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Book Review

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Book review

Computer Vision for Structural Dynamics and Health Monitoring

Dongming Feng and Maria Q. Feng. Wiley, Hoboken, NJ, USA, 2021, ISBN 978-1-119-56658-8 (cloth), £99.00, 235 pp.

Civil engineers have a recognised history, dating back to the mid-nineteenth century, of using cameras to aid their work. Today, Wikipedia reveals that the Mars rover vehicles have an impressive array of camera-type instruments for various scientific and functional purposes. It is not surprising then that the profession is now actively exploring the possibilities afforded by emerging developments in digital cameras to manage infrastructure. Using the umbrella term 'computer vision technology', this book records the current state of that exploration, focusing on its relevance to dynamically responsive structures such as bridges. It describes the equipment, the mathematics, the calibration and validation, the potential field usage and the case studies that collectively show the viability of this technology for displacement measurement and for displacement time history output. From that, real-world structural frequencies, mode shapes, structural stiffnesses and in some cases applied loads/internal forces can be derived, for comparison against design values. These comparisons can contribute to asset management through both design model updating and structural health monitoring (SHM).

The book is divided into eight chapters. Where relevant, computer script is provided to exemplify the practical application of relevant mathematics to algorithms.

Chapter 1 introduces SHM and includes a handy tabulation of the advantages and disadvantages associated with each of the real-world structural frequency measurement methods, including of course computer vision technology. Chapter 2 gives the fundamentals of computer vision technology for deriving displacement time histories from video images, including typical hardware and software; template-matching algorithms for tracking targets; and image pixel conversion algorithms for determining physical displacements (i.e. the scaling factor).

Chapter 3, the longest in the book, presents a wide range of dynamic displacement measurement tests in both the laboratory and the field, to evaluate the performance of computer vision technology against reference methods and under various environmental conditions. A reliable template-matching algorithm for the field is identified; the use of, for example, rivet and corner features instead of deliberately installed high-contrast artificial markers for target tracking is established; the capability of a single camera system for simultaneous displacement measurements at multiple points is demonstrated; and while satisfactory measurement accuracy with small camera tilt angles can be achieved, it is noted that scaling factors in both the horizontal and vertical directions should generally be estimated. Chapter 4 explains the difference between theoretical and experimental modal analyses and how the latter can be of use for updating an analytical

model and hence for long-term SHM. In the laboratory, it is shown that computer vision technology can cost-effectively achieve high-spatial-resolution multipoint displacement measurements not only for experimental modal analysis but also for structural parameter identification, for frequency domain model updating and for structural damage detection.

Progressing logically, chapter 5 describes an approach for SHM of ageing short-span railway bridges, which are ubiquitous in the USA and elsewhere. Typically, their natural frequencies are much higher than the excitation frequency of the trainload, and thus, there is no ambient vibration. However, using computer vision technology including time domain optimisation, it can be established that the instantaneous displacement amplitude is significantly more sensitive to the bridge stiffness EI than to other train-track-bridge parameters. For such bridges, the technology facilitates girder stiffness model updating, and so also long-term SHM.

As it is often difficult to measure excitation forces in real-world structures, chapter 6 explores, in the laboratory, a displacement response method for simultaneous identification of not only structural parameters but also unknown excitation forces. This work is successful but is suitably caveated. Chapter 7 presents two case studies of the field application of computer vision technology for the estimation of tension forces in roof structure and bridge cables. Without interrupting operations, computer vision technology is shown as an exceptionally suitable and cost-effective means of estimating real-world cable forces, and so also for long-term SHM.

Chapter 8 provides an extensive overview of the current state of computer vision technology. A very useful literature review and a summary of this book are firstly provided. Challenges, including hardware limitations and measurement error issues, are discussed. The unique advantages of the technology over conventional sensors for SHM (no installation costs; no installation implications on operations; both single- and multiple-point displacement measurement capabilities; and high-amplitude low-frequency dynamic measurement capability, which is typically difficult using accelerometers; etc.) are summarised.

The authors hope that this book will inspire continuing research into other computer vision technology applications for solving civil and structural engineering problems. They acknowledge that it is an emerging technology, and an example of that is the associated field of digital image correlation, first mentioned in chapter 8. While most civil engineers will find this a very interesting book, it is expected that civil engineer specialists in asset management will also find it a very important book.

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