MECHANICAL ENGINEERING

CRT/DIMEAS - Rotating Structure Testing with Optical Methods

Funded By	Dipartimento DIMEAS FONDAZIONE CRT CASSA DI RISPARMIO DI TORINO [P.iva/CF:06655250014]

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Context of the research activity	In the aerospace sector, stringent certification requirements demand rigorous structural design and testing to guarantee safety and performance. Experimental and Operational Modal Analysis play a central role in this process by enabling the identification of a structure's dynamic properties. Non-contact, full-field optical measurement techniques—such as Laser Doppler Vibrometry (LDV) and camera-based approaches grounded in Digital Image Correlation (DIC)—provide researchers with powerful tools for this purpose. This activity will investigate advanced image-processing strategies for using cameras as dynamic response sensors. Particular attention will be given to motion-enhancement methods, including phase-based motion magnification.

	The proposed activity is detailed below. 1. Using Video Motion Magnification as a Pre-Processing Step for DIC Digital Image Correlation is highly sensitive to image texture quality and signal-to-noise ratio, especially when measuring small dynamic displacements near the noise floor of the camera. Phase-based Video Motion Magnification (VMM) can amplify subtle, spatially coherent motions prior to running DIC, potentially improving correlation robustness and expanding the measurable displacement range. Key research questions include: How does magnification affect speckle patterns, correlation stability, and measurement accuracy? What magnification factors maximize modal visibility without introducing phase or amplitude distortions? Can VMM reduce the need for high-speed cameras by enhancing low-frame-rate sequences? A rigorous evaluation framework—synthetic data, controlled experiments, and real structural tests—would be part of the investigation.

Objectives	2. Extending Optical Modal Methods to Large Rotations Most DIC-based modal analysis workflows assume small displacements. However, rotors exhibit rigid body rotations that challenge standard algorithms. Extending the approach entails: - Developing or adapting DIC formulations capable of tracking large rotations (e.g., multi-scale correlation, incremental warping, or regularized optimization). - Investigating whether motion-magnified videos remain reliable when the underlying motion exceeds the small-motion assumption of the magnification model. This line of research can broaden the applicability of camera-based sensing to more realistic rotating structures. 3. Integrating Stereo Matching: Feature-Based and/or Structured-Light Approaches To obtain full-field 3D modal information, stereo imaging or multi-view reconstruction must be integrated with the motion-magnification and DIC pipeline. Two complementary strategies include: - Feature-based stereo matching Using robust feature detectors and descriptors (e.g., SIFT, ORB, or learned keypoints) to establish correspondences between views. This can improve reconstruction stability on low-texture surfaces or in regions where DIC speckles are sparse. - Structured-light or fringe projection Projecting artificial patterns (grids, dots, fringes) to enrich texture and improve correlation accuracy, especially for smooth aerospace surfaces. Combining structured-light stereo with VMM offers the possibility of amplifying 3D motions in a geometrically consistent way. Research target: Fusion of stereo depth maps with DIC displacement fields for more accurate 3D mode-shape extraction. Investigating how motion magnification interacts with stereo geometry—whether magnified videos can still be triangulated reliably. Developing real-time or quasi-real-time processing chains for experimental modal testing.

Skills and competencies for the development of the activity	The successful candidate will have experience of structural dynamics, modal analysis and testing. Technical skills required: Knowledge of applications and software such as TestLab, Simcenter 3D, Solid Edge, SolidWorks and Inventor. Abaqus, Femap, LS-Dyna, Nastran, MATLAB and LaTeX. Language skills required: English at level C1 or higher is required. Excellent interpersonal skills are required.