Structured light scanning as a monitoring method to investigate dimensional changes due to climatic changes on cultural heritage

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For the long-term preservation of cultural heritage items, stable climate conditions are necessary. As in the future indoor temperatures will rise due to climate change, chemical reactions take place much more quickly. At the same time, however, relative humidity decreases, which can cause damage, especially in the case of objects consisting of organic composite materials. As reactions to changes in climate depend very much on the surrounding circumstances, on past climate patterns, and on the preservation history of an object (conservation treatments, changes in location, etc.), it is very difficult to forecast future damage to cultural heritage objects that might be caused by climate change.

Comparable damage patterns can be found on cultural heritage items, which have been subjected to the unfavorable climatic conditions over a longer period of time. This is usually due to excessive use, e.g. numerous events or conversion of cultural heritage items. This usually leads to inappropriate climatic conditions such as too high temperatures, too high or too low relative humidity, too high climatic fluctuations. Depending on the strain and the exposure time of the prevailing climate, this usually results in the appearance of cracks, loosening and loss of surfaces.

With the help of structured light scanning, it is possible to analyze the historic surfaces in detail and correlate the observed changes with climate measurements. This helps not only to conduct high-resolution monitoring, but also to carry out individual risk analysis for cultural heritage objects. Three case studies with different composite materials and questions will be used to demonstrate the potential of surface monitoring with structured light scanning: the effect of climate change on the baroque leather panels in Moritzburg Castle, the impact of the conversion of the former Dominican Church of St. Christopher in Bamberg on the medieval wall paintings and monitoring of the moistening of an anthropogenically damaged wooden panel painting in Freising Cathedral.

Climatic fluctuations have a different impact on artworks depending on their material properties and thickness. Artworks such as a panel painting usually consists of different materials and layers (e.g., priming, several color layers, coating), and each one reacts differently regarding swelling and shrinking. The divergent behavior of each layer can cause stress inside the composite material (BRATASZ 2013, ERHARDT 1994, LUKOMSKI 2012, MECKLENBURG 2010). Both short- and long-term fluctuations of temperature and relative humidity have an impact on artworks: Short-term fluctuations, which occur on an approximately daily cycle, will affect the surface more, especially when there is already damage present. Fluctuations, which occur over a longer period, will also affect the inner layers and the support. Therefore, depending on the frequency and amplitude, climatic changes can cause a variety of damage, such as deformation or cracking of the support or loosening of the surface. Thus, the question of which climate fluctuations are still safe for the exposed objects can be very complex.

Due to the individual manufacturing, object-, climate- and preservation history, each cultural heritage object reacts differently to changing climate. Therefore, the use of opto-technical methods for the in-situ investigation of the actual movement of cultural heritage items due to climate changes as the first indication for damage is a promising method to do an individual risk assessment. Here the analysis of the underlying (micro) climate is the key information for the interpretation of the data. Based on that an individual, sustainable concept to improve the climatic situation can be developed.

As an example the gilt leather panels in the hunting lodge of Moritz of Saxony from 1542, which was converted into a baroque palace under August the Strong in the 18th century are chosen. In order to show the extent to which even short-term or minor changes in the room climate causes deformation, the reference areas of leather panels which already show damage (deformation, tears, losses) are scanned several times and compared with each other with regard to the simultaneously measured climate (Fig. 1).

The location of the castle is known for its high temperatures, especially in the summer months. These high values also affect the indoor climate in the castle as there is no HVAC system installed. In summer 2020, high temperatures (Maximum: 29 °C) were recorded, the relative humidity falls below 40 % frequently. 25 % of the measured values are below 47 % RH; the minimum was 27.1 % RH (Fig 2).

The optic measurements have been conducted with a COMET L3D 5M structured light scanner (SLS) by Steinbichler Optotechnik. To examine the SLS data, two scans of the same surface are compared. In order to demonstrate how much the two scans deviate from each other, the software creates a colour-coded image illustrating the deviation. A dark green area means no change; areas, which are coloured light green (minimum) to red (maximum) indicate a convex warping has taken place, while colours from turquoise to dark blue indicate an increasing concave warping (Fig. 3).

Fig. 1. Examination of the leather panels in the Chinese room in Moritzburg Castle with the COMET L3D 5M. Next to it, the microclimate (surface temperature, relative humidity, and temperature) is measured (© Kristina Holl).

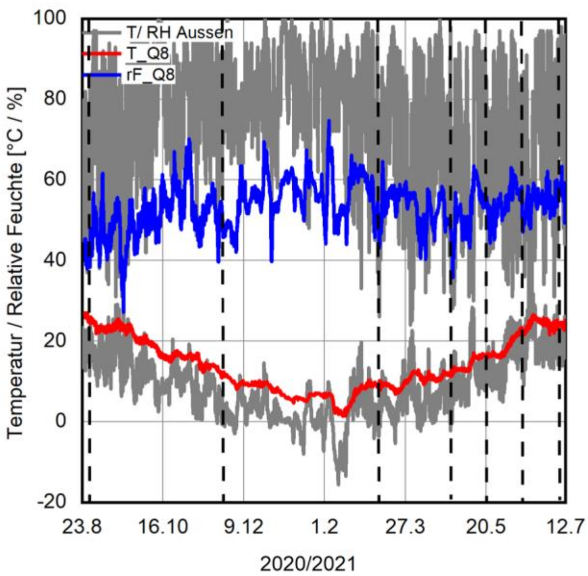

Fig. 2. Line diagram of relative humidity and temperature in Moritzburg Castle, Chinese room (blue and red) compared to the outdoor climate (grey) for the period from August 22nd 2020 till June 13th, 2021. The black dashed lines marked the times when the measurement campaigns were conducted (© Kristina Holl).

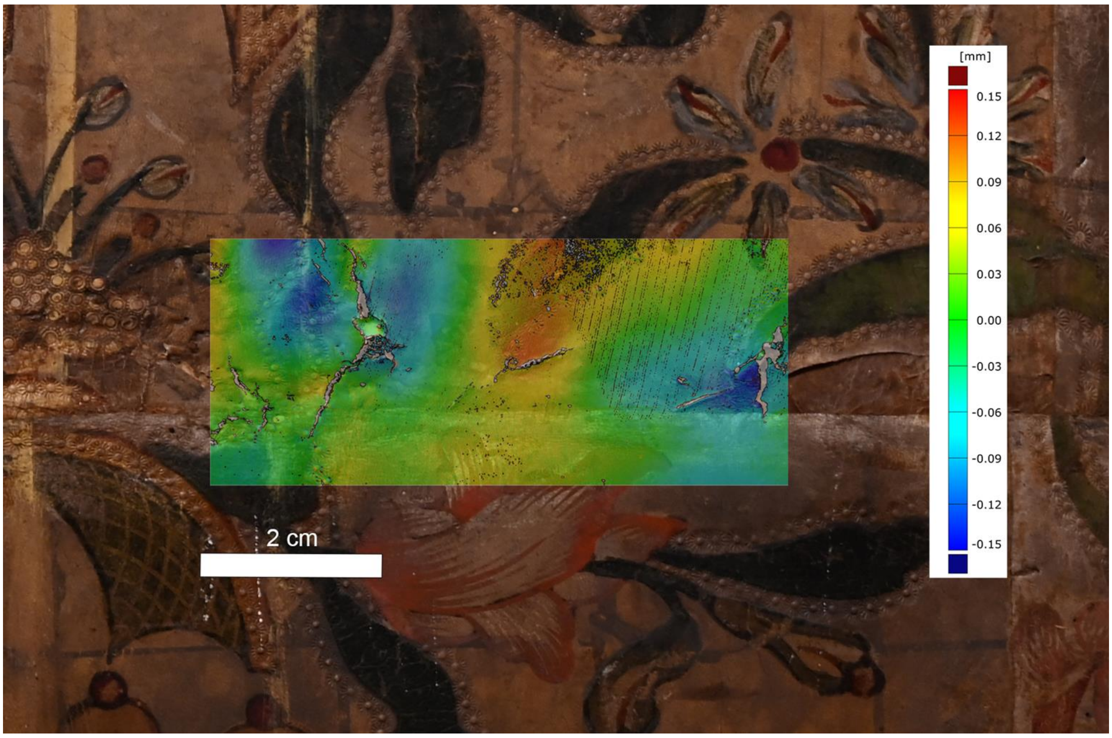

Fig. 3. The study area of leather panels in the Chinese room in Moritzburg Castle. Comparison August – October 2020. A clear shift of the leather is visible within the leather panel, especially in the already damaged surfaces (turquoise to dark blue: movement to the back, light green to red: movement to the front). The measurements were executed with a 30 µm resolution. Here a movement of about ± 0.27 mm is visible (© Anne Karl, Kristina Holl).

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