Model of a personal guide for museum exhibitions

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Abstract. Cultural and historical institutions in Bulgaria are often underfunded and do not provide sufficiently attractive digital services. All museums develop and maintain scientific passports of cultural artefacts, which contain photographs and specific characteristics of the exhibits. In some cases, they store digitized information in accordance with established standards for the digitization of cultural heritage, such as Dublin Core, SPECTRUM, LIDO, CCO, etc. The widespread use of smartphones provides museums with the opportunity to expand the museum service by dynamically and automatically delivering contextual information about the artifacts. The article presents an approach to creating a personal guide for museum exhibitions, which uses beacon technology to automate the process of providing contextual information about museum exhibits to its visitors.

1. Introduction

In the age of information technology, much of the business activity has gone digital. Museums in Bulgaria – the silent guardians of the past – fall behind in this regard. In most of them, the only experience offered is formal talks in which the visitors are passive users of information. To become more attractive, museums should abandon the practice of silently exhibiting valuable artifacts. They need to create new ways of offering valuable services – they need to start telling stories and providing unforgettable experiences. We should not forget the educational aspect of cultural institutions – to display and transmit knowledge to students in innovative and exciting ways. To do this, it’s necessary to build modern information ecosystems which would ensure a memorable user experience.

The desire to attract visitors has led to the creation of virtual museums in recent years. Some of them present only information and photos of the artifacts that are on display in the exhibition. Others provide virtual tours of museums through 3D technology. In most cases, virtual museums are closely related to the exhibition activities of a physical museum. But there are also entirely virtual museums which present artifacts that have no physical form. And despite the presence of attractive digital presentations, many people prefer to visit a real museum. To touch the atmosphere of the museum, to take a close look at the exhibits, to feel the spirit of the times…

Undoubtedly, the main obstacle to the development of digital services in museums is the lack of sufficient financial, human and material resources. It is generally accepted that the creation of such services requires huge investments. Our observations show that there is no universal solution for the selection and use of unified digital technology in museums. Different types of users have different needs that can be met with various technologies and devices.

All movable cultural values in Bulgaria, which have acquired the status of national treasures, are subject to description and museum identification which is done through the creation of a scientific passport. The minimum data that such a passport must contain are regulated in the Cultural Heritage Act and include: a photo or another image; information on type, size and weight, material and manufacturing
technique, special features; name and author, if they are known; date and location of discovery; short description; conservation regulations [1]. Some museums maintain more detailed information about the exhibits by following established standards for the digitization of cultural content, such as CIDOC-CRM [2], CCO (Cataloguing Cultural Objects) [3], LIDO [4], SPECTRUM [5], Dublin Core [6], etc. These standards describe the artifacts by a finite number of fields, partially duplicating the fields of bibliographic standards (ISBD [7], MARC21 [8]), but add fields related to automated data exchange.

2. Live walks
Virtual tours provide an opportunity to view some of the exhibits of a certain cultural and historical institution using technical means. However, they cannot replace the direct interaction of the viewer with the authentic atmosphere of the cultural institution, the invisible spirit created around each exhibit and the creative details invested by its creator. Therefore, for art lovers, onsite walks are the preferred way to see museums, galleries and all kinds of cultural and historical exhibitions.

Help in viewing the museum expositions is provided by guides who walk visitors around the artefacts and tell interesting stories about individual exhibits or groups of exhibits, about their authors or the era in which they were created. Many visitors are interested in specific artefacts. They would be happy to hear or see more interesting details about it while they are still on the spot. A web or mobile application of the institution accessible via the user’s mobile phone is a significant facilitation in this regard. It provides additional, easily accessible and well-structured information that can be enriched indefinitely over time. According to the wishes and capabilities of the institutions in a given period of time, the information could be presented in different formats such as audio, video, photos, text, games etc. or interactive pages containing various combinations of these presentations.

This raises the following technical question – How can the visitors quickly and easily get access to information about the exhibit they are viewing? The main technologies that enable visitors to receive interactive information during onsite walks are QR-codes, geolocation and beacon. The association of a museum exhibit with a corresponding identifier provides the opportunity for subsequent access to a digital resource related to the exhibit. Each of the exhibit identification technologies has its advantages and disadvantages, respectively specific challenges in their integration into software applications.

A static approach which is relatively easy to implement is the creation of a QR-code for the exhibit. It takes some effort on the part of the user – the code needs to be scanned at an appropriate angle and a suitable mobile application (QR-reader) must be installed.

The use of geolocation is a method in which the locations of the exhibits are preset in a museum application that supports GPS navigation. When the user approaches the location of an exhibit, an appropriate context menu is automatically activated in the user’s application. A problem with this method is the need to administer the locations with each relocation of the exhibits. The need to compare the location of the exhibits with the location of the viewer suggests potential conflict situations when choosing the nearest object. Although modern smartphones can be located with an accuracy of up to 1 meter [9], GPS coordinates are flat and in multi-storey galleries with exhibits, careful vertical planning of their location is necessary.

Beacons are small bluetooth devices with low power consumption (Bluetooth Low Energy – BLE) and long battery life. They periodically emit close-range identification signals with information about
the device and the exhibit to which they are attached. The signals are automatically picked up by the viewer’s mobile device, and then the functionalities provided in the museum application are automatically launched. Advantages of this technology are the automated identification of an exhibit in a certain environment. Unlike other variants that use geolocation, the risk of collision between exhibits is reduced if the requirements of the devices are complied with. When exhibits are moved, applications do not need to change their location data if they are moved with the beacons attached. The problem is the integration of new technologies such as beacons in legacy software applications. The main reason is that older versions of the API libraries (Application Programming Interface) do not support working with beacons. On the other hand, the use of a new version that supports beacons often causes incompatibility with other functionalities due to modified software interfaces.

The three approaches to identification – QR-codes, geolocation and beacon – are not mutually exclusive and could be used simultaneously. In all three approaches it is necessary to set an identifier of a museum exhibit and associate it with appropriate digital resources. The resources, in turn, can be organized in a shared database accessible through other specified interfaces. The development of a web or mobile application integrating all available digital resources of a museum institution in a common framework, facilitates both the administration and the access of the viewers to resources related to the exhibits.

3. Model of personal guide for cultural and historical expositions

The advantages of BLE beacons – the possibility of giving the viewers automated access to digital resources for museum exhibits and the low power consumption of the devices, determined the direction of our experiments in creating a prototype of the „Personal guide for cultural and historical exhibitions“ software application. An iBeacon device was used in the experiments conducted. The developed prototype works on devices with iOS version 8.0+ and Android version 5.0+. The use of web technologies for creating applications with responsive design [10] provides the opportunity to use it both with mobile devices and with desktop or other computers, and moreover eliminates the need to install specialized mobile applications. The digital resources associated with the exhibits are always available through the application, but the most important advantage is their automatic activation when the user is close to the beacon.

Beacon devices use 2 main communication protocols – iBeacon and Eddystone. The iBeacon protocol [11] was developed by Apple as a closed standard and has deep integrations with the iOS mobile operating system. The main parameter in the protocol is Unique Universal Identifier (UUID) through which the device is identified by various applications. Eddystone [12] is an open-source communication protocol developed by Google for improved integration with Android systems. In addition to a unique identifier – Eddystone-UID, signaling devices that support the Eddystone standard broadcast a URL – Eddystone-URL, as well as telemetry data for the battery – Eddystone-TLM. Eddystone-URL is a URL that can be read by any smartphone with Bluetooth activated.

One possible approach to the use of beacon technology in museums is through an application with a three-layer architecture (fig. 2), which includes frontend, middle layer and database layer. The user interface is implemented with React Native [13],

![Figure 2. Mobile application architecture and communication with a beacon.](image-url)
which is used to create Single Page Applications and can be run on both iOS and Android. React Native Kontaktio [14] in the frontend part is used to intercept events from any signaling device. The user can work with the application both remotely and during a live visit to the museum. In the second option, the conveniences provided by beacons can also be used. When the user approaches the signal range of a beacon, the device intercepts the signal. The operating system generates an event for a signal emitted by a beacon and transmits it to the application. The application in turn activates a contextual menu associated with the corresponding beacon, from which the user can select the desired operation. The business logic is executed on the Express framework [15] for web applications based on NodeJS [16].

The data is taken from the database layer.

The main business logic of the application (fig. 3) is as follows:
1. The user enters a cultural-historical institution with a Bluetooth enabled device (mobile phone, tablet etc.).
2. When viewing a museum exhibition, the user enters an area of signal distribution from a BLE beacon and the device receives a signal which starts the museum application through its corresponding identifier.
3. The application checks whether there are more than one active beacons in the range of the mobile device.
4. In both cases – one or more beacons in the range of the mobile device, the application selects the nearest beacon.
5. Depending on the identifier of the selected beacon, the application displays a corresponding context menu offering access to one or more digital resources with relevant information (contextually related information).
6. The user can choose a specific option to visualize a digital resource, and no action is required to cancel.
7. In the process of viewing the exposition, the user may repeatedly enter different beacon areas, each time steps 2 to 7 are repeated.
8. Upon leaving the cultural-historical institution, the user can deactivate the Bluetooth operation of their device.

![Figure 3](image.png)

**Figure 3.** The main business logic of the museum application.

*Avoiding conflict situations in which parts of the beacons’ active areas overlap* have two aspects: physical configuration and software processing.

With **physical configuration**, during installation it is possible to set the beacon network so that there is no overlap of the individual beacons’ areas. Transmission Power (Tx Power) is a characteristic on which Signal range, Signal stability and Battery life depend. The radius to which the signal is accessed can vary from 2 to 70 meters, with Transmission Power respectively from -30 dBm to 4 dBm (decibel-milliwatts) [17]. Transmission Power are defined in relevant standardized levels – from 0 to 7. Higher levels of Transmission Power are needed, for example at the entrance of the institution, and lower ones...
– for exhibits where the user approaches closely. Signal strength may vary depending on various obstacles (e.g. different objects, including the mobile user’s body), therefore the specified distances at different Transmission Power values are considered approximate. Another configuration feature that has a significant impact on Battery life and Signal Stability is the Signal Interval, but it does not affect the active area.

The software application must also support the ability to resolve conflicts in cases where there are several beacons within its range. One solution is for the user to choose from the list of digital resources for all visible beacons but if their number is large, this is not appropriate. A better option is to only display information associated with the nearest beacon. The algorithms for determining the distance from the receiving device to the transmitting device are based on indoor Path Loss Model [18], [19], [20], [21]. The formula for calculating the distance between the two devices contains parameters that are received and measured by the receiving device:

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distance = 10^{\frac{RSSI_{\text{const}} - RSSI}{10N}}, \text{ where}
\]

- \( RSSI \) (Received Signal Strength Indicator) – this is the strength of the signal transmitted by a beacon, measured by the receiving device.
- \( RSSI_{\text{const}} \) – factory-calibrated constant, part of the technical data which is automatically transmitted by the beacon together with the operating data. This constant is different for every Transmission Power level, and its values also differ between manufacturers. For iBeacon beacons this is the signal strength measured at 1 meter, and for Edystone beacons – at 0 meters. Using the values of \( RSSI_{\text{const}} \), it is easy to determine both the Transmission Power level and the specific value of the Transmission Power.
- \( N \) – a constant that depends of the surroundings and the signal strength. For BLE beacons, \( N \) is assumed to have a value of 2. If corrections are needed, the value of \( N \) in the formula might be changed after conducting experiments with the network of beacons put into effect.

The distance calculated by the specified formula is approximate. Given that all distances are calculated by the same formula, and if the physical setting of the beacons are the same, this would be a good basis for comparing distances. It should be noted that the recalculation of the distances is not done every time a signal is transmitted from each beacon and its corresponding interception by the mobile device. The libraries used in specific software implementations allow only the interception of desired events – such as beaconsDidUpdate, beaconDidAppear etc. in the library React Native Kontaktio – through which to minimize the calculations and the occurrence of unnecessary messages for the user.

4. Conclusion
The presented technology can be easily implemented by museums with small budget that already have databases with information about exhibits. The potential applications are many. When the artifact is approached, it is possible to visualize a restored version of it, display it on an appropriate background thus determining its context and application, various similar artifacts can be visualized, and many more. In some cases, the provision of rich information content for museum exhibits can lead to overwhelming the user with unwanted information. The proposed technology can use the opportunity to profile users (e.g. by age, interests – amateurs/professionals, etc.), and provide customized information to the different types of users.

The described technology reveals another interesting aspect for popularizing the cultural and historical heritage. We can think of the whole city as one big museum [22]. Every day, without thinking about it, we cross squares and gardens, we walk past old and new buildings… But do we have the eyes to see the city as one big museum – living, dynamic and without working hours? The technology we offer is extremely suitable and provides this opportunity.

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