Summary

This doctoral thesis discusses the several aspects related to the vibration-based inspection of structures and mechanical systems. Particular attention is dedicated to applications for Aerospace Engineering purposes. The discussion encompasses different forms of damage (specifically, the ones inducing a linear stiffness reduction and the breathing crack mechanism), plus other damage-unrelated structural changes such as varying operational conditions.

All these elements fall into the classic framework of vibration-based, Machine Learning-based Structural Health Monitoring (SHM). In the first half of this work, the main conceptual and theoretical points of SHM are defined. In detail, these include the definition of 'damage'(chapter 1), its specific effects on the vibrational response of the affected systems (chapter 2), and the several tasks involved in any damage diagnosis procedure (chapter 3).

The second half of this thesis follows the steps of the Statistical Pattern Recognition paradigm for SHM, seen as a matter of outlier detection. Therefore, the discussion touches on the following points: the enabling sensing technologies needed to capture these effects (chapter 4), the signal processing techniques which extract useful information from the raw data (chapter 5), the uses and properties of these synthetic, damage-sensitive features (chapter 6), and the several modelling strategies to define the 'normality' conditions of the system under analysis (chapter 7). All these aspects are presented with practical examples and applications retrieved from the researches performed during this PhD project. The Conclusions follow in chapter 8.

The main contributions of this thesis include: a novel interpretation of the classic Rytter's damage hierarchy for SHM diagnosis; a novel Multi-Objective Genetic Algorithm approach for Optimal Sensor Placement; a feasibility study on

the use of Phase-Based Motion Magnification for frequency- and mode shape-based damage diagnosis; several novel algorithms and strategies to be applied to high-speed, high-definition video recordings for the extraction of Backbone Curves, the instantaneous tracking of time-varying parameters, and Finite Element Model Update; the validation of two features (the Gammatone Cepstral Coefficients and the Teager-Kaiser Energy Cepstral Coefficients) as Damage Sensitive Features; a novel approach for mode shape-based damage detection based on the combination of Gaussian Process Regression and Extreme Function Theory; and a novel analytical formulation for the steady-state response of an equivalent Single Degree of Freedom system with generalised non-linear damping and stiffness.