Mona Lisa's digital twin: identifying the mechanical properties of the panel combining experimental data and advanced finite-element modelling

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Extract as much information as possible from the experimental tests carried out and, thus, reach a sufficient level of scientific knowledge of the boundary conditions and mechanical properties of the panel to build a predictive model

Experimental Data

The observation methods, partly described in early reports (Mohen et al 2006, Gril et al 2015), include: (i) optical measurements of the shape (Fig. 1, Brémand et al 2011); (ii) scientific and technological analysis of the wooden support; (iii) continuous monitoring of the forces applied by the crossbars on the back of the panel, and of the central deflections relative to an additional metallic crossbar equipped with transducers (Fig. 2); (iv) assessment of contact areas between the front of the panel and the rebate of the chassis using pressure-sensitive sheets (Fig. 3, Goli et al. 2013).

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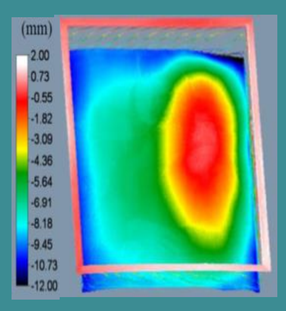

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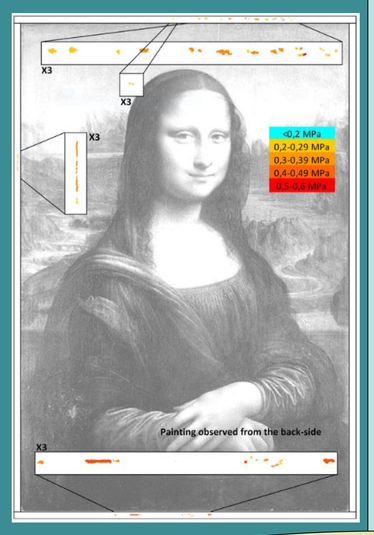

The Digital Twin

1.Acquisition of the object's shape through optical methods and reconstruction of a three-dimensional geometrical model.
2.Enrichment of this geometry with additional entities defining the boundary conditions. The location of the pith was also taken into consideration, for the definition of cylindrical coordinates to define orthotropic characteristics.
3.Acquisition and treatment of experimental measurements from load cells and displacement transducers that continuously record the panel status.
4.Construction of the numerical model using the finite-element method (FEM), evaluation of the discretization, modelling of boundary conditions and contact mechanics.
5.Iterative optimization procedure, through Nelder-Mead (downhill simplex) scheme, for the calibration of the mechanical characteristics of the model based on the experimental response and the control of results consistency.
All the analyses are performed with the FEM solver Code_Aster in the Salome-Meca ecosystem.

Mona Lisa's Digital Twin

identifying the mechanical properties of the panel combining experimental data and advanced finite-element modelling

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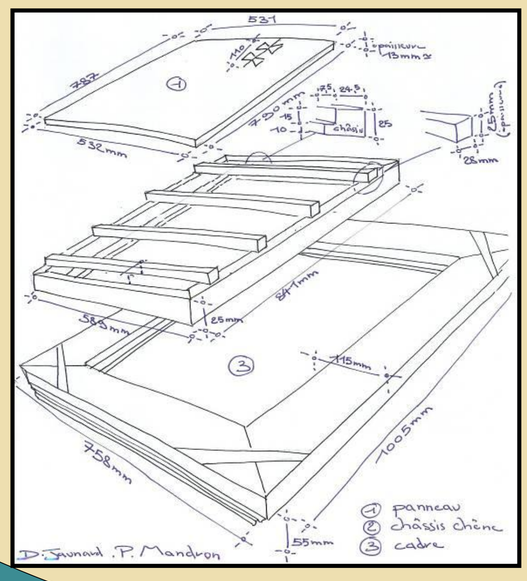

Assessment of the Panel

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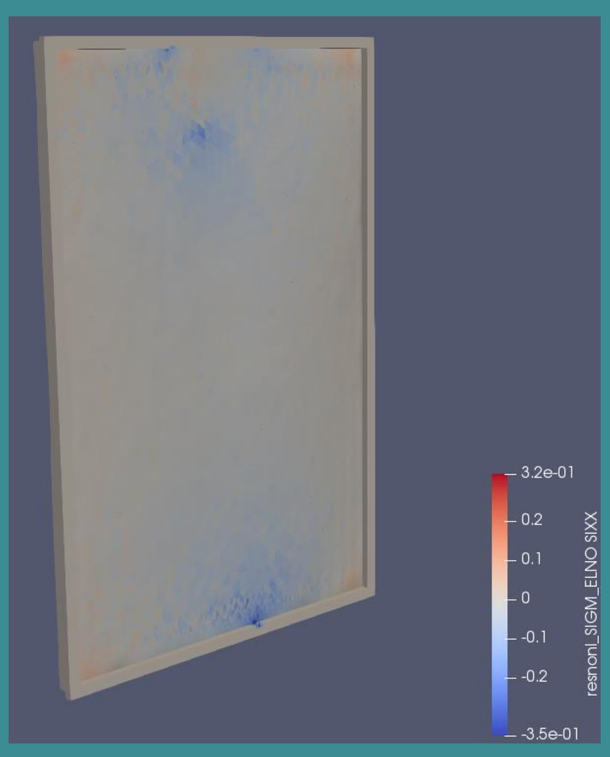

Starting from the shape detected by the optical measurements and through an optimization process that determined the elasticity properties of the wood, a non-linear model has been developed that accounts for the complex unilateral contacts detected during specific experimental campaigns, and for the orthotropic anatomy of the panel.
This calibrated model (digital twin) is then used to evaluate the stress and deformation states caused by changes in the boundary conditions, to correlate the forces (measured by the load cells the panel is equipped with, or hypothesized on a simulation level) and the stress states (Fig.4) to which the panel is subjected.

Provide Information for Conservation

The digital twin is also used to assess the effect of inserting a layer of a viscoelastic polymer foam for protective purposes between the painting and the chassis (in Fig. 5 the deformation of the viscoelastic foam 6 months after the load application; panel observed from the back).
A method for comparing two different mechanical configurations is proposed through the numerical computation of point-by-point stress and deformation differences, in order to provide information for the conservation, such as optimizing setting and constraints.

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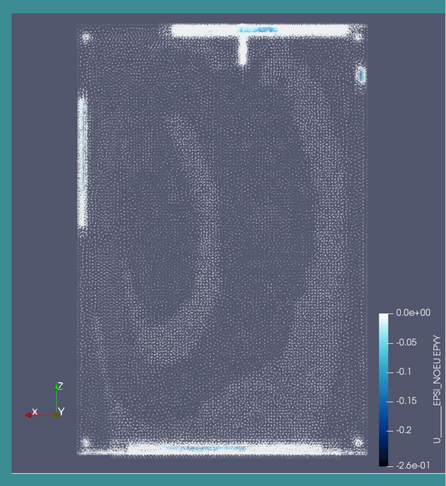
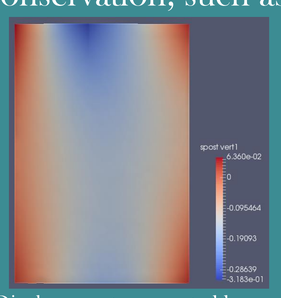
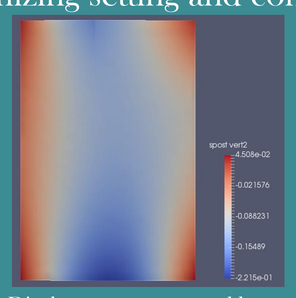
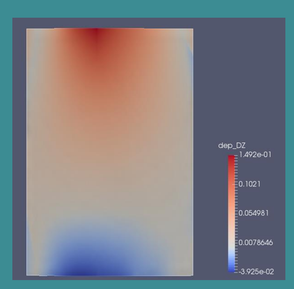




Displacements generated by wood-wood contact



Displacements generated by wood-foam contact



Point-per-point map of the difference between the displacements in the two configurations