

# Abstract

Fatigue cracking in metallic structures, particularly in aeronautical applications, remains a major cause of durability loss and operational risk. Evaluation of structural condition relies on Structural Health Monitoring (SHM) and complementary Nondestructive Testing (NDT) practices that aim to detect, localize, and assess damage without disrupting operation. Computer Vision (CV) methods are attractive in this context because they are non-contact and some are compatible with low-cost consumer-grade hardware. However, practical deployment is still impeded by several issues, including dependence on manual tuning of method parameters, limited robustness under varying conditions, and a lack of direct interpretability.

This dissertation develops a marker-free, CV-based workflow for automatic fatigue-crack assessment under periodic excitation, exploiting the crack-breathing phenomenon. The pipeline converts dense Optical Flow (OF) time series into frequency-domain amplitude maps, on which a scoring procedure localizes the crack tip automatically. The principal methodological contributions are the formulation of amplitude maps for visualization of breathing-induced motion around cracks, and an automated crack-tip localization procedure operating directly on these maps. In addition, a Local Orientation Inconsistency (LOI) metric is introduced to quantify the directional coherence of estimated motion in video recordings, enabling masking of regions with unreliably estimated motion and guiding Region of Interest (ROI) selection. The impact of phase-based motion magnification is also investigated, demonstrating its usefulness for amplitude maps generation in certain low-excitation cases.

The methodology is validated on multiple experimental specimens, including a compressor, a cantilever beam, and a plate-like aircraft-grade specimen, recorded under diverse setups with different measurement equipment, including a consumer-grade smartphone. The results demonstrate consistent performance across crack-growth stages and camera configurations. Quantitative evaluation against manual measurements shows that the Mean Absolute Error (MAE) of crack-tip localization is in most cases below, or very close to, the resolution of manual assessment, which is one millimeter. Practical aspects are examined through a comparison of key method parameter choices, confirming that the technique operates reliably without requiring precise tuning. The proposed processing pipeline reduces operator input, produces interpretable results, and remains feasible with consumer-grade hardware, supporting practical integration into NDT and SHM workflows.