IoT Based Smart Museum

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The internet of things technologies can be exploited to provide the museum visitors with many kinds of advanced services. The visitor interests are renovated and the smart environment within a museum provides an interactive experience for the visitor. In this work, we design a wearable museum guide which can automatically provide the audio description of the museum collection the visitor is observing. Along with the image recognition capability, the wearable device also has localization feature. The museum admin is able to continuously track the user within the museum. This is achieved using a Bluetooth Low Energy infrastructure installed within the museum. The localization information can be used to provide more services for the visitors and also used by the museum staff for museum maintenances. All the cultural contents are stored in the cloud and retrieved whenever they are demanded by the user. The item is identified, and the corresponding description is fetched from the cloud and automatically played as an audio or video. This system has helped the museum visitors to explore freely and make the museum visit a personalized one.

Keywords: BTLE, IoT, Smart Museum, RFID

I. INTRODUCTION

Art and culture have an inevitable part in human beings lives. Over the centuries, museums and art galleries have preserved our diverse cultural heritage. Museums like Encyclopaedic museums, Maritime museums, Medical museums, Science museums, etc are also important sources of education and learning. Museums have emerged as a tool of entertainment such as theatres or cinemas. Today, museums and art galleries usually give visitors either audio guides or paper booklets. People consider a visit to a museum as boring because the taste of each individual varies and he or she is forced to listen to the description of some museum collection he or she is not interested in. Interests are different from children to adults, students group from single visitor, casual visitor to fond visitor. A need for personalized and interactive museum visit appears here. The visitors are often provided with a large amount of information about the artwork they are exploring making them overwhelmed. In the limited amount of time they find it difficult to determine the relevant artworks. Usually the visitors do not have a proper plan before visiting a museum. If they are not directed to have a personalized and interactive experience, they will soon quit the museum tour halfway bored of looking at uninteresting collections.

Internet of Things can be used to realize a smart museum environment. As IoT connects all the small and low cost things to the internet, new advanced services to museum visitors can be easily provided. IoT can be used to build a better world for people, where smart objects around us act according to our likes and dislikes without explicit gestures. These smart objects have to be of low power and low cost to be efficient. But the high heterogeneity of these devices makes the widespread diffusion of smart objects difficult. Using a horizontal approach, we can achieve the transparent interoperability among the smart devices where the designers don't have to bother about the low level details of these devices.

Another issue concerning the smart environment is their capability to act as autonomously as possible, with minimal human intervention. This ability of evolving autonomously is very attractive and challenging at the same time. The user experience will definitely get better if a machine to machine model is used rather than human to machine model. To make this happen, multiple applications should constantly manage the interaction between smart devices, according to predefined business logic. Also, we can configure these services as location-aware services or applications driven by location information for example the location of the user in the smart environment. The technology using for location tracking in a museum environment must be low cost and low power consuming. Low maintenance and less invasive systems have to be used.

We propose a system in this paper which uses a wearable device as a museum guide interacting with an IoT-based smart environment and provides a real interactive cultural experience. The user experience can be enhanced by using the wearable device as a guide. When a user is in front of an artwork, details such as title, artist, and artwork description can be easily and automatically provided. The artwork details could be sent individually to a particular visitor or played on multimedia walls in that museum room. In this way we could help the visitors to appreciate the museum collections more deeply and the artwork details will be more accessible to everyone. Also, the information collected from the environment could be used for the management of the museum by the museum staff. For example, the number of users during the day can be used to reschedule the opening and closing times. Similarly the most visited rooms can be identified and maintenance works can be planned there.

The wearable device is able to capture video and images of the artworks. The image is sent to the processing

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centre where the details of the artwork are fetched from the cloud. The wearable museum guide does two main tasks: it continuously tracks the user by using a Bluetooth Low Energy (BLE) infrastructure, and identifies the artwork in front of the user by using its processing capabilities and localization information. All the cultural contents are stored in the cloud and fetched when demanded by the user. For Image recognition, local features are extracted from the input frame and matched with a candidate target in the database.

II. Related Work

A number of different research projects are exploring in this field to develop an enhanced museum experience for the visitors. A RFID based smart museum was developed in (L. Caviglione, M. Coccoli, A. Grosso, 2011). The rooms within the museum was installed with RFID tags for tracking the visitors. By using the RFID technology in the visitors smartphones or PDAs, description of the museum collections is played on the smartphones or PDAs. The entrance to every room within the museum an RFID gate is installed, which is used to track the location of the visitors. The processing centre of the museum keeps track of the position of the visitor within the museum and accordingly send the necessary details to the visitors device. To receive these contents the visitors device must be connected to the wireless network of the museum. When the visitors do not want to use their mobile phones they are given tickets with RFID tags. Point Of Interest (POI) or an RFID enable item can be a single item or it can be a complete room.

To get a customized experience in the RFID installed museum, a content management system was used. The user is identified while he passes through the RFID gate. This is with the help of the RFID tag assigned to him at the ticket counter. These RFID tags are associated with the visitor's mobile device. Thus an environment is set up for a two way communication with the help of RFID gates and tags. The network service can be done by using a simple server and a database. The content management system is built upon the database which extracts heterogeneous contents from the database decided by the ID provided by a tagged museum collection. The database can also keep the user profiles in it to create a personalized description of the exhibition.

For the system to be completely effective it requires the visitors to carry a smart phone with them. The visitors must carry smart phone devices with wireless connectivity and multimedia playback capabilities. In our project the visitors are provided with the wearable guide at the museum so we can easily make the system accessible to all age groups and those who don't use smart phones.

III. Proposed System

The paper proposes a wearable museum guide that can be used by museum visitors to have an interactive and personalized

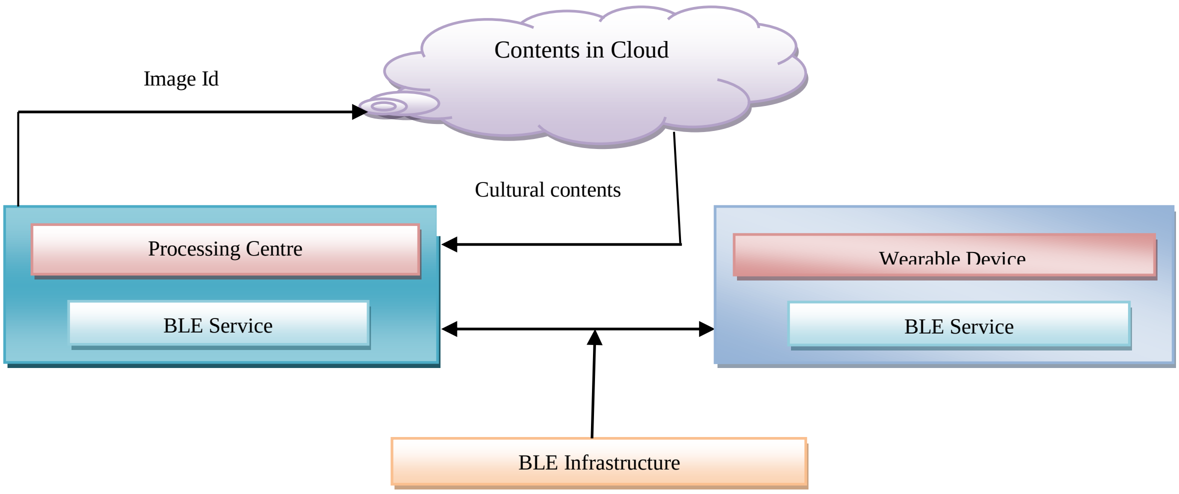

Fig. 1. The overall structure of the system.

museum experience. These days the museums are having paper booklets or audio guides or museum staff, which act as guides in museums. When students visit the museums from schools and colleges in groups, one has to listen to the museum collection description the guide is telling even if he or she is not interested. Using the wearable museum guide proposed in this paper one gets complete freedom to explore the museum in his or her own way. If you want to skip any of the collection you can skip it or if you want to know more about the collection all you have to do is to take a video of the collection using your wearable guide. The audio description of the collection will be automatically played. You will be using an earphone to make sure you won't disturb other visitors. The proposed system architecture is shown in fig 1.The complete system can be divided into three parts.

BLE Infrastructure: The localization service is implemented using a Bluetooth low energy infrastructure installed inside the museum. The wearable device will be having one Bluetooth module which acts as master and different slave Bluetooth modules are placed near all the artwork or museum collection. Whenever the wearable device comes within the influence of any of the slave Bluetooth modules, the corresponding position is identified. The museums generally do not encourage any kind of innovations that are highly invasive and affect the ambience of the museum environment. Location tracking using Bluetooth module infrastructure is the most apt service that can be used with minimum invasion. The other indoor localization methods like infra red positioning system will only give a rough estimate of the visitor position and thus errors can occur.

Compared with traditional Bluetooth, BLE consumes less power, and hence the wireless landmarks are battery powered and makes the BLE infrastructure more flexible and less invasive. The location identification (ID) and the transmission power value (TX) are transmitted by all the devices in the BLE infrastructure. The BLE service running on the visitor's wearable device gets the location data from all the landmarks within its listening range and then recognizes the room in which the user is standing. For this, a proximity index *d*, for each landmark must be calculated, using the corresponding value of the RSSI. The equation used is the following:

$$RSSI = - (10n\log10d + A) \quad (1)$$

where A is the received signal strength at 1 m, n is a signal propagation constant depending on the environment, and d is the distance from the sender(E. Lau and W.Y. Chung, 2007) . The landmark that has the lowest value of d is the user's location. The user's location can be used locally to speed up the image processing algorithm, and also used by location aware services running on the processing centre. The user localization process is shown in fig 2.

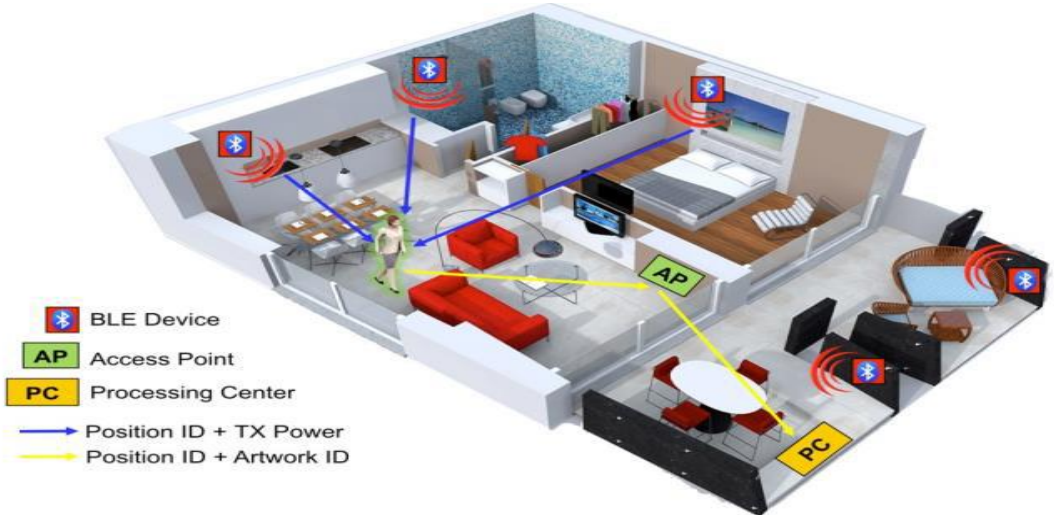

Fig 2. The components of the localization mechanism.

The position id and the transmitted power of all the BLE devices around the user are collected by the wearable device. The BLE device with the least value of d is identified, and this information is used to speed up the image recognition process and the artwork id and position id are made available to the processing centre of the museum. Using this information the processing centre can fetch the correct cultural contents from the cloud and also run location aware services for the user.

Wearable device: Once the visitor captures the video of the museum collection, the video frames are analyzed and the image is detected with high accuracy. The location of the visitor can be used for simplifying the image recognition. Before identifying the image a lot of pre-processing has to be done. Some part of the video can have high blur which must be removed to make the image detection process simple. Once the frames with excessive motion blur are removed, the image recognition process can be started. The Scale Invariant Feature Transform (SIFT) local descriptors are extracted from the frame to match it with its counterpart in the museum database(D. G. Lowe, 1999) .

The artwork recognition process is given in fig.3.Here we can exploit the location awareness of the system and reduce the computational complexity of the matching process and also greatly increase the accuracy. Since we need to use minimum power for the operation of the wearable device, the reduction of this computational effort will help to greatly reduce the power consumption. BLE technology requires very less computing power.

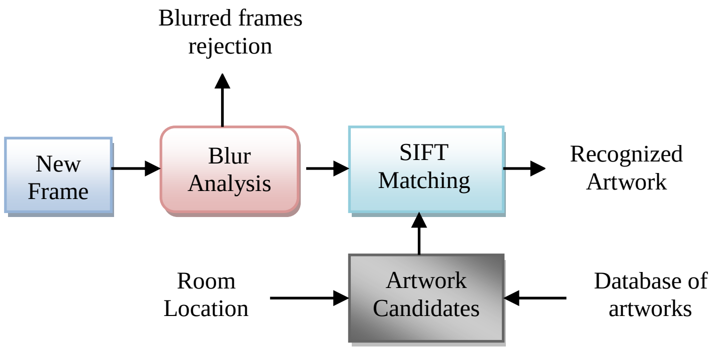

Fig. 3. The image processing

Processing Centre: After identifying the image, the corresponding cultural contents must be retrieved from the cloud and made available to the wearable device automatically. The processing centre has access to the cloud where all the cultural contents are stored. The flow diagram of the smart museum is shown in fig 4. Several location aware services are running on the processing centre which make use of the location information of the visitors and act accordingly. The statistical information about how busy the museum is can be obtained using the localization information. Exploiting this information we can rearrange the opening and closing time of the museum, also it can be used by external users to know in advance the length of the queue in certain areas of the museum. The most admired work can be found easily and the supervisors of the museum can schedule partial maintenance work there.

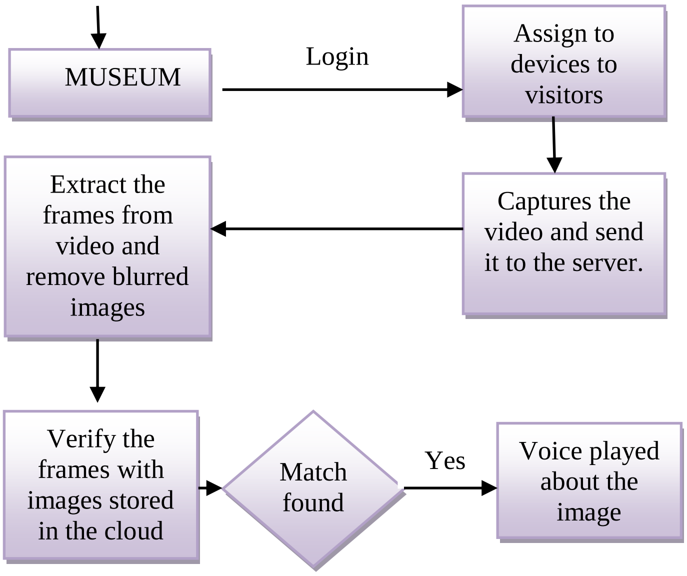

Fig 4. The flow diagram of the smart museum.

The cultural content delivery done by the processing centre can be done as an audio message played on the wearable device. When the number of users requesting the details of an artwork is large the processing centre can utilize the wired local networks to send the multimedia contents onto the totems or interactive walls of the museum. The location aware services running on the processing centre can also interact with heterogeneous devices. This is made possible by using a multi-protocol middleware that allows a transparent access to the underlying heterogeneous technologies. The multiprotocol middleware provides the services with high level RESTful APIs for communicating with the physical network. Also it contains specific software modules called adapters, which can interact with IoT devices in accordance with their standards and protocols. This modular structure of the multi-protocol middleware allows it to be easily extendable to new technologies. This makes the system flexible and scalable. Here we can use three software modules which help to interact with BLE devices, KNX and Constrained Application Protocol. KNX is the worldwide standard for home and building automation and CoAP is the application protocol used in IoT. We can add and remove new adapters to the middleware without bothering about the interfacing details. The multi-protocol architecture is given in fig 5.

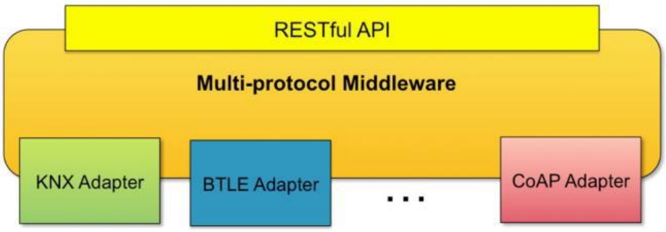

Fig. 5. The architecture of the multi-protocol middleware.

TABLE. I. COMPARISON BETWEEN PROPOSED ARCHITECTURE AND SIMILAR SYSTEMS

Reference Work	Technologies			Services Provided			Communication
	CV	RFID	Mobile	Personalized Audio Message	Interaction-less Requests	Location Awareness	
(A. Kuusik, S. Roche, and F. Weis, 2009)		✓	✓	✓		✓	None
(Y. Wang, C. Yang, S. Liu, R. Wang, X. Meng, 2007)		✓	✓				IEEE 802.11
Proposed	✓		✓	✓	✓	✓	BTLE

IV. RESULTS AND ANALYSIS

The components used for the system validation are a wearable device, a processing center and an infrastructure which can ensure the indoor localization service. The wearable device is implemented using Raspberry Pi [6] and also the processing center is realized using another Raspberry Pi. The indoor localization service is made using Arduino boards placed near the artworks with Bluetooth modules. The Bluetooth modules on the wearable device act as master and those on the arduino boards act as slaves. An RF camera was used with the wearable device to capture the video of the museum collection. The RF camera receiver was connected to a computer to do the image processing using MatLab. Python language was used to code the services in processing center and wearable device.The working model of the smart museum is shown in fig 6.

To provide a comparison with the proposed framework we took two examples, the smart museum in (A. Kuusik, S. Roche, and F. Weis, 2009) and in (Y. Wang, C. Yang, S. Liu, R. Wang, X. Meng, 2007) .

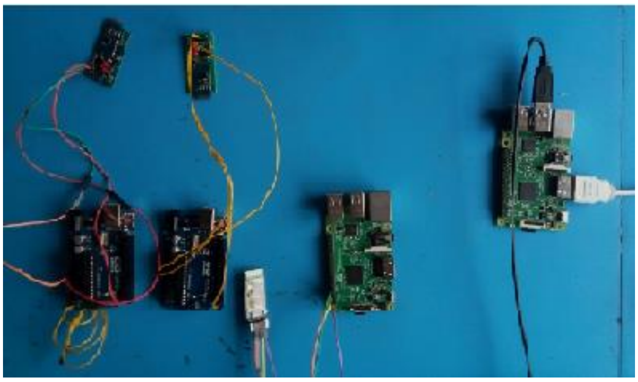

Fig. 6. The working model of the smart museum.

The technologies used and the services provided along with the type of communication used was compared. The results are shown in the table 1.

All the three cases analysed uses mobile technologies, which is an important feature of a smart museum. The technologies used to identify the artwork and localize the visitor differ. In (A. Kuusik, S. Roche, and F. Weis, 2009) two different methods are used to get the artwork details the user is interested in. The user can type a number related to the artwork in the PDA or scan the RFID of the artwork using the PDA. Once the artwork is recognized, the visitors are provided with personalized contents based on their profiles, which was previously made using a web app. This system requires the visitor's explicit action to achieve image recognition and localization. In (Y. Wang, C. Yang, S. Liu, R. Wang, X. Meng, 2007) the visitors can use their own mobile devices as museum guide.The guide system is based on a browser. The artwork details are displayed on the browser as audio, pictures or text. The artwork recognition is done using RFID tags.

In comparison with other systems, our smart museum has many additional features. The Iot architecture enables us to share the contents between many museums. The contents can be artwork details or visitor profiles. The proposed system eliminates the requirement of explicit action for image recognition, by using a computer vision (CV) algorithm. This enables the system to recognize the artwork the user is looking at in real time. The visitors are at ease because they don't have to meddle with any user interface continously. These features can be exploited to give informal learning to students at schools. Students can be introduced to the history of inventions, in physics, chemistry, botany, zoology etc. Students will become independent in learning. The existing infrastructure of the school can be used for this. Also airports, railway stations and places where people spend killing time are best to implement this system. Since all the data are available in the cloud, they can be fetched anywhere.

V. CONCLUSION

In this paper, we have designed an IoT based smart museum having a wearable guide. The wearable device has both image recognition and localization features. The visitor is automatically provided with the cultural contents of the observed artwork. The system avoids the need of using the personal mobile devices as a guide. Also, only low cost hardware was used to implement the smart museum. The localization feature is achieved by using a BLE infrastructure. The actual business logic runs in the processing center , where the image id is identified and the cultural contents are fetched from the cloud and delivered to the visitor. The processing center also has many location aware services running which can provide many advanced services to the visitors based on his location.

References:

L. Caviglione, M. Coccoli, A. Grosso, (2011) "A framework for the delivery of contents in RFID-driven smart environments," in IEEE International Conference on RFID-Technologies and Applications (RFID-TA), pp.45-49, 2011, doi: 10.1109/RFID-TA.2011.6068614.

E. Lau and W.Y. Chung, (2007) “Enhanced RSSI-Based Real-Time User Location Tracking System for Indoor and Outdoor Environments,” in Proc. Enhanced RSSI-Based Real-Time User Location Tracking System for Indoor and Outdoor Environments Convergence Information Technology, Gyeongju, , pp. 1213 – 1218.

D. G. Lowe, (1999) "Object recognition from local scale-invariant features," in Proc. of the seventh IEEE international conference on computer vision. Kerkyra, 1999, Vol. 2., pp. 1150-1157.

A. Kuusik, S. Roche, and F. Weis, (2009) “Smartmuseum: Cultural content recommendation system for mobile users,” in Proc. Fourth Int. Conference on Computer Sciences and Convergence Information Technology, Tallinn, Estonia, pp. 477–482.

Y. Wang, C. Yang, S. Liu, R. Wang, X. Meng,(2007) “A RFID & handheld device-based museum guide system", 2nd Int. Conference on Pervasive Computing and Applications (ICPCA07), pp. 308 - 313, July 2007.

“Raspberry Pi”. Internet: http://www.raspberrypi.org.