smARTworks: A Multi-sided Context-aware Platform for the Smart Museum

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Abstract: The technologies characterizing the Internet of Things domain allow realizing smart environments based on user-oriented localized services. In the last years, IoT has gradually acquired an important role also in the Cultural Heritage domain, in particular for Smart Museums, through the introduction of several solutions aimed to ensure immersive and interactive cultural experiences. In this paper, we propose a Multi-Sided Platform called smARTworks which relies on smartphones localization capabilities and Beacon devices to automatically provide the user with multimedia contents related to nearby artworks. Moreover, the solution is able to collect users' opinions to provide a series of methods useful for the management of cultural items.

1 INTRODUCTION

The spread of the Internet of Things and other related paradigms in everyday life is leading to a constant effort to introduce computational and communication capabilities in everyday objects, which are increasingly turned into *smart objects* (Kortuem et al., 2010; Perera et al., 2014; Catania et al., 2012): objects able to interact with each other, with the surrounding physical environment, and with people. These interactions can be enhanced exploiting the information coming from contextual data and, in particular, taking into account the position of all the involved entities. In facts, smart objects may adopt common indoor/outdoor localization technologies such as GPS and Bluetooth Low Energy (BLE) to be localized in scenarios ranging from the Smart Home (Jiang et al., 2004) to the Smart City (Nam and Pardo, 2011).

In the last few years, IoT is gradually acquiring an important role also in the Cultural Heritage domain valorizing artworks by means of innovative technological applications that create an interactive user experience able to reduce the distance among "cultural things" and people.

Recently, several innovative approaches have been adopted, the most relevant of which include the use of headphones or robots for an immersive fruition of artworks, supported by smart-phone applications to collect opinions, wishes, and users' suggestions.

This paper proposes smARTworks, a Multi-Sided Context-Aware platform aimed to enhance the user experience while visiting a museum, an archaeological site, or the monuments in a city, and to simplify the process of information retrieval connected with the discovery of nearby artworks. The smARTworks platform exploits widespread GPS and BLE technologies available in personal devices, i.e., smart-phones, supplying an application which exposes artworks multimedia contents.

1.1 Motivating Example

In order to involve more users and, above all, young ones it is necessary to provide for a significant technological improvement to ensure immersive and interactive user-experiences within cultural environments. We here propose to analyze an use case to validate the spread of IoT platforms within cultural spaces such as museums and archaeological sites.

This solution aims to increase the interest toward the Cultural Heritage domain according to the IoT vision. The introduction of new technologies does not necessarily include a massive use of invasive and expensive instruments and, to further reduce infrastructures' costs, it is possible to limit the use of additional devices. For this reason, this work proposes the use of widespread devices such as smart-phones to gather information and multimedia contents about the artworks within the surrounding environment.

Let us suppose that Sam is visiting a museum: thanks to the smARTworks application, Sam is able to retrieve the list of works in his nearby. In this way, he

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can evaluate artworks details, included audio, video, and texture multimedia contents.

In the case that the cultural environment includes totems, TV or image projectors, it is possible to exploit them in order to enhance users' experiences, in support of sharing information.

During his visit, Sam is also able to express opinions, writing comments or putting "likes" related to the artworks he has seen. These pieces of information are collected to provide data to Decision Support Systems (DSS) for the management of the cultural site and of the artworks it hosts.

The remainder of this paper is organized as follows: 3 depicts our proposal with regard to the system architecture, 2 presents the state of the art for what concerns IoT solution within Cultural Heritage domain. Finally conclusions are drawn in 4.

2 RELATED WORK

The term Cultural Heritage refers to a plethora of tangible and intangible elements regarding the culture of a group or a society (Vecco, 2010). Since most of these elements are linked to a physical place or area, the focus of the proposed work has been moved on the enhancement of the environments connected to the Cultural Heritage. These environments are, for example, museums, archaeological sites, and cities. Several solutions aimed to provide smart services within the Cultural Heritage environments have been proposed in literature (Chianese and Piccialli, 2014; Chianese and Piccialli, 2015; Mighali et al., 2015). In general, working with smart environments requires to face several challenges, in particular, localization of entities and proper exposition of services.

The most common localization techniques rely on computer vision (which analyze images and tags), audible sounds and ultrasounds, wireless Local Area Network (WLAN), RFID, and Bluetooth technology (La Delfa et al., 2016; Liu et al., 2013; Mandal et al., 2005; Mainetti et al., 2014). Among the others, the RFID technology is mostly placed within Smart Museums. For example, in (Wang et al., 2007) Personal Digit Assistants (PDA) manage the sharing of multimedia contents, with the support of RFID technology to uniquely identify each artwork and localize the user. The RFID technology is also adopted within the Smartmuseum solution (Kuusik et al., 2009) to enable the tracking of activities together with additional technologies such as mobile Internet, Geolocalization, and NFC. As suggested by this solution, the user is equipped with a mobile device to retrieve cultural contents according to his context and position.

Nevertheless, the use of RFID technology in smart museums is subject to some limitations: just as an example, not so expensive RFID-based solutions require a short distance among users and tags associated to cultural items.

Since the management of smart museums and/or archaeological sites represents an important open challenge, several systems able to support users within these environments were proposed in literature (Kuusik et al., 2009; Chianese and Piccialli, 2015; Alletto et al., 2016).

A recent vision which involves concepts and technologies typical of web of things and social networks has been proposed to enhance the world of smart objects (Catania et al., 2012; Atzori et al., 2014). In line with these concepts, authors of (Amato et al., 2012) propose a Social Network of Object and Persons (SNOPS) framework to create a network of interconnected people (e.g., citizens and tourists) and objects (e.g., machines, edifices, and rooms).

To support this vision, in recent years, the low-power version of the Bluetooth standard, namely Bluetooth Low Energy (BLE), has been exploited in indoor localization systems, since its low-cost technology is available in most of end-user devices (such as mobile phones, laptops, and desktops computers) and it is also easy to integrate in objects ranging from simple tags (called beacons) to the more complex embedded systems.

Indoor Location-Aware systems based on BLE are proposed in (Chianese and Piccialli, 2014; Chianese and Piccialli, 2015; Mighali et al., 2015; Alletto et al., 2016) to bring museums into the IoT paradigm. In these works authors combine computer vision algorithms, BLE-based localization services, and wearable devices to deliver multimedia content related to the artwork observed in a specific moment by users. Other systems based on BLE technology have been proposed in (He et al., 2015; Frasca et al., 2015) to share artworks-related multimedia contents.

All the works described above require an expensive (in terms of time and cost) setup. In contrast with them, this paper proposes an simple and effective platform that includes, other than the use of BLE Beacons, a simple Sensor layer thought to easily maintain BLE Beacons data. Furthermore, the platform here introduced, combines the use of BLE technology with the capabilities of users' smartphones and the CDWA Lite standard to realize an unambiguous DB to describe artworks, enabling the interoperability and scalability of the platform itself. The CDWA Lite schema is an XML schema to describe core records for works of art and material culture, based

Table 1: Comparison of main Smart Museum Solutions.

Solution	Indoor positioning	Outdoor positioning	Support to DSS	CDWA Lite
(He et al., 2015)	IBeacon	No	No	No
(Frasca et al., 2015)	BLE Beacon	No	No	No
(Chianese and Piccialli, 2015)	BLE Discovery/Advertising	No	No	Yes
The Narrator (Ali, 2014)	Wi-Fi	No	No	No
(Yoshimura et al., 2017)	Bluetooth tracking system	No	Yes	No
(Mighali et al., 2015)	BLE Landmarks	No	No	No
smARTworks	BLE Beacon	GPS	Yes	Yes

on the Categories for the Description of Works of Art (CDWA) and Cataloging Cultural Objects (Stein and Coburn, 2008).

Table 1 reports a comparison among some Smart Museum solutions that have in common several features with our proposal. This table compares different solutions, focusing on differences in terms of Indoor and Outodoor positioning technologies, APIs and/or dashboards able to support DSSs, adoption of the CDWA Lite schema, and availability of code sources.

3 SMARTWORKS ARCHITECTURE

The smARTworks platform is thought to provide educational visits according to user's context and preferences by means of widespread devices (*i.e.*, smartphones). These device exploit a centralized architecture, depicted in 1, which exposes "Artworks as Services".

Then, the smARTworks smart-phone application highlights the most interesting artworks, with the goal of optimize the quality and duration of each visit. Through this application, a user can also choose to view multimedia contents related to nearby artworks and express opinions such as "likes" and textual comments. These "likes" are very meaningful to build statistics aimed to the maintenance of cultural environments. For example, an artwork that has attracted more interest than others, could be supported by additional elements such totems or image projectors in order to improve the quality of experience.

Furthermore, the proposal involves the use of BLE Beacon devices to localize items within a Cultural Heritage environment. During the deployment phase the transmission power of these Beacons is regulated to reduce coverage overlapping.

In the following subsections, an overview of platform's layers is provided to detail the architecture of the proposed system.

3.1 Sensor Layer

The first tier in the architecture is represented by the Sensor Layer. This Layer manages all the Beacons able to cover the considered environment. Through a configuration phase, each Beacon's Identifier is linked (with an one-to-one relation). In this way, the BLE broadcasting process allows users to recognize an artwork and to retrieve proper pieces of information and multimedia contents.

3.2 Service Layer

The Service Layer includes all existing services connected to the network, and enables the management of artworks within the cultural environment. Each single service is able to give a "Virtual Sense" of an artwork and to handle the related information. In facts, a Database containing entries' descriptions (in JSON format) can be queried. In particular, Table 2 shows some artwork's features such as, id, indoor and outdoor coordinates, and URIs of multimedia content, stored in the DB.

Built in line with RESTFul paradigms, the service exposes several managing APIs for cultural items. Below, has been listed a series of the most relevant functionalities provided by Services.

- Method for the association of single artwork to a specific beacon.
- Method for the update of the artwork's description.
- Method for the addition of multimedia content as Video o Audio.
- Method for the retrieving of the artwork's information.

These functionalities, with other, are described by means of a JSON Template, which aims to give details of RESTFul request like type, request and response parameters. Practically, this template aims to describe the Service interface which has an high important in communication process between the Service and the Engine. For this reason, Template information are maintained in a Database accessible from the Engine

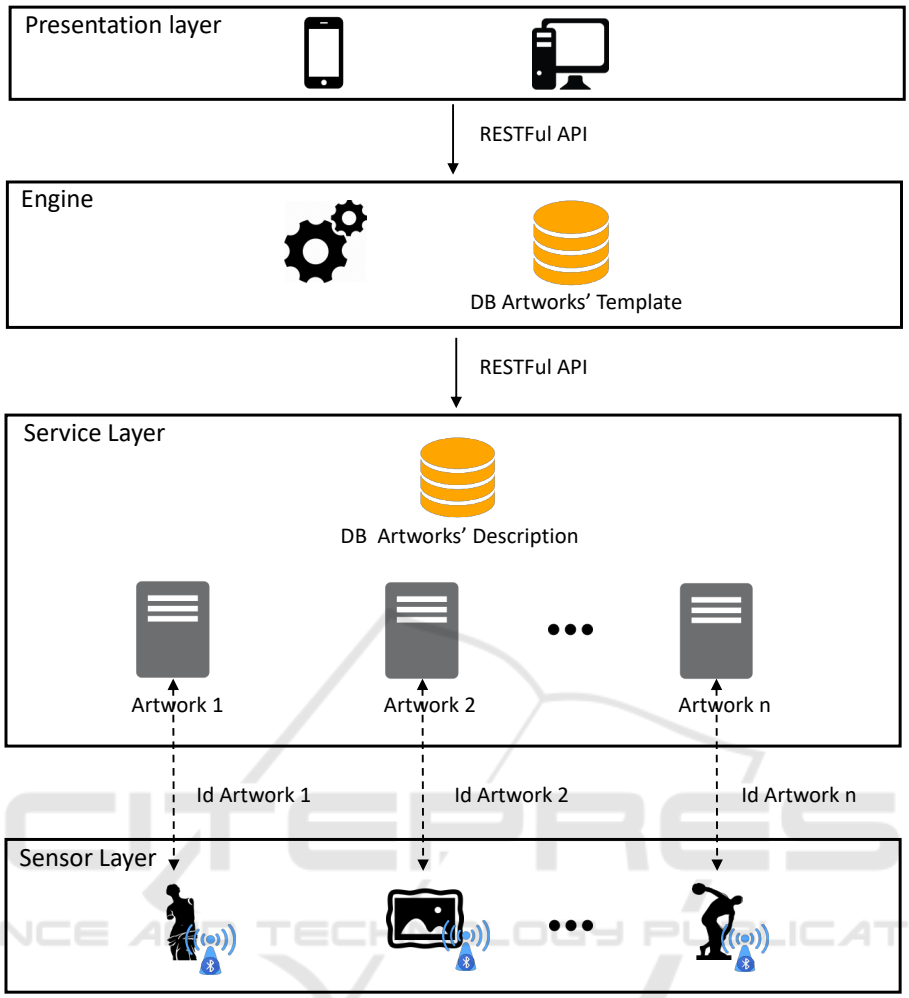

Figure 1: smARTworks Architecture.

Level. According with architectural requirements, it is possible to select until two type of implementation patterns: the first, which needs a single Service for each artwork(one to one), and the latter that provides a single service able to manage more artworks reachable from different URI.

3.3 Engine Layer

The Engine represents the core of the platform. As central part of the architecture, it covers several tasks including the collection of user context's information and the production of a list of artworks. Therefore, the Engine aims to share the artworks' descriptions towards smart-phone application as response to an incoming request. In details, the implementation of this layer is in line with the RESTFul paradigms, and it equips the platform with a series of APIs, including functionalities for the management of opinions and affluence related to users and artworks. In line with results obtained, the managers can take decision aimed to increase the quality of visits. In order to give a complete vision of Engine capabilities, a full list of functionalities is reported below:

- Management of users' profiles.
- Retrieval of JSON descriptor for a specific artwork
- Retrieval of artworks' information.
- Management of comments and LIKEs for a specific artwork
- Retrieval of statistics information for each artwork(number of likes, number of user that express interest for artworks).
- Retrieval of statistics related to affluence.

In addition to these functionalities, the Engine take-charge of communication with all Services aiming to retrieve cultural items' information.

Table 2: Artwork's Attributes.

Attribute	Description
Id	The artwork identifier
IndoorPosition	The ID related to the Beacon
OutdoorPosition	A geometric polygon representing the area that contains the artwork, represented through a GeoJSON format
ObjectWorkTypeWrap	Wrapper of work type information
TitleWrap	Wrapper of title information
DisplayCreator	Creator information
CultureWrap	Information about art movement
Images	Array of Images' URIs
Videos	Array of Videos' URIs
Audios	Array of Audios' URIs
Tags	Keywords useful for categorizing artworks

3.4 Presentation Layer

The presentation layer includes applications aimed to provide a User Interface (UI) that allow to exploit the functionalities of platform. For example, a smartphone application is able to give an overview of the surrounding environment in term of services and multimedia contents linked to artworks. Is important to highlight the use of a Dynamic User Interface (DUI) to generate the appropriate graphical interface for the cultural item. The notation chosen to represent this description is SWAGGER. The DUI block is essentially a java-script script which transforms the SWAGGER definition of the artworks into an HTML page which contains the appropriate User Interface.

Furthermore, in order to supply functionalities for supporting managers decisions, an DSS dashboard ca be equipped with graphic instruments built on top of Engine layer.

3.5 Artwork Description

The structure of descriptive JSON file follows the CDWA Lite schema(Stein and Coburn, 2008). Thus, the CDWA Lite element set consists of twenty-two elements of which nineteen are for descriptive metadata, tree for administrative metadata and only nine are required. A main characteristic of the CDWA Lite format is the division of the descriptive metadata in display elements on one hand, optimized for presentation purposes, and indexing elements, optimized for retrieval on the other hand. Indexing elements, as they usually should refer to authorities for actors, places, or to controlled vocabularies, are provided with attributes for storing a respective URI (termsource and termsource ID), assuring the identity of a term in a larger context.

The use of CDWA standard allows to introduce the smARTworks platform within exiting environments that hold CDWA Lite description database. For this reason, a converter module has been developed, and generates a conversion from XML format to JSON format.

An example of User interface generated by DUI is depicted in 2. In particular, this picture shows the UI as result of a specific use case, which involves the use of a service named Artwork-service. This service is able to give information related to several artworks by means of a Database that includes several JSON descriptors. Therefore, we have assumed to localize "il David di Michelangelo" sculpture by means of a Beacon device, accompanied by a JSON descriptor object that include two multimedia contents (image and video).

3.6 Setting of Preferences

After the installation process, this phase aims to collect information related to interesting art movements for users. In particular, the user has available a list that includes artistic movements, types of artworks and artists. Supported by this list, the user can select several meaningful options saved in a JSON object (Listing 1), in order to highlight the interesting items.

The database of artworks, is queried in order to retrieve the nearby items that meet the user's preferences, through discriminants such as artistic movements, types and authors of artworks. In relation to a selected item, a series of additional linked artworks provided, aimed to enhancing the cultural level of the visit.

Listing 1: Preferences JSON.

```
Preferences = {
    id_user:00232,
    art_movements:[id_art_mov_1,
        id_art_mov_2...],
    types:[type1,type2...],
    artists:[id_artist_1, id_artist_2
        ...]
}
```

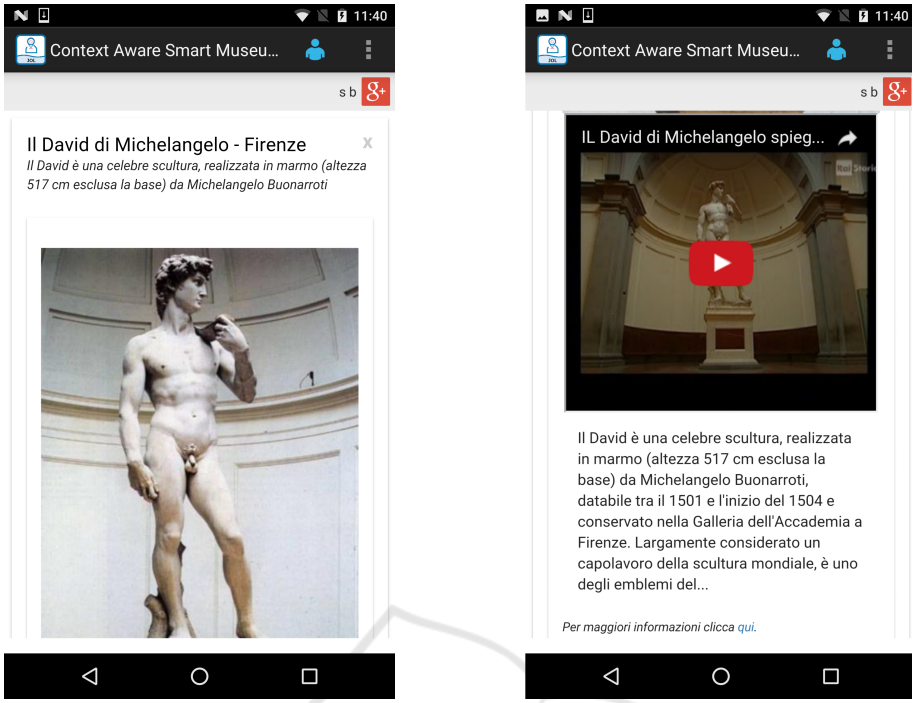

Figure 2: HTML Interface as output of DUI.

4 CONCLUSIONS

In this paper, a low-cost system that introduces the IoT vision into Cultural Heritage environments has been proposed. The system aims at making the user experience more interactive taking into account contexual information and preferences. It also may help administrations to better understand which are the visitor-flows in order to manage exhibitions.

As reported on the table 1, the proposed platform is able to provide users' location within an indoor/outdoor smart environment, expose lists of nearby artworks of interest, and offer APIs to support the development and use of management tools such DSSs also thanks to the CDWA Lite schema thought to maintain a standard description of artworks.

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