Hybrid Indoor Location System for Museum Tourist Routes in Augmented Reality.

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***Abstract*:** At present, indoor positioning systems is one of the areas of research that is continuously growing. The main aim here is to develop a system of indoor location with a similar functionality to outdoor location systems such as GPS (Global Positioning System). The main difficulty of indoor location systems lies in their establishment costs given the resources they initially need. This paper presents an innovative indoor location system based on the fusion of information from multiple sensors on a smartphone. This proposed system is evaluated in a case study with the aim of obtaining locations within a museum and displaying on the screen of a mobile device information about the paintings we are seeing in real time, thus improving the efficiency of the existing systems that rely on audio-guides.

Keywords: *augmented reality, Wi-Fi, indoor location,*

I. INTRODUCTION

Currently, when a user visits a museum, several supplementary materials are offered to the user such as audio guides, brochures, or even books, in order to allow visitors to understand or expand the information about the items displayed in the museum in a simple way. However, these systems have several disadvantages, the most prominent being not having enough supplementary materials for all visitors, followed by the depletion of brochures or even the need to revise or expand any information in these, which would trigger an expensive reprinting. In fact, this last disadvantage is common since musueums are constantly modifying their collections. Currently, the evolution of technology allows us to represent multimedia content on mobile devices. Moreover, accessibility is facilitated because this content can be customized, for seniors for example. Its is much easier for seniors to listen to a spoken phrase than to read an informative poster. It is vital to mention the high cost of current systems based on audio guides which are closed systems and whose modification or adaptation to certain scenarios is a very complicated task. In museums that have these systems [5], it is necessary to deploy a series of RFID beacons (Radio Frequency IDentification) or QRCodes (Quick Response Code), which often aesthetically mar the environment [8]. Another deficiency in existing systems of this type resides in the boundary distances between frames, as they can not be placed too close together so that the beacons do not interfere with each other. Moreover, analysis of the behavior of musuem participants, whether they be visitors or staff, is increasingly required today by museum directors. For example, it is important to know which exhibit is most popular and what áreas of the museum receive the most foot traffic. This paper presents an innovative indoor location system for museums whose objective is to improve the services provided by the existing audio guide systems using current techniques of ambient intelligence and reducing start up costs. The combination of sensors and cameras for pattern recognition and the use of Wi- Fi technology [4] to estimate the position of the visitor allows us to develop a rich set of information for museum directors and which allows for multimedia content such as paintings, videos, and sets of photographs to be viewed on a mobile device by an end user, a task not allowed by audio guides [9]. The rest of the paper is structured as follows. The next section discusses the museums that make use of new technologies. Section 3 presents the proposal for a guided study visit in a Spanish cathedral, and finally Section 4 outlines the conclusions and the future work to be carried out.

II. BACKGROUND

The use of new technologies in the tourism sector [2] is continuously increasing. At present, there is a conference held annually at the European level that addresses the use of new technologies in museums. The conference, called "Museum Next", seeks to present and discuss new trends and the most innovative and efficient ways for museums to learn to creatively use the technology currently available.

A. Use of Smartphones in Museums

The importance and potential impact of new technologies for museums [6] and cultural spaces is vital. At present, there are several museums where solutions have already been introduced to provide visitors with new experiences relying on these mobile devices. [7]

The famous "Tate" galleries in [22] the United Kingdom were among the first to recognize the value of the Internet, both to attract visitors and to offer multimedia guides for its exhibitions and activities. They have more than 16 applications, most of them are free and cover topics such as education (guide of art terms) or fun with augmented reality apps.

The "Museo Del Prado" [22] is also a pioneer in this field. Their new app features 400 works from the permanent collection. These are presented chronologically in a classification by international schools and other features. In addition, a selection of 50 masterpieces with large images for navigation in them is available.

Another of the leading applications in this field is that of “Gagosian Galleries " [22], the free application is updated 4 times a year with exhibitions and multimedia packages on the 12 Gagosian galleries.

The “State Hermitage Museum” [22], in St. Petersburg, also has its own application. You can get a great virtual tour of the museum with 100 major 3D panoramas, along with descriptions of individual works of art.

In the Hungarian capital, the "Museum of Fine Arts" [22] also has a unique application. Earlier this year, the museum presented an application for hearing impaired visitors. It features videos in several languages of international signs and 150 paintings from the collections of the museum with an interactive map and 3D images.
After carrying out this review on the use of smartphones in cultural centers, we can see more and more museums around the world who start developing applications for mobile devices in order to provide their users with a new experience during their visits.

B. Wireless Location Technologies

Next, a review of the state of the art that will address the analysis and study of the various existing technologies today that allow to estimate the position of a user in a closed environment becomes.

Infrared: Infrared localization [18] is not suitable for indoor location due to two factors, the first is its short range "about two meters," and because it requires the use of auxiliary links with a line of sight between two extremes. Because of its limited scope, it is necessary to use a very large number of infrared emitters. In addition, the problem of not having direct view from all locations would prevent us from detecting certain positions. We note the existence of a well-known project called WISP "Wireless Indoor Positioning System" that uses infrared localization to estimate the position of a user.

Wi-Max: Based on the IEEE 802.16 [20] protocol, with a transmission rate of up to 70Mbps, it was intended to interconnect large areas of about 50 km. However, due to the large scope of this technology, its use is not recommended for determining interior position.

Bluetooth: The main advantage of this system is its low cost. However, it has a very limited range and requires a large number of devices to cover a building. It presents an approximate average error margin of 2 meters. A location system based on this technology, checks the number of bluetooth [16] devices detected around and then proceeds to determine its position by way of a triangulation algorithm. The disadvantage of this system lies in the number of devices needed to provide an accurate system and the RSSI (Received signal strength indication) indicator that has very unstable values.

Ultra WideBand: As one of the most used technologies for indoor location [19], it is characterized by a very high transfer rate, and an accuracy of about one meter. Is a candidate technology to help the problem of low accuracy presented by the other systems, offering a great sturdiness against changes in the environment including "doors, walls, presence of objects or movements of people." The main disadvantage of this technology is that its use is not regulated and therefore it cannot be used freely as with WiFi airwaves of “2.4 Ghz " systems.

ZigBee: ZigBee [17] technology, based on the IEEE 802.15.4 standard, is characterized by its low power consumption devices, its use of mesh topology, and the ease with which it can be made, since the current electronic devices using this technology are very simple. Today, we can say that ZigBee is the most appropriate technology along with WiFi [21] networks to develop indoor locations motors. Its main advantage is its low cost and low power emission; however, its main disadvantage is that it has a very small bandwidth which means that it can not offer other services such as streaming, internet etc.

C. Indoor Localization Algorithms

There are main*ly three types of algorithms* [*1*] used by RTLS *(tracking* systems in real time) to determine the location of mobile nodes: Triangulation, Fin*gerprinting and multilateration*. Triangulation allows for the coordinates of the element we wish to locate by calculating the length of the sides of a triangle from incoming angles of the signal received at each antenna, which is required to have at least 3 points of reference*. The Fingerprinting [11],* also known as location or symbolic signpost, is based on the study of the characteristics of each location area, making measurements of the characteristics of radio frequency and estimating what area of influence each device is located. Finally, the multilateration based on the estimated distance from the reader to the mobile device, by measuring this parameter as the RSSI (Received Signal Strength Indication) or TDOA (Time Difference of Arrival), so that the distances intersect estimated from each device at three or more fixed nodes called beacons can determine the points at which such devices are located. Multi*lateration achieves maximum outcomes [12*] outdoors with triangulation*,* but significantly lower performance indoors because RSSI levels vary depending on the presence of elements (people, objects or animals) and also based on distance calculation, so it is necessary to make a prior estimate of the*se* distances from RSSI values which are constantly chan*ging* shape. Localization techniques based on triangulation and multilateration are inefficient because the signals are very much attenuated by the different elements of the room (walls, doors, walls).

III. MELDING SYSTEM INFORMATION

The main objective of this section is to propose an architecture that combines information from multiple sensors, allows us to estimate the true position of a user within a museum, and can also, show the mobile end-user, multimedia content on what we are watching at that moment.

The Wi –Fi system allow us to estimate a first level, the area where a user is located, then to refine the location and know what monumental work is looking at the time, the user can use the camera. We can note that the use of the location on two levels, makes our proposal unique , that is, on one level the Wi -Fi technology is used to distinguish that room is and then proceeds to download user terminal patterns of the pictures that can be displayed in that room so that finally , with the help of an image recognition algorithm , we detect on that chart is , in other words, if a user is in a room initially apply only classifier which to distinguish that picture is seeing all possible in that room and not unload hundreds of images of pictures that are not close to such user that may impair the efficiency of the algorithm.

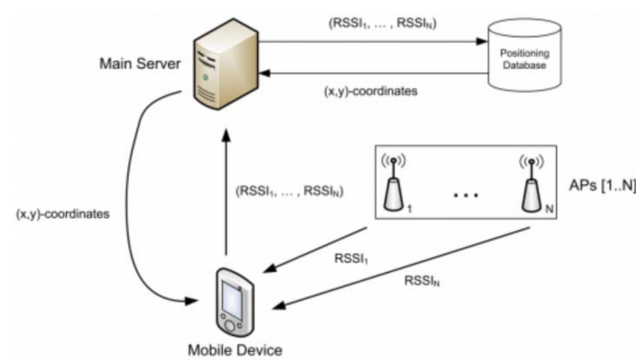
The use of a location on two levels, using fusion technology (camera -WiFi), promotes efficiency in data consumption by mobile terminals, as the Internet data exchange is reduced.

A. Location System

Due to the particular constraints of the environment (“the case study will be validated in a cathedral ") and the requirement of cost, has taken the wireless infrastructure already deployed in the museum. The system used to estimate the position of the visitors in the exhibition is based on the use of Access Points (APs) that transmit a Wi-Fi signal, the signal quality is usually expressed in RSSI and is measured in dB allowing to estimate the position of a user by fingerprintg technique. For this, two distinct phases, in the first phase, also called the calibration process has been carried out relating the environment mapping RSSI measurements from the APs to the coordinates (x, y) of the environment, this map being stored in a database for later use in the phase estimate. During the second phase, also called phase estimation or location, is the process in which the position of a visitor is estimated to be, the mobile who gets the RSSI measurements of the access points detected around at that point and are compared to the measurements stored in the calibration phase. In this comparison, the system is able to determine the coordinate (x , y) by utilizing Euclidian distance model [13] is defined as follows:

$$ED\,(MD, P) = \sqrt{\left(\overline{SS\_MD_{AP1}} - \overline{SS\_P_{AP1}}\right)^2 + \left(\overline{SS\_MD_{AP2}} - \overline{SS\_P_{AP2}}\right)^2 + \left(\overline{SS\_MD_{AP3}} - \overline{SS\_P_{AP3}}\right)^2}$$

SS is a measure of the signal strength, P is each point and AP1, AP2, AP3 are access points. The main advantage is the use of this technique is the low cost and the use of existing infrastructure also currently the most smartphones have Wi-Fi technology is not forcing the user to carry any additional beacon, simply visitor is located by its Smartphone. The process of collecting different RSSI levels from the mobile device is as follows:



To deploy the solution localization and reduce costs, we used the actual hardware, leveraging existing routers whose model is TL-WR740N. The main advantage of this device is the ability to install a Linux-based firmware that allows us to run programs in script mode, in our case, we have replaced the factory version for DD-WRT based firmware.

Fig 1. Used Wireless Router

Using a custom firmware allows the installation of a new software that analyzes all packets received by the router. This software also known as Wiviz is a small utility that open-source can be embedded in the firmware DD-WRT monitor and display allowing wireless devices that are close to the router. This utility can be invoked through the command line or through a Web interface. Below is a representative image of a nearby beacons elements shown.

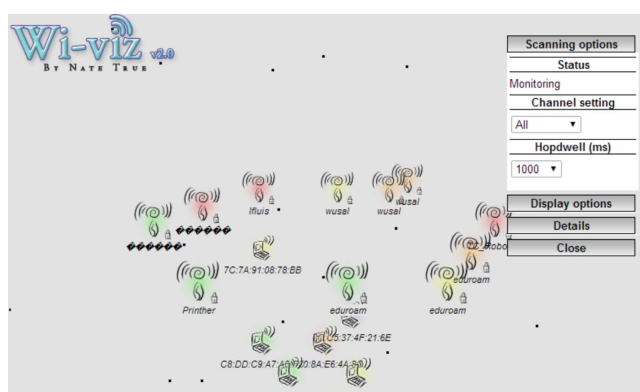


Fig 2. Nearby Wireless Devices

The main advantage of using Wiviz [2] is that it is not a necessary condition that wireless devices are paired to the router to be detected and get the signal level of each. Furthermore, we can detect near a hotspot mobile devices, without installing any software on the terminals of end users, it is very useful to evaluate the user behavior in a mall as the current commercial systems require the installation of an application on the end user device. To detect users who are located near a mark, used a small program that allows us to send bash information Wiviz a manager to estimate the position of the central server users.

This script is executed automatically by all routers in the cathedral, being the very basic operation, first and place once the boot process of the router finished the Wiviz software is started and the program output is redirected to a central server using port 3000 where the data are interpreted. This program runs in cycles and user information is updated every 5 seconds.

```
while true; do
        wiviz &
        sleep 5
        killall –USR1 wiviz
        cat /tmp/wiviz2-dump | telnet mainserver 3000
        killall –q wiviz
done
```

Then AP locations located throughout the exhibition which act as beacons to locate and serve different users within the exhibition.

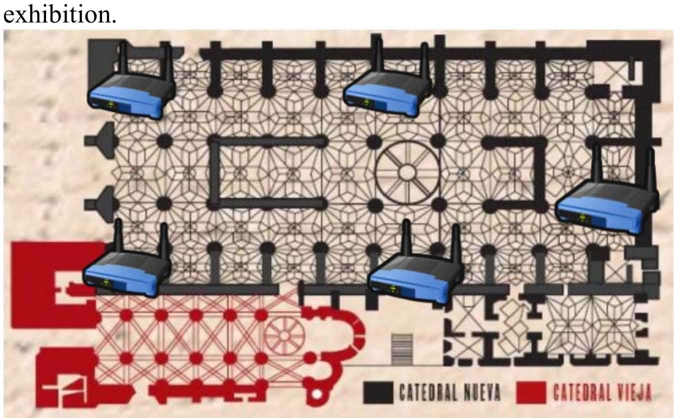


Image 3. Preinstalled Beacons in the Cathedral

The various works of art found inside the cathedral are located in showrooms about 20m^2 separating one of them from other work in about 3.5meters. Here is a picture of one of the exhibition rooms with different points of interest as well as the relative position of the access points used to estimate the user's position within a room is shown.

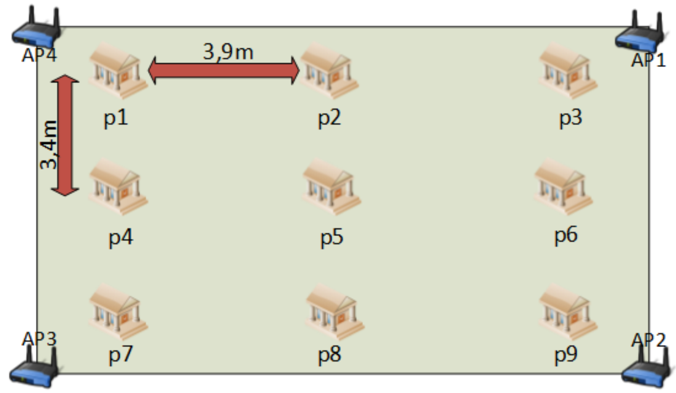


Fig 4. Location of artwork in a chapel of the Cathedral.

During the calibration phase, we use the four measures of AP in each of the nine points so generating calibration map taken. To evaluate the system, 4 random points, where users spent an average of 20 seconds were determined. The use of the fingerprint technique, in combination with the model of Euclidean distances, provides an average error of 2.40 meters, small error for a building of 4500m ^ 2.

Below is a table with the error obtained in meters at each of the points where the system was verified.

Test (point 5)				
Point	ED test1	ED test2	ED test3	ED test4
1	1,28	2,36	3,14	3,28
2	2,35	3,36	2,21	3,84
3	2,15	3,90	3,55	2,79
4	2,30	1,46	2,40	0,90
5	1,20	1,98	3,08	3,96
6	2,23	1,40	2,36	1,57
7	2,11	3,33	1,16	1,22
8	1,50	2,36	3,63	2,16
9	1,47	2,64	2,72	3,97
Result Point	5	6	6	5
Error (meters)	1,84	2,53	2,69	2,63
Average Error	2,43			

Table 5. Error average

If we propose a diagram of the architecture designed, could be the following:

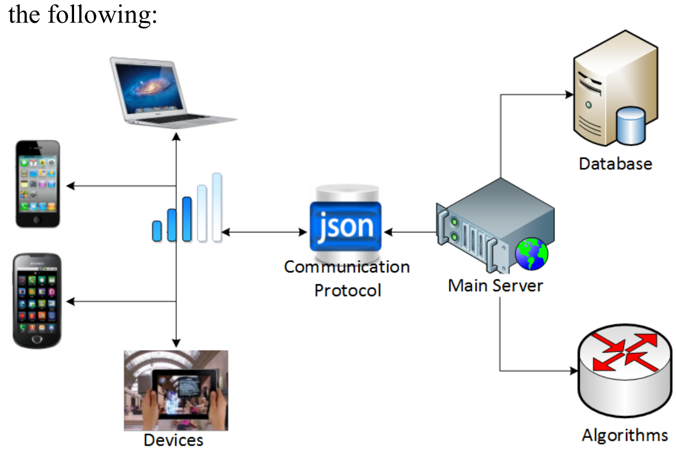


Fig 6. Architecture.

B. Pattern Recognition System

Due to technical limitations imposed by the use of mobile devices where power / battery efficiency ratio is important, it has chosen to use SURF algorithm to extract points of interest in an image. Also called SURF (speed up robust feature) is an evolution algorithm SIFT (Scale- invariant feature transform) that improves the robustness to changes in an image and has a faster computer without any loss of performance. In our case, the use of efficient algorithms, ensures a longer lasting battery. Using SIFT SURF front is mainly based on the velocity of the points of interest also known as keypoints, as these contain far fewer descriptors. Then, what is the procedure described SURF algorithm for detection of points of interest (keypoints) , assigning the orientation and finally obtaining SURF descriptor [15].

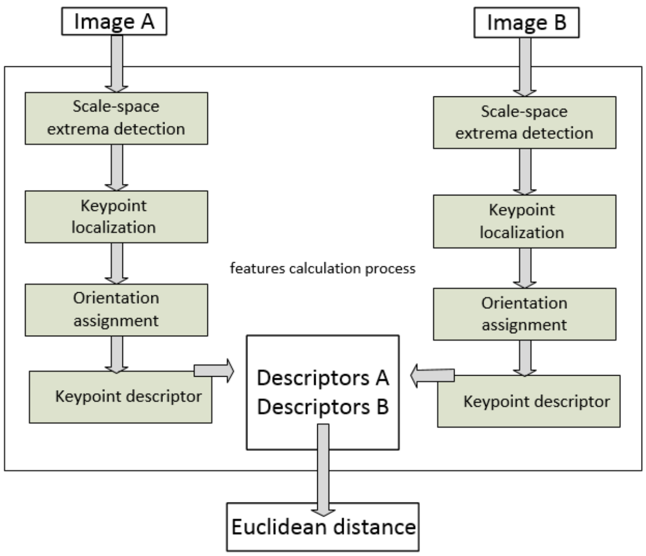


Image 7. SURF Detection Process

Detection of attractions is the first stage of the process in terms of extracting the keypoints. The high efficiency of this algorithm is based on this phase and is based on the use of the Hessian [14] array is defined as follows: Given a point P = (x, y) of the image, the Hessian matrix H (p, o) of the point p is

$$H(p,\sigma) = \begin{bmatrix} L_{xx}(p,\sigma) & L_{xy}(p,\sigma) \\ L_{xy}(p,\sigma) & L_{yy}(p,\sigma) \end{bmatrix}$$

defined by:

Where $L_{xx}(\mathrm{x},\sigma)$ is the convolution of the Gaussian second order, $\frac{\delta^2}{\delta x^2} g(\sigma)$ with the image I in point x, and similarly for $L_{xy}(\mathrm{x},\sigma)$ and $L_{yy}(\mathrm{x},\sigma)$. The approximations of the partial derivatives denoted as Dxx, Dxy and Dyy and the determinant of the matrix is calculated as follows:

$$det\,(H_{aprox.}) = D_{xx} D_{yy} - (0{,}9 D_{xy})^2$$

Orientation assignment: is to obtain the orientation of each of the points of interest obtained in the previous step. The orientation of the points is obtained by calculation of the Haar response.

SURF descriptors: for each point of interest, a square region 20s is constructed with the determined orientation and in the previous stage is subdivided into 4x4 sub-regions in which responses are calculated Haar apart 5x5 sampling. For simplicity, consider dx and dy the Haar responses [14] concerning the orientation of the point of interest. The representation of sub-regions is represented by a vector v of components: $\nu = \left(\sum d_x, \sum d_y, \sum |d_x|, \sum |d_y|\right)$

If we include the 4x4 sub-regions is SURF descriptor with a length of 64 values for each of the points of interest identified.

Following is an example of how the algorithm is able to determine the keypoints in common with two different images.

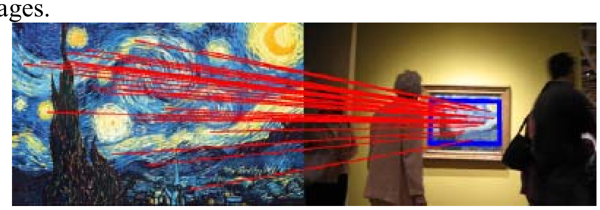
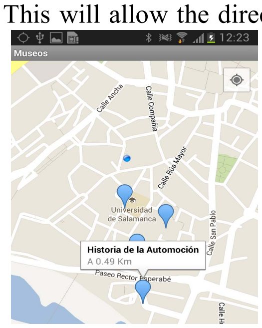


Fig 8. Keypoints correlation

CASE OF STUDY

The case study chosen to evaluate the proposal aims to develop a mobile application for Android and IPhone devices allowing the end user to make a guided tour of the Cathedral of Salamanca (Spain). To verify the overall operational functionality of the system, a Web viewfinder for the director of the exhibition will be designedin order to analyze the behavior of users within the exhibition.

This will allow the direct to know at all times which areas of the exhibition have more visitors or in which part of the exhibition they remain longer. To summarize the process of recognition of a work of art by an end user, this process includes the following steps: first, the visitor downloads a mobile application from various official marketplaces for Android / iPhone platforms, and with the help of geopositioning technology he is allowed to see the nearby museums feature our platform.



Once the user accesses the site, the application automatically will serve as an audio-guide throughout the visit, allowing the user to select the language of the virtual guide.

Fig 9. Main Menu in Mobile Application

Afterward, the location system estimates what part of the exhibition the visitor and once this area is identified, the mobile only downloads possible patterns of images of the paintings and monuments that are close to your position. Finally the user focuses on the box of which they would like information and the system accurately recognizes the table on which it is positioned.

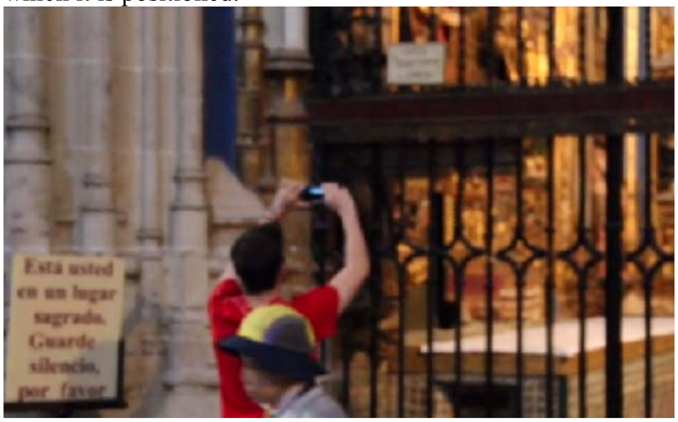


Fig 10. User Camera Focus ArtWork

Finally and once the image is recognized, a menu is made available to the user with information about the work that is currently displayed. This information can be an image gallery, related works, an explanatory video, text etc.

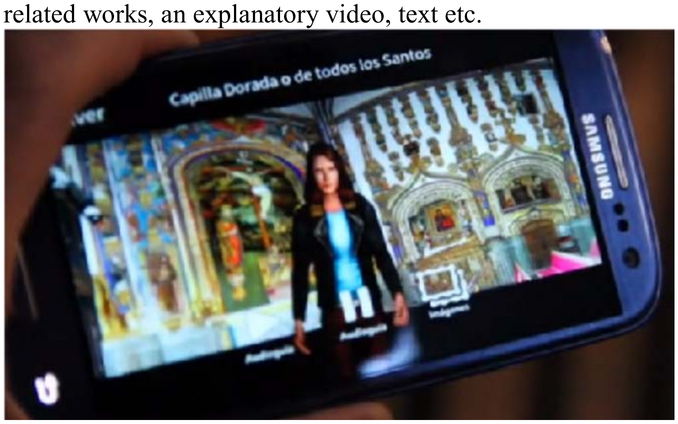


Fig 11. The virtual assistant informs you about what you're watching

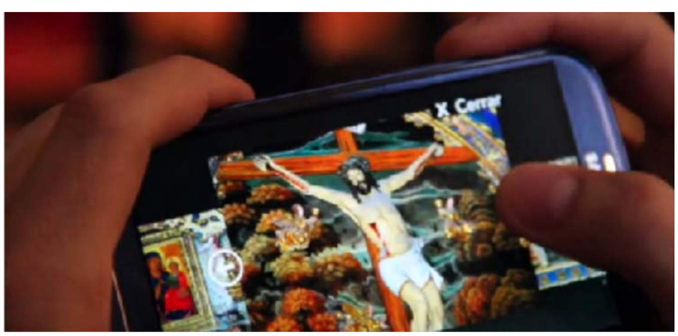


Fig 12. Gallery of selected monuments

From the point of view of the director of the exhibition, we can show the real time location of different visitors who are using the platform and on the individual pictures that are interacting at the time of the query.

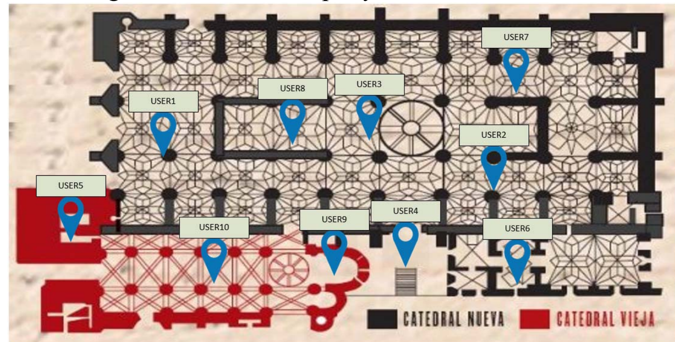


Fig 13. Locations of visitors

If we analyze the location of users over a period of time, we can obtain behavioral patterns. In the next picture, the areas where users have spent more time looking at the works of art can be seen. In the image areas reflect more intensity where users have been steadily for a long period of time. On the other hand less dense areas reflect traffic areas.

Fig 14. Map of heat generated during a period of time

IV. CONCLUSIONS

The proposed system allows for the ability to design an architecture that combines information from various sensors such as a camera and uses Wi-Fi technology to estimate the true position of a user within a museum, and can also show on the mobile of an end-user, multimedia content about what is being seen at that moment. The main advantage of our system compared with other existing systems is the low cost of implementation and the level of accuracy achieved because the Wi-Fi technology merged with pattern recognition of images that are taken by a camera estimate that part of the museum visitor is as specific box which the user is pointing his mobile device without any QrCode or RFID beacon.

By using a smartphone and reducing the cost required for maintenance of existing systems based on audio - guides, for example due to the updates that are triggered when we want to update the contents of an exhibition, due to the need to update each audio guide also using these devices allows us, for example, show much more elaborate, such as videos or any type of graphic explanation using a virtual interpreter multimedia content. Viewing a virtual guide produces an enrichment of the visit with the possibility to choose some kind of animated pet for a child audience. [7] When the application starts, the date of birth of the user is prompted, select the type of optimal route based on their age. In the next picture the exact location of the user is displayed in the exhibition and the works you should visit.

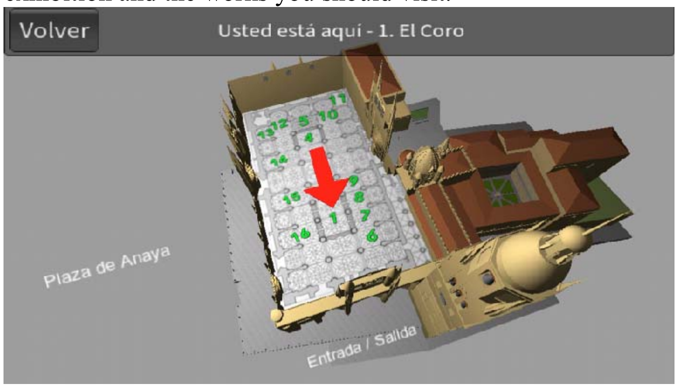


Fig 15. User Location

Content development is scalable, allowing multimedia content increase in a transparent manner, and that the update is immediate and simple for the user, the applications of the devices are updated automatically. We have managed to locate the user on a map in real time, can analyze the behavior of users within the exhibition. The application administrator can observe that part of the gallery visitors stay longer and show the guards in charge of security, which areas are more likely to be saturated at certain times through the development of a heat map.

V. LINES FOR FUTURE WORK

One possible future improvements that can be implemented in this system, is to add a recommendation system based museums tastes of users using data mining technologies [23]. Another possible evolutions is regarding the statistics generated by the web application, with the largest number of reports so that the administrator could have much more information about the tastes of the users. The use of the compass as additional sensor would offer the user guidance system indoors providing the real works marked by some kind of route based on your tastes path. Use accelerometer would determine the rate of movement of visitors and could analyze their behavior in more detail, such as whether certain hours its movements are faster.

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