Multimodal Museum Engagement Framework with Integration of Location Services

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***Abstract*—Museums are now competing to make a difference, which means that there is a need for finding new ways to measure effectiveness that do not rely solely on the number of visitors. As a result, the internets participatory culture is being brought inside the museum so that visitors can engage with the exhibitions. In addition, knowing the visitors location inside the exhibition adds a level of understanding about their behavior. It is also important to understand that visitors have different needs in the difference phases of the museum visit (pre, during and after), and by providing the information they are actually looking for, the museum provides visitors a better experience.**

While there is some work developed in this context, much is yet to be done. Most solutions focus simply on the moment of the physical visit and do not include location systems. Furthermore, even when the solutions include social media integration, usually that feature is not explored to its fullest. And while many solutions personalize the tours for the moment of the visit, they do not try to do the same by giving personalized content at a virtual level (after the visit).

This work proposes the MLime, a middleware that will provide museum with a system to manage their collections, allowing them to be presented for physical or virtual exhibits. This middleware will collect the users' behavior at a physical level and present information about the exhibit through a demonstration application.

***Index Terms*—museum framework, user engagement, indoor location services, museums, mobile applications.**

I. Introduction

THE arrival of the Internet compelled the museum community to start a discussion about how their visitors could benefit from the new emerging technologies. Even though there is plenty work done so far, there are still many questions to be answered and issues to be addressed.

The main idea expressed in many publications is that currently museums face a new problem: how to find effective ways to measure their performance. Anderson [1] states that art museums have shifted their focus away from collection-building and toward various kinds of attention to the public, therefore they must now compete with each other not for the best exhibition and the highest attendance but, rather, to make a difference.

Currently, the only quantitative metric used for evaluating a museums efficiency is the number of physical visitors. However, that does not equate to the quality of an exhibition, or expresses the real reason for the visit. Relying solely on the number of visitors ignores much relevant information. It would be important to collect feedback and understand what visitors enjoyed more and less about an exhibition. This would make it possible to adapt the exhibition and marketing to the museum audience and to assess any existing flaws.

Furthermore, using the "number of visitors" metric forces all the processes in the museum to be about increasing the number of visitors, and the efficiency of the museum is measured based on it, without acknowledging the effort put into improving the collections, the exhibits or the programs offered by the museum.

Another reason that makes this metric inadequate is that admissions income only provides an average of 12-15% of major art museums revenue [1]. While sales in tickets are not enough to ensure the sustainability of the museum, funders, on whom the museums rely for financing, will benefit from proof that their support was effective.

Regarding online museum visitors, the majority () (69,9 %) consider museum websites to be a deciding factor in their decisions to visit museums [2] but they also know that the real prize lies in the museum, and the majority of online visitors already decided to visit the museum prior to the website visit. It is important to understand that pre and post visitors have different needs (prior to a visit, online visitors generally look for useful information such as opening hours or driving directions, and after the visit they are more likely to look for information about future exhibits and special events). With that in mind, museums should design their online resources in order to capture people before the visit and encourage them to revisit it afterwards, by giving them what they are actually looking for.

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A. Problems with existing Solutions

Most existing applications for museums focus on the moment of the visit, and are designed for the tour, ignoring the pre and after visit situations. Some of those solutions are projected only to improve visitors experience, and do not consider in which way they should be designed in order to give useful information back to the museum. Moreover, most of them are static guides for the museum that do not adapt to the visitors behavior inside the exhibition.

Regarding the pre visit, there are tools that help museums to understand their online influence, and help measure the effectiveness of the website. One popular tool to do so is Google Analytics [3], which provides useful information about online visitors but does in no way connect the online visitor to the museum visitor.

In conclusion, the problems with the existing solutions are essentially the following:

- It is impossible to connect the pre visit to the physical visit;
- It is impossible to connect the physical visit to the post visit;
- There are no tools for personalize the post visit phase.
- Metrics used for evaluating the efficiency of museums are too generic;

B. Objectives

The main objective of this work is to create a generic framework that allows museums to manage their collections and that will provide museums more information about the visitors behavior in the pre, during, and post phases of the visit. This will facilitate the creation of new metrics for measuring museums effectiveness, while also improving the visitors experience, by giving them relevant information before their physical visit, content based on their location and profile during their visit and personalized content for after the visit. The aim is not to replace the museum curators, but rather to provide them with a digital tool that not only helps them organize the collections but also better understand their audience.

II. Background

This chapter provides an overview of the general concepts related with the work, some case studies and the existing solutions of applications for museums.

A. User Engagement

While several definitions for the term User Engagement (or Customer Engagement) is as a connection between a customer and a company or brand, that can be a reaction, an interaction, an effect or an experience that may or may not be sensorial [4].

The Oxford University Museum carried a research to measure how the visitors used their mobile devices while on the museum [5]. Not surprisingly, 95% of visitors carried a mobile device to museums. Also, 58% said that if they wanted further information about the exhibit they would use a search engine like Google, with less than 10% referring they would go to the museums website and 30% stating they would look for an application to download or scan QR codes or similar markers. This study highlights the importance of search engine optimization and directing users to relevant content when they log on to the museums WI-FI, captivating them before they go to a search engine. Another finding of this study is that 60% of the interviewed preferred to use their own device rather than one provided by the museum (like the traditional audio systems provided by museums), and for young people this preference was even higher.

The importance of bringing in a participatory culture to the museums has been emphasized by several academics [6], [7], who all agree in the need for museums to adopt the new learning agenda characterized by 21st-century skills of critical thinking, of creativity and innovation, collaboration, and civility [8]. This participatory culture changes the role of visitors, from passive elements that go to the museum and go away, to active elements that also bring their own experiences into the museum. This kind of new, distinct and fun experiences tend to bring a feeling of co-presence to the people involved, becoming a source of linkage among a group that otherwise wouldnt exist, which makes it more rememberable by the people involved in it [9], therefore having more impact in people.

While the visitors have much to gain from a more engaging museum, the museum also benefits from this approach: besides attracting more people to the museum with this kind of tools, the contributions of the visitors are of extreme importance for the museums, since they get honest feedback and understand what their visitors think, how they interact with the exhibition, and therefore if the message the curator wanted to pass is getting through.

B. Collection Management

Traditionally a museums inventory was made using physical support, both for the pieces and the exhibits: the inventory, the curation, and the design of all the exhibition relied solely on paper supports. But how has technology influenced the methods used by museums to make inventory, curation and design exhibitions? Besides the numerous research works on this topic, many technological approaches have been developed to help museums in this process. Here are some examples:

1) Matriznet: MatrizNet [10] is a Portuguese project coordinated by several Cultural public and private institutions that aggregates an online collective catalogue of museums. It gives public access to the information of those collections, allowing searches of the museums collections using several parameters.

Aimed both at professionals and students related to heritage and museums, but also to the general public, it is as a way for everyone to discover Portuguese cultural heritage. This collective efforts to create and maintain a public and crossed database of museums collections reveals that there is an interest of museums and public entities to adopt new ways of digital cataloging their contents, and sustains the idea that museums dont have to fear an open museum mindset.

2) Google Arts & Culture: Google Arts & Culture [11] is a global example of digital, public-accessed arts catalog. It allows public access to high-resolution images of artworks, enabling users to virtually tour inside the museums galleries, explore physical and contextual information about artworks and make their own virtual collection. It was launched in 2011, in cooperation with 17 international museums and it is growing. In Portugal some museums and cultural sites have already joined.

The Museum of Modern Art (MoMA) in New York City even registered an increase of 7% in website traffic within two weeks of the launch of Google Art Project, however, the number of visitors that actually go to MoMA as a result of the Art Project is not measured.

3) Omeka: Omeka is a free and open source web publishing platform. It is simple and flexible, targeted for scholars and

cultural heritage professionals. It aggregates Web Content Management, Collections Management, and Archival Digital Collections Systems that other systems have in separate [12].

It creates a website that represents the virtual exhibits and items. An exhibit is composed of several pages, each composed of blocks, that can have several associated items and different layouts. For instance, an exhibit page can present a gallery of items, a set of items with text associated or even just text. Moreover, Items can be included in Collections.

Besides the public website that is available through the browser and intended for presenting the virtual exhibits, Omeka has an administrator's panel where the website administrator can add and configure plugins, items and exhibits, customize the theme, and even access dashboards with statistics of the website usage.

It is at the same time an open source project with an active online community of developers, so it also provides the base for developing new features and extend the code to improve it's functionalities. Moreover, it already has a well-defined data model and implemented APIs (Application Programming Interface) for external access to its' contents and plugins.

C. Physical Exhibitions

During the course of this work no integrated tools for digital management of exhibitions were found, so all the management of the physical exhibition resorts to ad hoc means (resulting in physical isolated catalogues), as some professionals from museums (Museu do Azulejo [13], Museu Nacional de Arte Antiga [14], Museu Bordalo Pinheiro [15]) that were interviewed in the course of this work pointed out, and as a look into the curriculum for Curatorship in Faculdade de Ciłncias Sociais e Humanas [16] proves.

D. Indoor Location

A way to improve visitors experience in museums is to adopt indoor positioning systems by integrating them in mobile applications. From the visitors perspective, the information that can be presented is adapted in real-time to their location, therefore more relevant. For the museum however, the gathered analytics from location are important to understand their behavior inside the exhibit. It is possible to know for example how many people enter through a certain lobby, if there is an increase in the shop sales by visitors exiting a certain door, or if the coffee sales increase in a lobby if another lobby is busy.

E. Online User Tracking

It is relevant to measure how users interact with the museums website. A popular tool that helps to do so is Google Analytics [3], a service that tracks and reports website traffic, measuring the users behavior inside the website. However, it does not connect the online visitor to a visitor to the physical exhibit, therefore making impossible to use that information to make a profile for a single visitor.

The way to contour this issues is to use Login Sessions, so that the visitor explicitly gives permission for the website (or web service) to have access to their information. Login sessions can be done through social media integration (such as Facebook [17]), or by filling a form with basic information. From the museums perspective it is preferable if the user Login is made with social media, because it gives access all the public information that the user has on that social media network. The result of this approach is that not only the museum gets to know its audience better, but the information to be presented to the visitors can be personalized both during and after the visit, since it was a visitor X, an identified user, that engaged with a certain painting or was in a certain room, and not a random visitor.

F. Automatic User Recommendations

The information available online is so vast that searching for anything can be a really time-consuming task. For that reason recommendation systems, that is, systems that try to predict the preference or rating a user would give to a certain item, are increasingly important. As Ruotsalo et al. [18] state, the way recommendation systems interact with users is very important, from the way the feedback is received from users to the transparency on how the recommendations are given, in order to build trust.

G. State of the Art

In this section we will walk through the existing work in museums and technology.

1) Existing Solutions: Most applications are simply static guides that give extra information but do not connect the user of the application to an identified physical visitor to the museum. Even though each museum has their own application, they have similarities, which can generally be divided into the following categories:

- Tour - Presents a tour, i.e. a set of points of interest with information about the exhibition, the art pieces or the author;
- Tour Extension - Allows users to revisit the tour they did, with more relevant content for after the physical tour or allows to create a favorite list of pieces. Lets consider that there is no tour extension when the content presented is always the same, regardless of the user being physically at the exhibition or not;
- Social Media Login - The user creates an account through social media (for example Facebook) for signing in to the application. This way there is a connection between an anonymous visitor and an identified person, with all the information they provide through their social media;
- Share - The application allows the user to share media about the exhibition and the art pieces on social media (Facebook, Twitter,);
- Location - The application receives information about the location of the user;
- Personalization - Generates personalized tours for the user, so the presented content adapts either to the interests of the visitor or to their location;

H. Current Status Overview

At this point of the report it is possible to summarize the problems that are still ignored in most of the existing approaches:

- The digital collection management is unrelated to the physical exhibition, so the information about the physical exhibitions are not digitally stored, making it hard to reproduce them or create systems that extend the visit for a virtual scenario after the physical visit;
- The information about an online visitor to the website/application (prior to the physical visit) is not related to the visitor that uses the application during the physical visit;
- Some of the applications allow to share media on social media, however, most of them simply call the outside application that exists on the phone, and do not ask for any login through social media, missing the opportunity to collect more information about the users;
- Indoor location systems are not always used for enhancing the user engagement in the museum, nor for the post visit scenario to personalize content based on where the visitor was;

There are, nonetheless, isolated cases that use indoor location systems (beacons) to present contextual information to the visitors, like the case of the Near me function of the Guggeinheim Museum App. Moreover, some of the applications include features to encourage user engagement, like the case of the Canadian Museum for Human Rights App, that besides including the Near me feature, also uses a Mood Meter to collect feedback from the users.

III. MLime Requirements and Architecture

The first step of development of the framework is to identify its functional requirements considering the already mentioned objectives and both the museum and the visitors perspectives.

A. Web Application Requirements

Regarding the Web Application, the list of requirements and the identification of the entity (museum, registered user or unregistered user) for whom that requirement is, should be the following:

1) Edit items of exhibits - Museum
   a) Create, remove, update and delete items
   b) Add additional contents to items, such as files
2) Edit exhibits - Museum
   a) Create, remove, update and delete virtual exhibits
   b) Create, remove, update and delete physical exhibits
   c) Add description to the exhibit
   d) Add pages to the virtual exhibit
   e) Add rooms to the physical exhibit
   f) Associate items with the exhibit
3) Register - Unregistered users
4) See virtual exhibit using a browser - Museum, registered and unregistered user
   a) Rooms
   b) Items
5) Interact with items in the virtual exhibit - Registered users
   a) See
   b) Like
   c) Comment
6) Visualize statistics about visitors, in particular their interactions - Museum
7) Present personalized information based on user interactions - Registered users

B. Mobile Application Requirements

All the Mobile Application requirements are addressed to registered or unregisterd users, and they are the listed below:

1) Register - Unregistered users
   a) Register using a simple form
   b) Register through Facebook
2) Adapt to the exhibit the user is visiting, so it can be used in several exhibits and/or museums - Registered users
3) Present information about physical exhibit to the users - Registered users
   a) Exhibit
   b) Rooms
   c) Items (art pieces)
4) Use location to present contextualized information to the users - Registered users
5) Allow users to interact with the items
   a) See
   b) Like

C. Logical Architecture

Figure 1 presents the generic logic architecture of the system. The framework will be a Web Application that includes several modules and provides REST APIs so that a Mobile Application can access the Web Services. The User Management module will provide ways for registering the visitors (with a classic login form or through Facebook [19]), with the goalof identifying the visitors. The user should also be able to access the information about the exhibit, which is possible due to the Exhibits module, that allows the museum to create both virtual and physical exhibits, with all the associated information (items, pages or rooms).

While the Virtual Exhibit should be seen before or after the visit to the museum, the Physical Exhibit will help the museum prepare their exhibits. An item could be used in any number of exhibits and while the technical will be the same, the context of that item in that exhibit can be readjusted. The User engagement module allows to collect the interactions that users have with the exhibit. The Interactions module will provide the necessary means to store any kind of interaction. This information should then be used to generate suggestions for the user, to create personalized tours, within the Recommendations module.

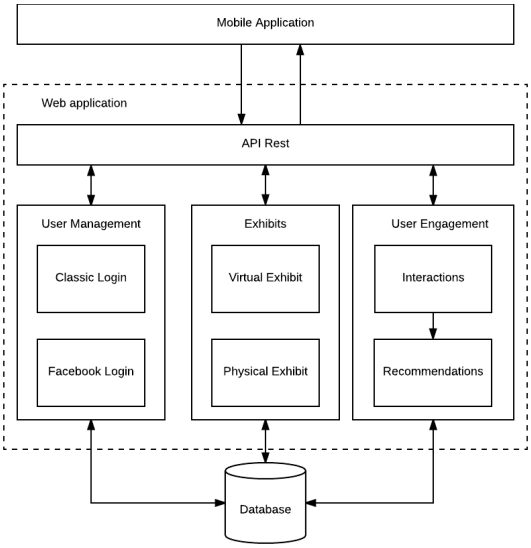

Fig. 1. Logic architecture of MLime.

D. Physical Architecture

Figure 2 shows the physical architecture of MLime. The logical components previously presented will now be separated into three different physical spaces: the server, the mobile app and the web app.

The Web App gets HTML from the server using HTTP requests, while the Mobile App will use the APIs to generate its own presentation. Each mobile component will correspond to a server component as follows:

- Authentication / User Management
- Exhibits / Exhibits
- Interactions / User Engagement

The Mobile App location component locates the user inside the exhibit and presents information accordingly.

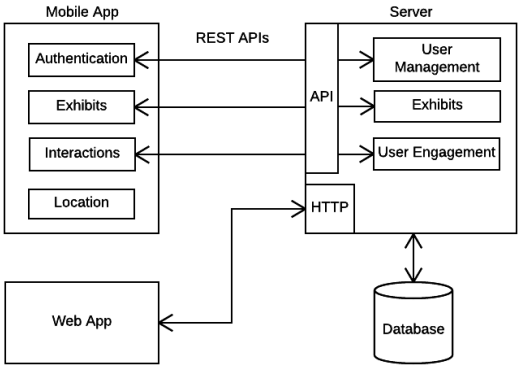

Fig. 2. Physical Architecture of MLime.

IV. MLime Implementation

A. Omeka - Web Application

The implementation of the described system would either be done from scratch or by extending an existing system. Because Omeka combines a platform for collection management and an open-source programming platform, it was selected and a supporting framework for developing the MLime system.

1) Exhibit Builder Plugin: With the Omeka's Exhibit Builder plugin the museum can create online exhibits using the items they have uploaded to Omeka. This is an original Omeka Plugin that was extended in this work in order to allow to create physical exhibits. In the extended version, the pages are called rooms and also have blocks with the items. With this approach, the museum can separate the exhibits that are meant for users to see online and also use the system to plan and design their physical exhibits.

2) Interaction Plugin: To implement a way to detect and store information about user's interactions with the exhibits, a new plugin called Interaction Plugin was developed. This plugin adds the following features to Omeka:

- New table in the database for storing interactions.
- New HTML with a new "Like" button in the item's public page, where users can click to "like" a certain item. This will create a "Saw item" interaction in the database.
- New HTML "Exit" button in the item's public page, where users can click to go back to the home page. This will create a "Saw item" interaction in the database.
- New REST API that allows to get and post interactions from/to the database.
- New administrator dashboard to show statistics about users.

Omeka already had the Commenting plugin, that allows users to comment items and collections, which creates an isolated element that represents a comment. The present work proposes a broader approach in which users interact with items, and those interactions can then be a comment, a like or any other type of interaction, making the system more extensible.

3) Recommendations Plugin: The stored interactions can be used for presenting recommendations for similar content to users. Since this kind of "post visit scenario" was part of the scope of the current project, a new plugin for Omeka called Recommendations was implemented. This plugin creates what has been called a recommendation in the item's page, based on previous user interactions. An HTML section that includes a link to an item that the museum suggests users to see and a text explaining users the reason why they are seeing that recommendation is added to the items' public page.

The implemented recommendation algorithm finds a recommendation for a user based on the interactions that other users have done with a certain item. Since the focus of this work was not to implement a complex recommendations system, but to leave foundations for further improvements, the plugin is extensible, in such way that it is possible to replace the recommendations algorithm.

B. MLime Mobile App

As already mentioned, since most people already bring their smartphone into the Museum, creating a mobile app became the obvious choice for giving visitors the tool to engage

with the museum. The development of the MLime mobile application was done using:

- The Ionic framework, an hybrid and open-source SDK for mobile app development
- AngularJS for the presentation layer
- Apache Cordova for interacting with the native API of the mobile device hardware
- Omeka is the web application that will provide information to the mobile application

1) Authentication: In order to use the application the visitor has to be identified, that is, to be authenticated, either by using the Omeka credentials or a Facebook login mechanism, provided by the Facebook APIs.

2) Exhibit configuration: The first step for visitors, when visiting an exhibit, is to scan a QR code that will configure the application for the current museum and exhibit. Configuring the application means to define the server that the application will connect to and which exhibit it should get information from. This approach allows the same application can be used for different museums or even, in the same museum, for several exhibits.

3) Exhibit information: The information that is presented in the mobile device about the exhibit, from the items to the exhibits, is fetched from the Omeka web application using the Omeka's APIs, and presented in different pages (organized in "tabs").

In the "rooms" tab visitors can see information about the rooms and the rooms' items, so when in a room they can know more about what they are seeing. The "items" tab lists all the items of the exhibit. Each item detail page indicates which room the item is in, which will help visitors to navigate inside the exhibit to go to a certain art piece they are looking for. Moreover, each room can include a description and each item of that room can also include text, so it is possible to give a context to the items for their room: while in the "items" tabs an item has the general information about the art piece, in the "rooms" tab it can have a specific description and context for the room.

4) Location: The application includes a barcode scanner feature, so users can get more information simply by pointing the phone's camera to a QR Code in the physical exhibit. This QR code will have the url for the public page of the item or exhibit room, so when the MLime application reads it, it will send a request (through REST) to the API of the server asking for the information about that room or item. After receiving this information, the mobile device will present the "item detail" or the "room detail" view, accordingly. This API request will enable an interaction in the web application, so besides fetching the information from the database, the server will create a "scan" interaction will be stored in Omeka's database through Interaction Plugin's API, so the museum will know exactly what users scanned.

The QR code is an indicator for the location of users inside the museum, which is an important information about the visitor's behavior.

5) Interaction: The MLime application allows visitors to interact with the exhibit by doing "likes" on items, which will generate a new entry in the database for that interaction.

V. MLime Evaluation

A. Functional Evaluation - Web Application

1) Edit Items of Exhibits: It was mandatory to have a system that allowed to create, update and delete items with content that could be text fields to describe it or images that represent them, which is done in the administrators dashboard. The items can also contain several files associated.

2) Edit Exhibits: The framework should allow to create, update and delete both virtual and physical exhibits, which can be done through the administrators' dashboard. The button "Add a Physical Exhibit" was added to the original Exhibit Builder dashboard. Both the virtual and physical exhibits have a title, a slug, can include credits and description.

A Virtual exhibit is composed of pages that have blocks, that have different layouts that define how the content should be displayed - for example, as a gallery, a set of files with text associated, just text.

In the case of Physical Exhibits, the pages are actually Rooms, and the blocks define the representations of the physical items: for example, a text block can be the description of the room, and a gallery may have the items that represent the art pieces of that room. This exhibits and exhibits' items can be accessed from any browser, or through the application, where the information is handled to be presented in a more mobile friendly way, and also with the purpose of being seen in the physical exhibit.

3) User Registration Exhibits: Users can can register using the website form.

4) See virtual exhibit using a browser: With a browser users can see virtual exhibits in Omeka. By going to the page of the exhibit, Omeka presents the items of that room.

5) Interact with virtual exhibits: Omeka already offers a plugin that allows users to leave comments in the public items. However, that creates a specific element for comments and the objective of this work was to have generic interactions. The Interaction plugin developed in the course of this work allows to create any type of interaction. As a result of this new plugin visitors could "Like" items, creating a "Like" interaction in the database. Moreover, when they clicked on the "exit" button on the item public page, a "Saw item" interaction was also created in the database.

6) Visualize statistics about visitors: The Interactions Plugin allows to visualize statistics about visitors, in particular their interactions with certain items.

In this work the only sensors used were QR codes, that allow the museum to identify which exhibit and which rooms the visitor was in. It also tells which art pieces the visitor was interested in. In order to collect more information about the location of the users inside the museum, more sensors had to be used, but that was not the goal of the present work. Notice that the interaction includes fields for time and date in order to measure times users spend on certain points of the exhibit but the QR codes provide an isolated date and time for the interaction.

7) Information Personalization and Recommendation: The Recommendations plugin uses the collected information about user's interactions to present suggestions to users, based on

what other users also liked. This is a simple personalization for visitors but more complex algorithms could be presented. The recommendations appear in the public page of each item.

B. Functional Evaluation - Mobile Application

1) User Registration: Users can can register through the mobile application using a form or a Facebook login. This last option is more convenient for the visitors but also allows to get more information about the visitor to present to the museum, since they have to give access to their public profile.

2) Adapt to different exhibits / museums: To adapt to the exhibit the user is visiting, so it can be used in several exhibits and/or museums, the visitors should scan a QR Code scanner to configure the application, or in other words, that will connect the application to the server and configure the correct exhibit to present.

3) Present information: The application can present information about physical exhibit to the users: the general information about the exhibit, the complete list of items, information about each room and each item of the room.

4) Location based interaction: Another requirement of this work was to use location to present contextualized information to the users. That was achieved by using QR codes in the exhibit to present information based on the location. Figure 3 shows a visitor scanning a QR code to see information using the QR code scanner related to that specific location.

Fig. 3. Physical Architecture of MLime.

5) Interact with exhibits: Visitors were able to interact with the physical exhibit by seeing and ”liking” items. They were also able to scan QR Codes, which is a type of interactions, so by doing that they created a ”Scan” interaction in the database.

C. Demonstration

To evaluate and validate the work, a demonstration was implemented in the Bordalo Pinheiro museum for the temporary exhibit ”Lisboa de Bordalo”, an exhibit with several illustrations of the artist Rafael Bordalo Pinheiro grouped by 9 zones of Lisbon city, and also 9 panels with images of figures that Bordalo created to represent the typical Lisbon people. In the physical exhibit each illustration had a label with:

- Title of the art piece
- Type of the art piece
- Publication of the original illustration
- Description

The exhibit had a representation in Omeka, that included the information about all the art pieces present in the physical exhibit, including some information that wasn’t available to the visitors without the application: besides the image and label (which existed in the physical exhibit) for each art piece, the visitors had access to links to ”Hemeroteca Municipal de Lisboa”, plus the Google Map [20] for the zone of Lisbon represented in the exhibit and even information about the figures in the panels, which otherwise wouldn’t have any context.

By adopting the MLime system, besides including on the Omeka’s collection database all the information that was on the art piece’s labels, the museum was able to added the following **new information** to the exhibit:

- A link to ”Hemeroteca Digital” [21] was added to the illustrations, that shows the original publication where the illustration was taken from.
- Completely new information about the Panels:
  - Description and contextualization of the ”Typical figures” panels.
  - Image of the ”typical figure” represented in the panels.
  - Image of the original illustration where the ”typical figure” was taken from.
  - Description about each ”typical figure”.
  - Link to ”Hemeroteca Digital” that shows the original publication where the figure was taken from.
- A google map associated to each ”Zone”.

This representation of the physical exhibit in digital format and the extension of the exhibit with new information was done in only one week.

1) Museum demonstration: On the 30th of March of 2017 a group of people with different backgrounds and interests was invited to the Bordalo Pinheiro museum to test the MLime application in the ”Lisboa de Bordalo” exhibit. The visitors were asked to fill out an anonymous inquiry (which can be consulted in with the purpose of having data to analyze. This analysis will be separated into three parts: visitor demographics, registered interactions and results of the inquiry.

The visitors profile varied significantly in all the categories: regarding age, gender, qualifications and professional area. From people working in technology, to culture and heritage professionals, from young to older people, etc, it is evident that it was really heterogeneous group, which is interesting since the goal of the system is to reach out to a wide audience.

The visitors had to install the MLime App, then login in the application (either by using their Facebook account, registering with the application’s form or using one anonymous user given for the purpose of this test), and finally explore the contents that the museum prepared. To do so, they could either read the available QR Codes, which presented items and room information.

Every time a user scanned an item, the application would create a ”Scan” interaction using the Interaction API previously explained. The same applied to the ”Likes” visitors did in the application’s items. This resulted in the registration

of users' behavior, so that the museum could understand which art pieces had more attention from the visitors. This demonstration resulted in a total of 111 interactions created in roughly two and a half hours. The information regarding items that had more interactions. It is interesting to note that while the item that has more scans was on the entrance of the exhibit, the remaining were spread in different parts of the exhibit.

After using the application in the "Lisboa de Bordalo" exhibit, the visitors were asked to respond to a simple inquiry regarding their habits when visiting museums (in general) and the MLime application (in particular).

The results of the inquiry were clearly positive, with the majority of visitors indicating the the application was relevant, innovative and useful for having a better experience in museums, but no difference was found between the various subpopulations.

The interest in this application from the museum was so much that the application remained in the museum after the day of the test, was announced in their newsletter and became available to the museum's public. It was accessed several times after that.

D. Results

This sections will present the results achieved with this work. Firstly, the system resulting from this work lets museums manage their collections and use them for presenting information to the public. For that, besides extending some of the plugins of Omeka, some new plugins were developed. Moreover, the MLime application was, at the moment of writing of this report, the first mobile application found for Omeka that includes user authentication, interactions and indoor location capabilities. Finally, it is relevant to emphasize that the demonstration of the work was done in a real context, which results in more tangible results. The results of this work can be summarized as follows:

1) At a higher level:
    a) Creation of generic and reusable platform for managing physical exhibits
    b) Development of a mobile application for Omeka with Facebook Login and integrated QR code scanner functionality
    c) Possibility to have virtual and physical interactions with the exhibit
    d) Creation of recommendations for users based on interactions
2) In Omeka:
    a) Extension of virtual exhibits to physical exhibits.
    b) Addition of new interactions with items (new plugin).
    c) Implementation of extensible recommendation system (new plugin).
3) Regarding the demonstration:
    a) Demonstration of the MLime App in a real exhibit
    b) Implementation of a virtual exhibit in a short period of time.
    c) Adoption of the system from the museum right after the demonstration.
    d) Possibility of extending the exhibit, beyond what was already available to users.
    e) Visitor behavior recorded
4) For the museum:
    a) Possibility to extend the physical exhibit.
    b) Interactions at virtual and physical levels.
    c) Framework that provides statistics about visitors' behavior.
    d) Demographic information about users, resorting to the Facebook Login.

E. Discussion

This section initiates a discussion about the achievements of the present work. Firstly, with this system it is really easy to create exhibits, so that no more than a week was necessary to digitalize the "Lisboa de Bordalo" exhibit. In that particular case all the items had to be added to the database individually, but if the inventory was already digitalized it would be even more simple.

Another relevant aspect to be considered is that the system also allows to extend the physical exhibits by adding new contents to physical exhibits, that otherwise wouldn't be available, either by lack of space or design choices for the actual exhibit, or because those contents cannot be represented in a physical form.

Users were very enthusiastic when trying the MLime App, which shows in the inquiry results. They suggested improvements (such as to add audio), but the responses were all positive.

Regarding Omeka, while it facilitates the creation of data specifically for museums, its' data model is rather complex. However, this work proves that it is possible to use a collection management system, usually used by the museums, to present information to the public.

By doing a mobile application and not a generic website, it is possible to use the same application for several museums just by connecting to different servers. So this work could provide a system that aggregates several museums using the same Mobile Application. Moreover, if the application is not connected to any server, and even if it is offline, it could also present some information that is stored in the App, and does not come from any museum or entity's server.

VI. Conclusion

The need to finding new quantitative ways to measure museums' performance aligns with their need to know more about their audience. Visiting a museum is a process that starts with searching for useful or general information, then with the actual visit and finally the curiosity of knowing more after the visit. However, most existing applications for museums focus solely on the moment of the visit, and don't try to connect the several stages of the exhibit to adapt to the needs of visitors in each moment.

Adopting a new participatory culture into the museum is very important both to the visitors, who can have a richer

experience, but also to the museum, that learns about its audience. For the museum, having this type of information can provide new metrics to measure performance. Besides asking the visitors to engage with the exhibit, the implementation of indoor location systems provides visitors with an even more personalized experience, and it also gives museums much relevant information about visitors' behavior. But personalizing is not possible if the visitors are anonymous, so it is mandatory to have authentication systems in order to associate an anonymous visitor to a real visitor.

Collection management systems, specially integrated with user engagement, is still somehow an unexplored area for museums. This work shows the benefits of using a platform that combines both.

The aim of this thesis was to provide a solution for museums that integrated collection management and a system for representing virtual and physical exhibits, but also to have a Mobile application that allowed visitors to know more and interact with the exhibit, and then present that interaction information to the museum, therefore creating new ways to collect feedback and generate statistics about visitors' behavior.

Both a web service and a mobile application were implemented to achieve the objectives of this work. This system was based on the Omeka platform, and was designed with the objective of being as extensible as possible, so that extra functionalities could be implemented later. For example, the implementation of a Recommendations plugin that used interactions to present suggestions for other items for users, in the "after visit" context, but that can in the future be extended for more complex algorithms.

The MLime application communicated with the Omeka-based platform to present information and let users register through Facebook. It also presented contextualized information based on location to visitors, by providing a QR code scanner that visitors could use to scan QR codes to know more about the exhibit.

To validate the work, the MLime system was implemented in a real exhibit, in Museu Bordalo Pinheiro. The results of this demonstration highlighted the relevance of this work: both the inquiry answers and the museum feedback were really positive, and the museum decided to provide the MLime system to their audice right after the demonstration.

A. Future Work

In the demonstration of this work only QR Codes were used, but it would be interesting have more complex location systems by including more sensors to have other kinds of interactions and to draw other types of conclusions about visitors. Moreover, more sensors would allow to personalize the visit even more, for example by having a "near me" button that used the real location of visitors inside the museum.

The App could be significantly improved. It could, for example, have a navigation system, that is, a map with the museum plant which could even adapt to the position of the visitor inside the museum. This second feature would require that the museum installed indoor-location systems. Another relevant aspect, that was even mentioned in the inquiries, would be to include audio to the application, which would replace the traditional audio guides that visitors are used to see in museums, and that would also give blind visitors the chance to have a better experience when visiting museums.

The recommendation system implements a rather simple algorithm, so it would be interesting to create other recommendation algorithms that could provide better suggestions for visitors.

One aspect that could also be explored is the creation of reward or achievement systems for users, that museums could use and adapt to their own marketing model, in order to incentive user active engagement with the museum. For example: the museum could have e-tickets with discounts for visitors that bought it through the application. By encouraging to use the application in the several stages of the visit, the museum gets a broader view of visitors' behavior.

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