An Introduction to Structural Health Monitoring

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Abstract This introduction begins with a brief history of SHM technology development. Recent research has begun to recognise that a productive approach to the Structural Health Monitoring (SHM) problem is to regard it as one of statistical pattern recognition (SPR); a paradigm addressing the problem in such a way is described in detail herein as it forms the basis for the organisation of this book. In the process of providing the historical overview and summarising the SPR paradigm, the subsequent chapters in this book are cited in an effort to show how they fit into this overview of SHM. In the conclusions are stated a number of technical challenges that the authors believe must be addressed if SHM is to gain wider acceptance.

1 Introduction

The process of implementing a damage identification strategy for aerospace, civil and mechanical engineering infrastructure is referred to as Structural Health Monitoring (SHM). A wide variety of highly-effective local Non-Destructive Evaluation (NDE) tools are traditionally available for such monitoring. However, the majority of SHM research conducted over the last thirty years has attempted to identify damage in structures on a more global basis using permanently installed sensors. The past ten years has seen a rapid increase in the amount of research related to SHM as quantified by the significant escalation in papers published on this subject. The increased interest in SHM and its associated potential for significant life-safety and economic benefits has motivated the need for this book.

In the most general terms, damage is usually understood as changes introduced into a system that adversely affect its current or future performance. Implicit in this definition is the idea that damage is not meaningful
without a comparison between two different states of the system, one of which is assumed to represent the initial, and often undamaged, state. This book is focused on the study of damage identification in structural and mechanical systems. Therefore, the definition of damage will be limited to changes to the material and/or geometric properties of these systems, including changes to the boundary conditions and system connectivity, which adversely affect the current or future performance of these systems.

In terms of length-scales, all damage begins at the material level. Although not necessarily universally accepted terminology, such damage is referred to as a defect or flaw and is present to some degree in all materials. Under appropriate loading scenarios the defects or flaws grow and coalesce at various rates to cause component, and then system-level, damage. The term damage does not necessarily imply total loss of system functionality, but rather that the system is no longer operating in its optimal manner. As the damage grows it will reach a point where it affects the system operation to a point that is no longer acceptable to the user. This point is referred to as failure. In terms of time-scales, damage can accumulate incrementally over long periods of time such as that associated with fatigue or corrosion damage evolution. On relatively shorter time-scales, damage can also result from scheduled discrete events such as aircraft landings and from unscheduled discrete events such as enemy fire on a military vehicle or natural hazards such as earthquakes.

The SHM process involves the observation of a structure or mechanical system over time using periodically-spaced measurements, the extraction of damage-sensitive features from these measurements, and the statistical analysis of these features to determine the current state of system health. For long-term SHM, the output of this process is periodically updated information regarding the ability of the structure to continue to perform its intended function in the light of the inevitable aging and damage accumulation resulting from the operational environments. Under an extreme event, such as an earthquake or unanticipated blast loading, SHM could be used for rapid condition screening. This screening is intended to provide, in near real-time, reliable information about system performance during such extreme events and the subsequent integrity of the system. A more detailed description of SHM can be found in Worden and Dulieu-Barton (2004).

Damage identification is carried out in conjunction with five closely related disciplines that include SHM, Condition Monitoring (CM, see Bently and Hatch (2003)), Non-Destructive Evaluation (NDE, see Shull (2002)), Statistical Process Control (SPC, See Montgomery (1997)) and Damage Prognosis (DP, see Farrar et al. (2001, 2003)). Typically, SHM is associated with on-line, global damage identification in structural systems such