A Vision-based IEKF Full-Motion Estimation on Long-Deck Suspension Bridges

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Abstract The communication describes a kinematic model-based solution to estimate the motion of a structure from a sequence of images captured by a set of cameras along the time. Using an arbitrarily number of noisy images and assuming a smooth structure's motion, an Iterated Extended Kalman Filter (IEKF) is used to recursively estimate the 6-D structure's motion (displacement and rotation) over time. The requirements are a minimum of two cameras and a minimum of three non-collinear targets (control points). Results related to the performance evaluation, obtained by numerical simulations and real experiments, are presented. The scenario conditions created for the numerical simulations were inspired in the suspension bridge 25 de Abril over the river Tagus, in Lisbon, whilst for the real experiments we used a reduced structure model to fix the targets and to impose the controlled motion.

1 Introduction

A significant mount of work has been developed in the area of Structural Health Monitoring (SHM), with special emphasis on the last decades. The research growth on SHM is justified by its role in the assessment of structure's health, having in mind its own safety as well as of its users. This activity is essential to detect and to identify any failures that may occur at any component that comprises the structure during the service life of the structure, as well as during the construction and demolition stages. Without an efficient monitoring system, a component failure can cause irreversible damages in the structure and, eventually, a possible loss of human lives. SHM is the key to increase the confidence of structure owners and users and to protect it from serious damages.

The SHM accomplishment requires the measurement of several quantities, some of them related to the external actions that act over the structure (e.g. wind, load) and others related to the respective structure response (e.g. deformation, displacement). In the last group are the displacements and rotations of the structure, where its measurement is very important for the structure safety assessment. However, in general case, the traditional transducers and measurement techniques cannot be applied since the displacements of the structure can, usually, reach high amplitude (more than one meter) and, most of the time there is not a fixed point in the neighbourhood of the part of the structure to be monitored. A common solution is to measure the acceleration, and sometimes the velocity, and estimate the displacement by mathematical integration. Though, this solution has many drawbacks since the degree of accuracy depends on various factors, such as the sampling rate, the data record length, the drift and the offset of the electrical signal, etc [1].

To overcome the aforesaid limitations, we developed a non-contact vision-based measurement system, with dynamic response, accuracy and amplitude range well-suited to the