Preventive conservation of historic structures and artefacts by intelligent wireless sensor networks

Markus Krüger*, H. Pongratz*, T. Mülleder*, P. Lovric* and J. Willeke†††
* TU Graz – Institute of Technology and Testing of Building Materials (IMBT)
Inffeldgasse 24, 8010 Graz, Austria
e-mail: krueger@tugraz.at, e-mail: helmut.pongratz@tugraz.at,
web page: http://www.tvfa.tugraz.at
††† TTI GmbH – TGU Smartmote
Nobelstr. 15, 70569 Stuttgart, Germany
e-mail: willeke@smartmote.de
web page: http://www.smartmote.de

Keywords: *preventive conservation — wireless sensors — deterioration risk assessment — environmental guidelines for museums*

CHNT Reference: Stéphane Hury, Louis Vernhes, Stéphane Hury, Viktoria Ackerl, Markus Krüger, Helmut Pongratz (2020). `Decision needs and strategies´, SensMat Deliverable D6.1. Technical report provided within the Horizon 2020 project SensMat (No. 814596), www.sensmat.eu

Introduction

Within the project SensMat[1], which is funded by European Union's Horizon 2020 research and innovation programme under grant agreement No 814596 the area of preventive conservation of artefacts but also historic structures by applying wireless sensor systems is raised to a new level of networked systems. This applies not only to the networking of self-sustaining sensors and their sensor data, but also to the networking and utilization of relevant information for the building or artefacts condition assessment. One main outcome of the project is the further development of existing components in the interaction of the various systems for exemplary application scenarios and their integration into a cloud-based, scalable, but also highly efficient and interoperable system.

The starting point for further developments was provided by the existing technologies of the involved partners, which is a wireless sensor system originally developed by TTI GmbH – TGU Smartmote and further improved by TU Graz and Smartmote. In order to obtain information relevant to a predictable risk assessment of historic structures and artefacts, analysis and prognosis procedures have been further developed, adapted and evaluated with the aim of on-site data cleansing and simultaneous data reduction and data fusion. Data models as well as analysis tools were developed and integrated into an interoperable software framework. The latter enables the status information to be displayed in the form of a georeferenced digital twin via web user interfaces.

[1] SensMat project details: https://www.sensmat.eu

Wireless sensor network system

Within the SensMat project three different types of sensor systems were developed, of which one is an IoT ready wireless multi-sensor platform with wireless data transfer using battery powered low cost sensor nodes for continuous monitoring (RH, T, UV/light/IR, VOC, TVOC; particulate matter/dust, shock/vibration) with active control/alarm functionality. Figure 1.a) shows an example of wireless sensor developed within the project. Figure 1.b) shows a sensor, which was developed by Smartmote outside the SensMat project. It was designed to withstand harsh environments so that it can be used outdoors.

a) b)

Fig. 1. a) conventional thermohygrograph (left) and wireless sensor (right) for RH/T and corrosion risk assessment within museums; b) outdoor wireless sensor for inclination and RH/T measurement at a historic column (© Markus Krüger).

Figure 2 shows the monitoring system overview and the different components required (e.g. wireless sensors, gateways and servers that run different software).

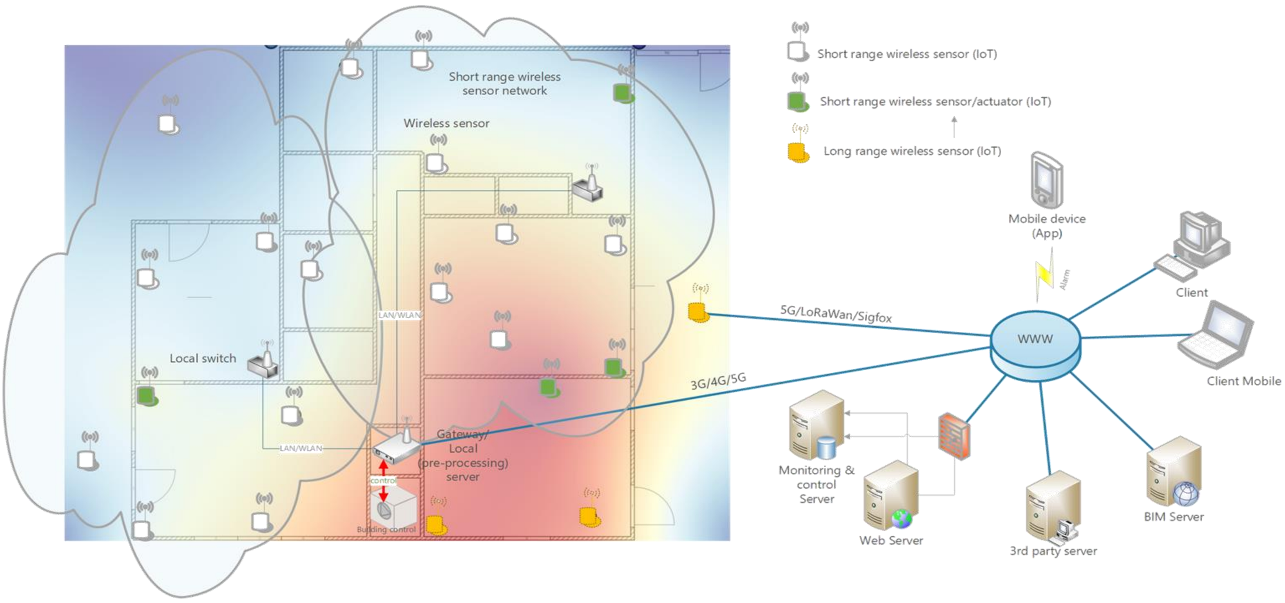

Fig. 2. System overview of the wireless monitoring system (© Markus Krüger).

Software framework for data visualisation, risk assessment, alarming and reporting

The risk assessment inside museums by using monitoring systems has to consider many different aspects and input parameters and complexity of system maintenance and data assessment increases with an increasing number of artefacts and sensors applied. To guarantee easy application and user satisfaction some essential issues to be considered are basic classification schemes of risk assessment, their basic mathematical operations and the graphical representation as well as a reporting tool that allows archiving the monitored data associated to the artefacts. The system must provide information that helps in decision making and that is more than just a database containing only time series of sensor data. Thus, for initializing any preventive conservation measure it is essential to take into account the following aspects:

- Building type (esp. building envelope) and location
- Type of indoor environment control (e.g. natural ventilation, HVAC etc)
- Usage of the building resp. rooms (exhibition, depot etc.): the usage determines the proposed environmental conditions because a compromise must be found between visitors well-being, artefacts conservation strategy, environmental control systems, building type, energy efficiency etc.
- Sensitivity as well as significance of the artefacts
- Outdoor weather conditions (daily and seasonal variation); thus, preventive conservation strategies and measures may be subject of change

A risk assessment itself can be made on building level, room level (showcase level), artefact level or point level. And it has to be noted that the different levels might be combined. Martens (2012) proposed two different risk assessment schemes, which are the

- general risk assessment resp. risk assessment on building level and the
- specific risk assessment resp. risk assessment on artefacts level.

The general risk assessment scheme evaluates the quality of the building and the corresponding climate system with respect to the desired and achievable environmental conditions inside the building/room. General risk assessment schemes are e.g. RH/T assessments according to ASHRAE or ICOM-CC or the assessment of TVOC, light etc. The building and building location may strongly influence the environmental indoor conditions not only with respect to climate, but also to light, vibration, pests etc. In this context Martens (2012) has defined different building envelope classes to describe the quality of the building envelope. Such a building envelope characterization is also implemented into the developed software framework.

Although the usage of the building/rooms is considered, it does not give detailed information on specific risks associated to the artefacts. This is done in the specific risk assessment, which considers also the different agents of deterioration and their damage risk to the artefacts resp. building or room. Specific risk assessments consider biological degradation like mold risk (Sedlbauer 2001) etc. or chemical degradation, e.g. by calculating lifetime multiplier (Michalski 2003) or by defining threshold level concentration of VOC, TVOC (Martellini 2020) etc. Within the software framework developed by the authors, such general and specific risk assessment schemes can be applied and associated to the different levels (from building down to artefact level). The assessments are visualized in form of dashboards containing analysed sensor data from the collected time series or directly by visualizing status information and alerts in a customizable map, showing e.g. the floor of a building with rooms, artefacts etc. (see figure 3).

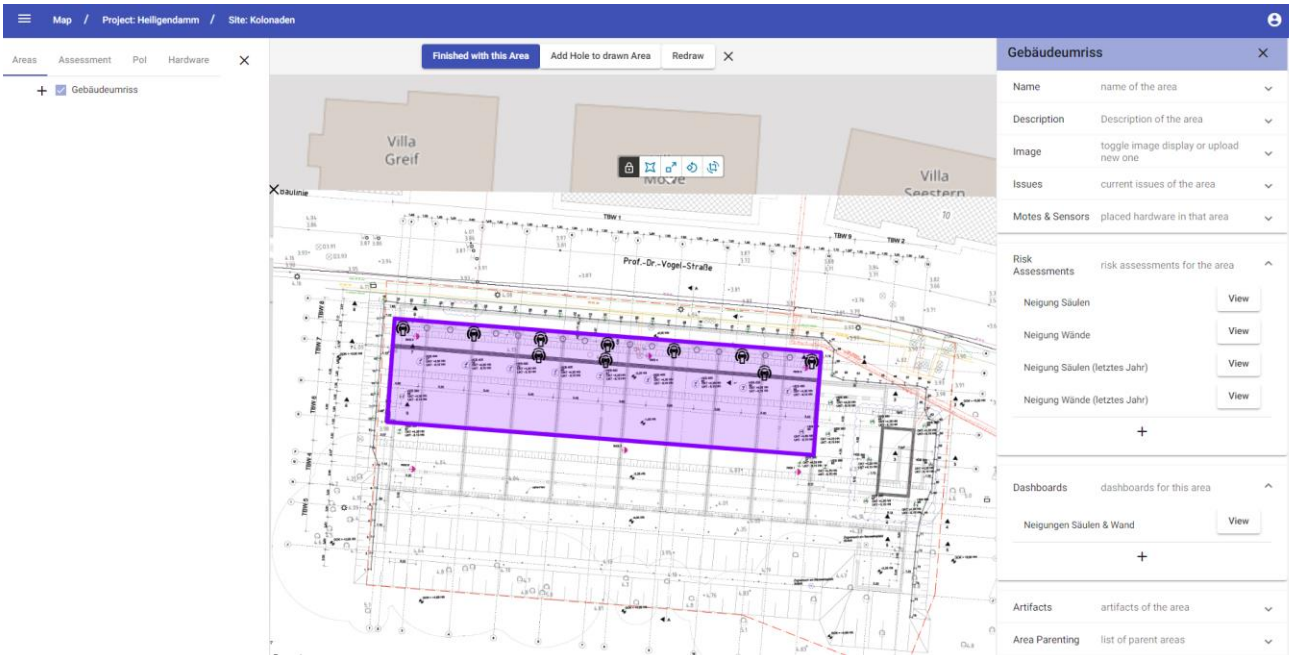

Fig. 3. Software framework with graphical web user interface for data visualisation and risk assessment (© Markus Krüger).

Outlook

Actually the wireless monitoring system is applied and further evaluated in several museums within the SensMat project (incl. Landeszeughaus Graz and Depot of Universalmuseum Joanneum, Graz). Demonstration can be offered on request.

References

Martens, M. H. J. (2012). Climate risk assessment in museums: degradation risks determined from temperature and relative humidity data. Technische Universiteit Eindhoven. https://doi.org/10.6100/IR729797 .

Sedlbauer, K. 2001. Prediction of mould fungus formation on the surface of and inside building components. Fraunhofer Institute for Building Physics.

Martellini, T; Berlangieri, C; Dei, L; Carretti, E; Santini, S; Barone, A; Cincinelli, A. (2020): Indoor levels of volatile organic compounds at Florentine museum environments in Italy. INDOOR AIR Volume: 30 Issue: 5 Pages: 900-913 DOI: 10.1111/ina.12659

Mecklenburg, M. F., Tumosa, C. S., & Erhardt, E. 1998. Structural response of painted wood surfaces to changes in ambient relative humidity. Painted wood: history and conservation: 464-483. Los Angeles: Getty Conservation Institute.

Michalski, S. 2003. Double the life for each five-degree drop, more than double the life for each halving of relative humidity, ICOM committee for conservation, 13th triennial meeting Rio de Janeiro preprints vol. 1, pp 66-72.