements, and analysis of these features to determine the current state of the structure [4]. Damage identification is one of the research topics that have been extensively investigated. The vibration-based damage assessment of the bridge structures and buildings has been studied since the early 1980s. Doebling et al. [5] summarized the researches on the vibration-based damage identification and health monitoring. Sohn et al. [6] reviewed the technical papers in structural health monitoring, published between 1996 and 2001. Most conventional structural health monitoring methods are modal analysis based. Modal parameters, such as natural frequencies, damping ratios, and mode shape curvature, have been the primary features used to identify damage in structures. Recently, a number of new approaches, such as statistical pattern recognition [7,8] and neural network [9–11], have been proposed for the damage diagnosis. For example, Sohn and Farrar [7] proposed a statistical pattern

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