Chapter 3.15
Self-Organising Impact Sensing Networks in Robust Aerospace Vehicles

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ABSTRACT

An approach to the structural health management (SHM) of future aerospace vehicles is presented. Such systems will need to operate robustly and intelligently in very adverse environments, and be capable of self-monitoring (and ultimately, self-repair). Networks of embedded sensors, active elements, and intelligence have been selected to form a prototypical "smart skin" for the aerospace structure, and a methodology based on multi-agent networks developed for the system to implement aspects of SHM by processes of self-organisation. Problems are broken down with the aid of a "response matrix" into one of three different scenarios: critical, sub-critical, and minor damage. From these scenarios, three components are selected, these being: (a) the formation of "impact boundaries" around damage sites, (b) self-assembling "impact networks", and (c) shape replication. A genetic algorithm exploiting phase transitions in systems dynamics has been developed to evolve localised algorithms for impact boundary formation, addressing component (a). An ant colony optimisation (ACO) algorithm, extended by way of an adaptive dead reckoning scheme (ADRS) and which incorporates a "pause" heuristic, has been developed to address (b). Both impact boundary formation and ACO-ADRS algorithms have been successfully implemented on a "concept demonstrator", while shape replication algorithms addressing component (c) have been successfully simulated.

INTRODUCTION

Structural health management (SHM) is expected to play a critical role in the development and exploitation of future aerospace systems, operating in harsh working environments and responding to various forms of damage and possible manufacturing and/or assembly process variations. SHM is a new approach to monitoring and maintaining the integrity and performance of structures as they age and/or sustain damage. It differs from the traditional approaches of periodic inspection and out-of-service maintenance by aiming for continuous monitoring, diagnosis, and prognosis of the structure while it is in service, damage remediation and, ultimately, self-repair. This requires the use of networked sensors and active elements embedded in the structure, and an intelligent system capable of processing and reducing the vast quantities of data that will be generated, to provide information about the present and future states of the structure, and to make remediation and repair decisions.

This chapter outlines an approach being taken to the development of next-generation SHM systems, and the development of a flexible hardware test-bed for evaluating and demonstrating the principles of the approach. This introductory section will outline the general requirements of an SHM system, provide an overview and relevant details of the hardware test-bed, and introduce our approach to the systems-level issues that must be solved.

Structural health management systems will eventually be implemented in a wide range of structures, such as transport vehicles and systems, buildings and infrastructure, and networks. Much of the current research effort is aimed at the highvalue, safety-critical area of aerospace vehicles. CSIRO is working with NASA (Abbott, Doyle, Dunlop, Farmer, Hedley, Herrmann et al., 2002; Abbott, Ables, Batten, Carpenter, Collings, Doyle et al., & Winter, 2003; Batten, Dunlop, Edwards, Farmer, Gaffney, Hedley et al., 2004; Hedley, Hoschke, Johnson, Lewis, Murdoch et al., & Farmer, 2004; Price, Scott, Edwards, Batten, Farmer, Hedley et al., 2003; Prokopenko, Wang, Price, Valencia, Foreman, Farmer, 2005a) and other key industry players to develop and test concepts and technologies for next-generation SHM systems in aerospace vehicles. While many

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