



An energy-efficient internet of things (IoT) architecture for preventive conservation of cultural heritage



Angel Perles^{a,*}, Eva Pérez-Marín^d, Ricardo Mercado^a, J. Damian Segrelles^e,
Ignacio Blanquer^e, Manuel Zarzo^c, Fernando J. Garcia-Diego^b

^a Instituto ITACA, Universitat Politècnica de València, 46022-Valencia, Spain

^b Department of Applied Physics, Centro de Investigación Acuicultura y Medio Ambiente ACUMA, Universitat Politècnica de València, 46022-Valencia, Spain

^c Department of Applied Statistics, Universitat Politècnica de València, 46022-Valencia, Spain

^d Instituto Universitario de Restauración del Patrimonio, Universitat Politècnica de València, 46022-Valencia, Spain

^e Instituto de Instrumentación para Imagen Molecular (I3M), Centro Mixto CSIC-Universitat Politècnica de València, 46022-Valencia, Spain

HIGHLIGHTS

- IoT architecture proposal specific for Heritage Preservation need.
- Sensor node life-span of 20 years without battery replacement.
- Wireless technology based on subGHz bands capable of passing through tick walls.
- Stand-alone sensor based on Sigfox for direct connection to the cloud.
- Evaluation done for typical RH and temperature monitoring needs and based on Italian, European and American standards.
- All kind of artwork containers covered: single isolated artwork, typical artwork containers (museums, churches, etc.), power supply constrained sites (open-air archaeological sites, etc.).

ARTICLE INFO

Article history:

Received 8 February 2017

Received in revised form 29 May 2017

Accepted 27 June 2017

Available online 26 July 2017

Keywords:

Cultural heritage

Preventive conservation

Internet of things

ABSTRACT

Internet of Things (IoT) technologies can facilitate the preventive conservation of cultural heritage (CH) by enabling the management of data collected from electronic sensors. This work presents an IoT architecture for this purpose. Firstly, we discuss the requirements from the artwork standpoint, data acquisition, cloud processing and data visualization to the end user. The results presented in this work focuses on the most critical aspect of the architecture, which are the sensor nodes. We designed a solution based on LoRa and Sigfox technologies to produce the minimum impact in the artwork, achieving a lifespan of more than 10 years. The solution will be capable of scaling the processing and storage resources, deployed either in a public or on-premise cloud, embedding complex predictive models. This combination of technologies can cope with different types of cultural heritage environments.

© 2017 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Modern societies tend towards a globalized world with many challenges. One priority is to defend and promote the particular aspects of native cultures in each region and country. Culture is expressed in multiple ways such as art, linguistic aspects or architecture. Cultural Heritage (CH) has an important value that must be promoted and safeguarded for future generations, because

the deterioration or destruction of artworks is a serious loss that cannot be recovered in many cases. Also, CH is a source of wealth as it promotes tourism, creative art and native culture. Millions of tourists choose their destination every year based on the artistic and cultural interest of the places visited, such as monuments, museums, exhibitions, historical villages, ruins, etc.

The protection and conservation of CH is an issue of particular interest because every artwork undergoes certain deterioration with time. Such degradation depends on the type of material, the action of external weather conditions and human factors. The ideal is to keep artworks under stable and controlled climatic scenarios, which should be properly monitored and registered, but such conditions are often achieved only in museums.

* Corresponding author.

E-mail addresses: aperles@disca.upv.es (A. Perles), evpema@crbc.upv.es (E. Pérez-Marín), rmercado@itaca.upv.es (R. Mercado), dquilis@dsic.upv.es (J.D. Segrelles), iblanque@dsic.upv.es (I. Blanquer), mazarcas@eio.upv.es (M. Zarzo), fjgarcid@upvnet.upv.es (F.J. Garcia-Diego).

The use of controlled atmospheres can be necessary in some cases in order to avoid oxidation (e.g., the Turin Shroud or the US Declaration of Independence). Light-sensitive artworks also require special environments. Nevertheless, in most cases, reasonable conditions are achieved with an appropriate control of temperature and relative humidity (RH) [1]. As a previous step for deciding the best alternative for a microclimate control system, it is necessary to record and monitor the ambient conditions around artworks, particularly in the case of historical buildings. This approach is useful to assess deterioration risks and evaluate the susceptibility of any artworks kept in these places.

As the effects of ambient conditions on a given artwork are cumulative, it is necessary to record real-time measurements in order to detect as soon as possible unexpected harmful events or dangerous conditions, particularly in those places with risk of vandalism, robberies or accidents (e.g. water leaks), the on-line control of artworks would improve its safety and preventive conservation.

Remote monitoring of factors affecting the conservation state of artworks may improve their long-term preservation and promote the value and enjoyment of CH for future generations. According to the current technology, remote monitoring is mainly based on the Internet of Things (IoT) paradigm, where a “thing” could be any type of artwork. An IoT approach for art conservation would involve the installation of small sensor nodes and gateways for data transfer to the cloud. The application of this IoT approach would allow on-line monitoring and continuous supervision of individual pieces, given the easy access from the cloud to data recorded from electronic sensors, improving its safety and preventive conservation.

Such systems would optimize resources and avoid expensive in-situ installations, allowing massive supervision of artefacts contained in museums, historical buildings, open-air archaeological sites, etc. Monitoring these conditions would allow a precise diagnosis of the key factors affecting art displays. This information is useful for restorers and curators in order to identify the zones or items with the highest deterioration risk, as well as to decide any actions to be implemented.

A team formed by experts in art restoration, climate monitoring, statistics, wireless technology, and cloud data processing from the UPV (Universitat Politècnica de València) has launched a project aimed at developing an IoT for CH. The multidisciplinary research team involved in the present research work has experience in microclimate monitoring of open-air sites like the ruins of Pompeii [2,3].

In most cases, given the particular requirements for the preventive conservation of pieces, it is necessary to design specific nodes for data transmission that should be able to efficiently monitor climatic conditions without for short-term maintenance. Therefore, the most critical issue for an IoT approach in CH is the appropriate design of nodes regarding power consumption and communication distances.

The typical IoT systems based on the ISM (Industrial, Scientific and Medical) band at 2.4 GHz are usually developed using available technology, but it cannot be applied to this context given the peculiarity of the sites to be monitored (i.e., thick walls, considerable distances, etc.). It is therefore necessary to apply particular technologies to be able to cope with these problems. The ITACA Institute has experience in the design of ultra-low power consumption miniaturized wireless sensors which have been successfully applied to recording conditions in buildings and wooden materials by means of hidden nodes; overcoming the above-mentioned adverse situations.

As the ideal technical solution does not yet exist, one of the targets of the present work was to develop and compare the our custom previous design and two leading options: LoRa [4] and

Sigfox [5]. Both LoRa and Sigfox are LPWAN (Low-power Wide-area networks) commercial designs for wireless sensorization which are being extensively used for the paradigm of smart cities. These proposals use the European ISM bands of 433 MHz and 868 MHz, and they have provided the best results in previous projects of our research group, hence, they were considered to develop our solution.

The different types of nodes evaluated in the present work span different environments for art conservation. The problems arising from an art display (or archaeological excavation, church, museum, etc.) with an electric power supply and Internet connection are different compared with isolated pieces, for example a statue in the middle of a city; and different to sites without power supply (archaeological excavation, isolated church, etc.). Such different scenarios are represented in Fig. 1, including our proposals discussed later.

In order to assess the performance of our proposal, the scenario elected was the Church of Santo Tomàs y San Felipe Neri in Valencia (Spain). Preliminary tests on the nodes' wireless operations were carried out at this Church and proved to be satisfactory. Then we evaluated the power requirements of the nodes for a standard monitoring problem of air temperature and humidity. As discussed below, the results suggest that it is possible to create a node with a life-span of more than 10 years using standard batteries.

Also, we designed a appropriate cloud infrastructure to deal with CH monitoring requirements. The proposal is based on criteria such as scalability, ease of deployment, openness and flexibility.

The article is structured as follows; the second section presents the related work of previous studies, detailing several examples. In the third section, we summarize the ideal requirements for an IoT for CH implementation. The fourth section describes in detail the proposed IoT solution for CH implementation. The fifth section is focused on assessing the performance of the proposed node from the point of view of radio communications and energy requirements. Finally, the main conclusions and future work are presented in Section 6.

2. Related work

Microclimatic control of museums is quite simple and effective; for example, in a room with paintings on canvas, the requirement is to ensure constant air temperature and humidity throughout the year, with the minimum daily and seasonal oscillations. But if pieces exhibited inside the room are made of different materials, microclimatic control is more complex, given the requirement to achieve specific conditions for certain art displays. In many cases, artworks are protected by hermetic display cases with a confined mass of air that may undergo dramatic RH changes in case of sudden temperature variations. Such oscillations could be extremely harmful for certain art series (e.g., paper is sensitive to relative humidity (RH) changes, though they can be attenuated by using inert buffering agents like silica gel).

In complex cases, pieces are kept under conditions between the most unfavourable case (i.e., open-air archaeological sites) and the optimum situation of a controlled environment in a museum [6]. Such intermediate situations corresponds for example to religious buildings, where the direct action of wind, rain or solar radiation is prevented, but generally it is not possible to control the hydro-climatic conditions [7–10]. Sometimes, it is even possible to deal with problems of rain leaks or condensation. In such cases, the monitoring of microclimatic conditions is important to assess the deterioration risks and to decide corrective actions.

In this context, it is important to monitor air temperature and RH in the long term to evaluate the state of conservation and assess the artwork vulnerability. In the short term, on-line monitoring can detect sudden unexpected situations that should be corrected

Download English Version:

<https://daneshyari.com/en/article/6873301>

Download Persian Version:

<https://daneshyari.com/article/6873301>

[Daneshyari.com](https://daneshyari.com)