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Perceiving Ancient Landscape in Digital Simulation. Preliminary Consideration on the Case of the Missing *Auser* River in Pisa (Tuscany, IT)

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Abstract – Reconstruction of archaeological landscapes is known to be a valuable tool for analysing and interpreting the historical landscape. The present project seeks to provide a replicable, low- cost method for simulating any archaeological context and its surroundings with the aim of creating, in a collaborative digital environment, the possible perception of the ancient river landscape. In fact, this appears functional to the study of the interaction between river and users and to understanding how much the Auser river itself may have played an agency in shaping the inhabitants' identities. The paper presents some preliminary considerations on the method, the expected results of the ongoing research project and some challenges.

Keywords: virtual landscape archaeology; virtual reality; perception.

I. PROLOGUE: RECONSTRUCTED LANDSCAPE AND PERCEPTION

In recent decades, debates on reconstructing landscapes in archaeology have focused on the applications of multidisciplinary approaches with the purpose of analysing the historical landscape. In particular, the concept of virtual cultural landscape has been introduced in recent years [1]: virtual reconstructions, becoming image of a possible place that can be experienced, make it possible to reproduce landscapes that are hard to understand or have now disappeared. Furthermore, the introduction of virtual reality systems has made it possible to focus not only on the physical visualisation of reconstructions but also on the analysis, interpretation, and simulation of the 3D landscape [2]. Indeed, the multimodal aspects of a virtual environment, capable of generating multiple past realities by catalysing evocative perceptions [3], makes the elements of the landscape ecosystem usable and interactive. Continuous interaction between the user and the landscape can facilitate the investigation of the

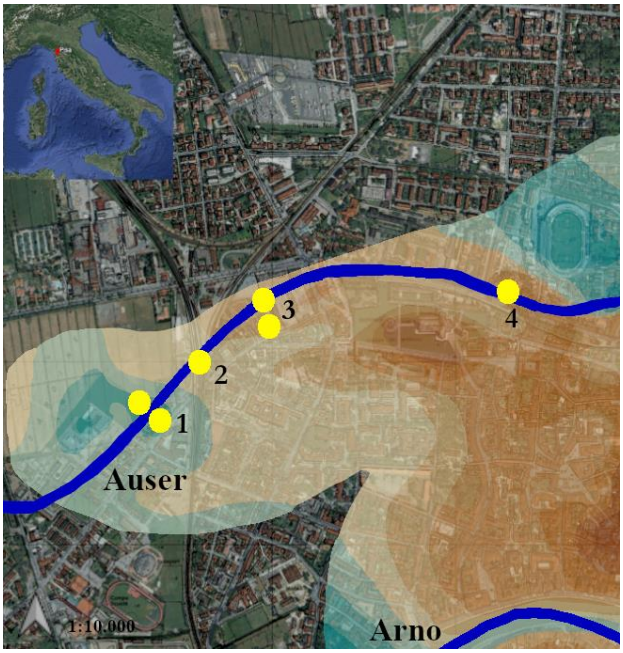

Fig. 1. Western suburb of Pisa. The possible course of the Auser river in Roman times with indicate in yellow the recently acquired data to be integrated into the DEM (redesigned from Campus, La Rosa 2021, fig. 1): 1)Area 4 and 5- Area Scheibler, excavated by the University of Pisa in 2020-2022; 2) Railway station underpass of San Rossore, unpublished excavation of the 1999, SABAP Pisa, Lucca e Livorno archive; 3) Piazza A. del Sarto, excavated by the University of Pisa and the SABAP Pisa, Lucca e Livorno in 2021-2023; 4) PFM88-Via Contessa Matilde, unpublished excavation of the 1988-1989, SABAP Pisa, Lucca e Livorno archive.

environment itself through an ecological approach, according to which the subject needs to understand all that is offered to him by his surroundings - the environment itself- in order to achieve a meaningful and complete perception of a possible reality [3, 4]. The possibility of perceiving ancient landscapes in virtual environments, so as to be able to simulate, and thus

understand, the relationships between all the elements of the ecosystem, is particularly interesting in the case of vanished riverine contexts. The no-longer extant *Auser* river, in what are now the suburbs of Pisa, is an ideal case in this approach: reconstructing the totally changed river landscapes of the Roman age, allows to simulate how the ancient citizens lived in it and how much they were influenced by the presence of the river in their choice of technical solutions and lifestyle. Multidisciplinary studies in archaeology and geomorphology previously conducted [5, 6], together with archaeological investigations carried out as part of the "Pisa Progetto Suburbio" by the Dipartimento di Civiltà e Forme del Sapere of the University of Pisa, have recently identified the possible course of the riverbed north of Pisa and some infrastructure related to navigation along its course [7, 8, 9]. In addition, an elevation map of the course of the river in Roman times has been proposed: it restores the morphology of the terrain in two dimensions [10], which can be refined with newly acquired data (Fig.1).

II. EXPERIENCING VIRTUAL CULTURAL LANDSCAPE: FROM EVIDENCE TO PEOPLE

So how do we move from the single reconstructed elements to an interpretation of human-river landscape interactions? How can we perceive it?

If "the landscape is the world as it is known to those who dwell therein, who inhabit its places and journey along the paths connecting them" [11], it is useful introduce the concept *riverscape*. Just as the seascape presupposes an individual's perception out of sight of land [1], so the riverscape also incorporates an individual's perception placed along the current or on either bank of the river itself. The perception of the possible articulation of the riverscape and its surrounding allows us to verify, at the very least, the objectivity of the dimensional aspects: the reconstruction allows us to move within these complex landscapes and evaluate with our own experience the possibilities that they could offer to the ancient frequenters for the activities that took place there [12]. This suggests that virtual cultural landscapes are the most suitable tool for investigating human-environment interaction, allowing to simulate possible past scenarios. However, it is important to emphasise that the reconstruction of a landscape shows a possible reality of the past at a given time, which by its very nature is constantly changing, thus influencing the activities performed there by its inhabitants. The virtual simulative environment can indeed be investigated with a phenomenological approach, without projecting our sensibilities and concepts into a past with different contexts but considering historical changes. Landscapes and monuments change continually and however, according to Barret and Ilhong, the material properties of them are not objective, but are construed through culture and meaning that also change over time [13]. Another

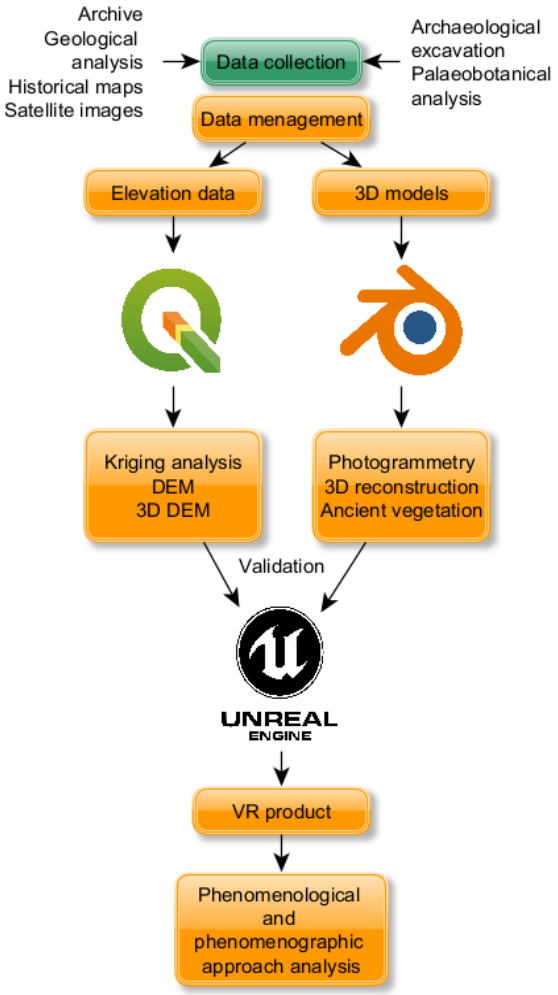

Fig. 2. Scheme of the proposed simulation process.

method is the phenomenographic one, which emphasises the collective understanding of a phenomenon according to different perspectives and sensitivities: as recently experimented in some British context [14], considering multiple experiences in the same collaborative environment, it has proved successful in the study of the virtual cultural landscape.

If one can count on a solid theoretical basis on the use of virtual reality in archaeology, there is still few methodologies that, beginning with the collection and investigation of data from archaeological contexts, allows one to reproduce multiple realities of the past landscape in its constituent elements. In any case, any project that aims to simulate a riverscape, or a landscape in general, must consider several kinds of data and integrate it in a virtual environment. The integration of documents, spatial analysis, data, and, finally, communication require a multidisciplinary approach. The proposed case study is a striking example: the no-more exist *Auser* riverscape,

Fig. 3. PFM88-Via Contessa Matilde excavations. 3D model obtained by SFM techniques with the software Agisoft Metashape.

nowadays part of a densely built-up modern suburb, yet to be investigated in its possible ancient perception, led to the formulation of an *ad hoc* method. As we shall see, the method is based on a multi-disciplinary approach using data from archival, archaeological, geological, and palaeobotanical sources in order to return a simulation that is as plausible as possible, capable of providing an interpretation of human behaviour in relation to the landscape of the past.

III. METHODS AND ONGOING RESEARCH

The pipeline to creating and perceive virtual cultural landscape completely disappeared required a mixed method approach by archaeology research (environmental, settlement, and geo archaeology), geospatial analysis and Virtual Reality (Fig. 2). Starting point is the collection of archaeological, geological, and palaeobotanical data available for the area of investigation and a creation of a GIS background where store and menage all the data. The recently proposed DEM of the *Auser* basin it is integrate with recently acquired data. Using the open-source GIS software QGIS, elevation data were categorised into chronological periods, reporting all values on the same absolute scale (msal) and finally interpolated with kriging analysis [15], useful to create a prediction surface of the ancient topography. The two-dimensional DEM can be rendered three-dimensionally using several QGIS plugins. QGIS2threeJS plugin is useful for visualize DEM and vector data in 3D and combining different spatial elements (DEM, Vectors, water surfaces) and therefore indicated for an inter-media evaluation of the reconstructed environment in a GIS environment. However, if this already allows exporting the 3D model into glTF format, is useful integrate it with DEMto3D plugin. This one allows digital elevation model files to be transformed into stl format files, i.e. three-dimensional documents with the highest accuracy, and after managed in a computer graphic software. Environment and terrain can be simulated with various software and plugins, open source (Blander-True Terrain, TerrainScapes 2, etc.) and free-to-use (Unreal Engine, for research purpose), both under consideration. In the current state of research, the Unreal Engine 5 software, developed by Epic Games, has been tested. This is, to date, one of the most powerful graphics engines capable of structuring photorealistic and fully immersive virtual reality projects, and meets the criteria of transparency, cost-effectiveness, and scientific accuracy. Using the open-source plugin "Cesium for Unreal", we can integrate the ancient environment model maintaining all the characteristics of a GIS since data are totally geo-referenced according to spatial coordinates. Once the lay of the ancient terrain has been simulated, we proceed to the archaeological evidence reconstruction according to well-codified criteria of reliability, as required by international conventions, and to the creation of the ancient vegetation on the basis of palaeobotanical analyses. At the same time, excavation data of the different archaeological context in the *Auser* riverscape it's reconstructed: in the case of more recent investigations, photogrammetric models are the reconstruction base, while in the case of older ones, digital reproduction of the contexts is carried out based on known plans. However, in the case of the 1988 excavation of Via Contessa Matilde (Fig. 1, 4), thanks to the large number of good quality photos recovered from the archives, it was possible to create a 3D model of the excavation using SFM techniques (Fig.3). Each reconstructed element will be able to be informed by data deduced from the archaeological excavations, typological comparisons and possible structural analyses aimed at confirming the validity of the reconstructive hypothesis performed. However, the modelling of archaeological reconstructions and vegetation is performed with the open source software Blander (Fig. 4), then integrated into the terrain modelling in Unreal that allow a real-time rendering and the creation of immersive environments. In this way we will produce the *Auser* riverscape simulations in Roman times at the current state of archaeological research, with the possibility of implementing the virtual environment. In fact, the last step of the research will be the evaluation of experiences made in the virtual riverscape by different groups of people from the scientific and civil communities, investigating the sense of place that people can have in the same riverscape/landscape.

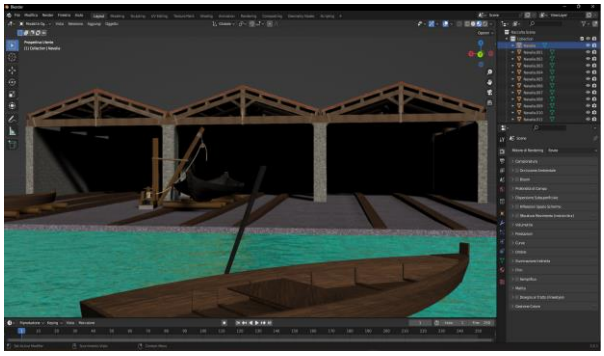

Fig. 4. The reconstruction of archaeological contexts in Blender. Modelling and texturing of the commercial dockyards on the river Auser.

IV. EXPECTED RESULTATE AND CHALLENGES

As mentioned above, the research aims to make multiple methodological, practical, and historical-archaeological contributions in the context of the current scientific and technical debate on the simulation of ancient landscapes and digitisation of heritage with extended reality applications. It seeks to provide a replicable low-cost method approach for simulating archaeological contexts and its environment. The pipeline developed lead to the creation of an immersive and interactive virtual environment, in which the source data and hypothesised reconstructive models can be validated or challenged by the scientific community, so as to generate multiple realities within the same simulation, with as diachronic perspective as possible.

Thus, the production of desktop and HMD VR applications, that allow a complete immersive perception of the virtual environment, clashes with the limits imposed by hardware with low computing power that would hinder the proper enjoyment of the simulated environment by users. To overcome this problem, the testing of ATON, an open source framework developed by the Italian CNR-ISPC [16], is planned. The framework is configured as a modular tool for the realisation of Web3D and WebXR applications capable of automatically adapting the interaction models and interfaces to the devices used, as well as providing integrated components for the execution of collaborative and synchronous interactions. This experience elevation, from single to multi-user, is indispensable for the phenomenological and phenomenographic study approach of the riverscape simulation. As argued, for quantity and quality of data available, the case study of the disappeared *Auser's* riverscape makes it possible to perform a simulation capable of evoke the impact that environment, spaces, and architecture could have had on the ancient inhabitants. However, as Brück argued [17], it will be important to be careful not to project our experiences and sensitivities backwards in time. The final product in Virtual Reality, valid both for the specialized public and for the entire heritage community, will giving the opportunity to meet with others in the simulation, where interact and experience together. By simulating the river landscape of the *Auser* in Roman times, it will permit to assess the role of the river in the lives of the local inhabitants and those who travelled along it and to analyse a wide range of human activities on the landscape, at multiple temporal and spatial scales, ultimately as the river landscape shaped social relations in a broader sense.

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