Abstract

This thesis presents the development and validation of an integrated optical sensing and data fusion framework for aerospace systems lifecycle management, based on Fiber Bragg Grating (FBG) technology. The work adopts a system-level perspective, addressing the entire data chain from sensing to information extraction. Starting from the design, characterization, and integration of FBG sensors within different materials, dedicated calibration methodologies were developed to ensure reliable strain and temperature measurements under operational conditions. To support scalable and real-time data handling, specific telemetry architectures were designed and implemented. In parallel, data visualization tools were introduced to enhance human–machine interaction, including desktop-based applications and augmented reality interfaces. The proposed framework was validated through a progressive experimental campaign, ranging from laboratory tests to full-scale flight experiments on instrumented UAV platforms. Distributed FBG sensor networks embedded within the aircraft structure were used to acquire high-resolution strain data under real operating conditions. The core contribution of this work lies in demonstrating that FBG data, when properly processed and fused, can be used not only for structural health monitoring but also for the estimation of complex parameters, such as flight dynamics ones. By exploiting physically-based models and appropriate combinations of strain measurements, key quantities such as load factor, roll rate, and pitch rate were reconstructed directly from the optical data. The comparison with inertial measurement unit (IMU) measurements shows strong agreement, validating the proposed data fusion approach in real flight conditions. These results highlight the potential of optical sensing technologies as enabling tools for multifunctional monitoring, supporting both structural assessment and dynamic state estimation. Overall, this research demonstrates how distributed optical sensing and data fusion can contribute to the development of intelligent aerospace systems, capable of self-monitoring and enhanced decision support across their operational lifecycle.