

Improving User Experience of Cultural Environment Through IoT: The *Beauty or the Truth* Case Study

Angelo Chianese and Francesco Piccialli

Abstract Internet of Things (IoT) computing applied to the Cultural Heritage domain is an emerging discipline which consists of the application of intelligent sensors and technologies within cultural sites; it is strongly related to the development of systems able to be pervasive and ubiquitous with the definitive goal of rethinking such spaces. IoT paradigm can constitute a powerful tool to enhance people fruition and enjoyment of such spaces; thanks to ICT technologies, a cultural object can be effectively “dressed” of its context and juxtaposed into it. In this paper, an intelligent IoT system, designed with the aim of improving user experience and knowledge diffusion within a cultural space, is presented. The paper describes the hardware/-software system components, and presents a case study of a sculptures exhibition named *the Beauty or the Truth* (<http://www.ilbellooilvero.it>) in Naples where the system was deployed. Furthermore, the paper provides the results of an users behaviour analysis which revealed up a significant increase in user satisfaction and cultural knowledge diffusion.

Keywords Internet of things • Cultural heritage • Mobile systems

1 Introduction

Cultural Heritage represents a world wide resource of inestimable value, attracting millions of visitors every year to monuments, museums and art exhibitions. It has been playing an increasingly important role in the cultural fabric of society; in the current rapidly changing and globalization world, museum collections, ancient ruins, and artefact exhibitions represent at the same time sources and instruments of education that should to be available to a wide range of people. Indeed, to achieve

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a wide fruition of a cultural space and its objects that is effective and sustainable, it is necessary to realize smart solutions for visitors interaction to improve their experiences. In this context, new emerging technologies offer new opportunities and environments to create, exchange, discuss and disseminate cultural content. The adoption of Future Internet (FI) technology, and in particular of its most challenging components like the Internet of Things (IoT) and Internet of Services (IoS), can constitute the basic building blocks to progress towards unified ICT platforms for a variety of applications within the large framework of smart cities. IoT paradigm supports the transition from a closed world, in which an object is characterized by a descriptor, to an open world, in which objects interact with the surrounding environment, because they have become intelligent [5, 6]. Accordingly, not only people will be connected to the internet, but objects such as cars, fridges, televisions, water management systems, buildings, monuments and so on will be connected as well. Indeed, thanks to recent advances in miniaturization and lower cost of RFID, Bluetooth Low Energy, sensor networks, NFC, wireless communications, technologies and applications, IoT is gradually acquiring an important role in several research fields [7]. In this paper, we focus specifically to design an IoT system that is able to enhance the users' experience during a cultural visit within a smart environment, improving the related knowledge diffusion. Moreover, we present and discuss an useful case study of the proposed architecture, immersed in an art exhibition of sculptures, *the Beauty or the Truth*, located in Naples. The paper is organized as follows: Sect. 2 explains the background, Sect. 3 describes how IoT can be applied to the Cultural Heritage domain, Sect. 4 describes the case study. Finally, Sect. 5 concludes the paper with some considerations and future works.

2 Background and Related Work

In order to better understand motivations behind the design of the proposed IoT architecture supporting the development of a smart cultural space, it is important to deeply analyse the kind of relations that exists between such spaces and people. Accordingly, the behaviour of a person/visitor, when immersed inside a space and consequently among several objects, has to be analysed in order to design the most appropriate architecture and to establish the relationship between people and technological tools that have to be non-invasive. For this reason, it should be preferable to provide cultural objects with the capability to interact with people, environments, other objects and transmitting the related knowledge to users through multimedia facilities. In an *intelligent* cultural space, technologies must be able to connect the physical world with the world of information in order to amplify the knowledge but also and especially the fruition, involving the visitors as active players which offer the pleasure of perception and the charm of the discovery of a new knowledge. In the last months, the authors of this paper have experienced the design and the application of location-based services and technological sensors applied to Cultural Heritage environments (especially indoor), in [1–4]. These presented prototypes aimed to transfer

a *smartness* to cultural sites, applying different communication technologies and sensors. In addition, several papers and projects have been proposed, by using technological and multimedia facilities to enhance cultural items; since the promotion and the fruition of cultural heritage are probably the most interesting and useful applications of modern technologies. Accordingly, the authors in [8] stated that technology can play a crucial role in supporting museum visitors and enhancing their overall museum visit experiences; content and delivery must provide relevant information and at the same time allow visitors to get the level of detail and the perspectives in which they are interested. The authors in [10] propose a mobile recommender system for the Web of Data, and its application to information needs of tourists in context-aware on-site access to cultural heritage. In [9] the initial steps of a project aimed at creating mobile apps to facilitate the usability of museum visits for differently-abled and special-needs users are discussed. *DALICA* [11] is another agent-based Ambient Intelligence for outdoor cultural-heritage scenarios that it sends information about nearby points of interest from sensors, while in [13] the authors propose a general architecture of a SNOPS (Social Network of Object and PersonS) Platform and present a specific smart environment related to the archaeological site of Herculaneum. The authors in [12] present a first prototype of a wearable, interactive augmented reality (AR) system for the enjoyment of the cultural heritage in outdoor environments by using a binocular see-through display and a time-of-flight (ToF) depth sensor. In [14] a system, called SMART VILLA, based on a set of mobile applets, each interfaced with a NFC based subsystem, related to particular sites (SMART BIBLIO for ancient books, SMART ROOM for particular rooms and SMART GARDEN for surrounding historical gardens) is presented. The diversity of the mentioned methods and applications, highlights that in most cases, they remain isolated “exercises” and do not arouse effective interest due to the lack applicability and difficulty of reuse in different environments and scenarios. It is evident that, for improving users experience and knowledge diffusion, in all its forms and needs, there is the necessity of designing an integrated system following the IoT paradigm, that can be exploited and adapted to the different scenarios.

3 IoT and Cultural Heritage: Designing a Smart Exhibition

In this section, the architecture of an IoT system, the technological sensors immersed in the environment and the communication framework are presented. The sensors aimed to transform cultural items in smart objects, that now are able to communicate with each other, the visitors and the network; this acquired identity plays a crucial role for the smartness of a cultural space. Indeed, as stated in [15, 16], smart objects represent an important step on an evolutionary process that is affecting modern communication devices and has been triggered by the advent of IoT. Accordingly, in order that this system can perform its role and improve end-users cultural experience transferring knowledge and supporting them, a mobile application has been designed; in this way people have the opportunity to enjoy the cultural visit and be more at ease simply using their own mobile device.

3.1 The IoT Architecture

To describe the proposed system we resort on the three-layer architectural model for IoT presented in [17]. It consists of: (i) the sensing layer, which is devoted to the data transfer and acquisition, and nodes collaboration in short-range and local networks; (ii) the network layer, which is aimed at transferring data across different networks and applications; and (iii) the application layer, where the IoT applications are deployed together with the middleware functionalities. Figure 1 shows the resulting three-layer architecture. The three basic elements of the proposed system are: the CHIS (Cultural Heritage Information System) server, the gateway, and the sensor layers.

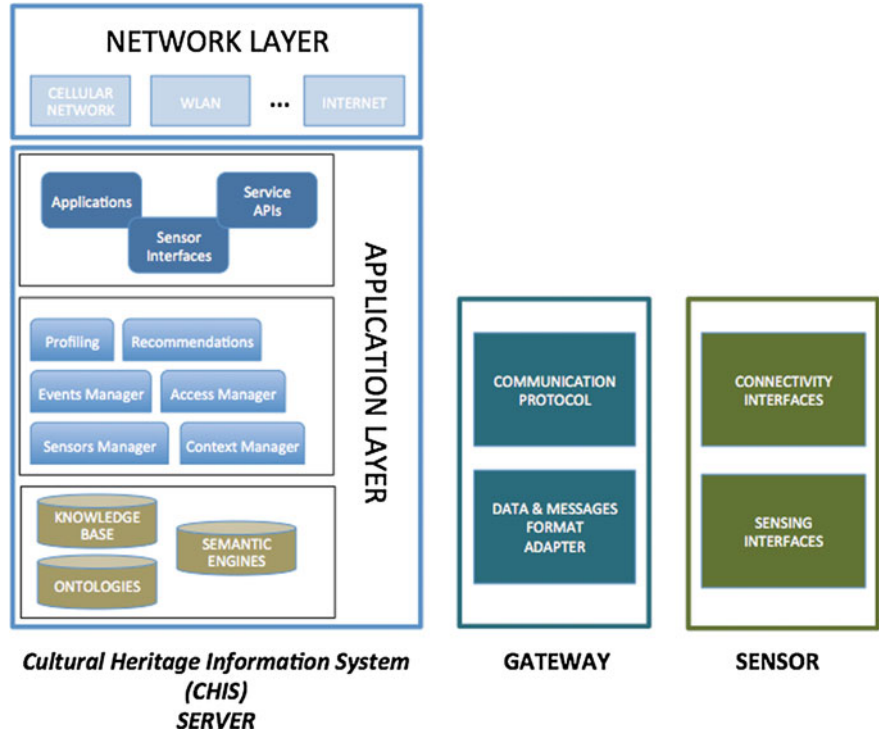


Fig. 1 A representation of the IoT architecture for a cultural space

CHIS Server As depicted in Fig. 1, the Cultural Heritage Information System server is composed by the Network and the Application layers. The Application Layer is modelled by three sub-layers. The first sub-layer includes (i) the knowledge base for the storage and management of the content, (ii) the ontologies used to represent a semantic view of the cultural heritage domain and (iii) the semantic engines used to provide a framework for representing functional and non-functional attributes and

operations of the IoT objects. The second sub-layer includes the instruments that implement the core functionalities of the CHIS system (Fig. 1).

Gateway and Sensor The *Gateway* module is enabled to manage the overall communication between the sensors and the CHIS server; moreover it is responsible to adapt and deliver the environmental data captured by the sensors. The *Sensor* module is aimed to provide the connectivity interfaces that enable the sensors functionalities according to the different types of sensor nodes.

According to IoT requirements, two types of sensor nodes are designed in order to make *smart* the cultural items inside a museum or an art exhibition.

- **SERVER node:** this type of node stores on board the content related to the items where it is placed and creates a Wi-Fi coverage area; the App automatically connects to this network and retrieve the content. Moreover, in absence of connectivity, this node can be equipped with a UMTS/GSM module, in order to manage the status of this node and communicate with the CHIS server.
- **SLAVE node:** this type of node can placed (i) near or on a single artwork, (ii) near a subset of artworks very close together; the user mobile device can be sensed by this node, since it creates a Bluetooth Low Energy surrounding area, and requests to the SERVER node transferring to the App the related multimedia content.

From a point of view of communication and interaction, the sensor nodes are equipped with the following features:

- **Discovering the neighbours:** A sensor node, thanks to a proximity technique using the Bluetooth Low Energy (BLE) protocol, is able to sense the neighbours SLAVE nodes; this feature allows any node to contextualize itself inside the space and enable mechanisms of content recommendations or visiting paths inside the cultural space.
- **Discovering the visitors:** A sensor node, thanks to a proximity technique using the Bluetooth Low Energy (BLE) protocol, is able to sense the visitors inside the surrounding area; this feature allows any node to present itself to an user and deliver to him multimedia content.

4 The Case Study: The Beauty or the Truth Sculptures Exhibition

In this section we present the case study, it consists of an art exhibition consisting of 271 sculptures, divided into 7 thematic sections and named *the Beauty or the Truth*. This exhibition shows, for the first time in Italy, the Neapolitan sculpture of the late nineteenth century and early twentieth century, through the major sculptors of the time. The sculptures are exhibited in the monumental complex of San Domenico Maggiore, in the historical centre of Naples.



Fig. 2 The main screens of the mobile application

4.1 Implementation Details

The proposed IoT system was entirely deployed inside the exhibition, as illustrated in Fig. 3. Each sculpture of subset of them were equipped with a sensor SLAVE node, while in each room was deployed one or more sensor SERVER node. In detail we deploy over than 70 SLAVE nodes and 10 SERVER ones. The mobile application, named *OPS Opere Parlanti Show* (the Talking Artwork Show) is currently available on the main smartphone app stores (see Fig. 2). Visitors can download and install it on their mobile device in order to start a novel visit experience. The multimedia collection is constituted by about 1500 images, 500 audio files (Italian and English languages), 300 video files and over than 1000 text files, all about the exposed sculptures. The graphic elements placed in the rooms are represented by captions (one for each sculpture), indicating the name, the author, the historical period and the material, and information panels in each section. Currently, the exhibition records about 45,000 visitors from the date of opening (30 October 2014).

4.2 Analysis of User Behaviour

In order to analyse user behaviour during the visit and consequently (i) the user satisfaction related the proposed system and (ii) a real improvement in knowledge diffusion, we perform a number of trials recruiting 297 people. They have been divided in two groups, the first (151) that used the IoT system, the second (146) that represents a control group visiting the exhibition without any technologies. Three indicators related to the users behaviour and satisfaction have been analysed in both groups. The three indicators are: (i) the average time of total duration of the visit, (ii) the average number of artworks on which a visitor focused his attention, (iii) the average rating about the overall appreciation of the system.

Table 1 provides a comparison that emphasizes the increasing of the average duration of the users visits (by using the system) and the increased dwell on the presented artworks, thus allowing a more in-depth cultural and consequent diffusion of knowledge. Although the increase of visits total duration can be attributed to a playing

time of the visitor with the new technology, this can be considered a positive factor since the role played by technology is to put in contact users to the art through the game, the novelty, curiosity, etc. Finally, users that used the IoT system have a greater appreciation respect to the entire exhibition

Table 1 A comparison between using the proposed IoT system and without using it

Indicator	With IoT system	Without system
Average total duration of the visit (minutes)	72.7	48.5
Average number of artworks on which a visitor focalized his attention	70.3	40.2
Average rating about the overall appreciation of the exhibition (between 0 and 5)	4.1	3.5

To deeply analyse user behaviour during the use of the proposed system, the mobile app builds and sends to the SERVER nodes a LOG file (one for each visitor) structured as follows

Listing 1.1. The user behaviour structured LOG file.

```

1 <?xml version="1.0" encoding="UTF-8"?>
2 <USER ID="U1001">
3   <START_SESSION></START_SESSION>
4   <END_SESSION></END_SESSION>
5   <TRANSACTION>
6     <REQUEST>
7       <HTTP_METHOD>GET</HTTP_METHOD>
8       <PATH_INFO>/opera</PATH_INFO>
9       <REQUEST_PARAMETERS>
10        <CODEARTWORK>ART0224VICTA</CODEARTWORK>
11        <DATE>20/11/2014</DATE>
12      </REQUEST_PARAMETERS>
13      <REMOTE_ADDRESS>192.168.1.6</REMOTE_ADDRESS>
14    </REQUEST>
15    <PARAMETERS_LOG>
16      <HOUR_LISTEN_START>20/11/2014 13:58:12</HOUR_LISTEN_START>
17      <HOUR_LISTEN_END>20/11/2014 14:00:42</HOUR_LISTEN_END>
18      <AUDIOS>
19        <TOT_NUMBER>3</TOT_NUMBER>
20        <AUDIO ID="AU1111">
21          <HOUR_END>20/11/2014 14:00:42</HOUR_END>
22          <LENGTH>180</LENGTH>
23          <RATE>4.5</RATE>
24        </AUDIO>
25      </AUDIOS>
26      <IMAGES>
27        <TOT_NUMBER>11</TOT_NUMBER>
28        <IMAGE ID="IM1122"/>
29        <IMAGE ID="IM1134"/>
30        <RATE>5</RATE>
31      </IMAGES>
32      <VIDEOS>
33        <TOT_NUMBER>2</TOT_NUMBER>
34        <VIDEO ID="V13333">
35          <HOUR_END>20/11/2014 14:20:12</HOUR_END>
36          <LENGTH>180</LENGTH>
37          <RATE>4</RATE>
38        </VIDEO>
39      </VIDEOS>
40      <TEXTS>
41        <TOT_NUMBER>4</TOT_NUMBER>
42        <TEXT ID="TX4455"/>
43        <TEXT ID="TX4456"/>
44        <RATE>4</RATE>
45      </TEXTS>
46    </PARAMETERS_LOG>
47  </TRANSACTION>
48  <TOTALRATE>4.5</TOTALRATE>
49 </USER>

```

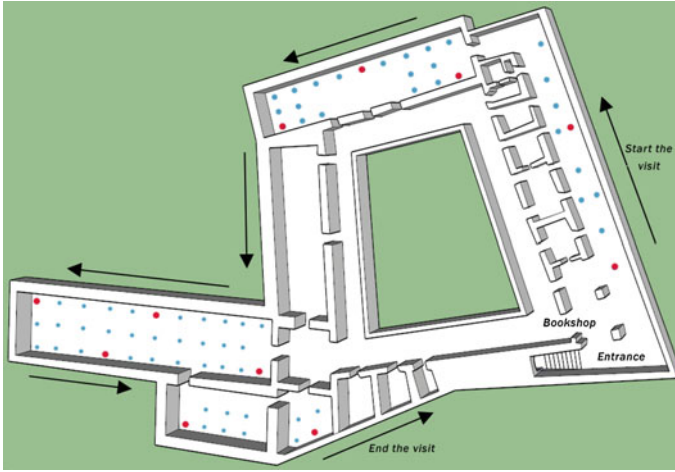


Fig. 3 The exhibition layout: The blue circles represent the SLAVE nodes whereas the red circles represent the MASTER nodes. The arrows indicate the exhibit itinerary

This LOG file stores the following visitor behaviour: (i) the beginning and the end of the visit (ii) all the mobile App requests to the retrieval of multimedia content (e.g audio, video, text, image) (iii) the start time and the end of listening/watching a audio/video file. Moreover, it collects a rate (between 0 and 5 stars) that the user can assign to each multimedia content. An ad-hoc algorithm parses the LOG, extracting some implicit information about the user, such as:

- User ID
- Average time observation of an artwork
- Percentage of observed artwork
- Visit duration
- Percentage of audio heard
- Percentage of videos viewed
- Average number of images displayed
- Average number of texts read
- Average of audio/text/video/images rating

An analysis of the collected LOG files of 151 people shows interesting results. The percentage of observed sculptures exceeds 50 % of the total (135 sculptures) in 82 % of the selected log files. The average rating about the audio/text/video/images is respectively 2.8, 4.2, 3.9, 4.5; this results suggest to improve the overall quality of the audio files. The percentage of viewed video file, for each log file, is extremely low; an average of 5.8 video files played for each visitor. This result suggests that usually users are not interested in the observation of supplementary video content during their visit. For what concern supplementary images related to the sculptures, we observe that the average of displayed images for each visitor is 70.1; 2.4 is the average for each sculpture.

At the end of the visit, each person of the two groups answered to three questions about the exhibition, in order to assess the knowledge diffusion improvement using our IoT system. The questions are: (1) *What are the names of the three main sculptures authors of the exhibition ?*, (2) *What is the material mainly used by the sculptures of this historical period?*, (3) *What is the theme that links the different sections of the exhibition?* (multiple choice question with three possibilities).

Table 2 Questionnaire results

Question	Correct answers with IoT system	Correct answers without IoT system
1	92	61
2	101	89
3	84	49

Table 2 shows the results of the questionnaire; the observed values indicates that the technology can significantly improve the user cultural experience during and art exhibition, increasing the knowledge diffusion related to the observed cultural items.

5 Conclusion

IoT constitute a powerful tool to address the design of the complex connection between new technologies, knowledge to be transmitted and visitors experiences of Cultural Heritage environments. As an effort in this direction, this paper define an architecture to represent and manage the smartness inside cultural spaces, adopting the IoT paradigm and supporting this direction with the design of a set of sensor nodes. The technologies cover the fundamental role of connector between the physical world and the world of information, in order to amplify the knowledge but also and especially the enjoyment. For these reasons, our research has been primarily focused on the design of IoT architecture for Cultural Heritage spaces. These sensor nodes have the capability to observe the environment and support the people enjoyment process, establishing multiple connections among the end-users through which convey information, stories and multimedia content. A case study, the *Beauty or the Truth* art exhibition in Naples, has been devised as a feasibility test of our system, the related sensor nodes and the users' satisfaction through an implicit (LOG files) and explicit analysis (questionnaires) of user behaviour.

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