Development of measurement techniques for aerospace components inspection

PhD Student	Gloria Allevi
Curriculum	Mechanical Measurement for Engineering and Space
Event	Request of admission to the second year of the PhD Course

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Shearography Inspection

- Quantitative defect size and morphology characterization in aerospace composites
- Improving the accuracy on the defect size estimation using wavelet transform

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«Quantitative Defect Size Estimation in Shearography Inspection by Wavelet Transform and Shear Correction»

G.M. Revel, G. Pandarese, **G. Allevi**

Work discussed during the International Conference «Metrology for Aerospace»

Padua, 21-23 June 2017

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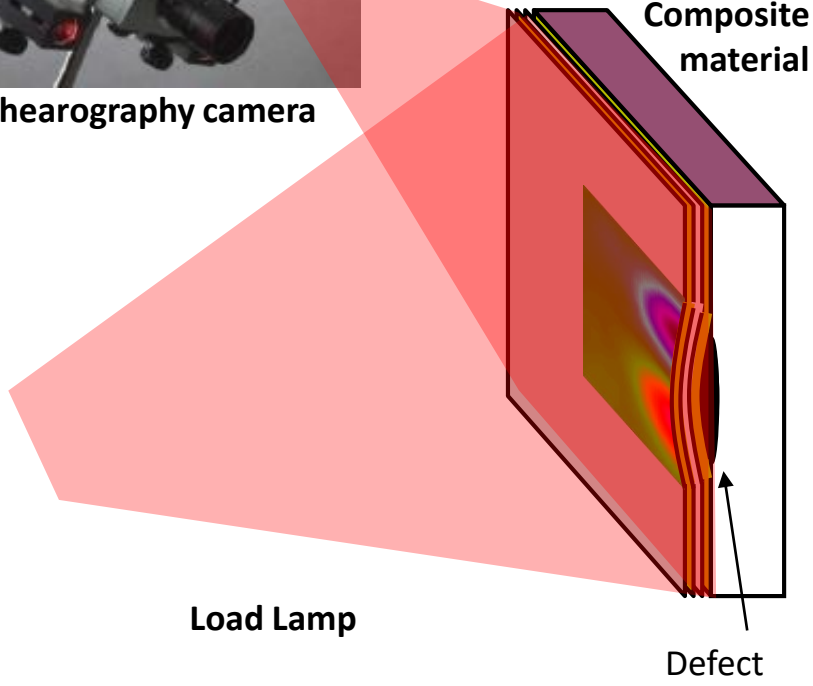
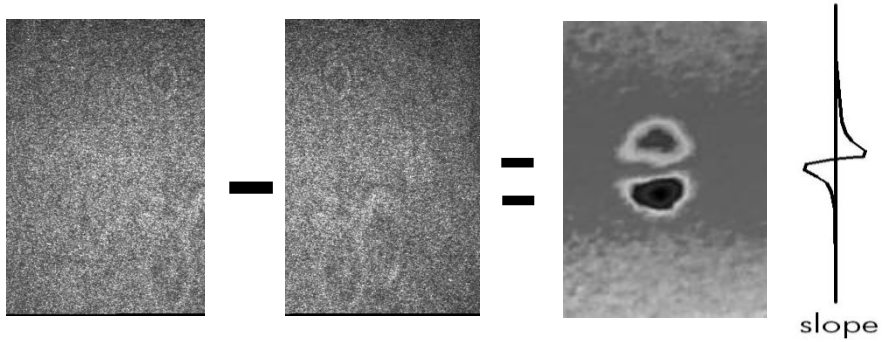
Shearography camera



- Interferometric, full-field technique
- Short time inspection large area
- Transportable - on field application
- No need of reference beam
- Output fist derivate along a specific direction (shear) of the out of plane – displacement of the observed surface

Speckle Images

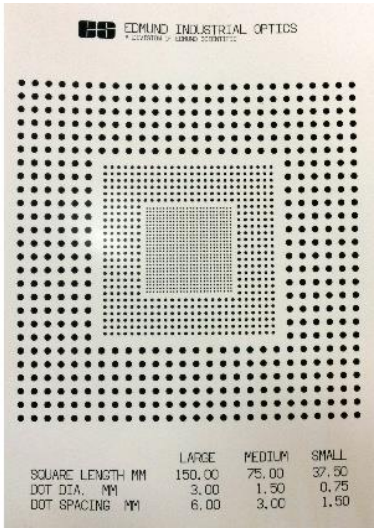
Phase image



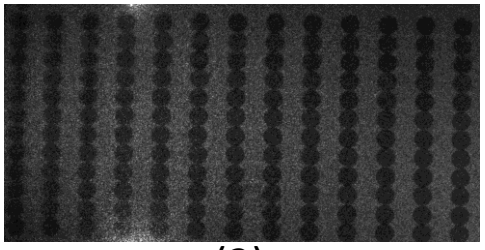
Optical effect of coherent light interacting with rough surface

Proposed algorithm

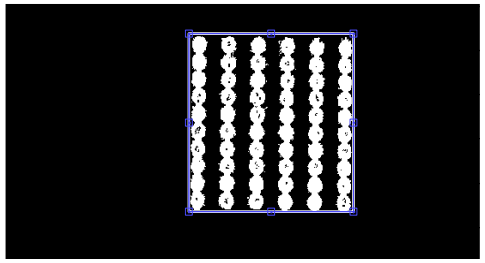
1. Localized shear computation



(1)



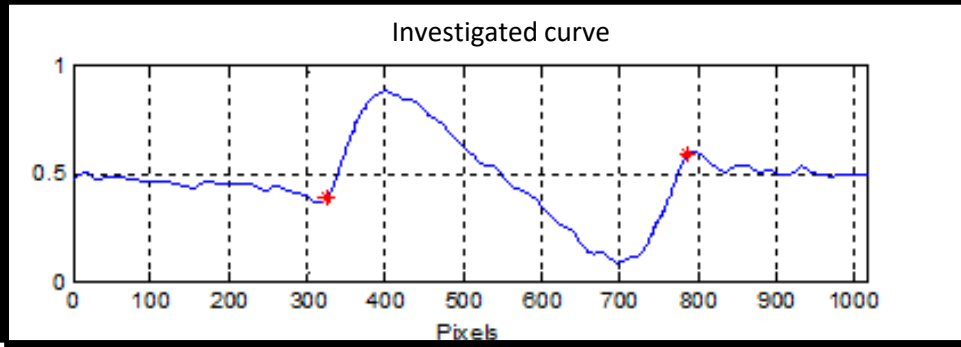
(2)



(3)

Proposed algorithm

2. Wavelet Transform Scanning on the unwrapped phase map



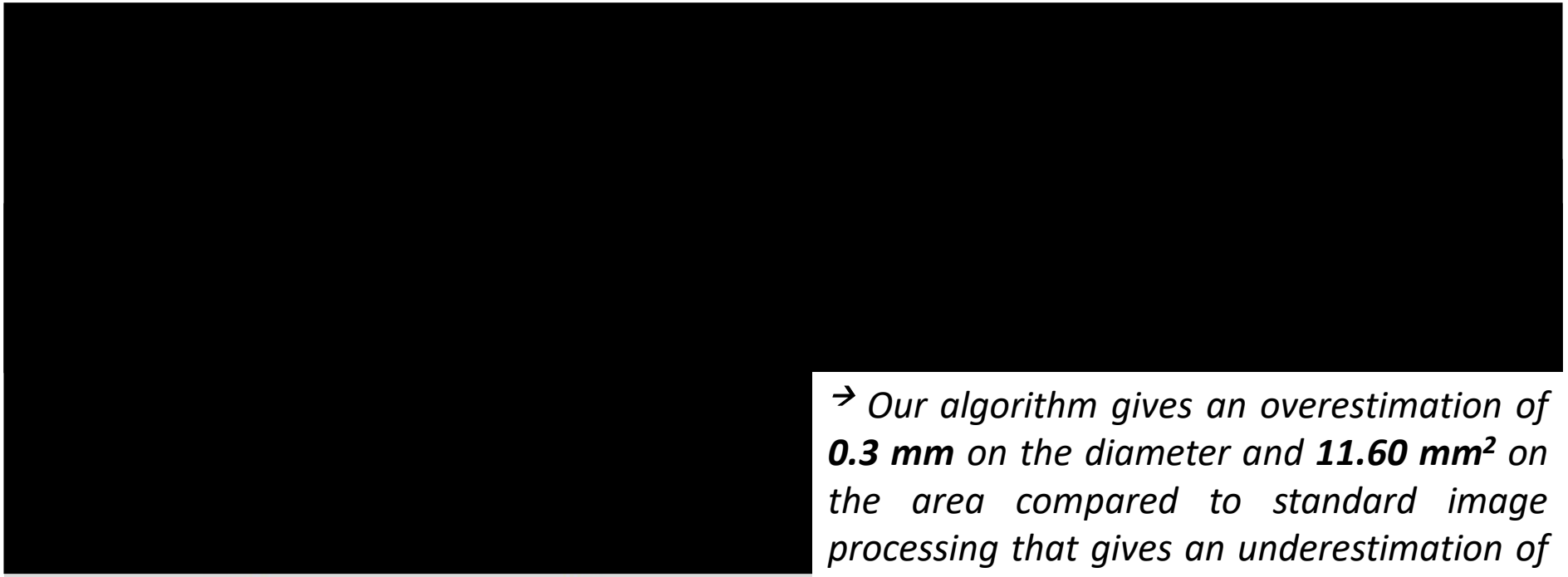
• Extracting the significant singularity of the wavelet representative of the edge of the profile (Mexican Hat Wavelet)

Algorithm validation on a calibrated specimen

PVC specimen with known defects: focus on the 24 +/- 0.05 *mm* diameter and 1 +/- 0.05 *mm* depth defect.

		y-direction	*x-direction*
ROI mean shear values	**[pixels]**	38.7	1.0
ROI mean shear values	**[mm]**	3.09	0.08

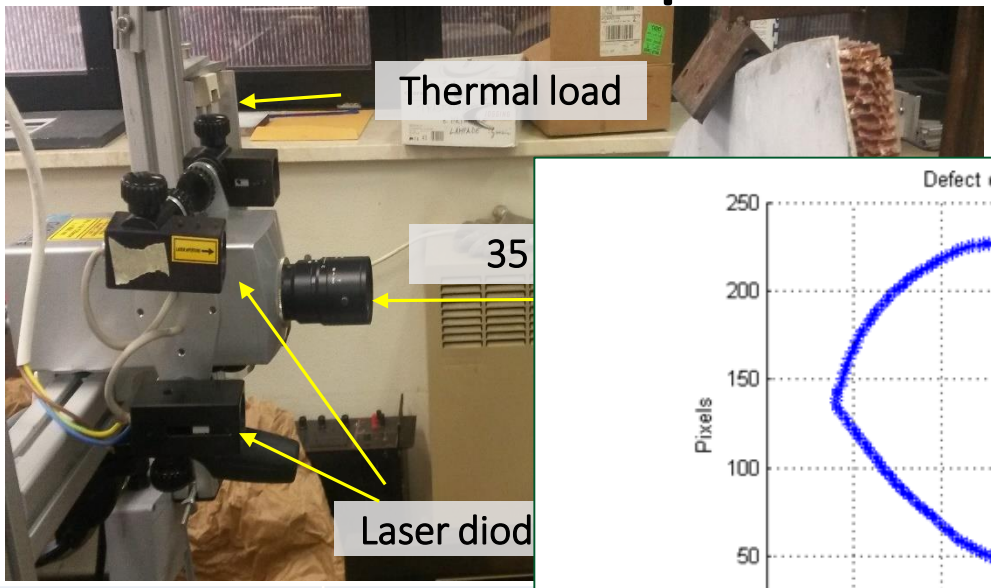
These values will be subtacted to the coordinates of each detected boundary



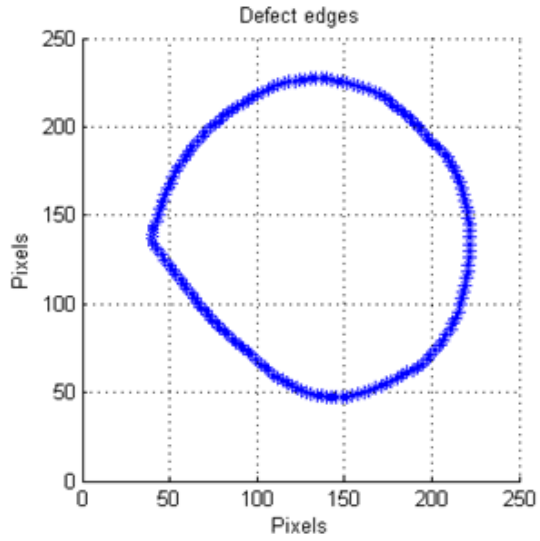
Evaluated diameter : 24.30 ± 0.05 mm
Evaluated Area : 463.80 ± 2.02 mm²

→ *Our algorithm gives an overestimation of* ***0.3 mm*** *on the diameter and* ***11.60 mm²*** *on the area compared to standard image processing that gives an underestimation of* ***1.8 mm*** *on the diameter and* ***66.6 mm²*** *on the area*

Application on an aerospace component



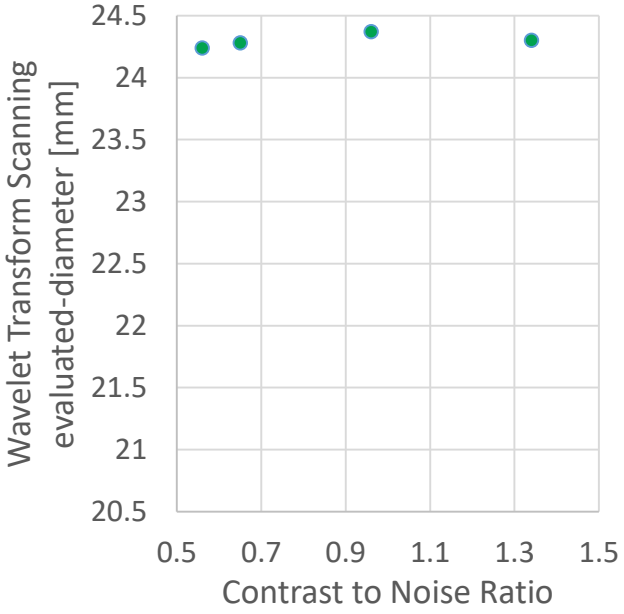
	Value
Calibration Factor	0.18
Y - shear	2.89
X - shear	0.16



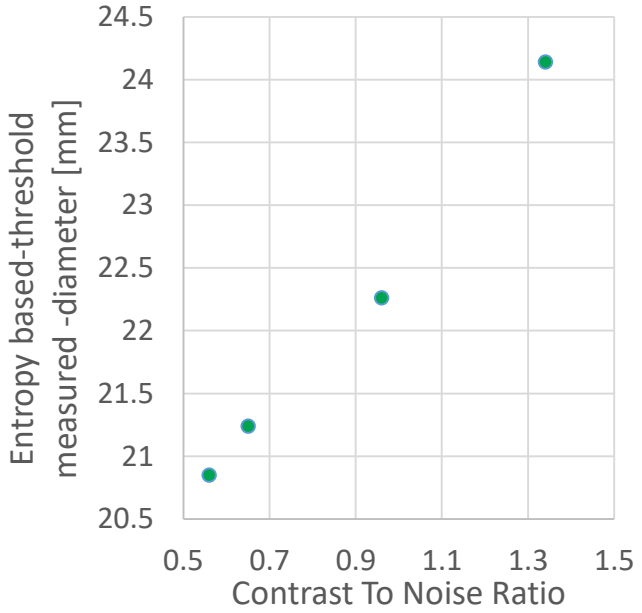
- [redacted]
- A delamination of unknown
- The processed image was st relaxation successive to a 5 s thermal load, at a distance of 35 cm from the surface

- *Estimated area : 765.50 mm²*
- *Equivalent diameter : 31.21 mm*

Our algorithm vs Contrast to Noise Ratio (CNR)



Entropy based-threshold vs Contrast to Noise Ratio (CNR)



$$CNR = \frac{\mu_{defect} - \mu_{back}}{\left[w_{defect} \cdot \sigma_{defect}^2 + w_{back} \cdot \sigma_{back}^2\right]^{\frac{1}{2}}}$$

$$w_{defect} = \frac{Area_{defect}}{Area_{back} + Area_{defect}}$$

$$w_{back} = \frac{Area_{back}}{Area_{back} + Area_{defect}}$$

$$\sigma = standard\ deviations$$

$$\mu = average\ intensities$$

Thermography Inspection

- Feasibility study of Thermoelastic technique on a 3D printed- titanium alloy bracket
- Stress analysis (TSA)
- Displacement field analysis (Optical Flow)

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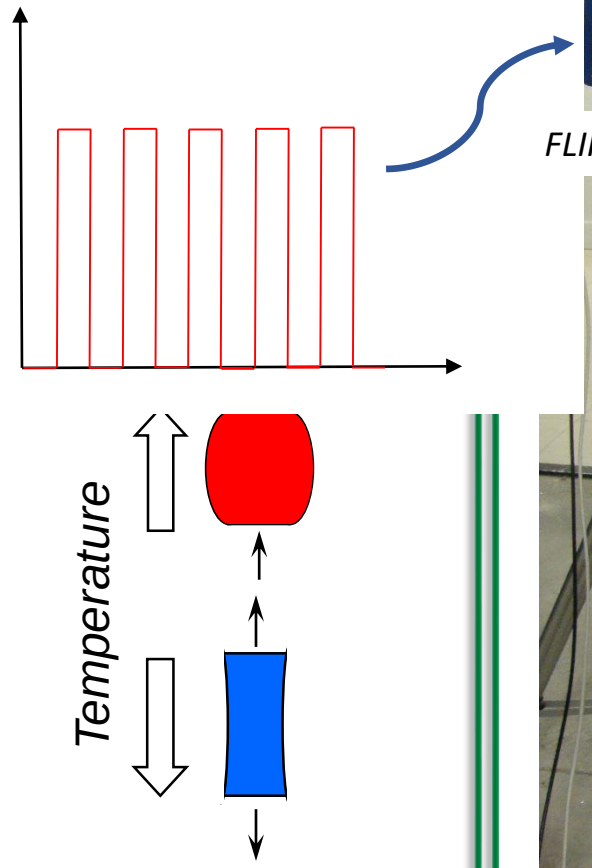
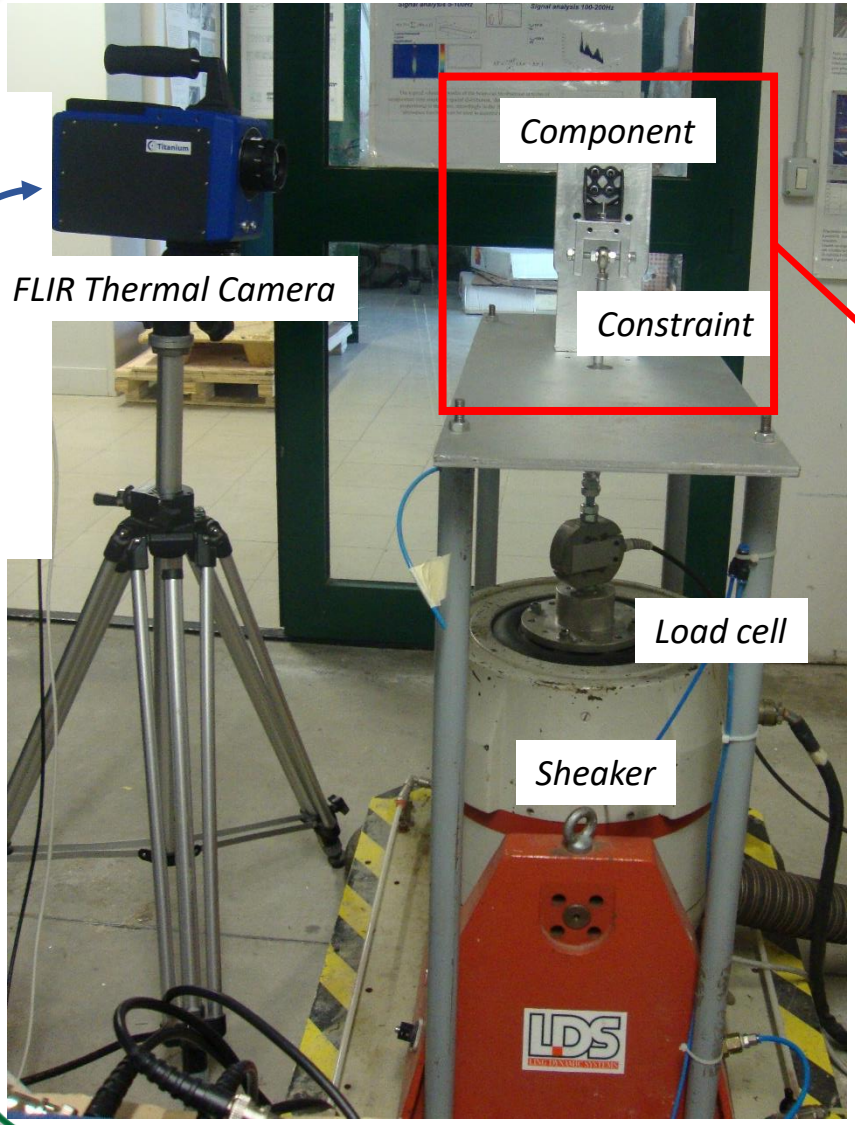
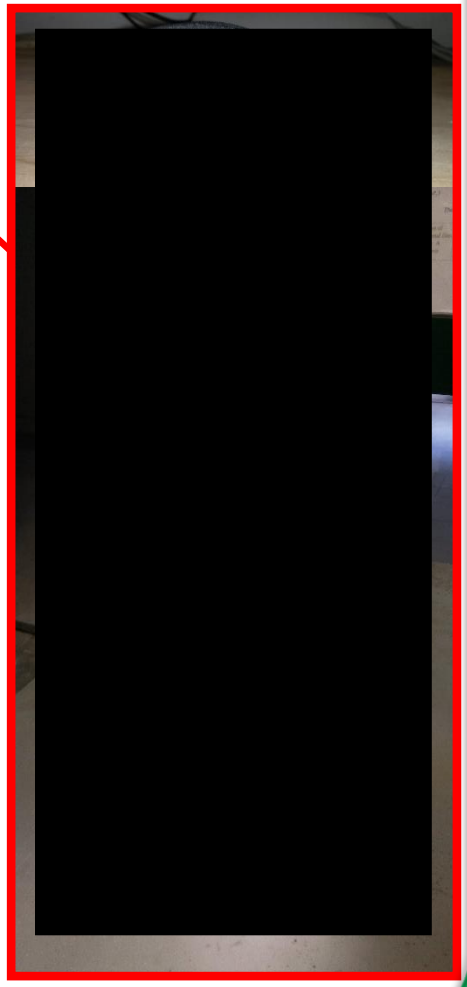
Thermoelastic







Amplitude (stress distribution) **Phase (stress sign → compression/traction)**

- Load 8 Kg
- Load frequency 30 Hz
- Sampling frequency 150 Hz
- Acquisition time 60 s

Comparison

Thermoelastic results

CAD evaluated FEM

3D reconstructed geometry-evaluated FEM

Optical Flow Analysis

- The hypothesis of brightness constancy is not valid!!!

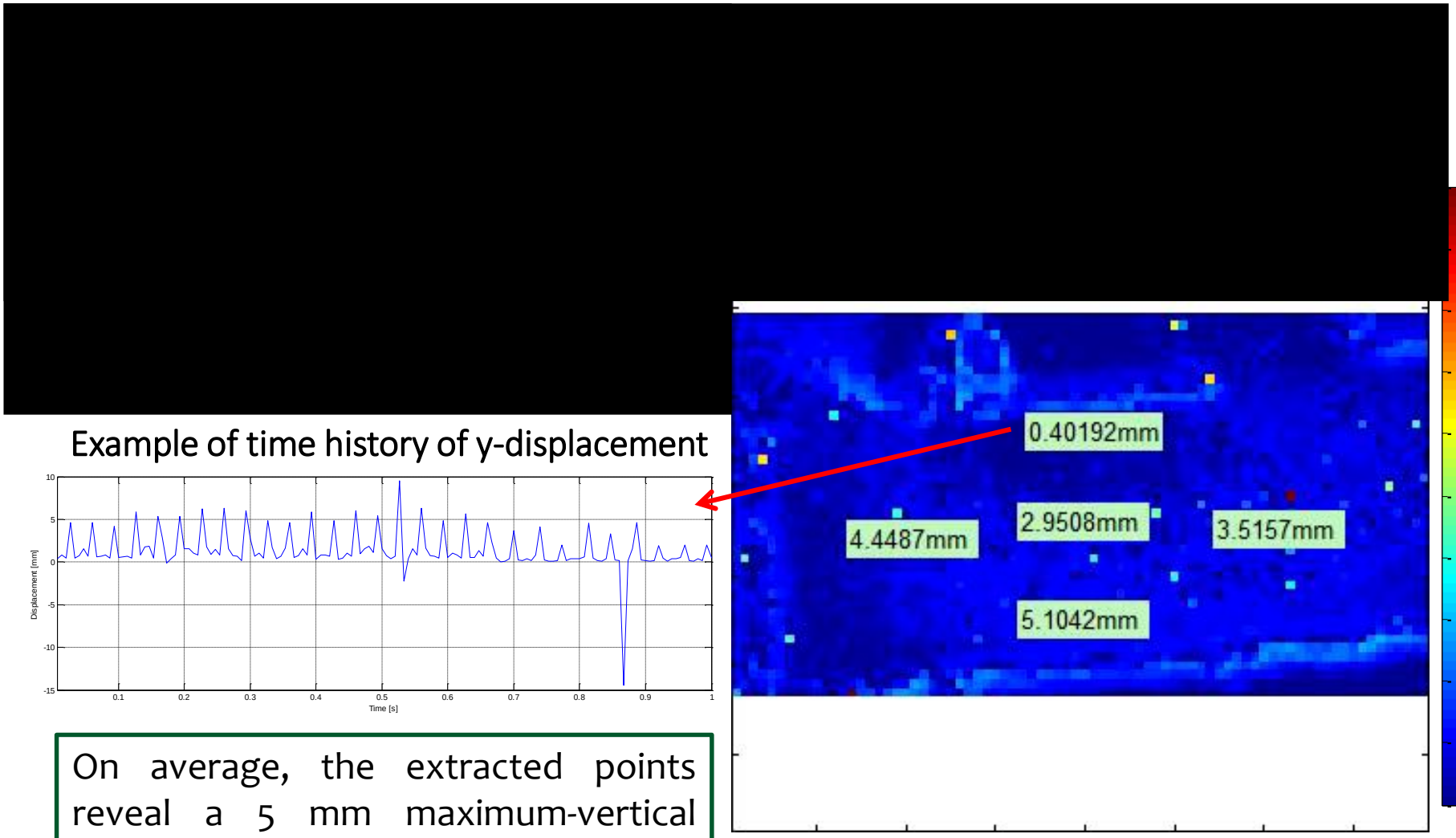
$$\Delta s = \frac{I_0(x_j, y_k) - I(x_j, y_k, t)}{|\nabla I_0|}$$

I_0: mean image

I: frame at istant t

I: frame at istant t

Δs: gradient oriented - displacement



Example of time history of y-displacement

On average, the extracted points reveal a 5 mm maximum-vertical displacement at the load frequency

Future work

Shearography

- Algorithm improvement
- Making results independent on test conditions (load, shear, distance from the surface…)
- Comparison with ultrasound tests results

Thermography

- Optical flow code validation
- Application on thermal deformations measurements (comparison with Digital Image Correlation)
- Application on thermal vacuum chamber-tests
- Thermoelastic/displacement modal analysis on aerospace structures

Thanks for your attention

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