WebGIS, 3D modeling and virtual tours to map, record and visualize the cultural, archaeological and landscape heritage: the *VisualVersilia* project

Martina Giannini[1], Cristina Castagnetti[2], Riccardo Rivola[3]

[1] *DIEF – University of Modena and Reggio Emilia, Via P. Vivarelli, 10, 41125 Modena,*
martina.giannini@unimore.it
[2] *DIEF – University of Modena and Reggio Emilia, Via P. Vivarelli, 10, 41125 Modena,*
cristina.castagnetti@unimore.it
[3] *GEIS - Geomatics Engineering Innovative Solutions Srl, Via P. Vivarelli, 2 – 41125 Modena,*
riccardo@geomaticsengineering.it

*Abstract –***This article describes the methodologies and technologies developed during the realization of the WebGIS (Geographic Information System) *visualversilia.com*, namely a multimedia guide able to map, survey, visualize the rich cultural, archaeological and landscape heritage of Versilia (northwestern Tuscany). It enables users to delve into different temporal settings and to contextualize the local cultural sites within the geographic space of their specific historical periods. The immersive experience is also achieved thanks to the realization of virtual tours and navigable 3D models of archaeological complexes concerning the past and current appearance. This WebGIS is a digital platform, soon available online, for viewing and managing data relative to the cultural sites of Versilia, through their localization on an interactive map with several thematic layers, divided into chronological sub-layers. The aim of the research project is to provide useful information for knowledge, protection and enhancement of the cultural heritage of the area.**

I. INTRODUCTION

The research projects *VisualVersilia* [1] [2] and *VisualVersilia 3D* [3] - promoted by the e-Gea Interuniversity Center - focus on the application of innovative methodologies and new technologies combined with the analysis and comparison of all available historical sources and maps relating to the area of interest, in order to realize a multimedia guide based on WebGIS (Geographic Information System), the *visualversilia.com*. This guide wants to map, record and visualize the cultural sites of Versilia in their historical landscapes.

Versilia is a sub region of north-western Tuscany, between the sea and the Apuan Alps, especially known for its seaside resorts, shipbuilding industry, mining and processing of the marble of the Apuan Alps. However

Versilia is also rich in archaeological sites, Romanesque churches, medieval villages, castles, which show the long history of the territory inhabited since the Neolithic and defined by a mosaic of landscapes that have been shaped over time (Fig. 1).

Fig. 1. Location map of Versilia.

Visualversilia.com consists of an interactive map and a series of dialog layers characterized by special icons for the various subjects addressed, which are in turn broken down into sub-layers; the latter are able to express the various historical phases analyzed through the use of different colors, in order to map, communicate and illustrate the wealth of Versilia's cultural, archaeological and landscape heritage from the first traces of human settlement to the 21st century (Fig. 2) [1].

In the *Archaeology* layer, for example, there is a pie divided into slices of different colors and corresponding to the various historical epochs. This method is particularly useful in the case of continuous attendance on the same cultural site.

The WebGIS represents, in fact, a highly innovative and complex tool in that it addresses many wide-ranging subjects, but also and above all, because it offers users the opportunity to move through a space/map and immerse themselves in different periods. This is possible thanks to several reconstructions of the landscapes of the various periods, which, through the special layer *The*

landscape as it was, more effectively contextualize the sites explored (Fig. 3) [1] [2].

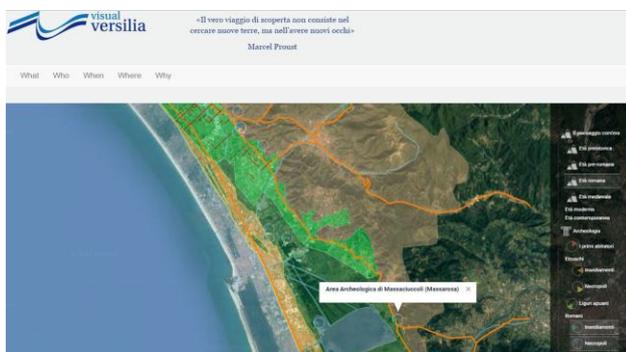Fig. 2. The layers and sub-layers of WebGIS visualversilia.com.

Fig. 3. Versilia in Roman times with the Roman age "settlements" and "necropolises" sub-layer activated as well. The Landscape as it was in the Roman era and the archaeological site of Massaciuccoli georeferenced on the WebGIS.

The contents of the multimedia guide have then been enriched with virtual tours and navigable 3D reconstructions of past and current appearances, specifically, of the archaeological complex of Massaciuccoli (LU) [3] [4] [5] [6], which is the best preserved site in Versilia. The 3D models make it possible to tell the historical architectural evolution of the rich *otium* suburban villa, built on the shores of the lake during the early decades of the 1st century A.D.; the residential quarters were built on the wide terrace on which then the early Christian church was erected, while initially a garden surrounded by a wall with towers was on the lower terrace. Later, during the renovation of Neronian and Flavian times, around the second half of the 1st century A.D., the garden was sacrificed to build thermal and living rooms, which, in the 2nd century A.D., were merged into a single and articulated thermal area, characterized by rich architectural decorations and polychrome marble. Indeed, the bath complex was part of a system of banqueting and resting spaces.

This guide, therefore, should be able to create an immersive experience and to contribute to the enhancement and dissemination of the cultural,

archaeological and landscape heritage of Versilia; it aims to be utterly innovative regarding the current opportunities in cultural tourism and cutting edge as to the research on the use of new technologies applied to the cultural heritage of this region. The purpose of the projects, hence, is the definition of a multidisciplinary methodology that can be re-used for other cultural realities and types of contents and contexts, through an inter-disciplinary approach.

II. METHODOLOGIES AND TECHNOLOGIES

The work carried out for the realization of visualversilia.com, thanks to the collaboration between archaeologists, geographers, computer scientists, historians and experts in geomatics engineering, can be schematically divided into two phases:

A. VisualVersilia WebGIS

During the creation of the first phase of the work different procedures were used depending on the specific theme and period examined, but in general, this process involved: analysis and comparison of documents and all kinds of available sources; localization of all the cultural heritage of Versilia; realization of WebGIS framework, layers and information boxes; georeferentation, wherever possible, of historical maps; creation of vector shapefiles through the open source software Quantum GIS (QGIS, http://www.qgis.org). These last two procedures were very useful to realize the layer *The landscape as it was*, divided into different parts, with the reconstructions of urban areas, roads, rivers, harbors, beaches, lakes, mountains, plains, swamps, the railway and coastline of Versilia in the prehistoric era, pre-Roman era, Roman, medieval, modern and contemporary ages. The most useful maps for the historical reconstruction of the geography were achieved in an optical mode and were converted from analogical surface to digital images, provided with pixels. The next scanning process, high definition, led to the creation of common raster files with the extension .jpg or .tiff. Once the latter were obtained, it was possible to examine the maps more carefully through the program for displaying images by using the different layers of zoom. The scanning of the images then allowed the creation of a Quantum GIS project, which was set as the Reference System EPSG: 3857, WGS84/Pseudo Mercator. The uploaded images in QGIS were georeferenced in a correct position using the Bing Maps or Google Maps background. A careful and meticulous observation of the cartographic background was subsequently carried out in the area corresponding to the representation of georeferenced map. Thus it was possible to identify the coordinates of specific and very visible points on the maps. The number of identified points appeared variable because of the type of available maps, however, ten points were noted for each chart; the coordinates of previously identified points were then assigned to the corresponding points on the map. This action displayed the final list of points known as Ground Control Point (GCP). Thereafter several attempts were

made to select the most appropriate type of processing according to the needs, with the aim of minimizing the error, namely the distance between the departure location of GCP and the same localization transformed by the polynomial coefficients in the geographic coordinate system, in which the GCP are taken. At this point, the georeferencing process for all the selected maps started and it allowed further observation, analysis and comparison of the maps thanks to the superposition of layers made up of the georeferenced maps (Fig. 4).

Fig. 4. From top to bottom pictures: GIS with the georeferencing of historical maps superimposed over present-day cartography and the creation of shapefiles.

Clearly, the accuracy of this transaction, a relatively correct georeferenzation, depends very much on the precision and quality of the available maps; thus it was obtained with geodetic maps of the nineteenth and twentieth centuries, while those of the eighteenth and seventeenth centuries delivered results with a greater margin of error. The geographic reconstructions from prehistoric age to the sixteenth century were carried out by analyzing previous studies of the area's geomorphology and geology in comparison with archaeological evidences, mainly from settlements along the coastal plains and in mountain caves, by studying *itineraria* from late antiquity (*Itinerarium Antonini, Itinerarium Hierosolymitanum,* and *Ravennatis Anonymi Cosmographia*), in particular the *Tabula Peutingeriana*, aerial photographs and place names.

After the georeferencing process and the loading of raster in the QGIS project, vector shapefiles were created to represent the different geographic features identified in the area of interest. To get the best possible graphical display, the vector properties were chosen very carefully, in particular the color linked to the type of geographical feature and the thickness of the same vectors. The reconstructions, in fact, were highlighted by creating different areas of colors overlaid on the current cartography base: brown for the elevations, dark green for the plains, olive green for the swampy areas, pale blue for the rivers, lakes and sea, beige for the dune ridges and beach, orange for the road conditions, black for the railway and gray for the urbanization phenomena.

Finally, the vector shapefiles were imported in WebGIS and displayed in an overlay on the geographical basis of Google Maps satellite version. Later layers relating to the reconstructions of historical geography were processed for Web display through online tools such MapBox (http://www.mapbox.com) or TileMill (http://www.mapbox.com/tilemill), which offer an online server to load customized thematic maps [2] (Fig. 3).

The various geographic reconstructions, divided by epochs and accompanied by information boxes outlining the geographic features of the period under investigation, can be activated directly from the layers menu or via a special command in the synthetic descriptive boxes of the cultural sites; in this last case it is possible to visualize the landscape reconstruction concerning the specific period of the cultural site in question, or the period that most characterizes it.

Thus in an innovative way, VisualVersilia enables users to create the perception of the environment where the cultural heritage lay, showing it in its original area and the spatial development of the past centuries.

B. VisualVersilia 3D

The *VisulaVersilia 3D* research project aims to enrich the content already on WebGis with 3D navigable multi-temporal reconstructions. The studies, excavations and surveys conducted over time on the Massaciuccoli archaeological site have therefore created the ideal conditions to try to further enhance a site already well documented and rich in history [3] [4] [5] [6].

The activities of the second phase of the project consist of: metric three-dimensional survey by laser scanning technology addressed to the evidences and buildings of the complex; laser scanning data processing; realization of virtual 3D rendering related to Roman and current condition for documentation and conservation purposes; creation of virtual tours of the site in its current configuration, on the basis of spherical images then enhanced by texts, 3D models of the Roman age and audio guides.

The three dimensional survey focused on the thermal area of Massaciuccoli archaeological park and it was performed in September 2016 with a time-of-flight terrestrial laser scanner, model *ScanStation C10* by *Leica Geosystems* (hds.leica-geosystems.com), which is ideal for architectural survey applications considering the ability to ensure the coherence of vertical components thanks to the internal dual-axis compensator .
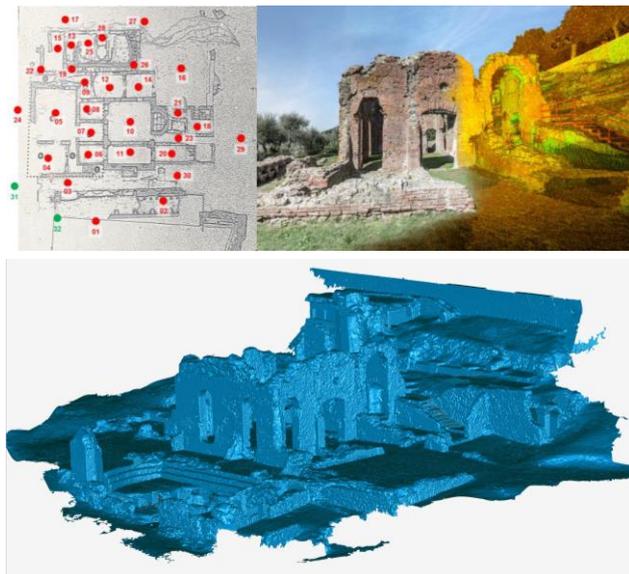
Fig. 5. Laser scanning survey of the thermal area of Massaciuccoli archaeological park. From top to bottom pictures: the planning of the scanning positions (top left) with the 3D point cloud with intensity false colors and photo-realistic appearance (top right); 3D model obtained through meshing process.

The survey consisted of 30 scans, provided by as many scanning positions (Fig. 5), for a duration shorter than two working days. The resolution was set at 5÷8 mm depending on the distance to the surveyed portion, so as to guarantee a full and comprehensive point cloud. After the scanner data collection, 360° photographic acquisitions with HDR (High Dyinamic Range) mode were performed from each scanning locations. The image collection was carried out by an external camera, model *Canon EOS 5D mark II* with calibrated 35 mm lens, in order to provide high quality spherical images with double purpose: first the panoramas were coupled to the point cloud obtained from the same location in order to enrich it with the photo-realistic appearance (Fig. 5); secondly the panoramas were then used for producing the virtual tour of the site. For each scanning position, the image collection consisted in capturing 60 photos at three different exposures, for a total amount of 180 photos.

The laser scanning data processing, performed by the software *Cyclone v.9.1* by *Leica Geosystems* (hds.leica-geosystems.com), involves removing the parts that are not of interest, filtering the noise in the dataset and mainly aligning each scan performed from the scheduled scanning locations. The alignment process combines all the point clouds into the same coordinate system, thus providing the overall 3D point cloud model of the investigated site (Fig. 5). The alignment was carried out by means of the manual identification of homologous points to be recognized within multiple scans. The surface matching is based on the Iterative Closest Point (ICP) algorithm [3] [7] [8] [9] and it allowed us to obtain a sub-centimeter average error of 7 mm in the final alignment process. For each scanning position, the HDR

spherical panorama was created by combining and stitching all the collected images; the procedure was carried out with the software *PT Gui v.10.0* (www.ptgui.com) that provided very high quality results [3].

Concerning the 3D modeling of the Roman age, the point clouds were processed through the software *Geomagic Studio* (www.geomagic.com) for creating and managing the meshes. Then, the software *Rhinoceros v.5* (www.rhino3d.com) was used to proceed to the geometric surface modeling by accurately following the geometric information of the current remains (given by the 3D mesh model provided by laser scanning survey) and produce the precise 3D reconstruction of the thermal area as appeared in the past age (Fig. 6) [3].

Fig. 6. 3D Model of Villa and thermal area during the Roman period in Massaciuccoli archaeological site.

The modeling activity is still in progress and it followed a rigorous scientific approach that combines the solid acquired metric information and philological conjectures, in order to create an emotional but truthfully 3D reconstruction. The complete survey of this structure allowed the creation of an accurate three-dimensional reconstruction of the current state of conservation of places and buildings for documentation and conservation purposes, making it possible to formulate suppositions about the complex of the Roman age and the articulation of the thermal baths. The technical expertise in 3D modeling and the historical knowledge, as to the way structures were built in the past, are essential to provide a good final 3D reconstruction. Therefore, the model related to the ancient period is the result of reconstructive hypothesis, thanks to the continuous comparison of precise metrical data of the 3D surveys with historical sources and with previous bibliography; in fact, the metric precision of the measurements imposed an equally rigorous architectural interpretation of the structures and their functions able to justify the collected data.

The spherical panoramas were then used to create an image-based virtual tour of the site. This tour, produced by the software *Easypano Tourweaver v.7.98* (www.easypano.com), briefly consists in: importing the

panoramas, creating a suggested path and still allowing a free navigation, inserting hotspots and adding commands able to access to many kinds of multimedia contents, external links and so on. The online interactive virtual tour, through specific commands, lets tourists remotely visit the complex, freely move within the site, listen to audio descriptions of what is visualized as well as read supplementary information boxes, see the 3D models of the Roman age, watch videos, visualize the plant of the complex and satellite map with a georeferenced icon about where the user is. The look of the tour is fully customizable and finally provides a link that can be included within any existing website; in this research project, the tour will be integrated in the *VisualVersilia* WebGIS (Fig. 7) [3].
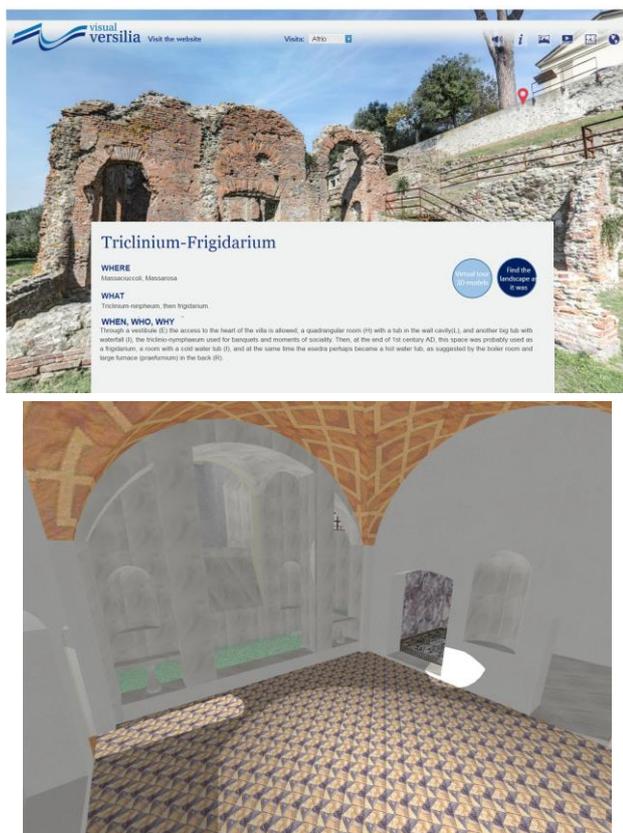
Fig. 7. Web view of the virtual tour. From top to bottom pictures: triclinium/frigidarium of the thermal area of Massaciuccoli archaeological site; 3D model of the Roman age, still in progress.

III. CONCLUSIONS

The WebGIS resulting from the case study can record, tell and visualize the cultural, archaeological and landscape heritage of Versilia; it allows the users to navigate within the various rooms of the studied complex, to find how the monument was in the ancient age and to insert the archaeological complex in the temporal and spatial context of reference, using the territorial reconstructions divided by epochs. The ideal user for this product can be a wide and varied audience consisting of citizens, students, tourists, technicians of the territory and anyone who wants to plan a visit by pc or tablet. So visualversilia.com makes it possible to have an immersive and enjoyable tourist experience both *in situ* and remotely, following a customized path in an interactive way; it lets present the area and its history as it has changed over time and to convey the complexity and richness of the cultural heritage, contextualizing it in the historical reconstructions of the landscape; it could be the starting point for studies about augmented reality from mobile devices, definitely a topic that to date, however, still has some open issues. In conclusion, the innovation of a project so conceived is especially in the research required to develop a methodology for supplementing the available sources and making use of modern technological tools, exploiting these tools' potential in terms of communicational immediacy and attractive graphics; so a methodology able to create a prototype easily reproducible in further places. This research project, therefore, has the potential to help foster greater knowledge about and resulting awareness of cultural, archaeological and landscape heritage, which will lead to safeguarding and valorizing the precious sites that bear witness to the history of this territory, and a right dissemination will be able to increase knowledge.

REFERENCES

[1] M. Giannini, "Visualizzare un territorio: il progetto VisualVersilia", BraDypUS Communicating Cultural Heritage, Visualizzare il paesaggio. Nuove forme di narrazione e rappresentazione dello spazio geografico. Chapter 3, 2016, pp. 55-81.

[2] M. Dubbini, M Giannini, S. Picone, "La cartografia storica della Versilia come strumento di ricostruzione del passato", BraDypUS Communicating Cultural Heritage, Visualizzare il paesaggio. Nuove forme di narrazione e rappresentazione dello spazio geografico. Chapter 6, 2016, pp. 117-154.

[3] C. Castagnetti, M. Giannini, R. Rivola, "Image-based virtual tours and 3D modeling of past and current ages for the enhancement of archaeological parks: the VisualVersilia 3D project", Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., vol. XLII-5/W1, 2017, pp. 639-645.

[4] G Ciampoltrini, "Gli ozi dei Venulei. Considerazioni sulle terme di Massaciuccoli", Prospettiva, vol. 73-

74, 1994, pp. 119-130.

[5] G. Ciampoltrini, G., 2009, "The villa: the Venulei's uncomfortable idleness's". Felici Editore, Massaciuccoli romana. Chapter 2, 2009, pp. 16-23.

[6] M. Giannini, "I Romani in Versilia: dinamiche di popolamento e organizzazione del territorio", Orizzonti, vol. XVI, 2015, pp. 81-91.

[7] P.J. Besl, N.D. Mckay, "A method for registration of 3D shapes", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 14, 1992, pp. 239-256.

[8] Y. Chen, G. Medioni, "Object modelling by registration of multiple range images", Image and Vision Computing, vol. 10, 1992, pp. 145-155.

[9] Z. Zhang, "Iterative point matching for registration of free-form curves and surfaces", International Journal of Computer Vision, vol. 13, 1994, pp. 119-152.

AUTHORS' INDIVIDUAL CONTRIBUTION

M. Giannini.: manuscript design, coordination and writing; corresponding author and fund raising for the project.
C. Castagnetti: 3D survey execution, writing section 2.B
R. Rivola: 3D survey design, execution and data processing.