

# Engaging and Shared Gesture-based Interaction for Museums

## The case study of K2R international Expo in Rome

Bruno Fanini, Enzo d'Annibale, Emanuel Demetrescu, Daniele Ferdani, Alfonsina Pagano  
CNR ITABC, VHLab  
Rome, Italy  
bruno.fanini, enzo.dannibale, emanuel.demetrescu, daniele.ferdani, alfonsina.pagano @itabc.cnr.it

**Abstract** — This paper presents a full life-cycle production and standardized workflow to deploy a shared and engaging gesture-based experience within a museum, connecting two different natural interaction applications. The research presented in this paper is specifically focused on *Admotum* and *HoloInt*, two gesture-based applications developed for the V-Must.net in occasion of “Keys to Rome” international exhibition on Roman Culture. The workflow described here includes 3D content production, application design, development and integration within flexible museum setups, together with evaluation activities to explore more on the user's' educational benefits and the potential of such collaborative museum experience.

**Index Terms** — Virtual Museum, Natural Interaction, Holographic displays, 3D reconstruction, Evaluation

### I. INTRODUCTION

This paper presents the interactive gesture based applications developed for “Keys To Rome” (K2R) international exhibition. A major challenge of the project was the improvement of a complete production life-cycle from the archaeological record to the final application involving 3D modelling, metadata management, interaction design, communicative aspects and final user experience evaluation. Our contribution is about a new way to experience the digital assets connecting two separate gesture-based applications in order to enable a shared and collaborative experience. “Keys To Rome”<sup>1</sup> is an international exhibition organized simultaneously in four European cities: Rome, in the Imperial Fora Museum; Alexandria, in the Bibliotheca Alexandrina; Amsterdam, in the Allard Pierson Museum; and Sarajevo, in the City Hall. The event is organized by the European Consortium V-MusT<sup>2</sup>, the largest European Network of Excellence on Virtual Museums. It is focused on the museum collections belonging to the Roman Culture and mainly to the Augustan age. Artifacts can be discovered and enjoyed through several multimedia tools: computer graphics movies, natural interaction installations, touch-devices, augmented spatial reality and mobile applications. Combining archaeological remains, their 3D replica and virtual historical environments, visitors can travel back in time, looking for lost objects, re-

discovering them in the original context of usage. The V-MusT network aims at displaying new tools and paradigms of cultural dissemination that could be a virtuous example for future virtual museums which are necessarily educational, enjoyable, long-lasting and sustainable. Interactive 3D technology used for a museum can offer additional benefits when enlarging the cultural offer to visitors creating connections and parallelisms among cultural artifacts. This can be enabled for instance by allowing visitors to be engaged in direct interaction with virtual copies through a gesture-based experience. In this sense, such installations go far beyond only displaying information. In this paper we will focus on the roman experience of K2R and in particular on the innovative trans-media installations “*Admotum*” and “*HoloInt*” and their combination into a collaborative experience by means of an extended interaction model. Concept, workflow, tools, innovation, design and user experience analysis will be discussed in the following paragraphs.

### II. CONTENT WORK-FLOW: AN ARCHAEOLOGICAL RECORD BASED PROTOCOL FOR DIGITAL ACQUISITION AND VIRTUAL RECONSTRUCTION

The 3D scenarios of the K2R applications include representative monuments and objects from the Imperial Age (like Imperial Fora, statues, capitals, busts etc.). Despite the importance of these contexts, several of them have been digitized for the first time (like the Chrysippus Head), while others (like the Forum of Augustus) have not been available (due to legal or technical reasons). The source-based models [3] (reconstructive models of no more extant monuments) have been made from scratch and specifically intended for real-time purposes starting from already validated hypotheses, like the case of the *Templum Pacis*' interiors (southern library). The whole content creation process has been focused on a) the coherence of the archaeological reconstruction with the available sources and quality of digital acquisition, b) serious game enabled computer graphic techniques for real time and c) an integrated and collaborative digital asset workflow able to combine a scientific approach (i.e. storing all the sources involved in the reconstruction process) with real-time, optimized props and scenarios. As a result, some best practices have been highlighted in order to standardize a wider protocol

<sup>1</sup> <http://keys2rome.eu/>

<sup>2</sup> <http://v-must.net/>

linking archaeological data to the final stage of serious game's development.

#### A. Archaeological record, digital acquisition and virtual reconstruction

The serious game and the holographic application developed for K2R involved a wide range of heritage assets (villas, temples, etc.) at different scales (small statues to landscapes), pertaining different scenarios (objects displayed in a museum, on-site monuments) and characterized by variable levels of physical preservation (fragmentary or complete). Hence, a primary distinction in all digital assets resulted in reality-based models [7] and source-based models [3]. The assets are organized in 3D scenes corresponding to large archaeological contexts (i.e. Forum Augusti, Templum Pacis etc.): this permits to re-distribute the museum's objects in their original position (i.e. the Chrysippus Head from the Trajan's Market Museum replaced in the library of the Templum Pacis). The activities carried out for the 3D digital reconstruction includes:

- Museum object digitization - Several 3D acquisition techniques have been used to digitise the museum's collection, such as laser scanning and image based modeling (IBM), according to the typology and material of the objects to be scanned and instrumentation available. In fact each museum of K2R network took indeed care of the 3D survey activities performing. More than 60 objects belonging to different periods and countries have been digitised and stored into the V-Must production platform.
- Virtual scenarios reconstruction - 10 different scenarios belonging to different roman periods have been designed in order to re-contextualise the museum objects: the Forum of Augustus and Forum Pacis (Rome); the Ilidza Roman Villa of Ilidza, its Thermal Bath and the Cim Basilica (Sarajevo); the Lowland Villa Mook, Villa of Volusii Saturnini and an Egyptian domus (Amsterdam); the Serapeum of Alexandria and the Lighthouse of the city (Alexandria of Egypt).

In order to achieve reliable reconstructions of the Imperial Age environments, a large team of experts from different countries has been involved in the interpretation and in the design of the reconstructive hypotheses. Several types of archaeological data, drawing, pictures, parallels and bibliographic sources have been analyzed and discussed. All scenarios have been designed by 3D modelers using computer graphic software based on interpretative studies. In most cases, the modeling work has been carried out starting from 2D images (plans, section or facades) and using an iterative workflow, employing a recursive approach among modelers and experts: 3D drafts and sketches have been used as starting point for discussions and interpretative decisions with consultants to refine the hypotheses.

#### B. Enabling digital assets for serious games purposes

The assets needed for the two applications, Admotum and Holoint, are the result of a long and accurate work of digitization related to museum's objects, virtual reconstruction and several virtual environments ("scenarios"). All the generated reality-based models have been optimized in order to fit the requirements provided by the developers. Since the digitized collections should have been interactively visualized in 3D, they needed to be optimized while being aesthetically pleasing and engaging. For this reason, we preferred to use low poly models using texture to simulate details like diffuse maps for colors, normal maps for reliefs and ambient occlusion maps for emphasizing surfaces (Fig. 1).

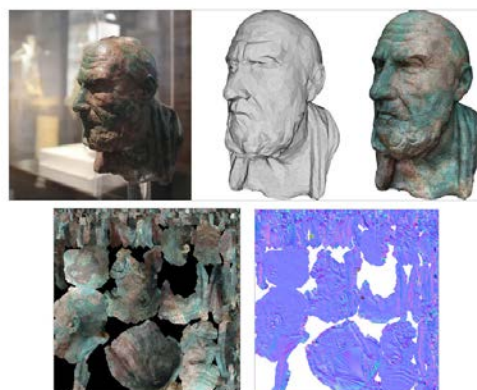


Fig. 1: Chrysippus head. One of the object from the Trajan Market Museum collection. On the left the object in the permanent exposition, on the right the digitized version (wire-frame and textured); Diffuse and normal maps for real-time.

All the source-based models - after the reconstruction process - have been finalized using a "real-time modeling" approach for a better performance in the game engine developed for Admotum (i.e. light baking, atlas textures, model segmentation, etc.).



Fig. 2: Virtual reconstruction of the interior of the Templum Pacis (southern library).

### C. Collaborative work-flow

Admotum and Holoint managed an huge number of 3D assets created using different approaches (see above). 3D modeling and digitization work have been carried out by several professionals and researchers coming from V-Must consortium. In order to coordinate the activities and develop the entire data-set in a collaborative way, different services - like Cloud, SVN, Trac and WebDav - have been adopted as platform for centralized data storage and online access to computer services and resources (Fig. 3). The services have been accessed through an online infrastructure called “Forge” developed by CINECA<sup>3</sup>. The scheme in figure 3 summarizes the daily activity of the partner. This scenario clearly needs a modular and ductile strategy able to organize the archaeological record (meta-data) and digital assets (3D reconstructions) in a convenient way - i.e. storing the sources used in the reconstruction processes. In order to achieve this goal we integrated all the information used to obtain the source-based reconstructive models into the repository.

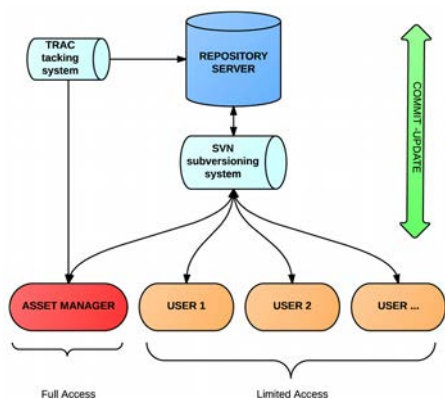


Fig. 3: SVN workflow adopted in the content development for Admotum and Holoint applications within Keys To Rome exhibition.

### III. INGESTION TOOLS

Serious gaming tools applied to Virtual Archaeology, often present a wide range of issues when dealing with validation and ingestion of 3D models. Two of them are: the iterative nature of the workflow and the range of different software for 3D modeling, applied to a distributed environment. Moreover, time constraints require a well organized pipeline and methodology in order to manage several 3D assets with different application requirements, including objects, user interface and scene dressing elements. The wide range of 3D formats and software have led to the development of open-source back-end tools. These include real-time authoring tools, preview and object painting tools (Fig. 4) aimed at scene dressing tasks, combined with versioning and cloud tools to control and manage distributed 3D asset collections. Such tools have been employed within the K2R exhibition by 3D modelers to preview and assess application items and scenarios while being reusable to ingest new 3D content and dress new scenarios. The workflow from assets production to interactive applications consisted of: 3D assets modeling (objects and

<sup>3</sup> <https://hpc-forge.cineca.it>

scenarios); Audio library creation (audio clips, soundtracks, UI sound effects, etc.); Optimization and ingestion of 3D assets for real-time applications; Scene dressing; Object arrangement; Soundscape creation and path planning for each scenario.

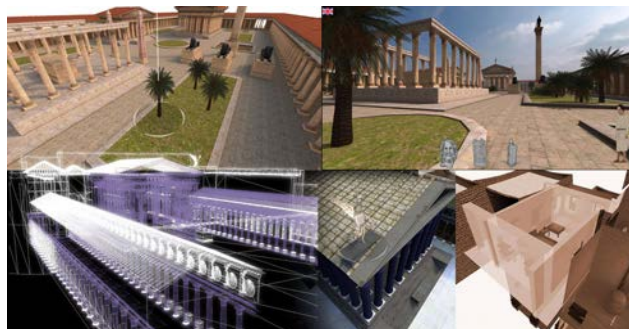


Fig. 4: Authoring, preview and scene dressing phases.

### IV. GESTURE-BASED APPLICATIONS

In order to deploy interactive gesture-based applications or installations in a museum, a widely used approach involves a physical 3D space where visitor can perform a pre-defined set of gestures through a proper 3D interface to interact [2]. Typically, the software application is equipped with a gesture recognition system through the use of a sensor, translating such physical movements into a set of predefined functionalities and actions [4]. Recent advancements in accuracy, speed and efficiency of consumer sensors, such as Kinect<sup>4</sup> and Leap Motion controller<sup>5</sup> [5], [8] are laying solid foundations to deploy astonishing interaction models, within temporary or permanent museum exhibits. The low-cost aspects combined with the consumer market’s availability of these sensors are very appealing to a museum. Obviously, there are limitations of such tracking controllers to be considered for the design of efficient interaction models, as device accuracy, occlusion and lighting conditions. Other crucial aspects to be considered are the application’s usability, the design of an efficient 3D interface and the impact of cultural factors on gestures [9]. The main goal of such gesture-based applications is to increase user engagement, for instance within serious games and applications, through a natural mapping from 3D physical space to a 3D virtual space. The following paragraphs will focus on the development of two separate gesture-based installations - Admotum and Holoint - and their combination into an extended gesture-based interaction model, enabling a shared and collaborative experience among museum visitors.

### V. ADMOTUM

Admotum is a serious game allowing a visitor to virtually explore 3D reconstructed environments using body gestures and motions. The objective of the exploration is finding and collecting the objects displayed in museums of the K2R locations, following the treasure hunt game mechanics. When an item is found and collected, an audio clip tells its story.

<sup>4</sup> <https://www.microsoft.com/en-us/kinectforwindows/>

<sup>5</sup> <https://www.leapmotion.com>

When all items are collected, the visitor is rewarded with the complete story of the current scenario, revealing pieces of historical events and curiosities. There is also the possibility to unlock additional online content. The visitor can do this either by reading a QR code with a smart-phone or by using the pass code appearing on the screen, both of them shown on the screen. The underlying technology of Admotum is the Microsoft Kinect sensor which makes it possible to implement a gesture-based interaction. The underlying concept of such interaction paradigm is to design interaction that comes naturally, while interacting with the technology, helping the user to quickly transition from novice to expert.

#### A. Software components

The developed application - including real-time rendering, physics, navigation system and gesture processing - is based on several frameworks and libraries, including for instance the open source OpenSceneGraph framework<sup>6</sup>, Boost libraries<sup>7</sup>, and the official Kinect SDK<sup>8</sup> to access the sensor used for natural interaction. The modular nature of the system (see Fig. 5) allows reuse and customization of software components such as navigation system, interface, gesture processing and recognition, as well as accessing game controller and manage external interactions, including remote control. The application is fully customizable through textual configuration files (module at the bottom of the scheme), using a developed API.

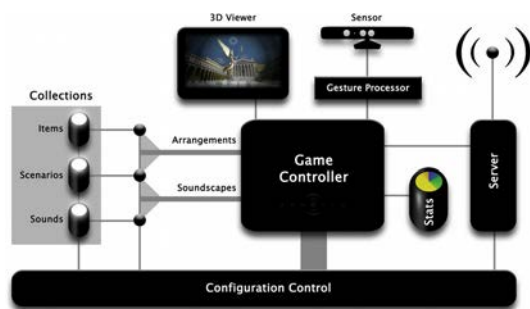


Fig. 5: The Admotum architecture.

The structure allows back-end personnel or external developers to completely access, control and customize 3D assets, as well as several game aspects and parameters. The main configuration allows specifically the definition of three main collections (left side in the scheme) after the ingestion phase: *Scenarios*: collection of virtual environments; *Items*: reconstructed objects to be arranged in scenarios (if sufficient information is available) and *Sounds*: audio library to create soundscapes for each virtual environment, audio-clips and interface effects. From the museum perspective, such modular architecture allows to customize Admotum to suit local needs and perform fine tuning, for instance different museums could require different sensor distances, timings, navigation control or game-related parameters.

<sup>6</sup> <http://www.openscenegraph.org/>

<sup>7</sup> <http://www.boost.org/>

<sup>8</sup> <http://www.microsoft.com/en-us/kinectforwindows/>

#### B. 3D User Interface Design

Gesture-based technology in museums can be viewed as an innovative educational development in alignment with *bodily-kinesthetic* intelligence [11]. The practice of using the body as a controller may have visitors more immersed in the simulated reconstructed environments. Admotum is very different from traditional 2D applications since it allows the visitor to navigate in and interact (specifically manipulation tasks) with a virtual environment in a three-dimensional context. Designing such a 3D user interface requires a great deal of design work in order to create a pleasant and efficient user experience.



Fig. 6: Admotum 3D interface.

Based on previous research [4], [23], [20] and projects [17], [9], first prototypes of gesture-based interaction model for Admotum were iteratively developed and tested within a lab setup through (1) video recording of users motions; (2) observation protocol focusing on gesture learning and motoric precision; (3) NASA Task Load Index [18] and (4) direct interviews. Such tools were applied to two main aspects (macro-tasks): navigation (traveling in virtual environments) and manipulation (grab and release virtual 3D objects – see Fig. 6)[2]. Obtained results led to a set of guidelines that have been deployed during the design phases of Admotum:

- Remember your audience - the “grab” gesture, for instance, has been designed to fit visitors with different arm lengths, i.e. adults as well as children.
- Reduce degrees of freedom when possible - the user’s movements inside the virtual environment are limited to translation and rotation in the horizontal plane.
- Non-isomorphic techniques are useful and intuitive [2] - the visitor can reach also distant and/or inaccessible objects with his/her virtual hands (Fig. 6).
- Use travel techniques that can be easily integrated with other interaction techniques in the application. For instance, the visitor’s movement come to a halt if he/she raises his/her arm in order to grab a virtual object.
- Remember that fatigue undermines gesture - the visitor never has to perform static or uncomfortable body movements that could lead to fatigue.

#### VI. HOLOINT

The concept behind HoloInt starts from the idea of virtual repatriation or in general virtual exhibition. HoloInt can be intended as a digital re-interpretation of a theatrical effect well-known as Pepper’s Ghost [19]. Thanks to the optical illusion the users visualise a virtual object fluctuating in the air or appearing in a specific area, providing the illusion of volumes, the stitching over a surface but also the wavering of objects.

Starting from the Pepper's Ghost effect, Holoint aims at expanding the content fruition by users. The spectator who passively takes part at the show, now becomes active user thanks to the chance of interacting with the content with his hand gestures. The realization of the whole system involves the design of three interconnected components that aim at producing a modular, portable and adaptable solution for museums. Specifically, Holoint is composed by: Ad-hoc structure; assembled hardware (PC, Monitor, Leap Motion) and software application.

### A. Software

The display systems to realize a Pepper's Ghost effect are many, from a smartphone to a theatrical solution. In order to handle projection systems that require higher resolutions and more dynamic content, we used a flexible platform. The installation has undoubtedly the hub of innovation in the software, developed in a work environment dedicated to the management of multimedia content in real time - which turned out to be extremely flexible (see Fig. 7).

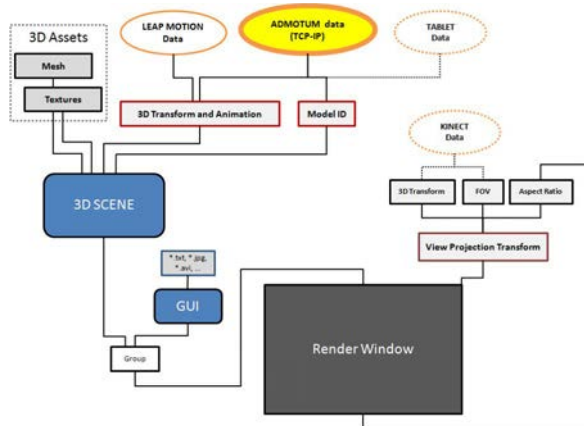


Fig. 7: The Holoint architecture.

The software is developed using *vvvv*<sup>9</sup>, an hybrid graphical/textual-programming environment for easy prototyping and development [22]. Given that *vvvv* is based on DirectX libraries and Visual C++, the software has been developed autonomously, creating ad hoc modules in order to fit the requirements of the interactive effect and maintain a flexible visual design. Of particular interest is the ability to manage 3D contents and high resolution video output. Moreover it is compatible with many interaction devices and peripherals (MIDI, Leap Motion, Kinect, etc.). The focus is on the 3D models and their textures, and special attention has been given to shaders, interaction and real time effects. The software includes indeed modules for: 3D model and texture ingestion; Leap Motion input data handling; Real time effects; Interaction design and communication with other devices or applications.

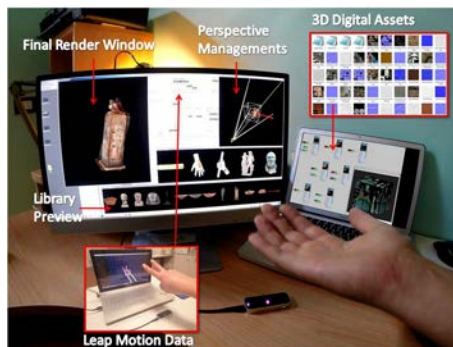


Fig. 8: VVVV interface and Leap Motion.

The final version used in K2R exhibition provides a mixed input for the management of the 3D items, in order to create a sort of “*magnifier*” unit, where users can visualize and interact with items, eventually incoming from external applications - like Admotum. Virtual items that appear in the little theater can be manipulated and inspected by the visitor using the Leap Motion controller.

## VII. EXTENDED INTERACTION

In order to improve and engage visitors into an extended and shared gesture-based experience, an advanced setup for cross-application communication has been developed between Admotum and Holoint installations. The Admotum application is able to communicate with a completely independent external “Inspection Unit” through message passing. The developed protocol and API allows to send and receive strings over TCP/IP that encode specific events between the two systems, in a local network or via HTTP protocol. Within local network an average of 0.1s latency was recorded (~0.5s between remote endpoints). The Inspection Unit can be either an interactive application such as Holoint or a simple screen that behaves conceptually as a magnifier. The objective of such unit is to allow the user to further investigate a virtual item or improving his/her own knowledge by providing additional information and creating a shared gesture-based experience for visitors. In fact, Admotum allows a visitor to virtually “pass” (left or right side) an item to an Inspection Unit using a simple gesture. The gesture design also fits the physical positioning of an inspection unit, conceived to not interfere with the Kinect sensor’s field of view (Fig. 9), avoiding unintended behaviors.

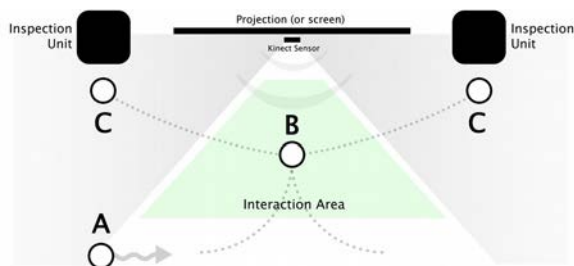


Fig. 9: Extended interaction setup.

This approach allows interacting visitors (B) interested in a specific object found within the game session to “send” the

<sup>9</sup> <http://vvvv.org/>

virtual item to another visitor (C) interacting with the inspection unit - the Holoint for the K2R exhibition. The Inspection Unit is typically a close installation: this placement aims to offer the visitor a contiguous visual animation and experience during the pass gesture between the two systems. Such gesture is realized through a natural movement of both arms aside, mimicking an object passing action. Furthermore, since both systems allows communication within a local network or even remotely over the web, a wide range of interesting possibilities can be enabled across different museums and remote Inspection Units. Another advantage of such communication consists in the remote control panel: such service is a useful web tool for museum personnel and/or tour guides, able to remotely control both applications and their behaviors, for instance directly entering a specific virtual environment while explaining the reconstruction hypothesis. It also offers a responsive interface for mobile devices, enabling even more extended and complex setups involving mobile devices within the museum.



Fig. 10: The final setup of Admotum and Holoint displayed at the K2R exhibition, Rome.

### VIII. USER TEST SESSIONS

Advanced experimentations in computer graphics and new modular communication strategies permit to enlarge the spectrum of possibilities offered by cultural institutions to learn more about History and Art by means of more and more tangible “realistic” interfaces. As largely discussed above, such technologies present some of the objects of the Imperial Fora Museum, during the K2R exhibition, in their original shape and context of usage, while enhancing their preciousness, the geometry and historical relevance. In this respect, they help connecting the objects exhibited simultaneously in the four locations unveiling intriguing stories and historical facts that happened at the four corners of the Roman Empire. Being like a summa of the museum experience thought for the K2R visitors, Admotum and Holoint are worthful of a preliminary evaluation of interface design and their related usability. Moreover, given the innovativeness of the shared collaborative experience, they turn to be useful for a prime investigation on visitors’ educational benefit on the proposed contents.

Usability here has been investigated starting from the definition given by ISO9241 standard [15]: “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use” and the questionnaire template has been inspired by the work of Jacob Nielsen [12], [13] and Don Norman [14]. Interface design has been hence studied taking into account the main elements that identify the collaboration mode of both applications: (a) clearness of visual indicators of object’s grabbing into Admotum and object’s transferring from Admotum to Holoint; (b) affordance of avatar suggesting the movements possible to do to shift one object to the next application; (c) relevance and suitability of audio activated once found an object. A scenario-driven interview has been conducted on 30 visitors during the month of November 2014. The chosen method allowed us to collect as qualitative as qualitative data, following such a template: a demographic section from questions 1 to 6 (gender, profession, age, provenance, and so on), the overall applications’ appreciation from questions 7 to 10 (expectations, willing to interact again, advantages/disadvantages of this type of double installation, the usability in general); feedback related to applications’ content and delivery from questions 11 to 16 (length of audio contents, accessibility and easiness of fruition of contents, language and pertinence of contents within scenarios). Last sessions compete the context of fruition and interface design from questions 17 to 21 (indications/tutorials, organization of the interface, (virtual) assistance availability, pertinence of technology proposed, panels clarity and completeness before entering the interactive space) and the closing questions from questions 22 to 24 (further suggestions, free opinions of visitors). The survey also saw a moment of direct exploration of users guided by interviewer so to accomplish specific tasks. In the end, it has been delivered in two different languages, English and Italian, on sheets that interviewer fulfilled together with users. Parallel to this evaluative activity, to support additional data related to the usability investigation, a suitable software component has been developed within the serious game application - Admotum. The component’s role is to monitor and record a set of basic variables related to user interaction, session duration and game status. Furthermore, additional advanced spatial records can be produced, to provide a more in-depth inspection. The main purpose is to automatically generate data records on disk, for later inspection, extraction or visual representation through external tools (e.g. Microsoft Excel, OpenOffice Calc, etc...).

### IX. RESULTS AND DISCUSSION

Results of scenario-driven interview firstly showed that the majority of users were male (22 out of 30), coming from Europe (21 out of 30) and of circa 26 years old. Almost the totality of them (24 out of 30) stated the serious game to be easy to use from the beginning (Fig. 11), even if observations carried out by interviewer revealed a not so easiness of visitors to access the Admotum application, due to a sort of embarrassment in practicing the needed movements to explore the 3D environment. They indeed preferred to watch at

somebody else playing with it. This datum does not depict negatively the application but gives suggestions on simpler gestures of natural interaction. The majority of participants (28 out of 30) affirmed that the main interface elements are good positioned and findable while being useful according to the task they needed to accomplish (80% of interviewees stated the functions were useful and interesting). Concerning the study of the interface (see Fig. 11), the clearness of graphic elements as signals, colors, and avatar explaining how to move have been highly appreciated, collecting a great number of participants (14 out of 30 said to be “very clear”; 8 out of 30 said to be “clear”). They affirmed that the indications suggested by the layout were easy to follow and minimal in the design. Moreover, the organization of 3D scenes and the objects’ disposition were considered “good” for 16 out of 30, and again for 9 out of 30 very good”. The collaborative interactive experience of Admotum and HoloInt installations turned to be totally new for more than an half of participants (20 out of 30), given that for the majority of them (25 out of 30), the innovative interaction based on arms, shoulders and foot and the intuitiveness of the object’s passage to HoloInt highly impressed them. Referring to the content’s accessibility of the serious game installation, 24 participants out of 30 again stated the information characterizing Admotum to be “very easy” to pick up and clear in terms of language and audio’s volume; likely, referring to the holographic display, its accessibility was “quite easy” - probably because of the uncertainty of the possible hand’s gestures to do with the Leap Motion sensor, after having interaction with Admotum and Kinect sensor. Nevertheless, for HoloInt, the interaction mode inspired them to know more about the 3D models and the themes of the exhibition (26 out of 30) - some admitted to be impressed by the proximity to the digital replicas and the chance to admire their details.

unit (HoloInt). That means that ¼ of found items were sent to the inspection unit over the recorded user set. The unlocking of shelves (local shelf completed) is about 10,75% of recorded users who completed the local shelf (Rome, in our case) thus unlocking the other three shelves (Amsterdam, Sarajevo and Alexandria) and related scenarios. Finally, duration of gameplay sessions for each scenario is clearly impacted by items’ arrangement and their visibility. In total, 856 users were monitored and recorded. The young profile of participants may have influenced the positive outcomes of both applications: the “predisposition” at certain interactive systems and the “education of the sight” at such visual expedients with 3D reconstructions and game interfaces, brought them to describe an user interface as simple as clear in lines, colors and shapes. Further analysis with small groups of adults in the later months will show instead difficulties in approaching such projected screen, the environmental setting and and the gestural modes. In general, when dealing with natural interaction applications for museum visitors, two main aspects have to be taken into account: (a) embarrassment towards digital products especially natural interaction ones. Given the gestural operations that user has to do in order to interact with the application, these may lead to his not fully concentration in the learning units available. He is thus stuck in a not comfortable situation of content’s acquisition; so the pedagogical affordance of the digital product may be diminished. Another element is (b) frustration in facing “complicated” applications. The usability - or easiness of usage - of digital products needs to be verified during pilot-tests and once they are on show. The easiness through which users interact with such applications, positively influences the learning mechanisms in action: not only users develop an attitude towards technology through memorization of buttons/icons and clear interface design but they can also learn by playing.



Fig. 11: Results of the UX evaluation of Admotum and HoloInt.

Results pertaining the automatic software, in the month of March, partially confirmed what already emerged for UX evaluation. They revealed that the average duration of gameplay session is of 4 minutes (4,18); the number of scenarios completed (Treasure Hunt sessions) is on average, one scenario per person. Most efficient users topped 8 scenarios completed. The Colossus Hall (Rome’s shelf) was the most accessed. The number of items collected (First-person or passed to external inspection unit) is on average, 1,976 (~2) collected in first-person, while 0,5 (half) sent to the inspection

### X. CONCLUSIONS

The production of 3D contents within a collaborative asset manager has improved a standardized workflow shared between the collaborators (3D modelers, archaeologists, curators, information scientists, programmers etc.). As a result, at the end of the project, the 3D assets resulted in a well-organized and ready-to-archive dataset. At this point a metadata creator, previously established within the V-Must, has been used in order to enrich semantically the 3D assets, especially the accuracy (for the reality based models) and the data provenance (for the source based models). The K2R exhibition made it necessary to publish a catalog (both hard copy and eBook) with all the contents of the four expositions. The multi-level production approach in terms of geometries and textures (from high to low resolution) allowed to produce different outputs like static renders, videos in CGI and an online digital library. Another major result within K2R exhibition, was related to the deployment of an extended gesture-based interaction inside museums - side by side with the historical objects - enabling individuals to perform real-time comparison, interpretation and contextualization through an engaging collaborative context. This was especially

valuable for young visitors (e.g. school classes), for whom a museum visit means an informal learning activity [1]. Combining two completely different technologies and software frameworks into a shared experience is challenging and it is possible through proper modularization and engineering of both software and hardware components. We believe the final product resulted of great benefit for a museum in terms of flexibility and customization for a wide range of needs and possibilities [21]. From a setup perspective, the design of both installations takes into account the issues related to the not always easy management of the museum areas, occlusion and environmental light. The two installations run independently, offering a secure and reliable context. The HoloInt components are simple, easy to assemble and ensure a good yield of the final visual effect in different environmental conditions. The Admotum setup, on the other hand, is cheap and flexible to suit several educational (and cultural) needs. These include also more immersive configurations - for instance using multiple projections - or the use of stereoscopic displays, thus boosting up the value and sense of 3D user interface. Furthermore, on the museum side, the remote control service could enable more advanced and engaging interactive spaces for visitors, including integration with mobile devices in a local network and also cross-museum gesture-based interactions.

#### XI. ACKNOWLEDGMENTS

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