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Determining control strategies for damage tolerance of an active tensegrity structure

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ABSTRACT

Tensegrity structures are spatial, reticulate and lightweight systems composed of struts and cables. Stability is provided by a self-stress state between tensioned and compressed elements. Tensegrities have received interest among scientists and engineers in fields such as architecture, civil and aerospace engineering. Flexibility and ease of tuning make these systems attractive for controllable and adaptive structures. However, tensegrities are often prone to difficulties associated with meeting serviceability criteria and with providing adequate damage tolerance when used as civil engineering structures. This paper extends research on active control of tensegrity structures to study self-repair of a tensegrity pedestrian bridge that is damaged. Self-repair is intended to meet safety and serviceability requirements in case of cable damage in the pedestrian bridge. Intelligent control methodologies that implement stochastic search with active member grouping are proposed. Case studies for several damage scenarios are presented to show the effectiveness of the methodology. Results from simulated damage scenarios show that self-repair can be successfully performed with a minimum number of active members leading to a reduction in control complexity.

1. Introduction

Recent advances in theory and practice of active structural control technology have modified the general perception of structural behavior. Through addition of sensors, actuators and computing methods, active structures can become capable of interacting with complex environments [1]. The aim of such structures is to enhance structural performance by sensing changes in behavior and in loading, adapting the structure to meet goals, and retrieving past events to improve future performance [2].

In building environments, structural control has been proposed for enhancing the safety of structures under extreme conditions since the last quarter of the 20th century. Control of civil engineering structures was first introduced by Yao [3] as a means of protecting tall buildings against high winds. A modern concept of an active structure was proposed by Soong and Manolis [4], who described an active structure as one consisting of two types of load-resisting members: static (passive) members and dynamic (active) members. Long-term reliability of control systems has been a matter of controversy in the case of actively controlled civil structures. Structural control has been employed for earthquake protection in the US and Japan, where earthquakes are a primary concern [5]. However, many engineers believe that active control is not the best way to protect civil engineering structures against phenomena that have long return periods because of questionable long-term reliability of active control systems [6]. Instead, actively controlled structures are more suited to satisfy serviceability criteria in changing environments [2].

Since tensegrity structures can be equipped with active control systems, they have the potential to be actively controlled for safety and serviceability purposes. Tensegrity structures are spatial reticulate systems that are composed of struts and cables. Stability is provided by the self-stress state between tensioned and compressed elements independently of all external actions. Tensegrities have applications in a range of fields such as sculpture, architecture, aerospace engineering, civil engineering, marine engineering and biology [7]. Most studies found in the literature investigated form-finding [8–12] and the design characteristics of tensegrity structures [13–16]. Statics and dynamics of simple tensegrity modules have also been investigated [17–19].

Research into active control of tensegrity structures was initiated in the mid-1990s. Tensegrity structures have several promising properties. A high strength to mass ratio provides the possibility of designing strong and lightweight structures. Tensegrities are attractive solutions for controllable and smart structures as often small amounts of energy are needed to change the shape of tensegrity structures [20]. Djouadi et al. [21] developed an active control methodology for vibration damping of tensegrity structures intended for spatial applications. Chan et al. [22] presented an experimental study of active vibration

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