A robotic and automatic solution for identifying frequencies and high-resolution mode shapes of bridge structures – an experimental study

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Abstract

This study presents an automated robotic solution for identifying frequencies and high-resolution mode shapes of bridge structures. In this solution, a programmable wheeled robot, whose movement can be precisely and remotely controlled, acts as the mobile platform that carries an accelerometer, and another accelerometer is deployed on the tested structure as a stationary reference. By exploiting a mobile modal identification scheme, this study adopts an output-only frequency domain decomposition technique to extract frequencies and high-resolution mode shapes from the acceleration signals captured by both the mobile and stationary accelerometers. To validate the solution, a field test is conducted on a footbridge, where the frequencies and high-resolution shapes of the first two structural modes are successfully identified, using only two wireless accelerometers. This confirms the effectiveness and efficiency of the proposed solution.

Keywords: Structural vibration; Modal identification; Mobile sensing; Wireless sensing; Automated robot

1 Introduction

Regular inspection and maintenance are essential for the sustainability of existing transportation infrastructures. In the past decades, the vibration-based testing has evolved into one of the mainstream methods for the inspection of bridge structures. Among various vibration-based methods, modal analysis and testing serve as the most accepted one for structural condition assessment [1]. At present, the most common form of implementing modal testing for bridge structures is deploying a sensor network on the tested structure to collect its dynamic responses, and these vibrational data are then delivered to certain modal identification algorithm to extract modal properties including the frequency, damping ratio, and mode shape. Since the sensor network is permanently or temporarily fixed on the structure, this manner of sensing could be named fixed sensing [2]. Although the fixed sensing has been validated by numerous studies and projects, it exhibits several disadvantages in practice. For instance, the deployment of a stationary sensor network and the associated transmission wires on an in-service structure is time- and labour-

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