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

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(Article begins on next page)

accordingly set up new strategies for real virtual exhibitions.

Keywords:

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

4 1. Introduction

5 The technological innovation developed over the past ten years plays a
6 pivotal role in the promotion, dissemination and enhancement of Cultural
7 Heritage (CH) (Fanini et al., 2019). Today, new technologies allow one
8 to make methods and studies more flexible, versatile and cross-disciplinary,
9 improving their understanding and making digital CH more accessible and
10 usable. In this context, multimedia technologies applied to territorial, ar-
11 chaeological and monumental assets are increasingly investigated, since they
12 enable the interaction in any place and time (on-line, off-line or via mobile
13 device) with a wide range of heterogeneous information (Pierdicca et al.,
14 2019b)(Pierdicca et al., 2019a).

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

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

24 and the territorial context in which they are inserted. In other words, if the
25 different fruition levels permit a higher understanding of the cultural con-
26 tents experienced at different dimensions (Pescarin et al., 2018).

27 The work here presented moves in this direction, by systematizing different
28 multimedia experiences from the user’s perspective, attempting to under-
29 stand their engagement in applications of cultural and archaeological her-
30 itage. For this purpose, we evaluate the quantitative and qualitative satis-
31 faction of the users on three different scales of archaeology: territory, museum
32 and artifact. Exploiting different data acquisition techniques (web analytic,
33 IoT solutions and focus groups), the article proposes new ways for collect-
34 ing and analysing user’s information. Figure 1 reports an overview of the
35 proposed research that considers the three levels of archaeological heritage
36 representation, as well as different monitoring tools (qualitative and quanti-
37 tative approach).

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

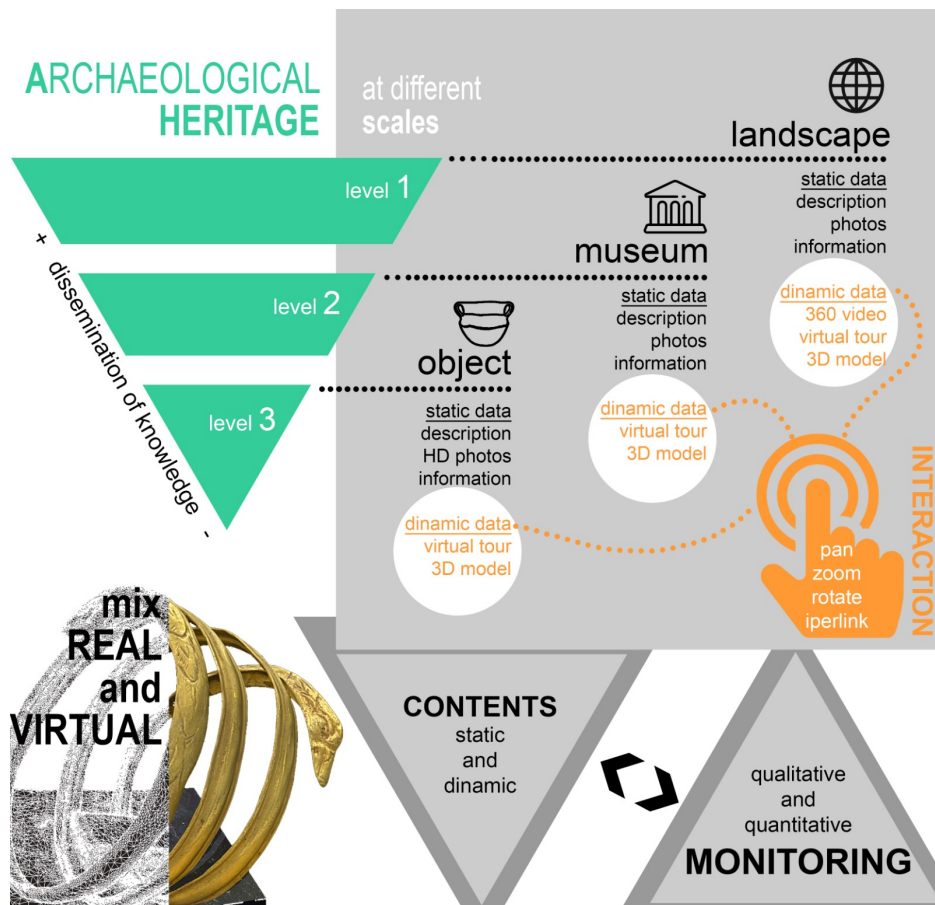


Figure 1: General overview of the proposed workflow: archaeological heritage at three different scales.

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

52 3/4D reconstruction. Today, technological advances ensure different meth-
 53 ods for acquiring 3D data and deploying them to a scalable 3D mixed reality
 54 (MxR) environments (Rahaman et al., 2019). Thanks to the contribution
 55 of artificial vision techniques, photogrammetric algorithms based on image
 56 processing have become more competitive for the generation of point clouds.
 57 Especially in recent years, structure from motion (SfM) is the most robust
 58 and accurate acquisition technique for archaeology, applied both on a large
 59 scale (Pierdicca, 2018; Lerma et al., 2010) and on the single artifact (statues,
 60 ceramics, and more) (Guidi et al., 2015; Evgenikou and Georgopoulos, 2015).
 61 Some works fill the gap of low-cost, open source, and automated solutions
 62 for the collection of numerous archaeological finds, especially considering the
 63 portability of these solutions (Gattet et al., 2015). Our experience in previous
 64 works has concerned the realization and validation of several SfM acquisition
 65 that represents the foundations of the digital photogrammetry pipeline (Clini
 66 et al., 2016; Quattrini et al., 2017; Pierdicca et al., 2016). In addition to the
 67 3D contents, panoramic images 360°, videos and virtual tours already demon-
 68 strated high acceptance by the users (Mah et al., 2019; Bolognesi and Aiello,
 69 2020).

70

71 Depending on their purposes, 3D models can be applied to different de-
 72 vices and there are currently many good practices in the use of these mod-
 73 els both for indoor communication tools and outdoor applications (Empler,
 74 2018). These tools have the aim to activate new forms of communication with
 75 the public, by placing the user at the centre of these operations (Maniello,
 76 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 (Pso-madaki 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 Athens¹ and Crete² 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.

123 3. Materials and methods

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

132 3.1. *Marcheology: web platform and mobile app*

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



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

147 narrate and georeference the place; b) information and tourist services re-
 148 lated to the place. The data structure was designed following the historical
 149 and geographical structure of the Region (Figure 3): a territory crossed by
 150 rivers and valleys developed perpendicularly to the coast, in which there are
 151 many important traces of Roman consular roads, for example the Flaminia,
 152 often visible for its morphological structure (Clini et al., 2019). An archae-
 153 ological heritage, therefore, can be geographically classified geographically
 154 (according to the fluvial arteries) and historically (according to the road
 155 arteries Flaminia, Salaria Gallica, Salaria Picena, Salaria Romana, Camel-

156 laria). Therefore, real visit routes were developed, ranging from the coast
157 to the inner areas, considering the relevant archaeological assets, their dis-
158 location, and the richness and offers of the cultural and landscape context.
159 Approximately one hundred other archaeological sites have been collected,
160 ranging in the offer both for the chronological fields (since prehistory to the
161 late ancient age), both for the dominant assets, as well as for the methods
162 of visiting the places. The presentation of the archaeological sites and the
163 museums has been tailored to scientific criteria and, at the same time, to
164 the need of a data displacement for a quick and comprehensive consultation.
165 Therefore, the mapping makes use of maps of the archaeological emergencies
166 characterized by a dry and lean style, which also indulge in a captivating
167 and seductive description of the sites, delineating on the territory histori-
168 cally determined routes and, at the same time, logistically easy to reach.
169 Once the database was set up, the second phase concerned the development
170 of the web site and mobile app: it is possible to search in an organized and
171 interoperable form all the information of interest to visitors to plan their
172 archaeological tour. Each place is geo-referenced, so the user can create a
173 personal itinerary or follow the paths suggested by archaeologists and ex-
174 perts. Observing Figure 2, the platform³ offers different possibilities: (i)
175 searching by keywords; (ii) choosing the sites according to the valleys; (iii)
176 searching with filters and elaborating customized routes, choosing points of
177 interest as well as the fastest geographic itinerary and, finally, saving the
178 route (on the page “places”); (iv) choosing among already available routes;

³<http://www.marcheology.it/it/>

179 and (v) searching for restaurants, hotels or events by inserting filters. Finally,
 180 thanks to the possibility offered by remote analytics tools, we were even able
 181 to collect user's statistics as shown in the next section. In parallel, with the
 182 same structure and graphic representation, a mobile application has been
 183 created for both iOS⁴ and Android OS⁵. The main focus in displaying con-
 184 tents was the chance of previewing sites and archaeological findings via web
 185 and ubiquitous systems, giving the possibility to use 360° Virtual Tour, 360°
 186 Video and 3D digital artefacts shown in the Digital Library (DL) (Figure 3).

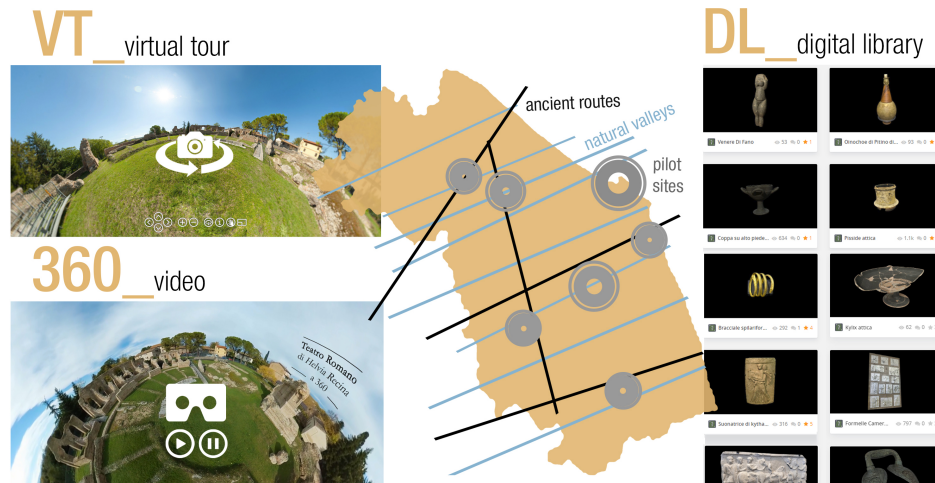


Figure 3: The main multimedia tools offered by the project: 360° Virtual Tour, 360° Video and 3D digital artefacts shown in the DL

187 3D digital data have been acquired for the pilot sites, in order to cre-
 188 ate remote navigation solutions, based on immersive and three-dimensional
 189 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>

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

197 3.2. *The Museum Analytics: observing user interaction in the museum*

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

209 The system, installed within the National Archaeological Museum of An-
210 cona, consists of six components: (i) Single Board Computer (i.e. Raspberry
211 Pi), (ii) Asus Xtion Pro live (RGB-D sensor), (iii) Wireless Adaptor, (iv)
212 SD/MicroSD Memory Card 8GB Speed 10, (v) Hub USB 2.0, (vi) Router
213 3G/4G Wireless.

214 The Single Board Computer is a computer built on a single circuit board,

215 with microprocessor(s), memory, input/output (I/O) and other features nec-
216 essary for a functional computer. This system was generally made as a
217 demonstration or development and educational system, or for use as em-
218 bedded computer controllers. It uses a SD memory card in which Debian
219 operating system is installed, that allows a simple configuration of RGB-D
220 sensor of Asus Xtion Pro Live compiling these modules: OpenNI Library³
221 and PrimeSense Sensor Driver⁴. The Asus Xtion Pro live is composed by an
222 infrared sensor, an RGB sensor and 2 microphones. In output it provides a
223 RGB representation of the environment and can reconstruct its depth map.
224 Each pixel in the map also codifies the distance of each element from 3D
225 scene. RGB-D sensor is supplied by the Hub USB 2.0. The RGB-D sensor is
226 installed in top view configuration at three meters of height from the floor. It
227 displays a maximum area in a two-dimensional projection (visitors tracking
228 area) of 1.8m x 3.2m. The tracking algorithm can be summarized in five
229 phases that have in input the image detected by the top-view camera and in
230 output the features extracted by the visitor's behaviour. In the first step, the
231 streaming video from the RGB-D sensor was acquired by the system. The
232 images are preprocessed by the background subtraction method, that is one
233 of the most commonly used approaches for identification of the objects in
234 motion within a sequence of images. This approach is reliable because each
235 pixel of the scene has the depth as further information and in this way, it
236 allows to detect the distance from each blob. Moreover, to avoid false pos-
237 itives in the phase of identification objects, the background is dynamically
238 updated. However, to identify positive signals that correctly detect moving
239 objects, avoiding false positives because of background noise, it is defined

240 a threshold value named “segmentation”. The next phase is the object de-
241 tection, which considers each meaningful blob and evaluates the boundary
242 and the maximum points. This latter discriminates the head of each visitor.
243 There is a successive evaluation where the blob is retained valid if the maxi-
244 mum point is included by a region of the lowest points comparable to jump
245 head (Migniot and Ababsa, 2013). Afterwards, there is the object tracking
246 algorithm in which each positive blob is recognized and tracked within the
247 streaming video, i.e. the pathways of different blobs in the frames are rec-
248 ognized and then tracked. The method is based on the depth, for which the
249 height is calculated by verifying that it is in the neighborhood of the height of
250 the visitor in the previously elaborated frame. The heads are tracked among
251 two successive frames and in both frames, the same blob is identified by the
252 same identifier, so the same blob tracked in the following frames. A unique
253 identifier univocally identifies each visitor. In this way, each visitor main-
254 tains an ID unique during the entire visit of the museum, always respecting
255 privacy, a very important aspect.

256 3.3. *The Digital Library at MANaM: interacting with the artefact*

257 Given the large number of artefacts of an archaeological museum, the
258 digitalization process has been optimized to limit processing times, exploiting
259 well-established pipelined based on close range photogrammetry and reverse
260 engineering. A fast and inexpensive acquisition system that ensures excellent
261 photographic quality has been realized. The 3D digitization process ended up
262 with the realization of interactive digital facsimile, that are be scalable and
263 adaptable to different technological solutions. The artefacts are generally
264 classified in three categories: movable, unmovable and very small objects

265 according to their size and position. This classification fits very well to
 266 archaeological museum collections and drove us to create a DL performed for
 267 the National Archaeological Museum of Marche Region as well as for different
 268 archaeological museums belonging to the Regional Museums System. This
 269 3D realization has different outputs: 3D visualization, stereoscopic view, 3D
 270 printing and more (see Figure 4).

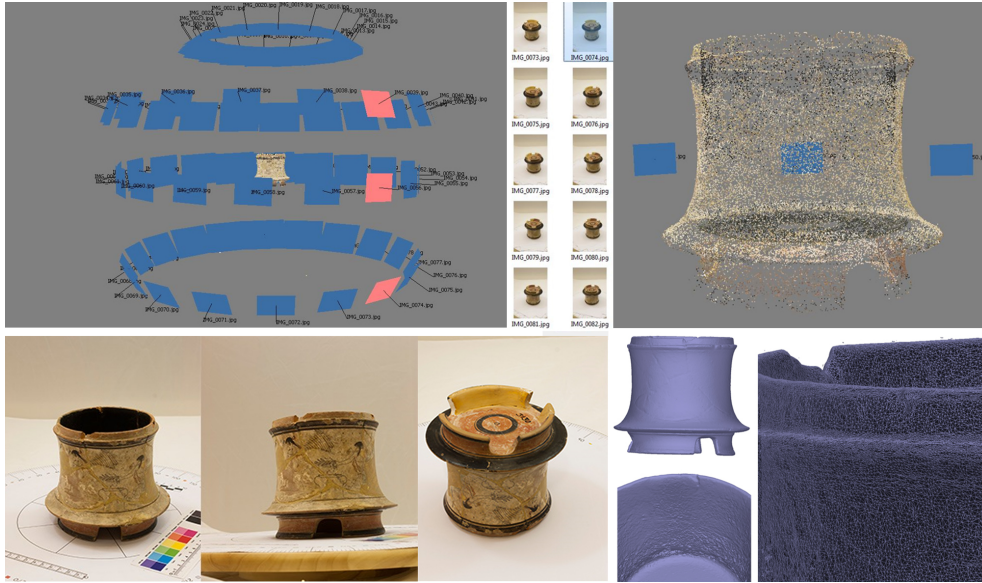


Figure 4: Artefacts photomodeling pipeline, which goes from the data acquisition with close range photogrammetry techniques to the creation of the textured model.

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

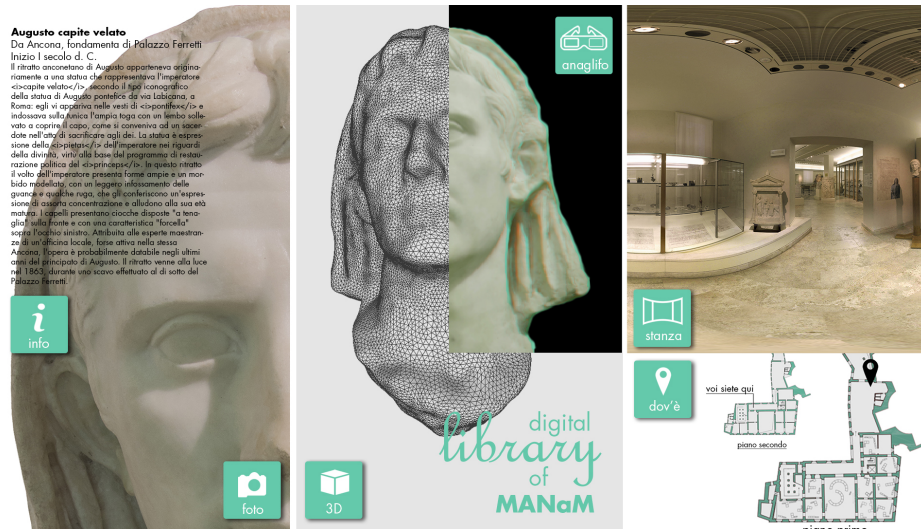


Figure 5: The DL as it appears in the HD visualization. In the example the artifact is showed with its explanation and its own localization inside the museum arrangement.

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

289 archaeological object, which otherwise would not be visible.



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

290 4. Results and discussion

291 The following results section is devoted at describing the user's response
292 for each experience. By analysing, at each scale of interaction, user's be-
293 haviours and insights, our endeavour is to share with the research commu-
294 nity useful data that can serve as guideline for future implementations. The
295 analysis has been set up depending of the representation scale of archaeolog-
296 ical matters, ensuing the schema of the project experiences described above.
297 Data have been collected in an interesting mix among the real and the digi-
298 tal environment, which can be seen as an seamless exchange of information
299 between the user and the space.

300 4.1. Web platform performances evaluation: analytics and user test.

301 The data collection period about Marcheology spans across one year of ob-
 302 servations —from November 2018 to November 2019 —analyzing data from
 303 both the web site and the mobile app; indeed, the potential and the draw-
 304 backs of the proposed methodology is considered for different media. The
 305 statistics of usage can be found in Figure 7.

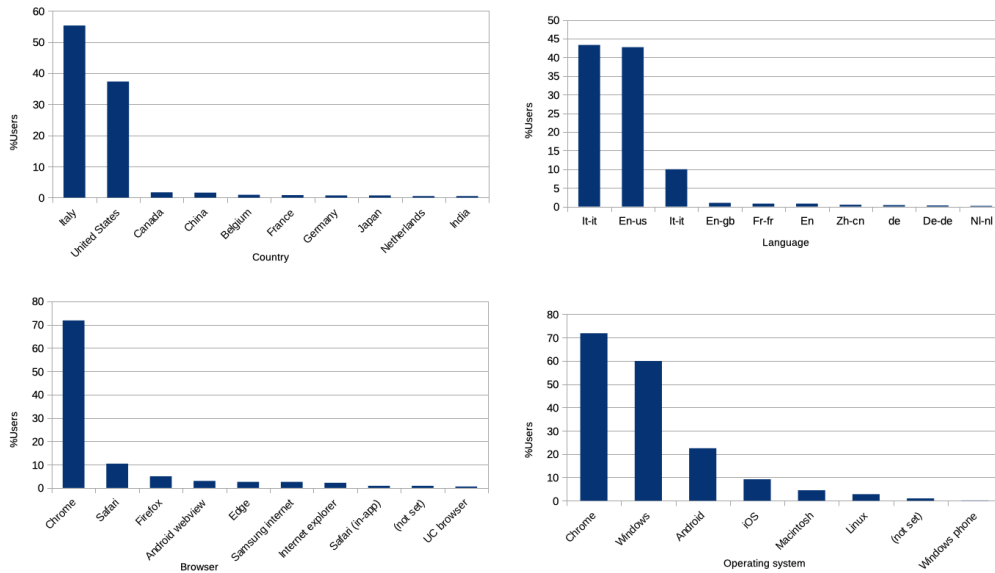


Figure 7: Histograms of rate of users according to different: country, language, browser and operating system

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

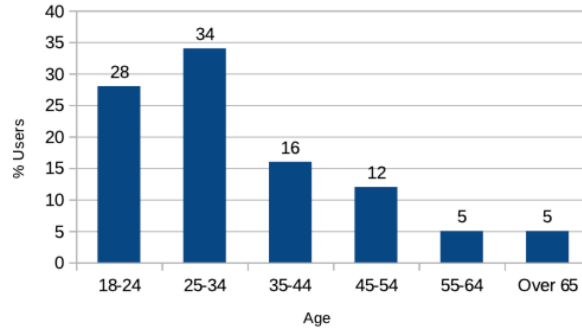


Figure 8: Rate of users divided for age.

312 with those related to the category of the device which confirms that most
 313 browsing on the platform is from desktop applications. It is worth noting
 314 that the majority of users make use of Google Chrome search engine, which
 315 is an indicator that the platform is well indexed and has a high degree of
 316 visibility on the web. The platform even reveals insights about geo-data,
 317 indicating languages and countries where the tool has been used the most. It
 318 is interesting to note the involvement of non-European users (but with low
 319 numbers), demonstrating that these kinds of applications allow to spread the
 320 knowledge of CH sites even for foreign countries. The Multilanguage func-
 321 tion of the platform is therefore needful. Further analysis of the data shows
 322 that the number of users approaching to the platform is almost constant
 323 during the period of observation. We can deduce that the visit of the site
 324 is not strictly dependent from the period of the year and that the interest
 325 of the users to archaeology can be exploited all over the year. For the sake
 326 of fairness, the performances of single users are noteworthy; by the way, the
 327 platform needs improvement in terms of engagement. In fact, each user have

328 revisited the platform just one time, and the average time spent interacting
329 with it is less than two minutes, that are not enough to achieve an in-depth
330 analysis of the contents. Other interesting insight to better know the type of
331 users can be found in Table 8. First of all, dealing with the age of sample, we
332 can affirm that the use of the platform decrease with the increase of the age.
333 This is not trivial, since it highlights that the digital divide is still existing
334 and that such kind of tools cut out a huge chunk of the population. Thanks
335 to the analytic tool, a gender and preferences analysis were done; first, the
336 ratio between males and females is almost equal. In the light of this informa-
337 tion, the potential of the platform is enormous for both visitors and policy
338 makers. An analysis of the data indicates that the former finds the platform
339 of interest and useful for increasing the knowledge and understanding of the
340 area they visited, while the latter has at their disposal a platform which at
341 the same time allows the visitors to be monitored and tourist services to be
342 promoted. This is, to date, the only way to improve the decision-making
343 process so as to intervene with a data-driven approach. The web-based anal-
344 ysis was preceded by a formative evaluation action, through the realization
345 of scenario-based usability tests on a mixed sample of end-users and a sub-
346 sequent summative evaluation intervention through the administration of
347 online questionnaires. The usability tests of the Marcheology platform were
348 designed and conducted using a scenario-based method. The objective was
349 to evaluate the user-friendliness, the degree of satisfaction and the memory
350 of the actions on 8 different scenarios of use. 10 participants representing
351 different user targets have attended the usability testing on “marcheology.it”
352 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.

378 4.2. Museum’s performances evaluation: on site analytics

379 In this section we present the installation of three cameras system located
380 in three different position of the museum MANaM⁶. The system has been
381 installed on a panel in the suspended ceiling of the museum. It gives in out-
382 put a significant data stored in a database and then successively analysed to
383 extract indicators. The real test has been realised installing three RGB-D
384 cameras for a time period of 12 months to obtain significant and real data.
385 In the MANaM one camera monitored the entrance, a second camera, the
386 first floor crown room (focus point 2, FP2) and a third camera the DL (fo-
387 cus point 3, FP3). These focus points are identified inside the museum in
388 order to analyse the preferences of visitors. The choice to put a camera near
389 the entrance allowed to exactly count the number of people who entered the
390 museum. Moreover, the three cameras properly positioned allowed to pro-
391 vide an analytic report and information about some indicators: “attraction”,
392 “attention” and “action”. So, the indices useful to evaluate the visitors be-
393 haviour, that can help the museum director and curators to understand their
394 preferences and so, to increase the experiences of the visitors are:

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

⁶The 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.

- 398 • $I_{atte}(\cdot) = t_s$ is the index of attention (i.e. the average dwell time stop-
399 ping in a zone);
- 400 • $I_{act}(\cdot) = N_p/N_i$ is the index of interaction with the proposals, touch
401 screen, armoured door, and so on.

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

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

415 The rate of attraction can be inferred by the values of $N_s(FP2)$ and
416 $N_s(FP3)$. The last row summarizes the total number of visitors in a year
417 for each statistic presented in this table. On the total amount of entrances,
418 the rate of $N_p(En)$ is 51% and the rate of $N_s(FP2)$ is 34%. While always
419 considering all the entrances, the rate of $N_p(FP3)$ is 99% and the rate of
420 $N_s(FP3)$ is 34% as $N_s(FP2)$. To evaluate the attraction of an artwork we
421 have to consider the average dwell time which is 31 seconds for the FP2, and
422 8 seconds for the FP3. Analysing the values for FP2, we can say that 6%

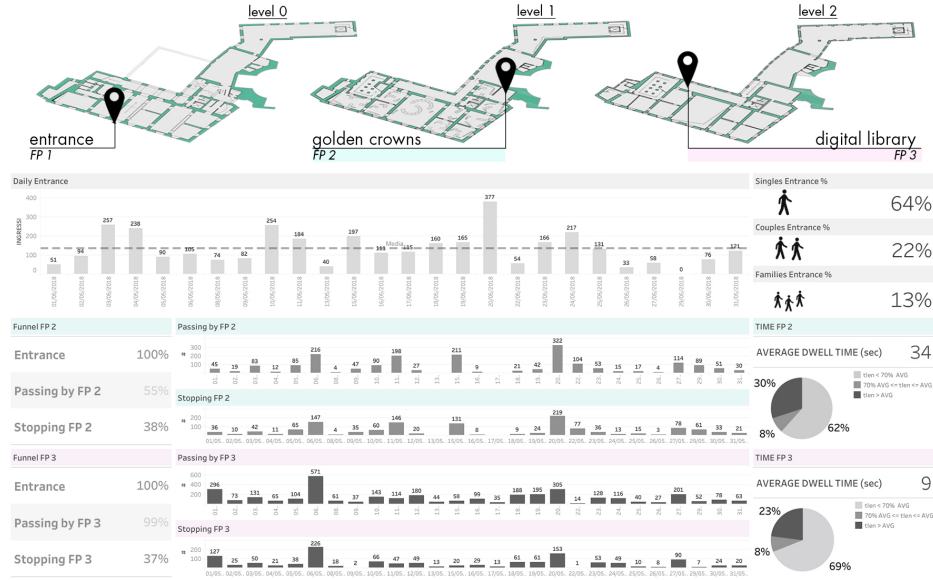


Figure 9: The three focus points of the museum installation, divided per floor and with the statistics of user's behaviours.

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.

434 school students.

- 435 • Phase 1: the activity involved two different opportunities for discus-
436 sion using the appropriately moderated and facilitated Focus group
437 technique, and a free visit with in-depth investigations was organized
438 at the museum spaces.
- 439 • Phase 2: To evaluate the performance of the technologies developed, in
440 this phase usability tests were administered to analyze visitor activities.

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

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

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

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

- 459 • feedback from the visit;
- 460 • memorisation of the objects;
- 461 • game of imagination.

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

472 5. Conclusion and future works

473 In this paper, CH related contents have been tested to understand user's
474 insights. To achieve the first results, here presented, we exploited two re-
475 search project to face the problem at different scales of representation. The
476 developed systems are able to connect archaeological resources and territories

477 through a network, thereby promoting historical centers, cultural heritage,
478 green areas and interesting places. The case presented in this paper gives
479 the vision of how the territory can be supplied with digital instruments, de-
480 veloped in order to be used by both locals and tourists. The research team
481 is constantly monitoring their impact thanks to the statistics, obtaining and
482 analyzing the tangible and intangible results, as shown in the paper. The
483 main contributions of the projects are in: i) the analysis of heterogeneous
484 data collected from the directly from the users; ii) development of best prac-
485 tices that can be exploited by small municipalities of a same territory to
486 share cultural and touristic information; iii) monitoring users preferences
487 and needs by collecting users generated data and iv) providing local admin-
488 istration with useful and meaningful statistics about the tourists, tested and
489 verified in real scenario with real users.

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

497 More in general, for archaeological finding it is possible to obtain a great
498 magnification of their characteristics thanks to ICT tools. The 3D virtual
499 replicas make culture accessible to the mass audience and the technological-
500 mediated fruition assumes a complementary role in the direct experience of
501 cultural good. It is clear that the digital interaction with artefacts does not

502 replace the direct one. The Cultural Heritage collection, conservation and
503 access in novel, accessible and attractive ways demand for digitizing museums
504 and archaeological/historical sites, as well as for designing methodologies to
505 represent, manage and exploit cultural heritage data at different levels. As
506 future works it is envisaged to reduce the *pen-and-pencil* approach by im-
507 proving the data collection strategies through digital tools. A future foreseen
508 implementation in the DL is, as example, to track user interaction with dig-
509 ital contents. Moreover, similar on-site analytics need to be serialized and
510 synchronized with data by Museum Analytics. Cultural Heritage still suffers
511 a division between the visitors and the real estate of cultural goods, that can
512 be overcome by adopting new strategies not only of digitization, but mostly
513 oriented at creating a link among the real and the virtual dimensions as a
514 whole.

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