Development of a network-based climate monitoring system for climate assessment and regulation

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Abstract

In the cloister (the so-called Schwahl) of the St. Petri Cathedral in the German town of Schleswig, the current situation of the historical wall paintings was investigated in the context of a research project funded by the German Federal Foundation for the Environment (German: "Deutscher Bund für Umwelt" – DBU). The project is focused on the investigation of the intense salt contami-nation and its connections with the climatic situation.

In this context, a network-based climate monitoring system was installed and tested in 2016. The data is accessible online, which is more convenient and advantageous than conventional data log-ger records for long-term climate measurement and evaluation, which can only be accessed in situ. It allows direct response to critical climatic values by connected alarm, control and regulation systems. This way, measurements can be taken promptly thus preventing damage and high resto-ration costs. Previously, climatic data had been collected in the course of the research project since 2007, the comprehensive evaluation of which served as a basis for the setting of the pa-ram-eters for the new system.

Measurement data are transferred directly to an open-source based server in-

Figure 1: The Schwahl in Schleswig, exterior walls with the chronological depictions of Christ's life cycle

frastructure, which is scalable and ready for future requirements. Due to the data being directly available on the internet, it is possible to provide a minute-accurate climate monitoring in real-time. Thus, the evaluation of an arbitrary number of measurement locations and the analysis of local causes (events, weather changes) can be put into practice.

The system was conceived and tested for the requirements of the Schleswig Cathedral. It can also be used in archives, depots and churches and thus constitutes a reliable basis for climate monitoring.

Keywords: Climate monitoring, climate data, networking-based monitoring, preventive conservation, regulation systems

1. The cloister in the St. Petri cathedral at Schleswig

The St. Petri cathedral in the north German town of Schleswig is one of the most important medieval monuments of the federal state of Schleswig-Holstein. The church, which was mentioned for the first time in 1134, was extended on the north side by a three-winged cloister between 1310 and 1320 by order of Bishop Johannes II von Bockholt. The cloister is called "Schwahl" (Danish: Svalen) which means "semi-open passage". The 24 yokes of the Schwahl are opened towards the courtyard by pointed-angled windows. Small slits are integrated into the windows, so that the cloister is a permanently unheated, slightly ventilated room under the partial influence of the external climate.

The Schwahl has been used as a walkway for processions and shows polychrome paintings on the arches of the 24 yokes. The paintings represent fabulous creatures and are largely well pre-served. Moreover, the wall panels shown in the picture below are covered by paintings giving a chronological depiction of Christ's life cycle.

Figure 2: Application of desalination poultices

Figure 3: After the application of desalination poultices

2. Necessity for a network-based climate-monitoring system

Starting with a comprehensive restoration and conservation measure in 2007, the condition of the stock of the Schwahl had been continuously observed. Here, an accelerated accumulation of gypsum and hygroscopic salts was observed on the outer walls causing intense damage to the wall paintings. Consequently, several work campaigns have been carried out to address this problem since 2010. Among other measures, these included the reduction of the accumulations of gypsum and salt by the application of poultices (compare *figures 2 and 3*). The campaigns were accompanied by comprehensive analyses prior to and after the concerning measures.

Subsequently, the complex causes and conditions of the given damage processes are being in-vestigated within in the framework of a research project funded by the German Federal Environ-mental Foundation (German: Deutsche Bundesstiftung Umwelt (DBU) since 2016 (compare [2]).

The primary goal of the project was to investigate the modification of the properties of gypsum due to the interaction with highly soluble salts depending on the indoor and outdoor climate. Here,

besides long term changes in climate conditions during a period of several days and weeks, short term changes in the indoor climate could have a relevant influence on the damage process. Thus, for instance, opening the exterior doors for a longer period of time under certain weather conditions could cause an unfavourable change in the interior climate thus causing a temporarily accel-erated damage progression on the wall paintings.

Since this is a common problem affecting a great number of architectural monuments, appropriate measures need to be taken to deal with this issue. Conclusively, this gave rise to the development of a modular and reusable solution for a network-based and real time-capable climate monitoring system. Thus, a remote observation of the conditions in situ can be realised and proper advice can be given in real time. This involves automatic alarms based on guidelines derived for the individual object as well as a remote evaluation of critical situations. In doing so, the authors aim to provide a tool to si-

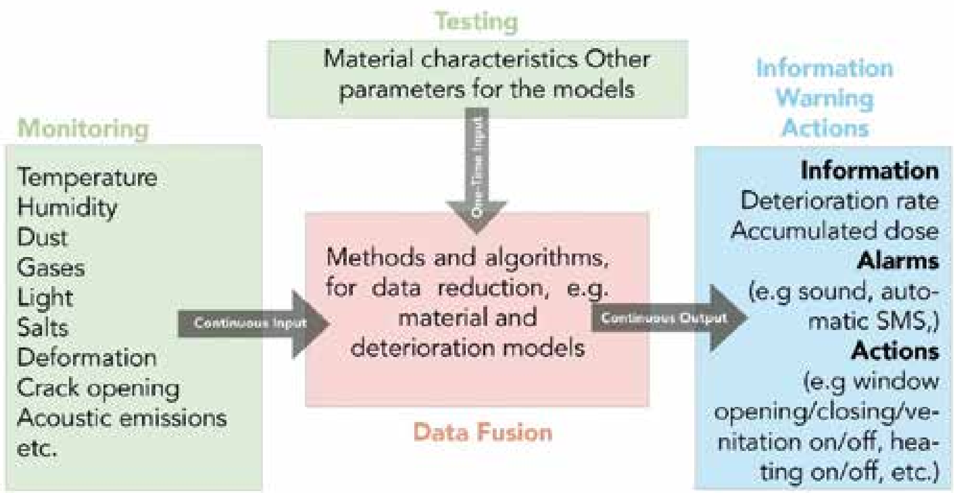

Figure 4: Principle sketch of intelligent monitoring and its integration in cultural heritage maintenance, based on [1]

Figure 5: Read the climate data from the Schwahl, via Mobilephone and PC.

gnificantly reduce the amount of damage caused by temporarily unfavourable climate conditions.

3. Development of a network-based climate monitoring – IMMOMON

Within the scope of the DBU project it was possible to develop a system for measuring and moni-toring the climate in real-time. This network-based climate monitoring system is named IM-MOMON (www.immomon.net) and was created by collaboration of restorers involved in the pro-ject and IT system architect Dirk Hoffmeister.

As an outcome of this cooperation, proper measuring locations, measuring intervals, holding time of the data, threshold values were determined based on the restorers‘ expert knowledge. Also, appropriate measures were derived to deal with alarm messages caused by critical climate condi-tions due to e.g. open exterior doors. The control of external devices (e. g. ventilation) can also be initiated by the system.

The climate data are measured with set intervals by sensors distributed in the monument, collected in a local data hub and then transferred directly to a secured internet server. In addition to the commonly requested data on room temperature and relative humidity, sensors for outside climate, etc. can be easily integrated into the system. Via authorized access rights clients can access their data in real-time.

Figure 6: Visualization of the measuring points on site, defective devices are displayed in real time (meas-uring point 5).

Finally, the read-out and evaluation of the climate data was usually carried out in an annual cycle prior to the installation of the network-based climate monitoring. Accordingly, the process of data evaluation becomes cumbersome and laborious due to the huge amount of data to be analysed. Furthermore, the association of the data to specific events (e.g. concerts, exhibitions, etc) and their effects on the climate becomes difficult this way. This issue can now easily be dealt with by regular evaluation of the data available in real-time *(figures 4 and 5)* on the servers.

4. Conclusion and outlooks

The recording and evaluation of the interior climate of historic buildings and historic items or art objects in exhibition or storage is a fundamental, preventive measure for preservation. Even costintensive interventions due to climateinduced damage processes can be avoided by characterisation of the climate profile and development of corresponding restoration recommendations.

Here, IMMOMON can provide a significant contribution. Thus, the network-based measurement, control and warning system saves the necessity for regular control in-situ and allows for immedi-ate response to irregularities or unfavourable climatic situations.

More information on the network-based climate monitoring can be found on www.immomon.net.

References

[1] ReMonitoring of historic structures, project smoohs, p. 17, www.smoohs.eu

[2] Project 3216945: The historical paintings in the silt of St. Peter‘s Cathedral in Schleswig: investigations on the conversion, mobilization and recrystallization of gypsum on heavily salt-laden ground