Digital interaction with 3D archaeological artefacts: evaluating user's behaviours at different representation scales

Ramona Quattrini[a,*], Roberto Pierdicca[a], Marina Paolanti[b], Paolo Clini[a], Romina Nespeca[a], Emanuele Frontoni[b]

[a] *Università Politecnica delle Marche Dipartimento di Ingegneria Civile, Edile e Architettura*
[b] *Università Politecnica delle Marche Dipartimento di Ingegneria dell'Informazione*

Abstract

Digital multimedia contents are gaining, in the Cultural Heritage domain, more and more importance. We should thus expect, in the forthcoming years, that archaeological sites and museums' administrators will undertake the digital approach as the mainstream for communicate their values. Although state of art technologies are ready, the public behave and acceptance are still broadly missing: few works are focusing on the user's feedback. The present work reports different multimedia experiences from the users' point of view, understanding their engagement. The paper shows a workflow tracing the quantitative and qualitative satisfaction for different applications dedicated to the archaeology, at three different scales: landscape, museum and object. Results demonstrates that the proposed approach provides insiders and art curators with meaningful data to analyze the user's and, consequently, to

*Corresponding author. Tel.: +39 3488800864.
Email address: r.quattrini@staff.univpm.it (Ramona Quattrini)

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accordingly set up new strategies for real virtual exhibitions.

Keywords:
UAV, digital photogrammetry, Data Integration, 3D modelling, Virtual reconstruction, Archaeology, VR.

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1. Introduction

The technological innovation developed over the past ten years plays a pivotal role in the promotion, dissemination and enhancement of Cultural Heritage (CH) (Fanini et al., 2019). Today, new technologies allow one to make methods and studies more flexible, versatile and cross-disciplinary, improving their understanding and making digital CH more accessible and usable. In this context, multimedia technologies applied to territorial, archaeological and monumental assets are increasingly investigated, since they enable the interaction in any place and time (on-line, off-line or via mobile device) with a wide range of heterogeneous information (Pierdicca et al., 2019b)(Pierdicca et al., 2019a).

Among the others, the use of 3D models, mobile applications and the Web have become very important, facilitated by the new frontiers of computer graphics (3D modeling, augmented reality, virtual reality, and more) (Luigini and Panciroli, 2018). In fact, multimedia systems allow the user to visualize and interact with virtual replicas of artifacts through virtual scenario and in their original contexts, even if no longer existing. (Clini et al., 2017).

An open challenge, much felt by both experts and institutions, is to understand if this interactivity allows a real improvement in understanding the relations between the archaeological sites (or the monumental complexes)

and the territorial context in which they are inserted. In other words, if the different fruition levels permit a higher understanding of the cultural contents experienced at different dimensions (Pescarin et al., 2018).
The work here presented moves in this direction, by systematizing different multimedia experiences from the user's perspective, attempting to understand their engagement in applications of cultural and archaeological heritage. For this purpose, we evaluate the quantitative and qualitative satisfaction of the users on three different scales of archaeology: territory, museum and artifact. Exploiting different data acquisition techniques (web analytic, IoT solutions and focus groups), the article proposes new ways for collecting and analysing user's information. Figure 1 reports an overview of the proposed research that considers the three levels of archaeological heritage representation, as well as different monitoring tools (qualitative and quantitative approach).

The reminder of this paper is organized as follows: the state of art in Section 2 provides the reader with the latest research trends about CH-related projects in which the user's behaviours are analysed; afterwards, Section 3 provides a general overview of the multimedia experiences and their set up from a technological point of view. Section 4 outlines the results of our experiments, achieved with both quantitative and qualitative methods of data collection and analysis. Concluding remarks and prospective outlooks of future implementation are reported in Section 5.

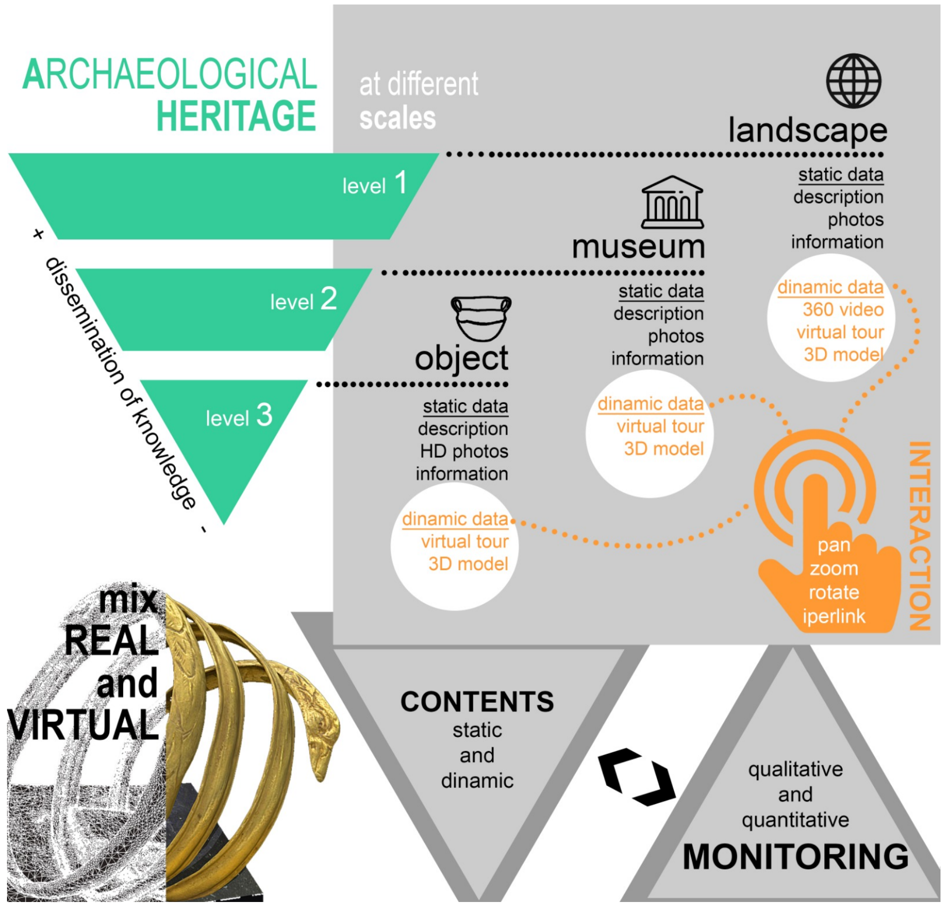

Figure 1: General overview of the proposed workflow: archaeological heritage at three different scales.

2. State of art

Applications based on digital three-dimensional models of cultural and archaeological heritage have acquired an important role in the enhancement of communication strategies, especially for the three levels of archaeological heritage (Gobbetti et al., 2015; Battini et al., 2019). The digitization process in the field of architecture and archaeological heritage (AAH) is based on the

3/4D reconstruction. Today, technological advances ensure different methods for acquiring 3D data and deploying them to a scalable 3D mixed reality (MxR) environments (Rahaman et al., 2019). Thanks to the contribution of artificial vision techniques, photogrammetric algorithms based on image processing have become more competitive for the generation of point clouds. Especially in recent years, structure from motion (SfM) is the most robust and accurate acquisition technique for archaeology, applied both on a large scale (Pierdicca, 2018; Lerma et al., 2010) and on the single artifact (statues, ceramics, and more) (Guidi et al., 2015; Evgenikou and Georgopoulos, 2015). Some works fill the gap of low-cost, open source, and automated solutions for the collection of numerous archaeological finds, especially considering the portability of these solutions (Gattet et al., 2015). Our experience in previous works has concerned the realization and validation of several SfM acquisition that represents the foundations of the digital photogrammetry pipeline (Clini et al., 2016; Quattrini et al., 2017; Pierdicca et al., 2016). In addition to the 3D contents, panoramic images 360°, videos and virtual tours already demonstrated high acceptance by the users (Mah et al., 2019; Bolognesi and Aiello, 2020).

Depending on their purposes, 3D models can be applied to different devices and there are currently many good practices in the use of these models both for indoor communication tools and outdoor applications (Empler, 2018). These tools have the aim to activate new forms of communication with the public, by placing the user at the centre of these operations (Maniello, 2018; García-León et al., 2019). As an example, since large digital libraries suffer the low accessibility for the general public, in (Machidon et al., 2019) in-search and navigation intelligent conversational agents are exploited. Recently, the decision making process for Virtual Reality (VR) applications are performed by artificial intelligence (AI), based on behavioral observation (Bozzelli et al., 2019). Moreover, some studies deal with observation of new trends in archaeological heritage, such as current tensions on social media usage from cultural organizations (*Instagramization*) (Kargas et al., 2020); others attempt to assess the potential of AR/VR applications specifically designed for CH and educational purposes (Pierdicca et al., 2020; Geris and Özdener, 2020).

In the context of the territorial scale, an original study is proposed by (Psomadaki et al., 2019), who introduced a model realized thanks to the public involvement and the collaboration of cultural organizations. Another application that involves people to share personal memories and promoting audience engagement is (Ringas and Christopoulou, 2013). Even if this application promotes this involvement, museum and institutions are not involved. Applications for the ancient Athens[1] and Crete[2] use virtual tools for a web navigation in space and in time, allowing a personalized navigation and enriched by VR/AR elements. However, these applications do not promote the audience engagement and the interaction between users.

From the point of view of archaeological museum, the first works studied how to monitor the moving of visitors in the rooms of a museum through Bluetooth data collected from mobile phones (Yoshimura et al., 2012; Pierdicca

[1]http://www.ancientathens3d.com/

[2]http://steamcommunity.com/sharedfiles/filedetails/?id=720174192

et al., 2019a). In a real environment the authors analysed the movement of visitors from the entrance, uncovering behavioral patterns. The limitation of these first works is their scalability and replicability; this kind of systems only cover the room that an individual is visiting in a given time. In another work (Dim and Kuflik, 2015), a system that measures the position and spatial orientation of individuals for behaviour classification of people pairs in a museum was presented. They classify the behaviour in six classes and use simple sensor data to identify social synchronization, attention to the companion and interest in museum exhibit. The problem is that due to the granularity of data is difficult to discern which zones the visitors frequent more. To overcome this problem, in the work of (Lanir et al., 2017), the authors presented a system based on radio-frequency identification (RFID) signal to detect the position of visitors. Their proposal has the purpose to help museum curators understand the different behavioural models of visitors. From the literature review provided so far, clearly emerges the need to enforce common strategies for collecting the feedback by the public. Although the user engagement is well recognized as a need by all experts and curators, there are still few cases in which technologies applied to CH are tested, considering their communicative effectiveness and usability. According to (Haugstvedt and Krogstie, 2012), there is a lack of shared methodologies of reference for measuring users' satisfaction, especially in real time. By summarising experiences from different research projects, this paper paves the baseline to pursue this aims at territorial, museum and artifact scale.

3. Materials and methods

The feedback of users has been collected exploiting two research projects dealing with CH promotion and fruition. Here following, the digital experiences are detailed from a technological perspective, in order to clarify which are the contents for which the evaluation data have been collected and analysed. The first experience, at territorial scale, concerns the Marcheology project (see subsection 3.1), whilst the museum and artefact scales have been faced exploiting the results of MANaM, experienced in the National Archaeological Museum in Ancona (see subsections 3.2 and 3.3).

3.1. Marcheology: web platform and mobile app

The Marche region has a remarkable and widespread archaeological heritage, which requires a priority and stimulating reference point to promote targeted knowledge within the Region's tourist-cultural landscape. It is rich in areas and monuments ranging from Prehistory and from the Piceno age to the late ancient and medieval period: 32 archaeological areas, 6 state museums and many archaeological town museums. The challenge of the Marcheology repository is to offer tourists an instrument of knowledge and planning of a journey into the archaeology of Marche. The architecture is based on the assumptions, therefore, to speak to the public of tourists, varied and demanding, focusing on the simplicity of use of the instrument and inserting the archaeology in the tourism consumer network. The design of the database starts from the choice of the type of information (what) and the structure of the data (how) to be organized. Regarding the archaeological data the architecture provides: a) descriptive and spatial contents, which

Figure 2: Home page of the web portal where the main features are visible.

narrate and georeference the place; b) information and tourist services related to the place. The data structure was designed following the historical and geographical structure of the Region (Figure 3): a territory crossed by rivers and valleys developed perpendicularly to the coast, in which there are many important traces of Roman consular roads, for example the Flaminia, often visible for its morphological structure (Clini et al., 2019). An archaeological heritage, therefore, can be geographically classified geographically (according to the fluvial arteries) and historically (according to the road arteries Flaminia, Salaria Gallica, Salaria Picena, Salaria Romana, Camellaria). Therefore, real visit routes were developed, ranging from the coast to the inner areas, considering the relevant archaeological assets, their dislocation, and the richness and offers of the cultural and landscape context. Approximately one hundred other archaeological sites have been collected, ranging in the offer both for the chronological fields (since prehistory to the late ancient age), both for the dominant assets, as well as for the methods of visiting the places. The presentation of the archaeological sites and the museums has been tailored to scientific criteria and, at the same time, to the need of a data displacement for a quick and comprehensive consultation. Therefore, the mapping makes use of maps of the archaeological emergencies characterized by a dry and lean style, which also indulge in a captivating and seductive description of the sites, delineating on the territory historically determined routes and, at the same time, logistically easy to reach. Once the database was set up, the second phase concerned the development of the web site and mobile app: it is possible to search in an organized and interoperable form all the information of interest to visitors to plan their archaeological tour. Each place is geo-referenced, so the user can create a personal itinerary or follow the paths suggested by archaeologists and experts. Observing Figure 2, the platform[3] offers different possibilities: (i) searching by keywords; (ii) choosing the sites according to the valleys; (iii) searching with filters and elaborating customized routes, choosing points of interest as well as the fastest geographic itinerary and, finally, saving the route (on the page "places"); (iv) choosing among already available routes;

[3]http://www.marcheology.it/it/

and (v) searching for restaurants, hotels or events by inserting filters. Finally, thanks to the possibility offered by remote analytics tools, we were even able to collect user's statistics as shown in the next section. In parallel, with the same structure and graphic representation, a mobile application has been created for both iOS[4] and Android OS[5]. The main focus in displaying contents was the chance of previewing sites and archaeological findings via web and ubiquitous systems, giving the possibility to use 360° Virtual Tour, 360° Video and 3D digital artefacts shown in the Digital Library (DL) (Figure 3).

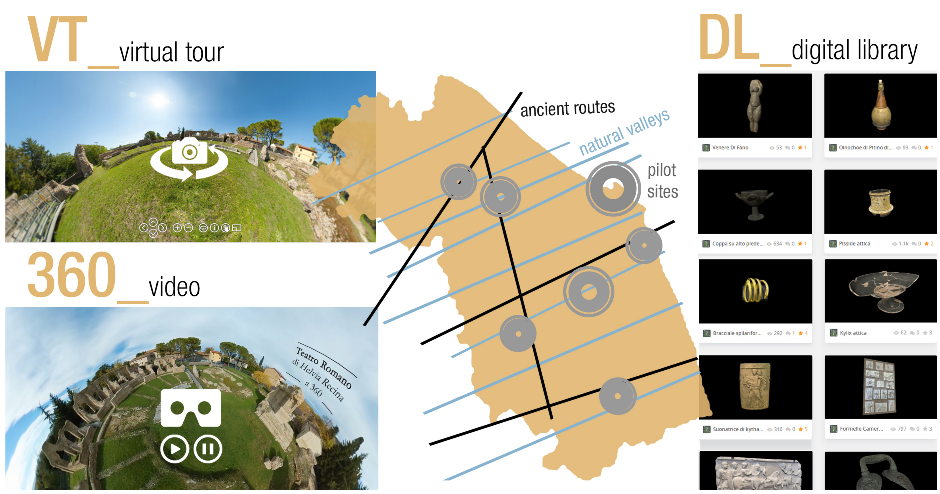

Figure 3: The main multimedia tools offered by the project: 360° Virtual Tour, 360° Video and 3D digital artefacts shown in the DL

3D digital data have been acquired for the pilot sites, in order to create remote navigation solutions, based on immersive and three-dimensional interaction. Beside static acquisitions we added dynamic (4D) acquisitions,

[4]https://apps.apple.com/it/app/marcheology/id138492994

[5]https://play.google.com/store/apps/details?id=it.jef.marcheology&hl=en

videos or timelapse, to 360°, realized through special cameras, on drone or auction. DLs, on the other hand, collect a selected set of the most representative pieces of the archaeological collections and were made using digital photogrammetry. The 3D models, excellent in quality, are browsable thanks to the inclusion on the open platform Sketchfab, which offers a good 3D viewer, light and intuitive. For an improved documentation of the findings, an archaeological description and the VR vision have been added.

3.2. The Museum Analytics: observing user interaction in the museum

In this section, we propose a software infrastructure coupled with a hardware technology to build a system for detecting and analysing the human behaviour in a museum. Using cameras and computer vision algorithms, the system can detect human motion and then describe visitors behaviour by quantitative parameters. Therefore, it detects and monitors people, using a distributed video sensor network. The installation of the system in several areas of the museum provides large volumes of multidimensional data on which to perform statistics and deduce insights. The analysis of these information offers a unique possibility to better understand several crucial aspects of a museum environment. This system can be easily scaled, from a single area installation to a large widespread grid of sensors.

The system, installed within the National Archaeological Museum of Ancona, consists of six components: (i) Single Board Computer (i.e. Raspberry Pi), (ii) Asus Xtion Pro live (RGB-D sensor), (iii) Wireless Adaptator, (iv) SD/MicroSD Memory Card 8GB Speed 10, (v) Hub USB 2.0, (vi) Router 3G/4G Wireless.

The Single Board Computer is a computer built on a single circuit board, with microprocessor(s), memory, input/output (I/O) and other features necessary for a functional computer. This system was generally made as a demonstration or development and educational system, or for use as embedded computer controllers. It uses a SD memory card in which Debian operating system is installed, that allows a simple configuration of RGB-D sensor of Asus Xtion Pro Live compiling these modules: OpenNI Library3 and PrimeSense Sensor Driver4. The Asus Xtion Pro live is composed by an infrared sensor, an RGB sensor and 2 microphones. In output it provides a RGB representation of the environment and can reconstruct its depth map. Each pixel in the map also codifies the distance of each element from 3D scene. RGB-D sensor is supplied by the Hub USB 2.0. The RGB-D sensor is installed in top view configuration at three meters of height from the floor. It displays a maximum area in a two-dimensional projection (visitors tracking area) of 1.8m x 3.2m. The tracking algorithm can be summarized in five phases that have in input the image detected by the top-view camera and in output the features extracted by the visitor's behaviour. In the first step, the streaming video from the RGB-D sensor was acquired by the system. The images are preprocessed by the background subtraction method, that is one of the most commonly used approaches for identification of the objects in motion within a sequence of images. This approach is reliable because each pixel of the scene has the depth as further information and in this way, it allows to detect the distance from each blob. Moreover, to avoid false positives in the phase of identification objects, the background is dynamically updated. However, to identify positive signals that correctly detect moving objects, avoiding false positives because of background noise, it is defined a threshold value named “segmentation”. The next phase is the object detection, which considers each meaningful blob and evaluates the boundary and the maximum points. This latter discriminates the head of each visitor. There is a successive evaluation where the blob is retained valid if the maximum point is included by a region of the lowest points comparable to jump head (Migniot and Ababsa, 2013). Afterwards, there is the object tracking algorithm in which each positive blob is recognized and tracked within the streaming video, i.e. the pathways of different blobs in the frames are recognized and then tracked. The method is based on the depth, for which the height is calculated by verifying that it is in the neighborhood of the height of the visitor in the previously elaborated frame. The heads are tracked among two successive frames and in both frames, the same blob is identified by the same identifier, so the same blob tracked in the following frames. A unique identifier univocally identifies each visitor. In this way, each visitor maintains an ID unique during the entire visit of the museum, always respecting privacy, a very important aspect.

3.3. The Digital Library at MANaM: interacting with the artefact

Given the large number of artefacts of an archaeological museum, the digitalization process has been optimized to limit processing times, exploiting well-established pipelined based on close range photogrammetry and reverse engineering. A fast and inexpensive acquisition system that ensures excellent photographic quality has been realized. The 3D digitization process ended up with the realization of interactive digital facsimile, that are be scalable and adaptable to different technological solutions. The artefacts are generally classified in three categories: movable, unmovable and very small objects according to their size and position. This classification fits very well to archaeological museum collections and drove us to create a DL performed for the National Archaeological Museum of Marche Region as well as for different archaeological museums belonging to the Regional Museums System. This 3D realization has different outputs: 3D visualization, stereoscopic view, 3D printing and more (see Figure 4).

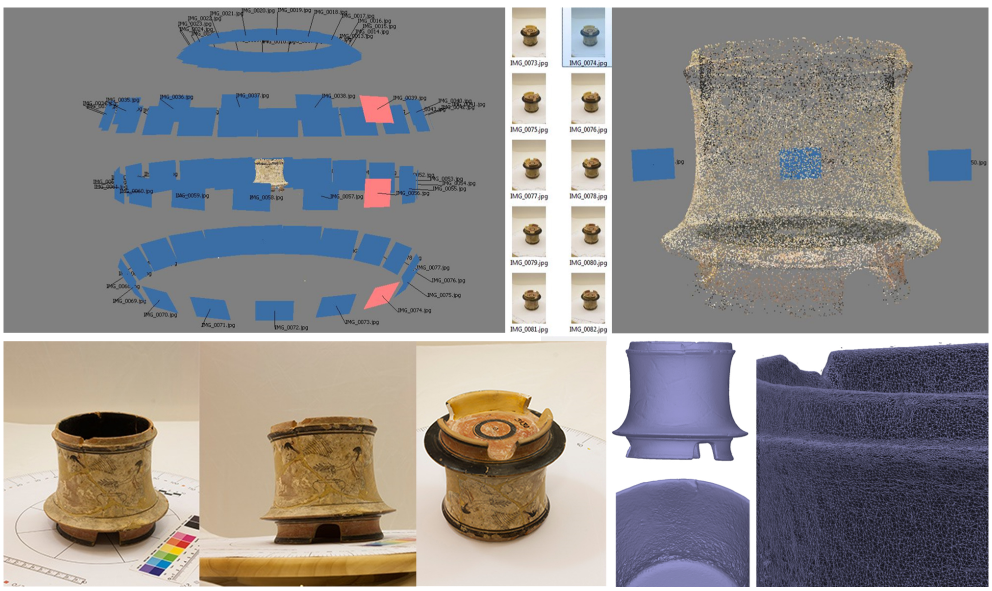

Figure 4: Artefacts photomodeling pipeline, which goes from the data acquisition with close range photogrammetry techniques to the creation of the textured model.

To enable the users to experience such digital replicas, a PC connected to a 4K monitor and second touch screen form the DL that allows an augmented experience with the artefact. The monitor allows to display 3D models and relative information in high definition, while the touchscreen allows to manage, manipulate and interact with the virtual object in the DL. Our architecture consists of two main components: (i) Touch Interface (TI); (ii) Main

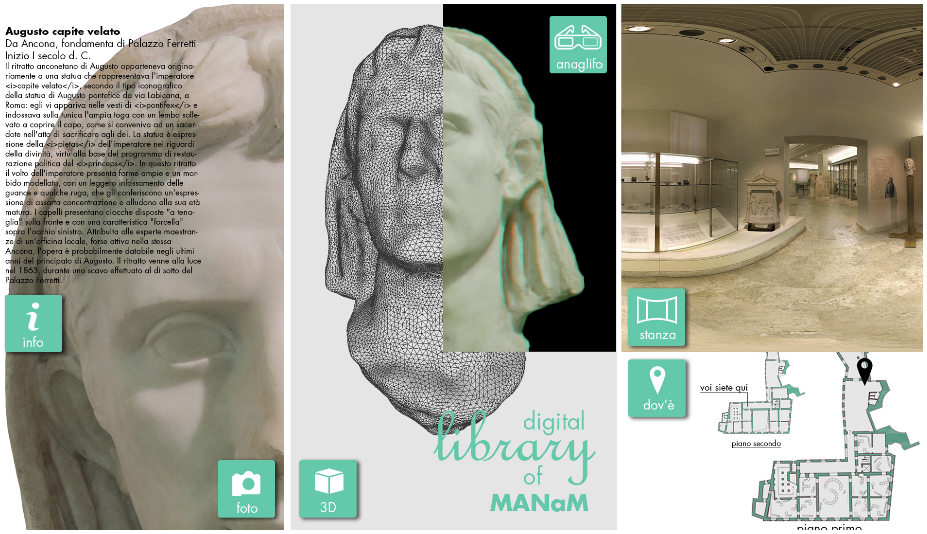

Figure 5: The DL as it appears in the HD visualization. In the example the artifact is showed with its explanation and its own localization inside the museum arrangement.

Visualization interface (MVI) (4k visualization). The use of TI is to control the visualization of a spherical panorama, of ultra-high definition images, of anaglyph 3D model, of 3D model and moreover to start/stop multimedia contents related to artefacts. All the contents are viewed in the main visualization interface (MVI). While in the graphic interface is organized the DL (Figure 6), where there is the possibility to choose the artefacts by the name, the category or the location. Many are the functionalities for the objects, in fact the users can visualize the 3D models, the location in the plan, the spherical panorama of the museum room which contains it, the historical information and high definition images. Since sometimes the objects are very small and / or enclosed in display cases, the high quality of the models and images allows to enlarge and make visible the small details of the archaeological object, which otherwise would not be visible.

Figure 6: An example of visualization of a complex 3D artifact within the Digital Library.

4. Results and discussion

The following results section is devoted at describing the user's response for each experience. By analysing, at each scale of interaction, user's behaviours and insights, our endeavour is to share with the research community useful data that can serve as guideline for future implementations. The analysis has been set up depending of the representation scale of archaeological matters, ensuing the schema of the project experiences described above. Data have been collected in an interesting mix among the real and the digital environment, which can be seen as an seamless exchange of information between the user and the space.

4.1. Web platform performances evaluation: analytics and user test.

The data collection period about Marcheology spans across one year of observations —from November 2018 to November 2019 —analyzing data from both the web site and the mobile app; indeed, the potential and the drawbacks of the proposed methodology is considered for different media. The statistics of usage can be found in Figure 7.

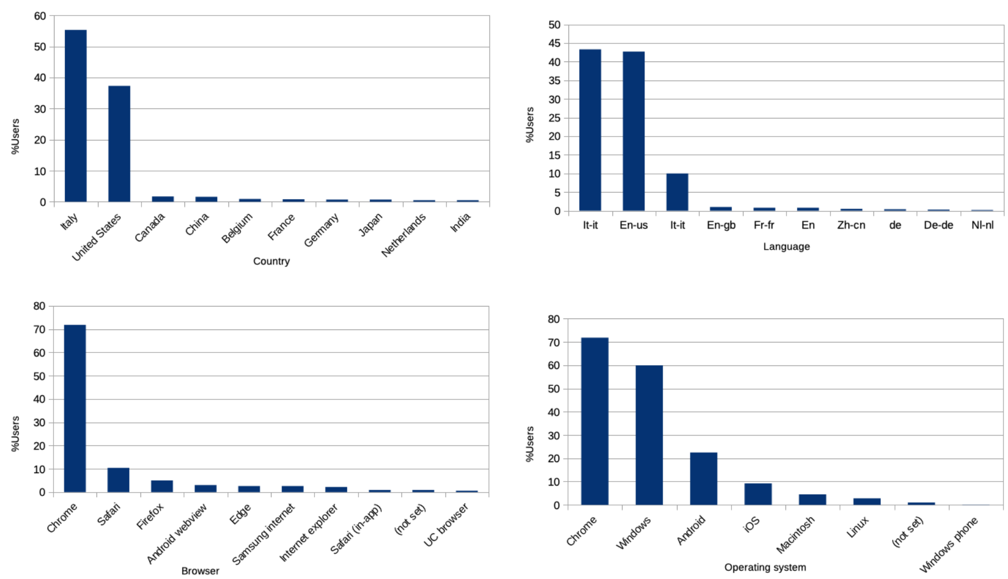

Figure 7: Histograms of rate of users according to different: country, language, browser and operating system

What emerges at first is that the desktop application (web-browsers) outperforms the mobile app. Hence, the tourists prefer to increase their knowledge of the archaeological sites before or after the visit. This trend is in line with the common trend of searching information from the web rather than with mobile apps, that should be more advertised by the insiders to make it useful even during the visit on site. All these data can be matched

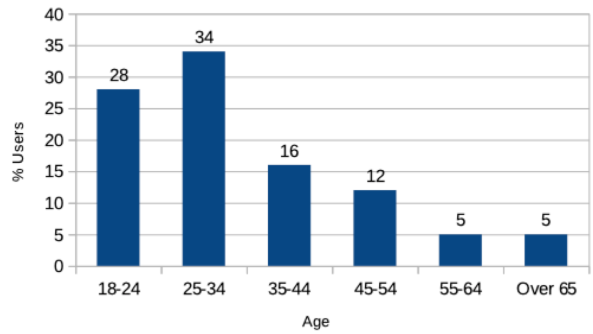

Figure 8: Rate of users divided for age.

with those related to the category of the device which confirms that most browsing on the platform is from desktop applications. It is worth noting that the majority of users make use of Google Chrome search engine, which is an indicator that the platform is well indexed and has a high degree of visibility on the web. The platform even reveals insights about geo-data, indicating languages and countries where the tool has been used the most. It is interesting to note the involvement of non-European users (but with low numbers), demonstrating that these kinds of applications allow to spread the knowledge of CH sites even for foreign countries. The Multilanguage function of the platform is therefore needful. Further analysis of the data shows that the number of users approaching to the platform is almost constant during the period of observation. We can deduce that the visit of the site is not strictly dependent from the period of the year and that the interest of the users to archaeology can be exploited all over the year. For the sake of fairness, the performances of single users are noteworthy; by the way, the platform needs improvement in terms of engagement. In fact, each user have revisited the platform just one time, and the average time spent interacting with it is less than two minutes, that are not enough to achieve an in-depth analysis of the contents. Other interesting insight to better know the type of users can be found in Table 8. First of all, dealing with the age of sample, we can affirm that the use of the platform decrease with the increase of the age. This is not trivial, since it highlights that the digital divide is still existing and that such kind of tools cut out a huge chunk of the population. Thanks to the analytic tool, a gender and preferences analysis were done; first, the ratio between males and females is almost equal. In the light of this information, the potential of the platform is enormous for both visitors and policy makers. An analysis of the data indicates that the former finds the platform of interest and useful for increasing the knowledge and understanding of the area they visited, while the latter has at their disposal a platform which at the same time allows the visitors to be monitored and tourist services to be promoted. This is, to date, the only way to improve the decision-making process so as to intervene with a data-driven approach. The web-based analysis was preceded by a formative evaluation action, through the realization of scenario-based usability tests on a mixed sample of end-users and a subsequent summative evaluation intervention through the administration of online questionnaires. The usability tests of the Marcheology platform were designed and conducted using a scenario-based method. The objective was to evaluate the user-friendliness, the degree of satisfaction and the memory of the actions on 8 different scenarios of use. 10 participants representing different user targets have attended the usability testing on "marcheology.it" platform. The tests have been conducted in a controlled testing environment, under the observation of three professionals with the task of collecting data, in order to optimize the performance in the final version. The total duration of each test was about 15/20 minutes. The scenarios were designed to allow the users to become familiar (basic level) and then proceed to intermediate and advanced level actions. The last two scenarios have tested the ability to remember the architecture of the website content, proposing tasks already present in previous scenarios. During each test, the staff members recorded the time taken for each action, the errors made by the tester, the outcome of each scenario and any notes or observations made by the user ("thinking aloud" method). These errors allowed to improve the site and the app before their publication, providing a solution to the actions that were most frequently characterized by critical errors. In the months following publication, the website was evaluated by using online questionnaires consisted of 10 questions (summative evaluation). By July 2019, only 23 questionnaires have been completed, providing a new measure on users satisfaction and effectiveness in communicating content. The questions also covered some general information about gender, age and the level of education, useful for profiling users. The questionnaires have provided results in line with the usability tests, with very positive opinions on the clarity of the contents and language and on the graphic layout. Users mainly highlighted the lack of updating of information on cultural events in that area and this led to results similar to the analytic one. For this scale of representation, that is the territorial scale, the research mixes traditional tool for analysing user experience with more innovative ones, obtaining a quite robust and real time assessment of the archaeological platform.

4.2. Museum's performances evaluation: on site analytics

In this section we present the installation of three cameras system located in three different position of the museum MANaM[6]. The system has been installed on a panel in the suspended ceiling of the museum. It gives in output a significant data stored in a database and then successively analysed to extract indicators. The real test has been realised installing three RGB-D cameras for a time period of 12 months to obtain significant and real data. In the MANaM one camera monitored the entrance, a second camera, the first floor crown room (focus point 2, FP2) and a third camera the DL (focus point 3, FP3). These focus points are identified inside the museum in order to analyse the preferences of visitors. The choice to put a camera near the entrance allowed to exactly count the number of people who entered the museum. Moreover, the three cameras properly positioned allowed to provide an analytic report and information about some indicators: "attraction", "attention" and "action". So, the indices useful to evaluate the visitors behaviour, that can help the museum director and curators to understand their preferences and so, to increase the experiences of the visitors are:

- $N_p(\cdot)$ is the number of passing in a zone;
- $N_s(\cdot)$ is the number of stopping in a zone;
- $I_{attr}(\cdot) = N_p/N_s$ is the index of attraction in a zone;

[6]The experiments and the installation, here presented, joined with other funded regional projects, allowed a technology transfer and to develop the MeMus product, by Marchingegno and Grottini Lab.

- $I_{atte}(\cdot) = t_s$ is the index of attention (i.e. the average dwell time stopping in a zone);

- $I_{act}(\cdot) = N_p/N_i$ is the index of interaction with the proposals, touch screen, armoured door, and so on.

All the contents are handled by a cloud-based service that unifies and shares all the information and multimedia contents while collecting different user statistics about the visitor's behaviour. In this section we focus on the results of 1 year (from March 2018 to February 2019) of field tests with full user data collection and project evaluation based on the visitor's behaviour, shared among all contents providers on a participatory planning view of the whole project. The position of the FP, with the respective statistics about values obtained by the daily monitoring are reported in Figure 9.

In Table 1 general statistics for the entire period taken into consideration are shown. The table considers the occurrences of visitors for each month of the year and shows the monthly aggregation level for the three cameras installed. Moreover, the system can determine the number of visitors for a day and/or a week.

The rate of attraction can be inferred by the values of $N_s(FP2)$ and $N_s(FP3)$. The last row summarizes the total number of visitors in a year for each statistic presented in this table. On the total amount of entrances, the rate of $N_p(En)$ is 51% and the rate of $N_s(FP2)$ is 34%. While always considering all the entrances, the rate of $N_p(FP3)$ is 99% and the rate of $N_s(FP3)$ is 34% as $N_s(FP2)$. To evaluate the attraction of an artwork we have to consider the average dwell time which is 31 seconds for the FP2, and 8 seconds for the FP3. Analysing the values for FP2, we can say that 6%

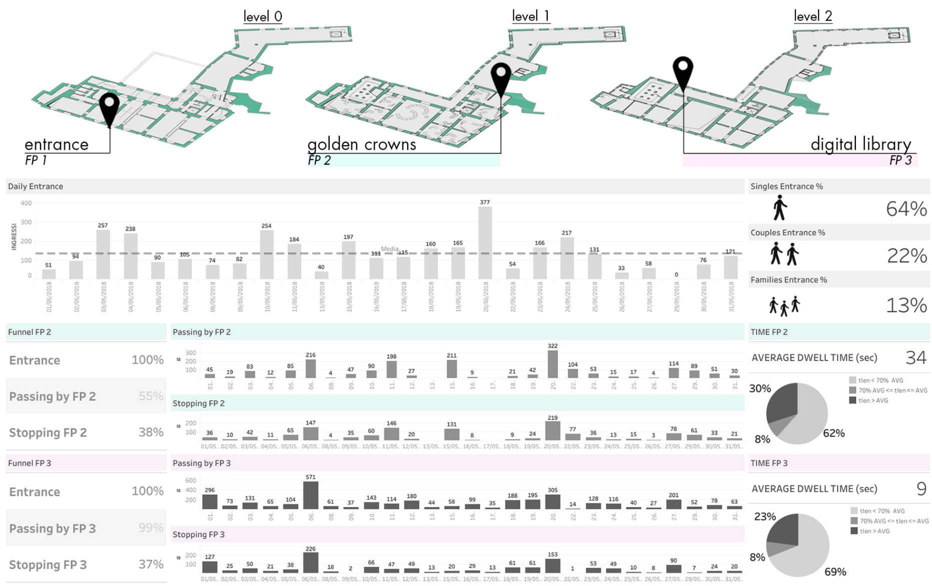

Figure 9: The three focus points of the museum installation, divided per floor and with the statistics of user's behaviours.

of visitors stopped less than 31 seconds, 28% more than 31 seconds and 8% stopped 31 seconds. Concerning FP3, the average dwell time is 8 seconds, in which 69% of visitors stopped less than 8 seconds, 23% more than 31 seconds and 8% stopped 31 seconds. Finally, since the system can detect the percentage of entrances in reference to single, or couple and/or family, we obtain 70% of singles entrance, 20% of couples entrance and 10% of families entrance.

4.3. Digital Library performances evaluation: focus group.

In the evaluation of the 3D models of the DL at MANaM, the necessary data were collected through actions of front-end evaluations, with the creation of focus-groups with a group of target users represented by secondary

Month	$N_p(En)$	$N_p(FP2)$	$N_s(FP2)$	$N_p(FP3)$	$N_s(FP3)$
Mar	2225	1725	1179	3097	1064
Apr	3032	2963	2001	4029	1417
May	3506	1908	1304	3418	1281
June	2567	1591	1038	2893	1099
July	3257	1501	928	2903	1081
Aug	2096	1923	1307	2299	459
Sept	2703	1136	809	2288	747
Oct	3092	555	359	1622	577
Nov	3367	1110	735	3222	1143
Dec	1892	647	434	2630	1000
Jan	2912	573	373	2853	1010
Febr	2319	1115	667	1253	441
Total	**32968**	**16747**	**11134**	**32507**	**11319**

Table 1: Statistics of the number of visitors for each month over 12 months (from March 2018 to February 2019). $N_p(En)$ is the number of visitors in the entrance of the museum; $N_p(FP2)$ indicates the number of visitors that pass in FP2 and $N_s(FP2)$ the number of visitors that stop at FP2. $N_p(FP3)$ indicates the number of visitors that pass in FP3 and $N_s(FP3)$ indicates the number of visitors that stop at FP3.

school students.

- Phase 1: the activity involved two different opportunities for discussion using the appropriately moderated and facilitated Focus group technique, and a free visit with in-depth investigations was organized at the museum spaces.

- Phase 2: To evaluate the performance of the technologies developed, in this phase usability tests were administered to analyze visitor activities.

The main task of this study is to identify a set of guidelines for the implementation of technological solutions.

The activity was structured considering 3 hours for each meeting in 3 different afternoons, attended by three High School Institutes of the Municipality of Ancona. The number of participants involved in the tests was 27, of which 18 girls and 9 boys. Each focus group had a duration of 60 minutes, where a moderator supervised and addressed the discussion, with the support of a verbalizer who highlighted the interventions, the relevant aspects of the interview and the single contributions. The activity was carried out in the following way:

- brainstorming ("what do you think if I tell archaeological museum?")
- our memories (questions about this and other museums)
- metaplan ("what I expect?", evaluation of expectations)

Following, the subjects involved in the tests freely visited the museum sites for about 50 minutes under the supervision of the operators who recorded the behavior of the students in front of multimedia contents, teaching aids, observation of the finds, and more. Finally, the last 60 minutes have been dedicated to:

- feedback from the visit;
- memorisation of the objects;
- game of imagination.

Before and after the free visit, the archaeological museum is considered as a place linked to the past, not active and static; moreover, the visit is not considered a fun and social experience to share with other peers. Thus, the need for more direct and interactive contact with the artifact emerges, a simple transfer of information is not enough to attract especially the younger ones. There is therefore the need for a subjective experience involving other senses beyond the sight. Table 2 and table 3 show the guidelines identified in the first phase. Currently, questionnaires are submitted to the real visitor of the Museum, in order to comprehend user acceptance as well as more useful contents and the perceived experience about 3D models.

Multimedia devices must:
be easily usable, understandable and accessible for all (for any age, nationality, disability)
be installed in close proximity to the exposed exhibit with interaction, or adequately integrate with the space of the Museum
be controllable if equipped with sound options, volume and playback
avoid actions with time limits or, if necessary, allow the user to extend the time limit
ensure a fast and pleasant experience (e.g. good resolution, fast loading times, and more)

Table 2: Guidelines for multimedia devices

For the user multimedia devices must:
Contextualize the discovery using information contents, easily comprehensible, evocative and efficient that, with the interaction, increase its value of experience, supply deepening and connections with the museum and monumental reality of the territory
Maximize the virtual reconstruction of an object in order to view the details with the naked eye
Virtually reconstruct an object of its missing parts in order to obtain the original
Perceive the find by touch and understand its weight, material and texture
Simulate the ancient use of the object
Create a copy or a personal reinterpretation of the finding departing from the virtual modelling of a block that simulates the same material in order to understand the practical difficulty that had occurred when it was created
Customize the findings from the virtual modelling of the object
Create a 3D print of the produced object

Table 3: Guidelines for multimedia devices from the point of view of users

5. Conclusion and future works

In this paper, CH related contents have been tested to understand user's insights. To achieve the first results, here presented, we exploited two research project to face the problem at different scales of representation. The developed systems are able to connect archaeological resources and territories through a network, thereby promoting historical centers, cultural heritage, green areas and interesting places. The case presented in this paper gives the vision of how the territory can be supplied with digital instruments, developed in order to be used by both locals and tourists. The research team is constantly monitoring their impact thanks to the statistics, obtaining and analyzing the tangible and intangible results, as shown in the paper. The main contributions of the projects are in: i) the analysis of heterogeneous data collected from the directly from the users; ii) development of best practices that can be exploited by small municipalities of a same territory to share cultural and touristic information; iii) monitoring users preferences and needs by collecting users generated data and iv) providing local administration with useful and meaningful statistics about the tourists, tested and verified in real scenario with real users.

Benefits of such approach are twofold and can be analysed as follows: for the insiders, the cooperation among different actors involved in the management of cultural goods opens up a new vision of tourism management, where the resources are placed in a unique system to wide up the application scale, which is too often limited to very small territorial areas. From the users perspective instead, statistics reveal that digital services represent the sole instrument able to convey information in a quick and agile way.

More in general, for archaeological finding it is possible to obtain a great magnification of their characteristics thanks to ICT tools. The 3D virtual replicas make culture accessible to the mass audience and the technological-mediated fruition assumes a complementary role in the direct experience of cultural good. It is clear that the digital interaction with artefacts does not replace the direct one. The Cultural Heritage collection, conservation and access in novel, accessible and attractive ways demand for digitizing museums and archaeological/historical sites, as well as for designing methodologies to represent, manage and exploit cultural heritage data at different levels. As future works it is envisaged to reduce the *pen-and-pencil* approach by improving the data collection strategies through digital tools. A future foreseen implementation in the DL is, as example, to track user interaction with digital contents. Moreover, similar on-site analytics need to be serialized and synchronized with data by Museum Analytics. Cultural Heritage still suffers a division between the visitors and the real estate of cultural goods, that can be overcame by adopting new strategies not only of digitization, but mostly oriented at creating a link among the real and the virtual dimensions as a whole.

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