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# The smARTS_Museum_V1: An open hardware device for remote monitoring of Cultural Heritage indoor environments

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ABSTRACT

This paper presents an easy-to-use, easy-to-customize, and low cost device for remote monitoring of Cultural Heritage environments such as museums, art galleries, and historical archives. The prototype allows measurements of temperature, relative humidity, and dew point. The chip used is an ESP8266 characterized by on-board Wi-Fi. The hardware design is flexible in order to host extra sensors via $I^2C$ bus and easy replacement of microcontroller and sensors in the event of either malfunctions or substitution with newer versions. The device is programmable using the Arduino IDE. The data are sent to an IoT platform that allows real-time visualization, analyses, and download. Tests were performed in laboratory and at the Casa de Convalescencia in Vic (Spain), by monitoring the microenvironment of an exhibition cabinet hosting 18th century ceramics. The results achieved are promising: the open hardware and software approach allows plan further implementations and provides a solid base for device customizations; in terms of technology applied to Cultural Heritage, the implementation of open hardware does not only can lower significantly the costs, but also provides scientifically reliable alternatives to off the shelf technology, as well as enhances end-users capability to develop customized devices that can better address specific needs.



Specifications table.

| Hardware name | smARTS_Museum_V1 |
|---|---|
| Subject area | General |
| Hardware type | Other: indoor environment monitoring |
| Open Source License | CC BY-SA 4.0 |
| Cost of Hardware | 13–22 € |
| Source File Repository | https://osf.io/6wg23/ |

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## 1. Towards a sustainable approach to technology applied to Cultural Heritage

Science and technology applied to Cultural Heritage experienced a progressive advance during the last decades [1,2] with a subsequent growing of the interest in analytical devices employed for the characterization and monitoring of a wide range of environments, materials, decay processes, conservation treatments, and preventive conservation in general. Nonetheless, such approach to high-tech devices largely depends on economic availability. These devices are not usually intended for artworks and artworks environments mapping, diagnosis and monitoring, thus implying additional costs for calibration and training purposes. Software copyright and hardware restrictions typical of industrial-oriented devices concur in affecting an economically sustainable approach to technology. Conversely, the recent proliferation of open-source and low-cost hardware and software, as well as the enhancing of digital accessibility to knowledge and expertise, is increasing the flexibility and capabilities in design and production of analytical devices [3–12]. An innovative bottom-up approach to technology is facilitating the worldwide diffusion of the "maker culture", with proliferation of hacker-spaces and fab-labs, even within the academic environment [3,13–17].

So far, the efforts towards a technological sustainable approach to Cultural Heritage conservation science have been addressed to a limited range of tasks. The design and implementation of low cost and – but not always – open hardware, generally focus on architectural monitoring by developing environmental data acquisition systems based on wireless sensor networks [18,19,21–23]; monitoring and survey [20,24]; museum environmental monitoring [25–27]. Often, devices based on sustainable technology concepts and designed for other fields of application, such as marine biology and biochemistry, or civil and environmental engineering, offer high degree of adaptability to be employed for monitoring and analytical task in the field of Cultural Heritage conservation science [8,28–31].

This paper presents the recent advance in designing, prototyping and experimenting low cost, easy to use and to customize, free and open source software and hardware devices for remote monitoring of typical indoor Cultural Heritage environments such as museums, art galleries, and historical archives. The smARTS_Museum_V1 device is the first prototype implemented within the smARTS-Smart Technology for Analysis and Monitoring of Cultural Heritage Materials project funded by the EU-Horizon 2020 research and innovations program (http://mon.uvic.cat/mecamat/smarts/). Likewise other monitoring devices, the smARTS_Museum_V1 allows to send the data collected to an open IoT platform that allows real-time visualization and analysis, as well as data download for further processing. However, the smARTS_Museum_V1 device differs from other Cultural Heritage environmental monitoring devices because is a free and open hardware and software device. On the one hand, its hardware architecture is modular and open, two features that allow full customization and further improvements that can be carried on by simply following hardware set up and guidelines provided as Supplementary material (https://osf.io/6wg23/). On the other hand, the use of the ESP8266 System on a Chip (SOC) as the device microcontroller (MCU) implies a further differentiation, as this MCU can be programmed by using several free and cross-platform development environments. This implies a higher level of freedom in programming, allowing both developers and end-users to choose the more appropriate - or user-friendly, programming environment. Moreover, the use of the ESP8266 is innovative, as it includes on board Wi-Fi, a feature that distinguishes this MCU from others commonly used that need additional Wi-Fi modules to be incorporated into the device architecture, which obviously not only would raise the price of the device, but also increases its final size, and needs a more complex programming. This first prototype has been design and developed to acquire temperature, relative humidity, and dew point data. Monitoring these data is mandatory in order to ensure a proper conservation of artwork collections, along with light [25,26,32–36]. Additionally, the device architecture has been designed flexible in order to host extra sensors, i.e. for UV, Visible and IR light measurement. In order to comply as much as possible with open hardware, Supplementary material are available at the Open Science Framework (OSF) online repository (https://osf.io/6wg23/).

## 2. Hardware description and methodology

The prototype proposed brings substantial benefits in terms of economic sustainability and analytical flexibility. The microcontroller, sensors, and electronic and assembling components selected, as well as the use of 3D printer for customizable cases, allowed prototyping a device that shows the following general characteristics:

- Low cost: 70–90% cost reduction if compared to proprietary devices (see Section 4)
- Customizable: easy replacement of components; easy to expand by adding additional sensors using free pins and $I^2C$ bus; easy to change and adapt the case shape and color to reduce visual impact in typical exhibition spaces
- Durability and low maintenance: low power consumption allows long-term functioning, so limiting maintenance
- Wi-Fi: remote data collection, and real-time visualization and management

The next sections describe hardware components used, highlighting general features, explaining technical choices, and, when available, providing web-based resources for developers.