Optimal control of mobile monitoring agents in immune-inspired wireless monitoring networks

Wenjia Liu\textsuperscript{a}, Bo Chen\textsuperscript{b,}\textsuperscript{*}

\textsuperscript{a} Department of Electrical and Computer Engineering, Michigan Technological University, Houghton, MI 49931, USA
\textsuperscript{b} Department of Mechanical Engineering – Engineering Mechanics, Department of Electrical and Computer Engineering, Michigan Technological University, Houghton, MI 49931, USA

\textbf{ARTICLE INFO}

Article history:
Received 13 June 2010
Received in revised form
5 November 2010
Accepted 11 December 2010
Available online 22 December 2010

Keywords:
Multi-objective genetic algorithm
Mobile monitoring agent
Artificial immune system

\textbf{ABSTRACT}

This paper studies optimal control of mobile monitoring agents in artificial-immune-system-based (AIS-based) monitoring networks. In AIS-based structural health monitoring (SHM) networks, the active structural health monitoring is performed by a group of mobile monitoring agents equipped with damage pattern recognition algorithms. The mobile monitoring agents mimic immune cells in the natural immune system and patrol a structure to detect damage patterns using their receptors (feature vectors), damage pattern recognition algorithms, and the dynamic response data of the structure. The optimal control of mobile monitoring agents includes agent generation and distribution. The generation of mobile monitoring agents is optimized to minimize the response time for the mobile monitoring agents to diagnose structural damage in a sub-network and maximize the average affinity of monitoring agents’ receptors to the damaged sensor data feature vector. The objective functions for distributing mobile monitoring agents are to increase the detection probability and extend network life by balancing energy consumption of sensor nodes in the network. The presented optimization algorithms are developed using multi-objective genetic algorithms. The impact of the algorithm parameters on the performance of the algorithm is also investigated.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

Monitoring networks have gained wide applications in protecting engineered systems and natural environment from unexpected failures. Due to ever-increasing complexity of systems and unpredictable working conditions, the monitoring systems will need to perform tasks with high quality, adaptability, and autonomy. To meet this requirement, a monitoring paradigm based on artificial immune system (AIS) concept has been proposed (Chen, 2010). In this paradigm, mobile monitoring agents mimic immune cells (such as B cells) in the natural immune system for the anomaly detection and pattern recognition in distributed monitoring systems. Mobile monitoring agents interact locally with monitoring environment, and respond to emerging problems through simulated immune responses. The monitoring tasks are managed automatically by a mobile agent-based network middleware. This bio-inspired monitoring paradigm has been applied to structural health monitoring networks.

The main features of the immune system include adaptive immune response to the invading pathogens and pattern recognition capabilities. When a pathogen invades a host, the host mounts a response that occurs at several levels of biological organization, including genetic, molecular, cellular, tissue, and system level. A number of host cells are called into action, such as B cells, T cells, and antigen presenting cells (Neal and Trapnell, 2007). The adaptive immune response achieves two goals: the number of B cells that are capable of responding to a particular antigen are multiplied through clonal expansion and these new generated immune cells are able to produce a large number of antibodies for binding to the intruders (Delves et al., 2006).

In AIS-based monitoring networks, a mobile monitoring agent is selected for cloning when it detects damage in a sensor unit. Multiple copies of this type of monitoring agents will be created. As a result, the type and amount of mobile monitoring agents are adapted to damage patterns detected in a structure. This paper presents multi-objective optimization algorithms for the optimal control of mobile monitoring agents in artificial-immune-system-based monitoring networks. To minimize the response time for the generated monitoring agents to diagnose structural damage and maximize the average affinity of monitoring agents’ receptors to the damaged sensor data feature vector, a multi-objective genetic algorithm is developed to find appropriate number of agent clones and the mutation value for the cloned monitoring agents. The newly generated monitoring agents are sent to sensor nodes close to the location where the damage is detected for further damage diagnosis. The distribution of mobile monitoring agents takes sensor data feature vector and the remaining