THE VIRTUAL RECONSTRUCTION OF TORRE GUACETO LANDSCAPE (BRINDISI, ITALY)

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1. Introduction

The search for alternative and technological solutions for enhancing the cultural and archaeological patrimony represents a difficult challenge for the Information and Communications Technology market. In recent years, there has been such a boom in the number of tools and applications for communication that it has become difficult to be innovative. Technologies such as virtual and augmented reality – commonly driven by giants like Apple and Samsung – have offered a new user-friendly approach to digital environments. As for cultural heritage, unfortunately, the widespread usage of new technologies has been associated with a lack of attention to scientific data and its "cultural" message. Thus, while in the last decade APP and multimedia products have impoverished scientific data in favor of entertainment contents, today there is a need to move beyond entertainment in order to support smart products that are able to enhance culture and research and to guarantee access to target users. To succeed, collaboration between different professionals with a variety of skills and proper scientific support becomes very important.

The present study brings together different methodological and analytical approaches that have enabled the testing of new technologies in the field of archeology in indoor and outdoor environments. The survey area was the Natural Reserve of Torre Guaceto, located between Brindisi and Carovigno (Italy), and the focus of the project was the Middle Bronze Age (15^{th} century BC) artifacts resulting from archeological survey activities carried out by the Historical Heritage Department of the University of Salento in the area of the small islands known as the Scogli di Apani (Brindisi, Italy) [1].

The aim of the study was to digitally translate, archaeological and environmental data in order to develop two kinds of applications: the first for visualizing digital contents through augmented reality and mobile phones, and the second based on mixed reality interactions, for the innovative Google Tango device. The innovative value of the present study is based on multidisciplinary research activities and on the re-use of the same digital data in different platforms.

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2. Archaeological Overview

The archaeological research project carried out by the University of Salento, Department of Cultural Heritage[1] in the Natural Reserve and Protected Marine Area of Torre Guaceto (Brindisi, Italy) concerns the investigation of the coastal landscape during the 2nd millennium BC and focuses on the Bronze Age fortified settlement of Scogli di Apani [1, 2]. Today, the protohistoric site of Scogli di Apani is about 1.5 hectares wide and 40% of its surface still has archaeological layers up to 3m thick; the two islets are situated about 500m from the coastline.

Figure 1. Scogli di Apani archeological excavations.

Two different areas were investigated on the larger islet of Scogli di Apani (Figure 1): Sector A, in the south-west of the island, is in the area of the fortified wall; Sector B, instead, is along the southern side and has thick archaeological layers [3-5]. The excavations brought to light at least two different layers of huts destroyed by fire, one on top of the other. Inside them, there were still preserved many artifacts, including pottery, bone and hard animal tissue items, flint and stone tools, etc. Many animal bones, marine and terrestrial mollusks, in addition to charred seeds, were also found and probably represent meal remains. It was also possible to document many well-preserved elements of the dwelling structures, as in the case of pole holes, daub pieces, mud hearth-plates, pavements and small base walls. Short-lived botanical remains from both hut 1 and 2 were sampled for radiocarbon dating and supported the indications of relative chronology from the pottery analysis to a late phase of the Middle Bronze Age (15th century BC) [6].

From the very beginning, the project paid special attention to mapping the geo-archaeological markers of changes in sea level and subsequently to the topic of reconstructing the paleogeographical and paleoenvironmental features of the coastline between the two Bronze Age sites of Torre Guaceto and Scogli di Apani[2]. Up to now, the collected data from terrestrial and underwater surveys as well as from the archaeological investigations [7] allow us to suppose a sea level during the 2nd millennium B.C. that was up to 4m lower than today [3, 8]. The fortified settlement of Scogli di

Apani was probably a peninsula close to a large coastal swamp; the data from the paleoenvironmental analyses carried out on four different core drillings taken up to a depth of 2.50m in this coastal area, strongly support this hypothesis.

3. Production of digital contents with high scientific value

The production of digital contents had two phases. The first one was related to the tri-dimensional digital reconstruction of the discovered objects and items. The second was directed at placing the models in the life context of the Bronze Age. The digital models have a high intrinsic value since they are the result of a complex scientific process. The latter was necessary to correctly interpret the archeological data of the finds (from their condition when discovered to their original state) and to provide real data for the reconstruction of the original landscape and the village of Scogli di Apani (C14 dating, conducted by CEDAD) [3].

a) 3D Models for the augmented reality application Smart Archaeological Landscape

The described activities concern the reconstruction of the 3D digital model starting from an archeological find. The same methodology was used for the reconstruction of the entire collection of the items chosen for the project.

The first step was the identification of the archeological finds to be digitalized. In this phase the Cultural Heritage Department of the University of Salento had an important role in the analytic scouting of the items discovered in the Bronze Age settlements at Scogli di Apani. With the use of software for 3D modeling such as Maxon Cinema 4D and Autodesk Maya, it is possible to entirely rebuild an object as it was in its original form, even though very little real data is available, such as for example, only a fragment of an artifact. Starting from scientific documentation and working with archeological experts, for the digital reconstruction we selected the finds with the most interesting information and the most representative of the investigated area. The selected items are currently preserved in the Archeological Lab of the Natural Reserve of Torre Guaceto. The digital models were used in the two sections of the augmented reality app described in more detail in the next paragraph.

- *Indoor section*: in the Archeological Lab of the Natural Reserve of Torre Guaceto;
- *Outdoor section*: in the area of the Natural Reserve of Torre Guaceto affected by the archeological survey.

In detail:

- Items in the indoor section:
  - kettle;
  - brassard (archer's armguard);
  - lithic axe;
  - deer antlers.
- Items in the outdoor section:
  - acorn;
  - swamp reed;
  - pole holes (evidence of the presence of huts).

b) Sharing the scientific data and 3D digital interpretation techniques of a fragment of kettle

In order to obtain the necessary information for the production of digital contents it was essential to carry out research in the Archaeology Laboratory where the finds are currently preserved, and also in the places where they were discovered inside the Natural Reserve. Information from the paleoenvironmental and geoenvironmental analyses was shared during the surveys conducted in the places of interest.

The first element analyzed was a "fragment of kettle" that represented the archeological data from which the reconstruction and interpretation of the original state of the object started (Figure 2).

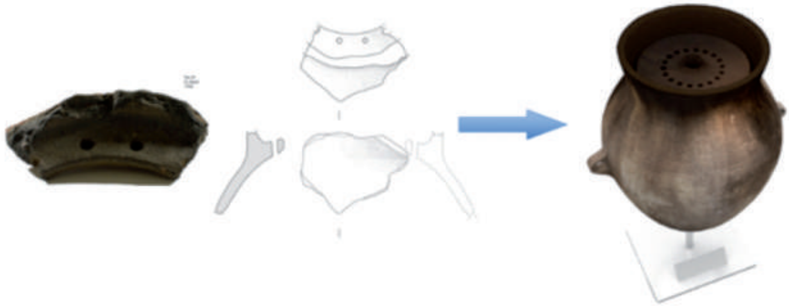

Figure 2. Digital translation stages: from archaeological evidence to 3D model.

Below are listed the activities required for the phases of the survey and the analysis:

- photographic campaign of the fragment;
- parametric evaluation of the fragment;
- data sheet with all information and archaeological survey data (hand-drawn), such as analytical descriptions, plans and orthogonal views;
- collection of data on the functionality of the object in daily life, necessary for the reconstruction of the contextualized scenario.

In order to exploit the archeological preserved data for later interpretation of the missing part (not preserved), we used techniques of *photogrammetry*[4], which gave the relief of the fragment with relative measurements. The data acquired was translated into a three-dimensional model and then processed through polygonal tracks and commands of *revolve*[5] in order to obtain an editable 3D surface. After all these operations, consistently performed with the scientific data support, the generated 3D digital model was characterized in the successive operation of *texturing*[6].

In order to give the 3D model the right texture, it was necessary to recreate it (terracotta material). For this purpose, we worked on the images of the fragment from the photographic survey, in order to extract the tangible data. After extraction and elaboration of the material's texture, obtained working on the relief, shadowing, contrast and specular effects, it was applied to the model through the mapping process called "UV mapping". After this operation, the model was optimized for real time visualization, through the following operations:

- reduction in the number of polygons in the original model;
- triangularization of polygonal faces;
- conversion of perpendicular lines and tangents;
- clean-up of surfaces.

We subsequently exported the model with different settings and tested each of them in a real time environment based on Unity 3D in order to evaluate the visualization quality of the model and the response time of the application. After defining the right standards for real time, the model was ready to be used in the AR application and loaded into the database of the app contents.

c) Digital interpretation of the Bronze Age Settlement at Scogli di Apani

The previously described kettle was found on the floor of a hut in the Bronze Age village at Scogli di Apani. This type of closed vessel with its pierced slat on which the lid was placed for boiling was probably used to make dairy products. With the aim of communicating to the user the context of utilization of the finds in addition to their details, we also interpreted, modeled and digitally reconstructed the entire prehistoric village, today recognizable only due to the presence, in the excavation site, of "pole holes" and finds including utensils, food and other items dating back to the Bronze Age. Therefore, scenes of daily life in the Bronze Age village were digitally realized, underlining the use of the kettle in its everyday functions:

- milking;
- filtering;
- cooking.

Using the milking scene as an example (Figure 3) it is possible to observe the digital reconstruction of the village at Scogli di Apani with its huts, and animal and plant species, as well as the people who inhabited the Reserve of Torre Guaceto. All the information visualized in the described scene is the result of specific investigations that have allowed environments, subjects and objects to be represented according to scientific analysis.

Figure 3. 3D "Milking" scene

The first scene shows a woman who is milking a cow. In this scene, the kettle was needed in the phase of milk collecting. In order to realize this scene we had to produce the following 3D models:

- of the cow;
- of the milkmaid;
- of the hut;
- of context objects;
- of the terrain, local flora and fauna.

At the same time as the modeling was being carried out, we did research and editing on the textures to respect the materials specified by the scientific consultancy:

- the coat of the cow;
- the clothes of the woman;
- the material of the hut;
- the materials of the flora, fauna and terrain

d) Digital reconstruction of the huts

In order to digitally reconstruct the Bronze Age hut we collected all the real planimetric and structural data coming from the archeological studies:

- plan of the hut;
- size of the pole holes and distance between them;
- overall height of the perimeter walls;
- types and materials of the walls;
- size of the roof;
- floor;
- textures of the entire building.

The skeleton of the building was created using a modeling procedure for polylines, later converted into polygonal objects using extrusion functions to produce “extrude curves” and “extrude surfaces”. The study and reproduction of the textures for each building material of the hut was a complex process and covered wood types, stones and metals, as well as the graphic transcription of hard materials (animal bones, tools, furniture, specific areas of the hut, etc.). Thanks to the digital reconstruction of the living area, it was possible to contextualize the archeological finds in the scenarios of Bronze Age life.

e) Digital reproduction of organic elements

Organic modeling is usually considered the most challenging since the elements are rich in particulars and characterized by soft geometries. Modeling is, therefore, generally a long process. In our project, it was important to refer to sources which illustrated the variety of plants and trees that were present in the period under examination: oaks, heathers, junipers and several plants of the Mediterranean maquis[7]. For the digital reconstruction of these elements it is common to use the spline patch modeling technique, which is based on a dense network of curves and control points that can be later transformed into surfaces, such as that of a leaf. Polygon extrusion is used for the stems and trunks.

f) Female character's 3D modeling and rigging

Creating this character (subject) was very complex. The anatomy of the body was realized following the traditional procedure of organic modeling, using surfaces and polygons. Through software tools such as union, difference, intersection, booleans, smoothing, sculpting, rounds and many other functionalities we were able to obtain the correct anatomic proportions of the female body. Afterwards, using specific Cinema 4D plug-ins, we created the clothes, characterizing them with stylistic shapes and materials of the Bronze Age. To begin with, the finished model of the subject is a rigid body with a static position, called "T position". It is then completed by building and embedding a complex skeleton system, which enables animation of the geometric model. The insertion of a virtual skeleton, composed of joints and IK handles, and the use of kinematic patterns, allowed us to handle the poses of the female model in the 3D scene. This phase is called "Character Set Up" (Figure 4).

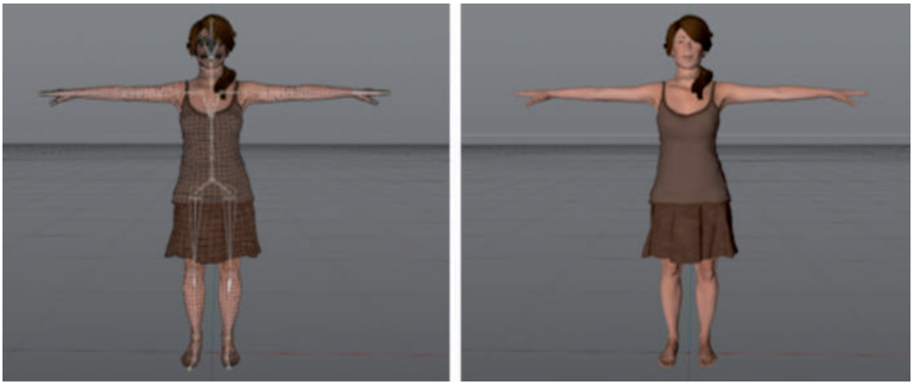

Figure 4. Female character set up

g) Completion of the scene and illumination setup

To obtain the best result in terms of graphic rendering, it is essential to correctly set up the lights inside the 3D scene. In this phase we also worked on optimizing the *bump8* parameters and reflection of the materials, functional to the improvement of the definition of surfaces and the incidence of the light source. In every scene we inserted natural sunlight to illuminate the entire environment on the basis of latitude and longitude coordinates. In order to make the subject stand out, we inserted additional light points. The settings for shading, depth of field, radiosity, anisotropy, intensity and warmth of light were carefully calculated.

4. Augmented reality for the visualization and enjoyment of advanced digital archaeological data

Old artifacts carry with them important data about the existence of our ancestors. If we know how to look at them, they can provide important knowledge of our past; they can make history come to life. Unfortunately, finds are not always discovered in their entirety and very often not in their original context. Examining them in detail, archeologists are able to identify them, understand their use and meanings, and locate them in time and place. The challenge for archeological exhibitions is to find a way to codify this specialized scientific information to make it accessible to a wider public in a realistic and effective way.

Augmented Reality is a valid instrument to achieve this goal, making it possible to present the artifacts to people in a way that enables them to see what no longer exists.

Augmented reality can indeed be defined as the integration of digital information with the user's environment in real time. Unlike virtual reality, which creates a totally artificial environment, AR supplements reality, rather than completely replacing it [9].

In past years, cultural heritage sites have been well provided with many types of electronic informative tools. More recently however, a large number of projects relying on handheld computing devices, such as mobile phones, have been proposed. Many of them are based on augmented reality technologies. One pioneer project is Archeoguide [10], which provides personalized tours and reconstructions of ruined sites, using augmented reality. Another example is the PRISMA project [11], a video see-through visualization system composed of a camera to record the real time video stream, binoculars as the visualization device and an inertial sensor to track the point of view and rotation of the binoculars. Another more recent work is Arac Maps [12], a concept for augmenting archeological paper maps with 3D models and additional interaction options. Another interesting project, developed by CETMA, is **JurAr** [13], a markerless AR mobile application prototype that allows the visitors of a paleontological site to point at one of the alleged dinosaur footprints present in the site with the mobile device camera and see the digital reproductions of the corresponding species.

Augmented reality, virtual reality, 3D visualization, social games are all powerful instruments currently offered, to enhance the enjoyment of archeological cultural heritage. However, these technology platforms are often not combined with attractive high quality multimedia content that pays attention to both the emotional impact they can produce and the cultural and scientific message they have to communicate.

In this article, we describe the methodology used to develop an augmented reality application for handheld devices that aims to achieve this precise goal. In particular, the augmented reality app relates to the archaeological finds belonging to the Middle Bronze Age found during the archaeological investigation in the fortified settlement of Scogli di Apani, two small islands, situated at a distance of 500 meters from the coast, which are part of the Natural Reserve of Torre Guaceto, in the province of Brindisi.

a) The AR app – Smart Archaeological Landscape

The Augmented Reality application, called Smart Archaeological Landscape, was designed for non-expert users to understand and enjoy the prehistoric finds in the Natural Reserve of Torre Guaceto. It uses the archaeological evidence housed inside the Archeological Lab of Torre Guaceto and the paleobotanical elements in the outdoor environment. The name of the app wishes to underline the vision of the landscape as a museum, and so a place for the dissemination and in-depth analysis of archeological knowledge. The application works on any recent handheld devices such as smart phones and tablets. It is divided into two main parts: indoor and outdoor.

The indoor section refers to the archeological finds dating back to the Bronze Age, inside the Archeological Lab and visitor centre of Torre Guaceto. In this section, users can see the artifacts preserved in the laboratory in augmented reality, digitally rebuilt in their original form, in their historical context and how they were used.

Figure 5. On the left, acorns dating back to the Bronze Age discovered during the survey; on the right, a rendering that shows the use of acorns in the Bronze Age.

The outdoor section refers to paleobotanical elements still present in the Natural Reserve of Torre Guaceto; clear evidence of their use during the Bronze Age was discovered during the survey conducted in the Scogli di Apani settlement. In this case, the application mixes, in real time, the real environment where the element is currently present, with the digital simulation of its use in the Bronze Age (Figure 5). In addition to augmented reality, the application has a section with textual and audio explanations in Italian and English about the items and their discovery, and a picture gallery with computer generated images showing scenes of objects in use during the Bronze Age.

b) Development and features – implementation

Smart Archaeological Landscape is an Augmented Reality mobile application based on a video *see-through system*[9], which uses the camera of the handheld device to capture the video stream and its screen for the visualization. We used Unity3D as a development platform and rendering engine for our 3D models and Vuforia as a mobile vision platform. To guarantee maximum robust tracking, required to properly display the information layer according to the user's current position, orientation and perspective, we decided to use a vision-based tracking technique based on fiducial markers. This method has been widely used in computer vision techniques because of its robust performance [14][14]. However, a potential drawback of this method is intrinsic in its own working principles, as the unnatural appearance of the external marker itself in the scene can spoil the aesthetics of the environment. Rather than using fiducial markers, camera pose can be determined using marker detection techniques that rely on naturally existing features, such as points, lines, edges or textures. This method has the great advantage of not introducing any artificial elements in the environment but is not always applicable and is usually less robust than fiducial marker tracking. In our project, we evaluated we could use fiducial markers without spoiling the aesthetics of the environment, so this technique was adopted.

For each augmented model, we created a specific marker designed to guarantee robustness in pattern recognition and accuracy in the pose detection and tracking.

Figure 6. Indoor utilization - Museum displays at Visit Centre Al GawSit (Serranova).

Figure 7. Outdoor utilization - Area of archaeological findings at the Natural Reserve of Torre Guaceto.

Each marker is placed near the real object (artifact or paleobotanical element). The user can observe both the real element and its digital reconstruction at the same time and watch how it was used in the Bronze Age (Figure 6, Figure 7). The methodology behind the design and development of the Smart Archaeological Landscape app was based on a strongly multidisciplinary approach. Different professionals worked on the project in order to correctly interpret the scientific data and encode the archaeological data, which otherwise would only be understood by expert users; visual data is thus accessible to a wider audience. The solution described here is a multimedia product that is the result of study, research and analysis that lasted several years.

c) Functionality

Smart Archaeological Landscape was designed to be used indoors and outdoors. Specifically, indoor utilization takes place where the archaeological finds are preserved (Archaeological Laboratory and Visit Centre Al Gaw Sit in Serranova), while outdoor utilization takes place in the Reserve of Torre Guaceto where the paleobotanical elements are still present today. The augmented reality is indeed used “to augment” the real environment with digital contents and 3D scientific reconstructions of the items present in the reserve/museum. The user can choose whether to access the indoor or outdoor section. After choosing, using the camera of their handheld device, users simply have to frame one of the markers in the environment to enjoy the linked multimedia contents.

For the indoor section the archeological finds visible in augmented reality are:

- kettle;
- brassard (archer’s armguard);
- lithic axe;
- deer antlers.

These finds were discovered during the survey conducted in the Bronze Age village of Scogli di Apani, and are now preserved in the Archaeological Laboratory of The Natural Reserve of Torre Guaceto. In many cases, they are just a fragment of the original object. Through the application it is possible to see the digitally rebuilt original object next to the real one, to interact with it, rotating and scaling it, and finally watch how it was used. Each detail of the digital model was built starting from archaeological data.

The app also provides a textual explanation and an audio guide in English and Italian with information on the object observed by the user. For each element there is a gallery of images created in computer graphics where it is possible to see a scene of the item contextualized in the Bronze Age (Figure 8).

Figure 8. App IU - Interior hut rendering.

The outdoor section presents similar features. The paleobotanical elements visible in AR are:

- acorn;
- swamp reed;
- pole holes (evidence of the presence of huts).

The pole holes, still present on the promontory ridge of Torre Guaceto, are holes in the rock, inside which one end of a wooden pole was placed and formed the perimeter and subsequent partitions inside the Bronze Age huts, as well as holding up the roof. Unlike the other artifacts, their visualization in the app is in virtual reality instead of augmented reality. In this case the app shows a reconstruction in VR of the environment in its original state. The user's input activates a real time animation where the poles are inserted inside the holes, revealing the original function of the pole holes. The app, moreover, allows users to appreciate the virtual reconstruction of a Bronze Age settlement.

The functionality and methodology described show an approach in which innovative technology plays an important role in communicating and promoting the cultural message of the archaeological and natural site. The technology platform relies on high quality contents, created with the support and contribution of different specialists and professionals. The objective was to grant visitors an enjoyable experience that allowed them to appreciate the archaeological heritage presented to them, giving users the opportunity to understand what would otherwise only be understood by experts. The most innovative aspect in the project is the fact that a multimedia product was built that could easily communicate scientific data coming from years of specialized research, in a simple and direct way, without losing any of its original meaning.

5. The Google Tango experience

The digital documentation and 3D modeling of cultural heritage monuments and sites has been a highly topical subject in recent years. This contribution is part of ongoing research and offers an approach dedicated to the enjoyment of archaeological heritage in the context of processes that integrate consolidated cognitive paths and technologies whose potential is still under investigation, including Augmented Reality. The data used by a scientifically consistent methodology are the result of calculations that critically use modeling software and engine graphics; the given example refers to a settlement dating back to the Bronze Age. The town was identified and investigated during the three campaigns of excavation carried out on Scogli di Apani, in the territory of the Natural Reserve and Protected Marine Area of Torre Guaceto, on the north coast of Brindisi in Italy.

Enhancement of the archaeological domain has led over time to combining traditional methods of valorization with more modern knowledge and communication tools that users, who are becoming increasingly computer literate, appreciate especially in cases where the sites concerned cannot be fully enjoyed at first hand.

Figure 9. Google Tango Interface.

This is the case of the archaeological site of the village near Apani (Brindisi, Italy) where the cognitive support tools on site fail to satisfy visitor expectations.

Our goal is to create a new interactive experience for users aimed at acquiring, understanding and retaining the experience of their visit. Knowledge of visitor needs consequently becomes a fundamental prerequisite for any cultural heritage policy, a way to interact with the public. The visitor experience adds to personal growth and becomes unique, something special to recount.

From a technological point of view, in the last two years, there has been a real revolution that has opened up new horizons for cultural consumption [15, 16]. In June 2014, Google unveiled the first release of the Tango project (Figure 9). It is a technology that combines hardware and software in order to solve the problem of localization in the absence of a GPS device. The technology is based on computer vision techniques by determining the position of the device in the environment. The objective is to allow mobile devices to understand space and movement. Google Tango uses three main methods: motion detection, recognition of space and perception of depth. This means that a Project Tango device can monitor its movement and orientation within a three dimensional space. Furthermore, the data regarding depth allows an application to detect the distance between visible objects and the device. The combination of functions of depth perception and motion tracking allow you to calculate distances between points or to select an area of interest. One of the first tests was carried out at Al Museu Nacional d'Art de Catalunya in Barcelona, in February 2016, where Google and Lenovo organized a special visit based on the use of a tablet equipped with this new technology. The device is able to locate its position and to display augmented contents. From the hardware point of view, the components included in the tablet are:

- screen: display 7.02 " 1920 x 1200 HD IPS (323 ppi);
- camera: 1MP front facing fixed focus with IR LED, 4MP 2 μm RGB IR pixel sensor;
- dimensions: 119.77 x 196.33 x 15.36 mm;
- operating system: Android ™ 4.4.2 KitKat ®;
- wireless: dual-band Wi-Fi (2.4GHz / 5GHz) Wi-Fi 802.11 a / b / g / n ; NFC (reader and peer-to-peer modes);
- weight: 370 g;
- audio output: two stereo speakers 3.5 mm audio connector;
- memory: 128 GB internal storage;
- RAM: 4 GB RAM;
- ports: USB 3.0 host via dock connector;
- micro SD card slot for nano SIM;
- battery: 4960 mAH cell (2 x 2480 cells);
- processor: NVIDIA Tegra K1 w/ 192 CUDA cores;
- sensors: motion tracking camera; 3D depth sensing; accelerometer; ambient light; barometer; compass; GPS; gyroscope.

One of the innovative features we used in the project concerns motion tracking, that is, the possibility of the device to determine its position by observing the area in examination. The libraries available allow you to obtain data relating to position and orientation (Figure 10).

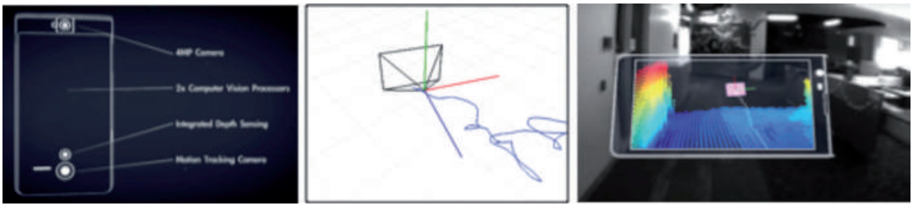

Figure 10. Tango tracking functionalities.

In general, the aim of this project, based on Augmented/Virtual Reality technology, is to allow visitors to enrich the ways in which they see the natural world and its past, through a journey in time. Using their mobile devices, visitors search for virtual items (Gateway) that will allow them to make the leap into the Bronze Age. Once they have stepped back in time, virtual reality technology will 'teleport' visitors to the Bronze Age village, so they can walk its streets and appreciate the elements of the ancient landscape (Figure 11). In the village, the houses have been rebuilt in 3D, structures in which the educational experience can be enhanced by observing objects from everyday life, some of which are made of fused metal or ceramics.

To facilitate interaction, a study on the graphical interfaces was carried out. At the start of the application, the visitor is guided along a path that highlights both the initial information about the village in question and the procedure to be followed for the visit.

Figure 11. Above - AR contents – below - VR contents.

After this initial stage, the visitor has to look in the real environment for the time "gateway", digitally added in augmented reality. The passage through the "gateway" allows him to time travel and to land in the Bronze Age village. Through a series of sensors dedicated to vision, the visitor can start his journey.

6. Conclusions

The notion of innovation described in this article leads to the conclusion that there is a real opportunity for researchers to explore and improve future and experiential projects.

In recent years, there has been an urge to push the traditionally static museum towards producing more interesting innovative activities, regarding organization and management, ticketing policies, opening hours, promotion and communication projects. The traditional museum container itself can be transformed into new entertainment spaces for events, cultural activities, themed exhibitions, etc. so as to attract wider audiences[10].

In this sense, Smart Archaeological Landscape is an innovative multidisciplinary experience which, on the one hand aims to satisfy a targeted public, and on the other, confirms the need to support scientific research in providing new user-friendly technological solutions. The applications described here, can therefore be used to disseminate information and enhance visitor experience by means of interactive tools which help to understand the meaning of the archaeological context and scientific contents at the same time providing easy access to all users.

Today however, there is a consensus that one of the most important problems for many cultural heritage structures is the management of IT tools; many of them, etc., have reported difficulties, for example, associated with the maintenance of technological equipment. Research into this issue is essential. For this reason, the app was developed to meet the following requirements.

1) **Installation problems with user devices**: real-time functionalities are very frequently not supported by users' mobile devices[11], therefore, the Al GawSit Visit Center will provide, provisionally, and without additional costs to tickets, pre-configured devices for visitors. In the Archaeological Laboratory, on guided tours and learning courses, the pre-configured devices will be used by operators for demonstrations and scientific purposes.
2) **Internet and wi-fi connection limitations**: Augmented and virtual reality applications require a high-quality internet connection to work with real-time downloads and to communicate with remote dataset. For small local structures however, the internet connection is not always guaranteed. For this reason the described applications have been developed to work with marker-based technology. For the Google Tango device, internet connection is not required;
3) **Outdoor functionalities**: most of the AR and VR applications use GPS recognition algorithms to track the user in the space and to visualize digital contents corresponding to the point of interest. However, it is known that the GPS signal has an error ranging from 1-10 meters. Therefore, the applications described rely on physical markers installed on the visit route of the Natural Reserve of Torre Guaceto. The Google Tango device instead, recognizes the interaction environment with its sensors, thus, the visualization of the augmented reality is automatic.
4) **Accessibility:** To develop accessible applications ensuring 100% of the interactive functionalities is a very difficult task. The described applications have therefore been developed to include accessibility tools: interfaces designed according to usability standards and in compliance with EU law, multi language audio assistant, and adjustable volume functionalities.

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Notes

[1] The research project started in 2008 under the scientific direction of Professor Riccardo Guglielmino; direction and scientific and technical coordination by Teodoro Scarano, who is also the scientific director of the Laboratory of Archaeology of Torre Guaceto.
[2] This specific survey activity was carried out in collaboration with underwater archaeologists, coordinated by Professor Rita Auriemma of the Department of Cultural Heritage of the University of Salento and with geomorphologists directed by Professor Giuseppe Mastronuzzi of the Department of Geology and Geophysics, University of Bari.
[3] Dating and diagnostic center, Brindisi.
[4] The result of a match of orthophotos taken from multiple points around the object.
[5] Common instrument of revolution of a curve around an axis, which automatically generates a polygon mesh.
[6] Method for defining surface texture or color information on a 3D model.
[7] Common Mediterranean ecosystem.
[8] Overlapping of a second texture used by the rendering engine to simulate grooves and protrusions
[9] In AR video see-through is a system in which a signal captured by a video camera is combined with virtual elements and displayed on a screen in real time.
[10] Source: National Institute of Statistics (Italy), “The non-state museums and similar institutions”, Informazioni n. 6, ISBN 978-88-458-1680-2, 2010.
[11] Reference is made to the loading and processing of 3D digital content in real time (AR/VR).

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