# Monitoring climate and deformation of panel paintings in San Marco (Florence) and other Museums



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# MONITORING CLIMATE AND DEFORMATION OF PANEL PAINTINGS IN SAN MARCO (FLORENCE) AND OTHER MUSEUMS

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**Abstract**
This paper briefly describes selected past and ongoing researches carried out by the Authors at DEISTAF - University of Florence, in the field of monitoring deformations of Panel Paintings exhibited in important Museums and Historical Buildings – mostly in Florence –, related to the variations of microclimatic conditions. From actual deformations, behavior and sensitivity of wooden supports may be studied, mathematical models can be calibrated, and stresses can be evaluated. A self-powered concept-apparatus named "Deformometric Kit" is also described, which was developed at DEISTAF in order to log during long periods the climate and the deformative behavior of the panels, or the forces acting on them, as in the Mona Lisa case. Some initial data and results from Deformometric Kits installed on two mock-panels placed in a room of the San Marco Museum are also described.

## 1. Introduction

During the last fifteen years the senior Authors developed several collaborations with Institutions taking care of important artworks painted on wooden support, dealing specifically, among other subjects, with the interactions between microclimate variations and conservation of the artworks.
Due to the large amount of WCHOs (Wooden Cultural Heritage Objects), Florence probably had the best conditions to start this kind of monitoring, and this approach found a rapid diffusion abroad because of the quality of the information it can provide, both theoretical and practical.
This paper briefly describes some of the case-studies with which the Authors dealt, and that can be useful to display the flexibility of the approach, highlighting that the deformative geometry of the monitoring apparatus must be chosen as a function of the desired type of response.

## 2. Case studies

### 2.1. Collaborations with Museums, in Florence

Usually the measurements were designed on the basis of specific questions asked by Restorers and Conservators, but these experimental also contribute to building up a useful database for modelling the behaviour of these precious objects.
According to this synthetic approach, here are described some of the case-studies carried on in Florence:

- the *Uffizi Museum* [1], where monitoring was carried on Giotto's *Maestà di Ognissanti* (~ 1303) (see Fig. 1), and on Alessio Baldovinetti's *Madonna con Bambino e Santi* (~ 1454); the structure of the laminated wood shield on which Caravaggio painted his *Medusa* (1547), was also thoroughly analyzed, by means of Computed Tomography [4] (see Fig.3);
- the *Argenti Museum*, in Palazzo Pitti, where microclimatic cases monitoring was required for a better comprehension of the interactions between the microclimate and the materials used in the cases;
- the *Opificio delle Pietre Dure* [2], where the discussions about the choices to be made for restoration and conservation started from very practical problems that the restorers wanted to solve;
- the *Orsanmichele Church* [3], under the Special Superintendence of the Florentine Museums Pole, where the monitoring of Bernardo Daddi's *Madonna con Bambino e Angeli* (1347) is still going on after more than seven years (see Fig. 2);
- the *Bardini Museum*: the monitoring on a precious wooden shield is going on, based on the past experience on the above mentioned Caravaggio's *Medusa* (see Fig. 3);

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- the *San Marco Museum*, first results of which will be discussed in a specific paragraph.

### 2.2. Collaborations with Museums, out of Florence

- the *Accademia Museum* in Venice: a painting by Vittore Carpaccio, *L'incontro di Gioacchino e Anna* (1515), had to be freed from its modern iron cross-beams system (that produced many conservation problems on the paint layer) and the conservator needed to have informations about the reactivity of the support to the climate variations in order to design the stiffness of the new cross-beams;
- the *Louvre Museum* [5], in Paris: a group, led by Joseph Gril, was formed to answer several questions, originating from the transfer of Leonardo da Vinci's *Mona Lisa* (1503-1516) from the old to the new display case; the questions included (a) if the actual thermo-hygrometric conditions of the display case could be improved, for the well-being of the artwork, (b) an evaluation of the sensitivity of its wooden support to microclimatic variations, and (c) the risk of propagation of a crack present since a very long time on the upper part of the painting. For this study, carried out in cooperation with several other Colleagues, a measurement apparatus was designed and implemented, allowing – among others – for the monitoring of both deformation at mid-height of the support and of forces acting between one of the cross-beams and the two upper corners of the support.

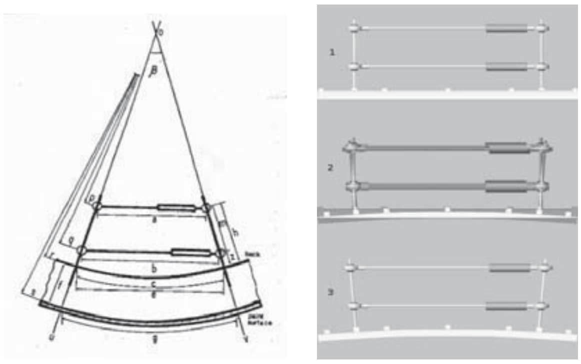


Fig. 1. The "Giotto" system: (left) its geometry; (right) the way it works.

## 3. Instrumentation

In 1992, for the monitoring of Giotto's *Maestà di Ognissanti*, a measurement geometry (developed specifically for panel paintings) was implemented. Two parallel displacement transducers were mounted on the back of the panel, at different distances from the panel's surface, in direction perpendicular to the grain (see Fig. 1); based on simple geometric relationships, and assuming that the cupping deformation can be schematized as an arc of a circle, the combined data from the two transducers allow to compute/estimate both the contraction/expansion of the panel in its "plane", and its cupping radius of curvature. If the exact geometry of the system is known, absolute measurements and not just only variations can be computed.
In these first applications the system couldn't be self-powered, because of the significant power consumption of the LVDT transducers and of the logging system.
Starting from 1999 a simpler apparatus was developed, using a commercial self-powered data-logger and potentiometric displacement transducers being powered by the same data-logger only at intervals, when measurements were recorded, typically at 15 minutes interval; such system was applied for the first time on the Daddi's painting, in the church of Orsanmichele (see Fig. 2), and is still used. The system required a cable connection to download the recorded data.
In 2006 Lucchetti and Dionisi-Vici [6] patented a self-powered system with very low consumption, equipped with a Bluetooth antenna, allowing a frequent download or verification of the recorded data, without any need for physical cable connection; it is especially useful when the logger is located in locations hard to be reached or in a sealed case, since no opening is required.
This system is presently installed on the back of the Mona Lisa, since November 2007.

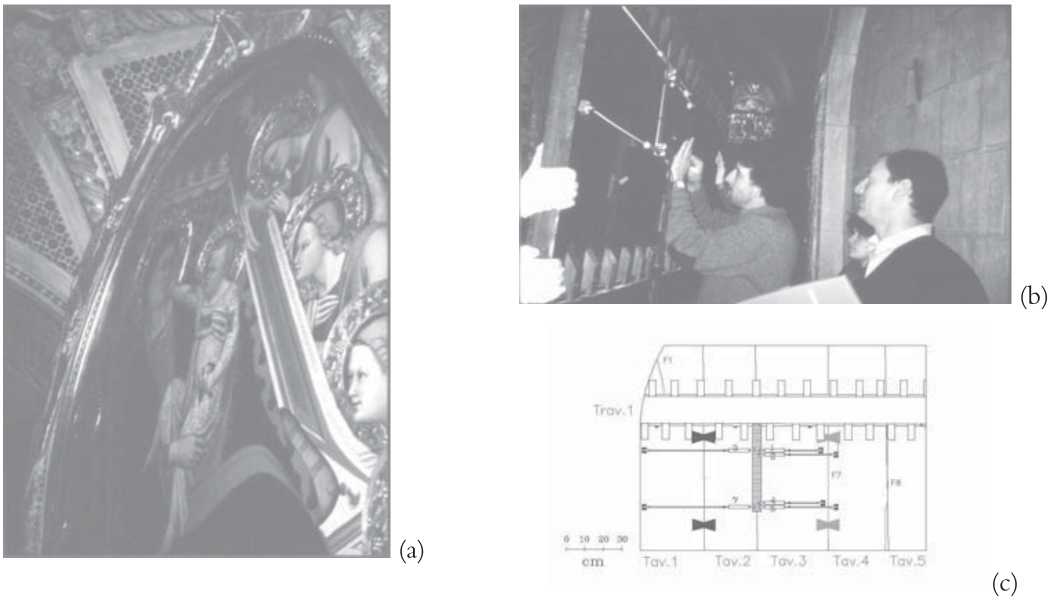



Fig. 2. (a) Daddi's *Madonna con Bambino e Angeli* (1347); (b) fixing in place the system of transducers; (c) schematic drawing of a part of the wooden support (seen from the rear face), and of the six deformation transducers applied on it, measuring only in-plane deformations.

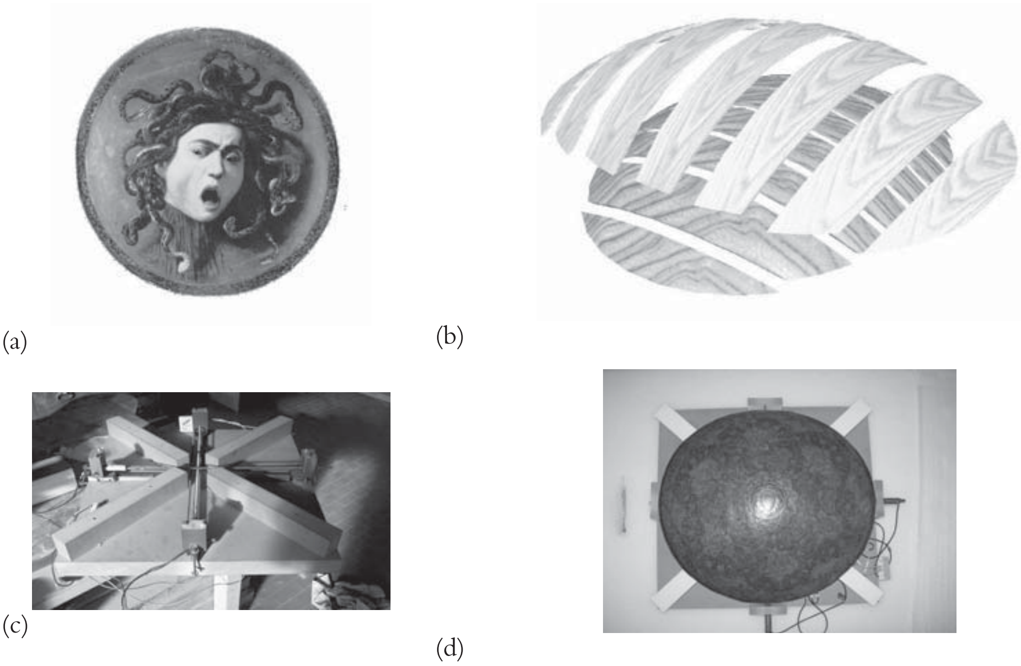



Fig. 3. a) the Medusa shield by Caravaggio; b) the virtual reconstruction of the wooden hidden structure; c) the support for the measurement setup; d) the measurement system applied on the Bardini Museum's shield

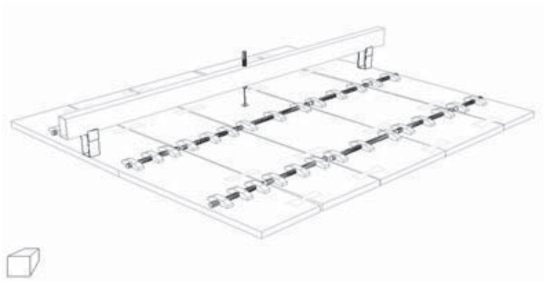


Fig. 4. Schematic drawing of the wooden support of Carpaccio's *L'incontro di Gioacchino e Anna* (1515), with its old metal cross-beams, during the measurement of its transversal profile.

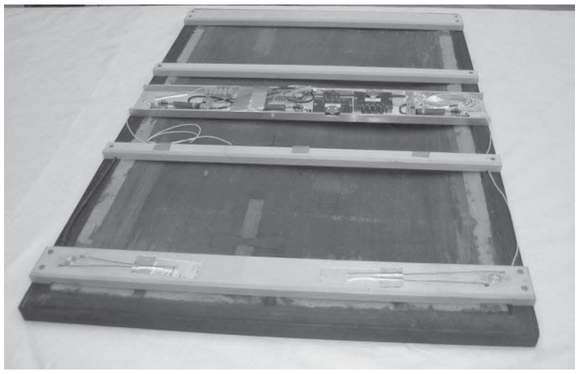


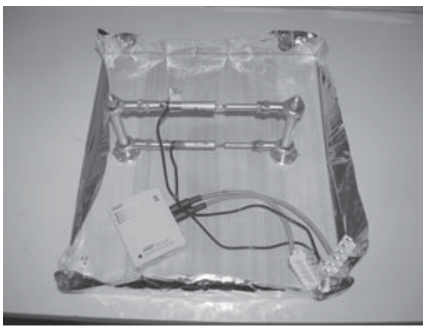
Fig. 5. The back face of Leonardo da Vinci's *Mona Lisa* (1503-1516), with the monitoring instrumentation installed. In the foreground (top of the painting) the cross-beam measuring the force acting on the panel; in the middle, the aluminium support carrying the displacement transducers and the data-loggers.

## 4. San Marco monitoring and initial data analysis

In cooperation with Dr. Magnolia Scudieri, the Director of San Marco Museum in Florence, a monitoring of the deformations of an original panel painting (the *Trittico di San Pietro* by fra' Giovanni Angelico, located in the *Sala dell'Ospizio*, the very room where this presentation has been given) is being planned. The knowledge of sensitivity and movements of the wooden support are anticipated to be most useful when the panel will undergo restoration, possibly in a few years.

While waiting for the original panel to be available, two mock-models of its wooden support have been designed, assembled, and located in the same room, in order to have available reference data from physical models of the original panel. As compared to the original (28-30 mm), the two mock-models have the same thickness (30 mm), are smaller in size (300 x 300 mm) but are expected to react and deform in the same way, and are equipped with the same instrumentation (one data-logger and two potentiometric transducers each); they only differ from each other because of the wood from which they are made: both are made of Poplar (*Populus alba* L.) as the original, but one (the "New": N) comes from a board sawn and seasoned since only a few years (possibly 5-7), whereas the other (the "Old": V – formed by two half boards glued along an edge, parallel to the grain) comes from an artwork (possibly a shelf) old over 150 years, kindly provided by the Uffizi's restoration laboratory.

Both mock panels have been vapour-proofed with aluminium foil on the front face, simulating a protective varnish, and on the four edges to eliminate the border effects.



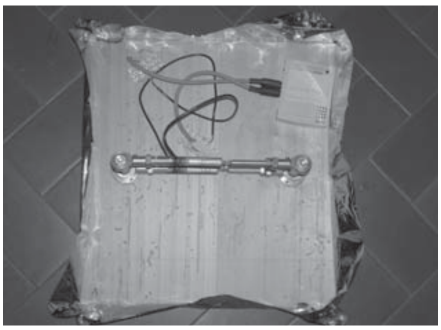
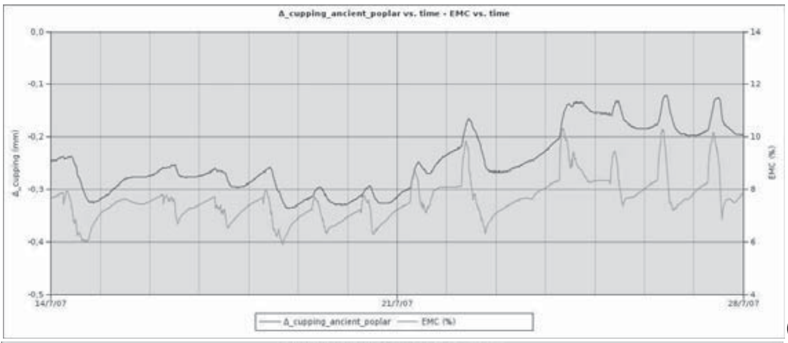
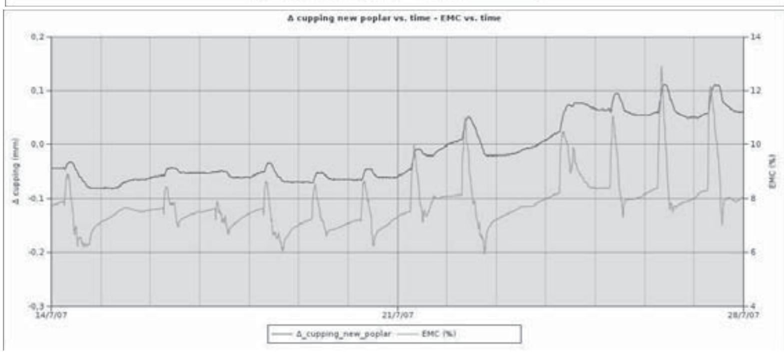


Fig. 6. The two mock-panel made of Poplar (*Populus alba*) wood, both are 300x300x30 mm in size, and have been vapour-proofed with glued aluminium foil on the front face and on the four edges. The N panel is made with "new" wood, the V panel with "Old" wood (over 150 years). The mechanical assembly, the ball joints allowing for self-adjustment during deformation, the blue transducers, and the data-loggers with their electrical connections, are clearly visible.

The mock-panels were put in two different locations in the *Sala dell'Ospizio*, (the "N" panel near a door facing the external open-air cloister, the "V" panel away from the drift's impact) and each of the two loggers monitored for the respective panel both the microclimate (Temperature and Relative Humidity of the surrounding air) and the deformations measured by the two transducers.
For data analysis the wood EMC (Equilibrium Moisture Content, derived from T and RH values) was adopted as a synthetic parameter to describe the microclimate. It should be emphasized that such EMC is not the actual MC (Moisture Content) of the wood, but just the equilibrium value towards which the wood's external layer tends, and that the whole board could approximately reach, if the climate remained identical during a sufficiently long time (approximately 2 months, for that thickness of Poplar wood).
Some initial results from the monitored data are shown in Fig. 7 and Fig. 8. At a first glance, the behaviour of the two panels is quite similar, although some individual differences become more evident at a deeper examination. The comparison with the original painting, exposed to the same climatic variations, will be of the utmost interest.
The processing and analysis of collected data is under way, in cooperation with the LGMC equipe, from Montpellier.

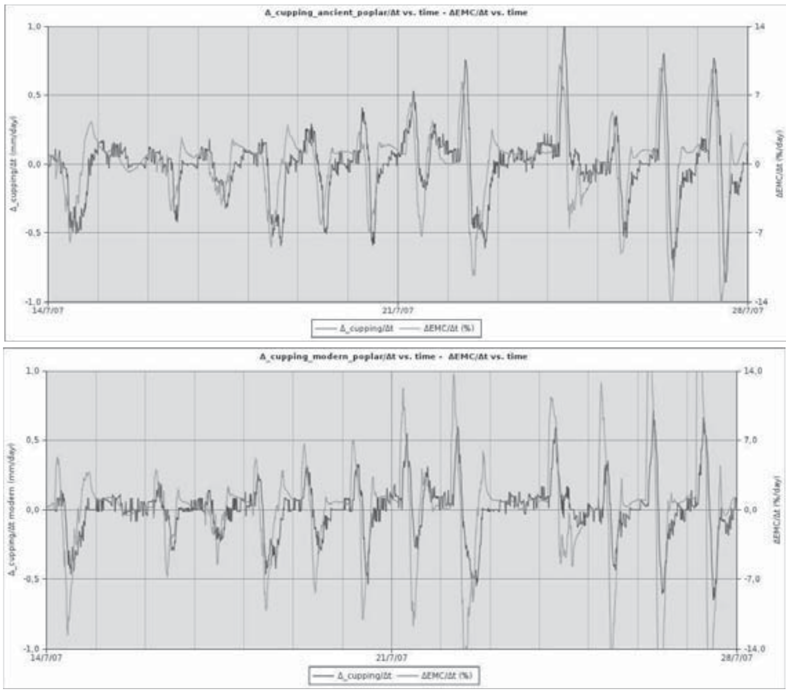


(V)



(N)

Fig. 7. Some initial results obtained from processing the recorded data. Purple lines indicate the variation in time of the EMC (%) of the surrounding air (scale on the right), blue lines variation of the camber (mm) of the cupping of the board. – A few comments: the daily variation of the climate is clearly visible in all graphs; variation of air EMC is very similar for both locations, although the one in front of the door shows larger excursions (distance between the two locations is approximately 10 m); deformation reacts promptly to climatic variations; the deformations of the "V" panel are larger, although it is located far from the door.




(V)

(N)

Fig. 8. Some more initial results obtained from processing the recorded data. Purple lines indicate the *instantaneous* variation in time of the EMC (Δ%/Δt) – with Δt very small – of the surrounding air (scale on the right), blue lines indicate the *instantaneous* variation of the camber (Δmm/Δt) of the cupping of the board. Though the response between the two panels is not significantly different, the ancient panel shows a more nervous variation to smaller humidity variations in comparison with the modern one.

## 5. Conclusions

All WCHOs differ one from each other for many reasons, including their physical-mechanical peculiarities, state of conservation, and past climatic history. Evaluating their individual sensitivity to actual exhibiting or storage conditions can provide a very useful support for decisions which need to be made for their optimal conservation, whereas the adoption of "standardized" criteria can be misleading and can lead to further conservation problems, even when storage or exhibition takes place in a climate controlled case.

Monitoring of deformations of wooden supports, in parallel to the climatic conditions producing them, can give useful information for the best understanding of unique artworks, and can provide to the conservators objective criteria for choosing the best environmental conditions.

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