Design of a monitoring, alert and control system for indoor exhibition spaces

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Design of a monitoring, alert and control system for indoor exhibition spaces

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Abstract. The environmental parameters (temperature, relative humidity, UV factor, light intensity and others) of an indoor exhibition space must be monitored and controlled in order to ensure proper conditions for artifacts' preservation. This can be done by a monitoring, alert and control system (MACS) consisting of a sensor network, a communication infrastructure and a central processing device. Data are measured and collected by sensors, sent by the communication network and, finally, stored and processed into the central node (NC). Based on the analysis of data, decisions are made, alerts are sent to the responsible personnel, by short messages to the mobile phone or by email, and commands are sent to the actuators in order to turn on the environmental control devices (air conditioners, heating or light control devices and others). The goal of MACS is to provide efficiently and economically a stable quality of the indoor exhibition environment. A case study is done for an exhibition room from the Metropolitan Museum of Iasi.

1. Introduction

Indoor exhibition spaces must have constant environmental parameters in order to preserve the exhibited artefacts (oil paintings on wood or canvas, textiles, old books and other kinds).

Indoor environmental conditions depend on time (night/day), on season (spring, summer, fall, and winter), day hour and so on.

The environment monitoring process is necessary to identify specific climate events like high temperature or high relative humidity (RH) that can affect irreversibly the exhibited objects [1]. Alerts should be created in these cases in order to command the environmental control system that turns on or off the specific devices such as heating, cooling or dehumidification devices.

The preservation of textile artefacts, in particular the ecclesiastic ones, requires specific climate conditions that can be ensured by using a monitoring, alert and control system (MACS) to control the environmental parameters.

This paper is intended to design the MACS for one exhibition room of the Metropolitanate Museum of Iași, so-called "Baptistery".

The system is composed by the monitoring wireless sensor network described in the second paragraph, the data processing (DP) device used to identify potential events and to create alerts (presented in Section 3) and the environmental automatic control system that is the subject of Section 4.

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2. Monitoring wireless sensor network

A wireless sensor network (WSN) is used to measure periodically the environmental parameters, temperature, relative humidity and light intensity, of the indoor exhibition space [2].

The WSN has to be designed based on the space size and shape. The number of sensors is chosen depending on the particularities of the space, not only its size. The central node of WSN has to be placed in a way that does not disturb the esthetics of the room [3].

"Baptistery" room of the Metropolitanate Museum of Iași was chosen as our study case for MACS design (Figure 1).

Figure 1. Photo of the Baptistery Room.

This is a round room, with a flower shape, placed underground, with a round window on the ceiling for lighting. Therefore it is not necessary to control the natural light intensity. In the same time, it has an increased relative humidity (RH) inside of it but the temperature variations are reduced.

The space is vaulted being sustained by eight columns and it has fourteen apses used for exhibition purposes.

In each apse, a sensor that measures the temperature and RH has to be placed, down on the floor.

The monitoring WSN designed for this room consists of 14 identical sensors, placed equidistantly on a circle, with a diameter of about 20 meters, and the radio gateway that collects data from the sensors and sends it to the data processing (DP) device, placed outside the exhibition room.

The WSN gateway is placed on the wall, near the access door of the room. The gateway is connected to the controller that sends the configuration parameters to the sensors, including the sensor identifiers and current time, and keeps tracks of the most recent transmitted data and the status of sensors and actuators. A simplified sketch of the monitoring WSN, designed for the Baptistery room, is presented in Figure 2.

Digital Humidity/Temperature Sensor (DHT) autonomous sensors are recommended. For our project, small size, low consumption and long transmission distance (20 meters) sensors RHT05 were chosen.

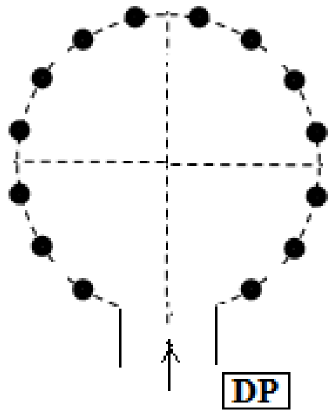

Figure 2. WSN sketch for the Baptistery Room.

The communication between the sensors and the gateway is done by a WiFi transceiver with a PCB antenna [4].

Each sensor and the associated transceiver are placed on a development board, for example Arduino or Raspberry Pi, inside a plastic case of a few centimetres. This small, inexpensive computing hardware is the hardware solution that combines sensors, microcontrollers or processors, wireless transceivers, tiny batteries and some diagnosis LEDs.

Small size coin batteries provide the energy needed for measurements and data transmission. The battery lifetime depends on the battery type and capacity and on the sensor energy consumption that is increased during the measuring process and reduced while the sensor is idle or sleeping. Measures are scheduled to be done hourly because the environmental control cannot be done too fast. Using high-capacity batteries, their lifetime can be up to two years [5].

3. Data processing and alert system

The data got from the sensors are recorded in a database and processed in order to find critical values of the environmental parameters [6].

The measured values are compared to the reference values that are optimal for the exhibited objects.

For example, for textile-based artifacts the optimum temperature should be between 20^{0}C and 24^{0}C and the relative humidity should not exceed 45% [7].

At a time point, a set of values is recorded but each value can start an environmental control procedure if it represents a critical value, out of allowed bounds.

In the considered "Baptistery" room, the temperature and relative humidity values have been measured for the entire 2018 year when no automatic MACS was used.

The temperature had a smooth variation of about 3 ^{0}C amplitude during a day, the room being well thermal isolated by the ground.

The temperature values depend significantly on the season, a heating system being required for the winter when the indoor temperature goes down to 16 ^{0}C and a cooling one for the summer months when the inside temperature reaches 26 ^{0}C. The temperature can be easily controlled from outside the exhibition room, through the ventilation channels placed inside the columns.

The relative humidity has large variation amplitudes so some dehumidifiers (DH) are needed.

Collected data about indoor RH is processed regarding the maximum, minimum and average values, standard deviation and monthly amplitudes (Figures 3, 4, 5, 6). The maximum recorded RH value was 83.5% but the maximum values of RH exceed the allowable value almost all year round. More than that, even the minimum values exceed the RH admitted value during summer.

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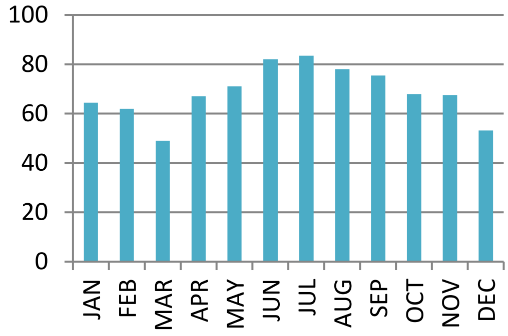

Figure 3. Maximum values of RH (%).

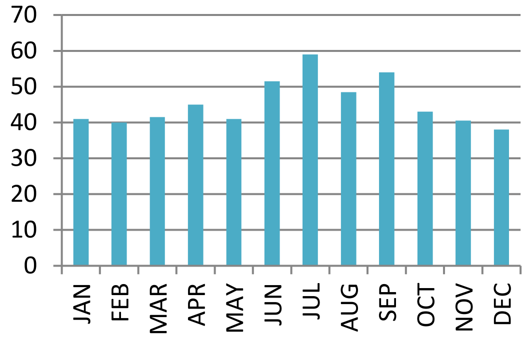

Figure 4. Minimum values of RH (%).

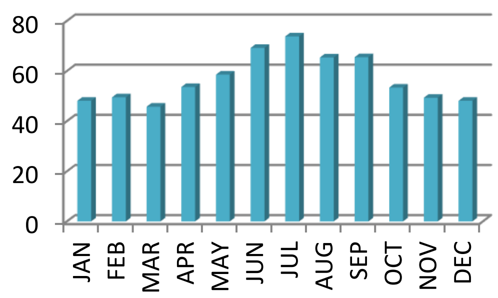

Figure 5. Average values of RH (%).

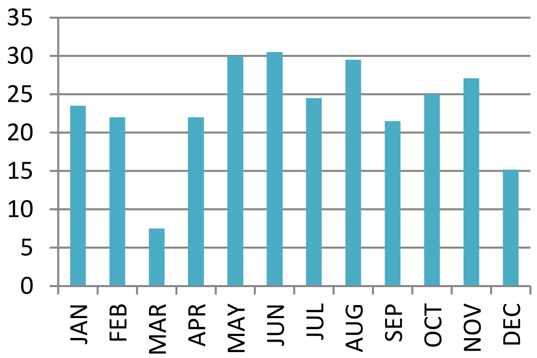

Figure 6. Variation amplitudes of RH (%).

The RH monthly variation amplitudes are high but the daily RH variations are only about 1-2 %, so a single dehumidifying system can control the indoor RH level.

Looking at the RH behavior of the analyzed space, it is strongly recommended that an automatic MACS to be used in order to preserve the exhibited artifacts.

The designed MACS, collects a set of 14 values of each environmental parameter, at one measure time point. All these values are compared to some thresholds (minimum or maximum, depending on the parameter time), in real time, in order to action the indoor environmental control devices.

A silent alert must be produced each time a threshold is overrun. The alert signal can be a visual one, like a flash light or a written message, on a display of a computer or of a mobile device used by the surveillance staff.

4. Environment automatic control system

An environmental control system must be started automatically each time a parameter is out of bounds [8].

This system must not interfere with any security device used in the exhibition space [9].

The data processing (DP) device acts as a controller that commands the actuators of the control system in order to turn on the air conditioning devices for temperature regularization and the dehumidifier for RH reduction.

The volume of the monitored room is an important parameter needed to choose properly the environmental control devices.

Relative humidity is highly dependent on the air temperature. When the temperature is decreased, the air pressure is modified resulting in the variation of RH. For example, if the RH is 32% at 30^0C in a room, then when the temperature decreases to 15^0C and no room ventilation is made, the RH rises to 78%. So, it is important to have small temperature variations, almost constant temperature, by heating the room during cold sessions using heating devices controlled by the system.

For the Baptistery room, the dehumidification system must be able to process at least 3000 cubic meters that corresponds to 3615 kilos of air at 20^0 C. If one percent of this air mass is represented by water vapors, then the dehumidifier has to eliminate 36.15 liters of water in order to reduce the absolute humidity by 1%. A high capacity professional dehumidifier has to be used in order to reduce the RH by 10 - 20% per day. The fan of the dehumidifier must have a high speed in order to process an increased volume of air per hour (for example, 1000 cubic meters per hour).

During the visiting time, RH is increased because each person produces air humidity by breathing, approximately three liters of water per day or 121 cubic centimeters per hour. So, if 100 persons visit the museum for one hour, 12 liters of water vapors are produced by breathing inside the exhibition room. Therefore, some limits for the visiting time, the number of visitors per day and the number of simultaneously visitors must be imposed according to the dehumidifier capacity.

In the same time, the dehumidifier must be a low-noise system because it is used in a museum. It is recommended that the dehumidifier noise level is less than 60 dBA corresponding to the normal conversation audio level in order to be used all the time. If it produces an increased noise level, then it can be used only outside of the visiting hours.

By dehumidifying automation, the RH is maintained in some limits and the electrical energy consumption is optimized.

5. Conclusions
In order to preserve the exhibited artefacts in indoor spaces, in particular textile-based objects, the environmental parameters (temperature, relative humidity and others) must be maintained with almost constant values that fall within optimal limits. This can be done by using an automatic monitoring, alert and control system (MACS), properly designed for the exhibition space. An exhibition room of the Metropolitanate Museum of Iași is studied in this paper and a solution for indoor environmental conditioning is presented. The proposed MACS includes a wireless sensor network with radio transceivers and a central gateway, a data processing unit that commands the environmental control devices chosen specifically for this room.

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