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A hybrid immune model for unsupervised structural damage pattern recognition

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ABSTRACT

This paper presents an unsupervised structural damage pattern recognition approach based on the fuzzy clustering and the artificial immune pattern recognition (AIPR). The fuzzy clustering technique is used to initialize the pattern representative (memory cell) for each data pattern and cluster training data into a specified number of patterns. To improve the quality of memory cells, the artificial immune pattern recognition method based on immune learning mechanisms is employed to evolve memory cells. The presented hybrid immune model (combined with fuzzy clustering and the artificial immune pattern recognition) has been tested using a benchmark structure proposed by the IASC–ASCE (International Association for Structural Control–American Society of Civil Engineers) Structural Health Monitoring Task Group. The test results show the feasibility of using the hybrid AIPR (HAIPR) method for the unsupervised structural damage pattern recognition.

1. Introduction

The structural health monitoring (SHM) is a process of observing a structure's dynamic response measurements from a group of sensors, extracting damage-sensitive features from these measurements, and analyzing these features to determine the current state of the structure (Kolakowski, 2007). Due to high instrument and installation costs of wired SHM systems (Sazonov, Janoyan, & Jha, 2004), the wireless sensor-network-based SHM is emerging as a feasible approach since it allows dense sensing through many inexpensive sensor nodes and is easy for deployment and maintenance (Xu et al., 2004). While sensor network approach presents a number of advantages, SHM sensor network systems currently face a number of challenges (Farrar & Worden, 2007). Major challenges in SHM sensor networks include: (1) how can we provide sustainable monitoring and control in an autonomous manner? For complex structures, a monitoring sensor network may consist of hundreds or thousands of sensor nodes and may be deployed in environments that are difficult to access (embedded in physical structures). Given such a deployment size and environment, sensor networks are required to monitor structural changes and perform damage diagnosis autonomously; (2) can we develop adaptable approaches to SHM that are able to dynamically adapt to changing monitoring conditions? Due to resource constraints in sensor networks, a SHM sensor network that is able to manage its resources effectively under different circumstances is critical; (3) how can we detect and identify structural damages in an active way? The passive monitoring of structures by continuously gathering real-time structural data causes data transmission problem due to limited bandwidth and power available in wireless sensor networks; (4) how can we establish an unsupervised damage diagnosis methodology?

The natural immune system is an effective defense mechanism for a given host against infections (De Castro, 2006). From a pattern recognition perspective, the most appealing characteristic of the immune system is its immune cells (B-cells and T-cells) carrying surface receptors that are capable of recognizing and binding antigens. The antibodies are soluble forms of the B-cell receptors that are released from the B-cell surface to cope with the invading nonself antigen. Antibodies bind to antigens leading to their eventual elimination by other immune cells (De Castro & Timmis, 2002). When a B-cell encounters a nonself antigen that has sufficient affinity with its receptors, coupled with a stimulation signal from T-cells, the B-cell is activated. It, therefore, undergoes a clonal selection that increases the number of the activated B-cell and the diversity of the antibody set. The generated B-cells with high antigenic affinities are selected to become memory cells that remain in the immune system for months or years. The first exposure of a B-cell to a specific type of antigen triggers the *primary response* in which the pattern is recognized and the memory is developed (Castiglione, Motta, & Nicosia, 2001). The memory cell for a specific antigen that had stimulated in the primary response will respond to previously recognized antigen in a much shorter time

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