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HULOT'S SELINUNTE: DIGITAL ANALYSIS AND VIRTUAL RECONSTRUCTION

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Abstract

Some drawings feature a powerful evocative nature, capable of presenting a truthful vision that can replace, in collective imagination, the actual expression of reality. This is the case of the "restorations" of Selinunte proposed by the French architect Jean-Louis Hulot (Paris 1871 -1959) which still today evoke the splendours of the ancient city. Thanks to his accurate surveys and inspired by the visit to the remains of further ancient cities such as Priene, Tera, Delos, and Pompeii, Hulot proposed in his watercolour drawings a vision of a "living" city, rendered at the height of its architectural and social magnificence. The paper presents a study on digital solutions that combine data from recent surveys with a 3D reconstruction based on Hulot's drawings, to propose a visual experience of the ancient city of Selinunte.

Keywords

Selinunte, Jean Hulot, Virtual reconstruction, 3D Camera tracking, Augmented Reality.

1. *Background*

"Undertaking the restitution of a Greek city with all its religious, civil and private buildings, reviving an entire vanished civilization through architecture, this is an ambition that may seem reckless. [...] The work I am presenting must be considered more as a reconstitution than as a pure restoration "[1].

The text introduces Jean Hulot's report attached to the fourth-year *envoi*, made of plates where the ancient magnificence of Selinunte comes back to life; the French architect does not limit his work to the reconstitution of the gone city from the ruins, but extends his work to the landscape surrounding the town, thus proposing a visionary overall view.

The concepts of "restoration" and "reconstitution", underlying Selinunte's drawings, are nothing more than the evolution and the final update of a research that Hulot had started few years earlier. As a winner of the Grand Prix for architecture in 1901 and *pensionnaires* in Rome at the French Academy in Villa Medici, Hulot had dedicated three years to the study, survey, and restoration of ancient monuments in Rome and in Sicily, as established by the Academy's program (Pinon & Amprimoz, 1988).

At a later stage Hulot moved to Sicily (1904-1905) and focused his studies on ancient Selinunte; in these years he carried out a vast campaign of surveys that led to the production of some plates where the actual state of the ruins was rendered. These plates will act as a reference for the later works of *restoration* and *restitution*[2] of the city: in this work, the French architect was supported by two friends: the painter André-Jean

Fig. 1: The picture shows the journey back from Selinunte by A. Monchablon, J. Hulot, H. Prost and the cart driver. A.-J. É. Monchablon, in the *Album de caricatures. II. Oeuvre des pensionnaires de la Villa Medicis. Travaux graphiques* (f. 82r). Rome, French Academy (Villa Medici), source gallica.bnf.fr / Académie de France à Rome.

[1] The quote is taken from the unedited Hulot's report of his fourth year as fellow at the French Academy in Rome; the report is unedited, but an Italian edition has been recently published (Fresina & Bonanno, 2013); English translation is due to the author.

[2] The drawings of the city of Selinunte, today stored at the École Nationale des Beaux-Arts of Paris, were published, in monochrome, to illustrate the book (Fougéres & Hulot, 1910). The coloured drawings are now published in the reprint edited by Fresina & Bonanno (2013).

Édouard Monchablon and the architect and urban planner Henri Prost, both fellows at the French Academy[3].

A realistic testimony of the activity of this period is constituted by two caricatures made by Monchablon, stored at the Library of Villa Medici in Rome, which, at an in-depth observation, show interesting information on the work of the architect; in these drawings the painter represents in detail the topographic instruments used for the acquisition of the measures.

In the first illustration the three friends - transported on a Sicilian cart driven by a local guide with *kepì* and pulled by a horse with the typical vestments - are represented on the return journey from Selinunte (May 27, 1904) with all their equipment in tow.

In another drawing Hulot, renamed by the painter "Jean de Selinonte", is portrayed while surveying the fortifications of the town; a gigantic helmeted figure of Hermocrates looms over him from behind the walls. This picture shows, on the right of Hulot, the instrument that he used for the acquisition of the measurements: a graduated square, having the shape of a tall cylinder, capable of measuring angles on a horizontal plane, with a compass mounted on the top; the graduated square was combined to a telescope and an eclimeter that allowed to measure angles on a vertical plane (Conti, 1878; Righini di S. Giorgio, 1863). This device had the same capabilities of a theodolite, even if it is reasonable to argue that the accuracy had to be lower. The eclimeter, combined to the telescope, allowed the measurement of elevations and depressions; a survey staff, visible in the first illustration, allowed the measurement of distances when collimated through the telescope.

Returning from the Sicilian countryside Hulot devoted himself to the realization of his restoration *envois*; he returned to the island again in 1908, during a second mission to Selinunte in collaboration with the archaeologist Gustave Fougères. This mission gave him the opportunity to integrate the surveys and propose further reconfigurations, illustrated in plates that were published, together with the academic ones, into the monumental volume entitled *Selinonte. La ville, the acropole et les temples*, published in Paris in

Fig. 2: (left) Jean Hulot while surveying of the fortifications of the Selinunte (A.-J. É. Monchablon. *Album de caricatures. II. Oeuvre des pensionnaires de la Villa Medicis. Travaux graphiques* (f. 82r). Rome, French Academy (Villa Medici), source gallica.bnf.fr/ Académie de France à Rome.
(right): a technical illustration of the depicted instrument (Righini di S. Giorgio, A., 1863).

1910. Hulot surveyed the acropolis, the great temples of the eastern hill and the sanctuaries at the western edge of the site. In the work on Selinunte he abandoned the traditional studies focused on large sacred monuments to turn his interest to the urban context with its public building and to the entire site, including the landscape. As for the acropolis, Hulot created several plates dedicated to the description of the ruins and the morphology of the site, documented by: i) sections along the great East-West and North-South axes of the Acropolis; ii) a view of the Eastern front; iii) a general plan of the acropolis.

[3] The painter André-Jean Édouard Monchablon (1879-1914), son of the painter X. Alphonse, visited Italy, as a winner of Gran Prix, in the years from 1903 to 1907. Henri Prost (1874-1959), a French architect and urban planner, was awarded the Gran Prix in 1902; he later became the head of the Istanbul Planning Office, where he worked for over 15 years. Further information on the fellows of the French Academy are reported in Verger & Verger, 2011.

Fig. 3: Hulot. Survey of the fortifications of Hermocrates in the north front of the acropolis of Selinunte, © Beaux-Arts de Paris, Dist. RMN - Grand Palais.

One of the plates was a detailed plan of the temples of the Acropolis; Hulot dedicated particular attention to the documentation of the fortifications at the northern edge of the acropolis, with the so-called walls "of Hermocrates".

Hulot's detailed drawings accurately illustrate the state of the ruins; the use of watercolour allowed Hulot to put into evidence the volumes of the buildings and, at the same time, to render the decay of stone blocks.

On site surveys provided the basis for the innovative and ambitious project of conjectural reconstruction proposed by Hulot: a reconstruction that aims at presenting Selinunte, in his words, as a "complete Greek city, a city maritime, with its citadel, its ports, its temples, its necropolis, [...]" (Hulot 1906, B11).

The reconstruction depicted a Greek town with all its architectural elements fully integrated into the urban context. In his report Hulot states that his "restorations" and "reconstitutions" were based on comparison and analogy with coeval similar sites.

Hulot will propose the "restorations" of all the architectural structures surveyed during his tour in Sicily; the reconstructions of the buildings that Hulot did not find on site, but characterized Greek towns, (agora, gymnasium, theatre) and the reconstruction of other buildings that will be excavated at a later stage, (residential areas), were performed by analogy with similar buildings and similar Greek towns.

Hulot especially refers to Thera, Priene, and Delos; these towns were excavated in the years when Hulot was working on Selinunte; the precious information on urban systems and public buildings of Greek towns, resulting from these excavations, inspired Hulot's reconstructions.

The site of Selinunte has always been a privileged subject for scholars; Selinunte is today the largest archaeological park in Europe; its ruins clearly show the traces of different construction phases and the changes in style that appeared in its long-lasting existence. Hulot must have been aware of these peculiar features and tried to put them into evidence in his idea of "restauration/restitution", as he clearly stated in his reports: "In this work, I showed all the monuments whose ruins still exist, although these works did not all exist in the same period" (Hulot 1906, B11). Therefore, we can argue that the town illustrated in Hulot's drawings "never existed".

The history and the construction events of Selinunte are actually very tumultuous: founded in 651 BC by Megara Hyblaea, the first Greek colony of Sicily sited north of Syracuse, the town was located on a promontory whose eastern and western edges were delimited by the rivers Gorgo Cottone and Modione (Selinus); the southern edge faced the Mediterranean sea. The town rapidly expanded northwards and three great temples were built on a hill beyond the eastern side of the river Gorgo Cottone.

In a quick time Selinunte reached a great economic and social development and became the second most important polis of Sicily after Syracuse. The ruins found on the west side of Gorgo Cottone river, close to its mouth, testify the presence of a large port facing a wide bay, protected by the surrounding hills.

This period of prosperity lasted until 409 BC, when the city was besieged and destroyed by the Carthaginians. Archaeological studies proved that, at a later stage, a small group of *Selinuntini* and Punic returned to populate the city in a narrow settlement corresponding to the acropolis. Hermocrates, coming to Selinunte after being exiled from Syracuse, started the construction of new fortifications; the masterpiece of this enterprise is the complex military defensive system that protected the northern access to the acropolis, consisting of circular towers connected by long tunnels and trenches. The city will no

Fig. 4: Hulot. Restorations of the east front of the acropolis of Selinunte, © Beaux-Arts de Paris, Dist. RMN - Grand Palais.

longer reach its ancient splendour, and its final fall came in 250 BC when it was besieged and destroyed by the Romans, during the first Punic war.

The town of Selinunte that is represented in the *envois* could be dated at the last decades of the fifth century BC. The great temples are pictured in their original magnificence; the walls delimiting the town, with the prominence of the walls of Hermocrates, are, according to Hulot, "too interesting and cannot be excluded from my restoration" (Hulot 1906, B11).

The temples and sanctuaries of Selinunte were studied since the second half of the eighteenth century: the watercolour views of Hoüel, followed by the first scientific studies of Harris and Angell (1822), opened a prolific period of research. In 1834 Cavallari and Serradifalco published a relevant work on the antiquities of Sicily; in 1870 Hittorf proposed a revolutionary study on the polychromy of Greek temples; in 1899 Koldewey and Puchstein published the first archaeological analysis of the temples of Selinunte[4]. At that time the original town and its extension had not been investigated. Hulot certainly knew the studies of these scholars, that are explicitly mentioned in his reports. Nonetheless, his interest was focused on the vision of the Greek town, and therefore the greatest number of his plates present the "restoration" or "reconstitution" of the ancient town and its surrounding landscape.

Hulot's drawings, which follow the formal characteristics of academic design, show the influence of Marcel Lambert, his teacher at the École des Beaux Arts and Grand Prix de Rome in 1873. Lambert cared the restoration drawings of the acropolis of Athens. Hulot's drawings are usually represented in orthogonal projection, but, in some cases, perspective projection is used[5].

Hulot aimed at representing the landscape with the greatest accuracy, including details that documented the materials and the texture of surfaces, the colour, the light effects, and the shadows were meticulously traced. This latter feature, associated with the wise use of watercolour, gave his drawings plastic-spatial values that made them highly communicative and easy to read.

Hulot's "restorations" and "reconstitutions" offer a picturesque panorama animated by human figures, pictured while carrying out their daily activities, or showed the remittances and fleets of ships, to suggest the idea of mercantile town; the depiction of *ex voto* on the acropolis witnessed the devotion of the inhabitants of Selinunte.

Hulot will produce an overall plan of the reconstructed town and its aerial perspective. Although later studies proved that the streets of the town had a more regular layout, consisting of two reticular meshes, respectively characterizing the southern residential area with the acropolis and the northern expansion in the Manuzza hill, the representations of the town have become part of the collective imagination of Selinunte. Other plates illustrate the restoration of the acropolis, rendered with the orthogonal projection of the Southern and Eastern fronts; the Hermocrates fortifications and the so-called Northern gate are represented with detailed plans, sections, and elevations. Some plates, dedicated to the "restoration" of Temple C, illustrate the reconfiguration of the main front and the details of

[4] An overview of the history of the excavations in Selinunte and of the related literature and bibliography, see Bonanno & Fresina 2013.

[5] The eminent architect Marcel-Noël Lambert (1847-1928), was Chief Architect of Versailles and of many French Historic Monuments. He carried out important works on the Acropolis of Athens, leading a campaign of excavations in the Erechtheion and a restoration of the west side of the Parthenon. About him and his works see Verger & Verger 2011.

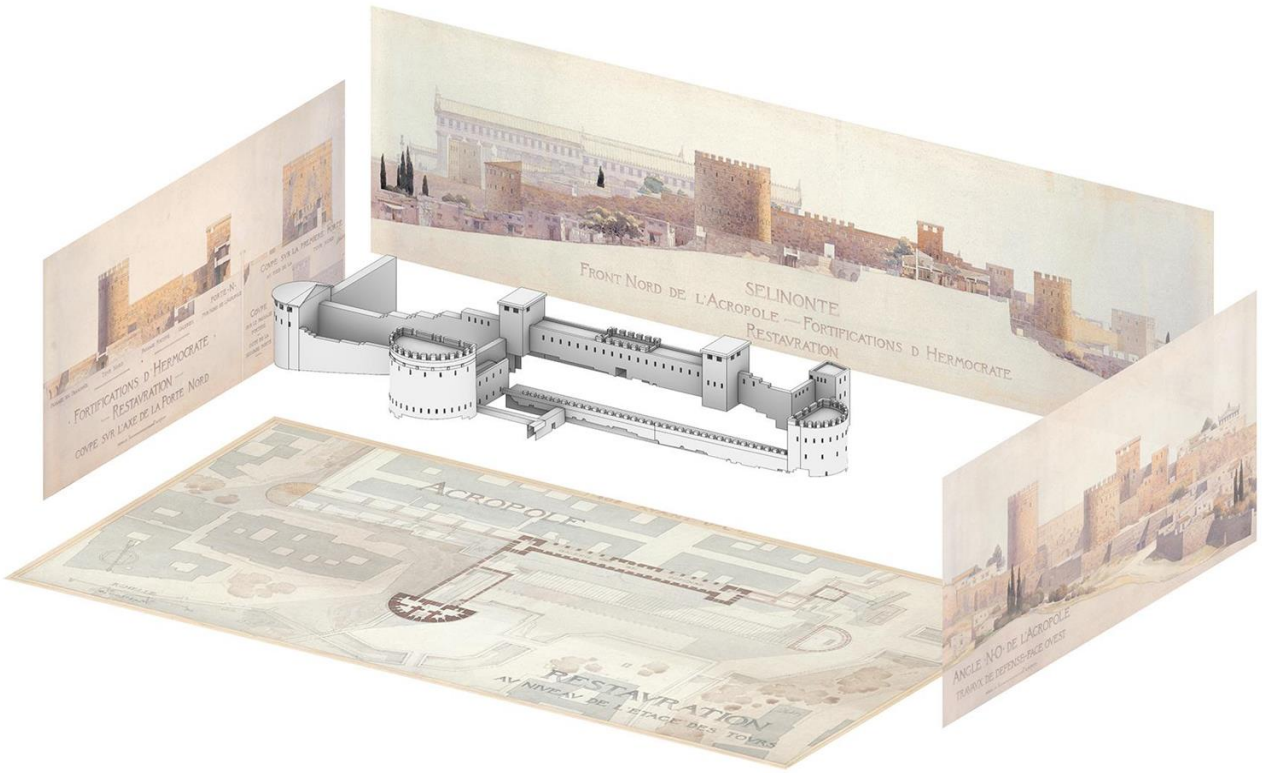

Fig. 5: Virtual reconstruction of the fortifications of Hermocrates (North Gate) from Hulot's drawings and laser scanning data.

the order; in this circumstance the triad of orthogonal projections (plan, elevation, and section) merge into a single drawing. Further drawings show the roof and its wooden frame, some details on the tiles and the eaves system; a drawing is dedicated to the polychrome and decorative features of the elements of painted terracotta placed at the top of the temple.

The restoration drawings of the great temples on the eastern hill, rendered in orthogonal projection, probably aiming at education purposes, lack the colour and the volumetric effects that characterized the previous works; these drawings were probably made during the second mission and aimed at being included in a later publication. The evocative and expressive character, on the other hand, re-emerges in the monochrome perspective drawings; in the first one, whose point of view is placed at the south eastern corner of the area, the temples are represented side by side, while the city with the acropolis and its defensive walls and towers appear in the background. The second and third perspectives are dedicated to temple G, with an internal view showing the hypaethral naos.

2. *Virtual reconstruction of Hulot's Selinunte*

The research aims at outlining a workflow for the implementation of a digital "restoration" of Hulot's Selinunte; the purpose of this reconstruction is to revive the atmospheres and colours and plasticity of his drawings, through representation techniques based on computer graphics and visual effects (VFX). Two different visualization techniques, both based on techniques that track the motion of a camera, address different fruition solutions: the first one uses motion tracking tools to produce a video that integrates digital reconstructions inside the footage of the site; the second one uses augmented reality technology for the real-time rendering in situ of Hulot's imaginative Selinunte.

Even if, under a conceptual point of view, the chosen visualization techniques share similarities, they differ for the role played by the observer: in the first solution the visitor is passively guided in a predefined journey; in the AR solution the observer plays an active role in the construction of the image.

The experimentation was developed in two areas of the acropolis: the Temple C and the

northern defensive fortification. The process started from the acquisition of laser scanning and photogrammetric surveys of these areas, aimed at processing two distinct mesh models, generated through the automatic processing of point clouds[6]. These models were used to validate the surveys and reconstructions proposed by Hulot and, at a later stage, for the construction of the 3D models. The comparison, as was to be expected, revealed some discrepancies that are certainly due to the accuracy of the instruments used by Hulot.

Highest discrepancies appear in the survey of large areas, e.g. in the alignment of the units of northern fortifications.

These remarks are not a criticism on the work of Hulot, who has achieved truly remarkable results and provided us a precious and detailed documentation of Selinunte as it appeared at the beginning of the 20th century.

The comparison plays a fundamental role in the development of the digital reconstruction model. In fact, the chosen techniques of

Fig. 6: Textured model of the North Gate superimposed to the 3D mesh model of the ruins.

Fig. 7: Virtual reconstruction of the Temple C from Hulot' restoration and surveying data.

[6] The mesh models were generated with the plug-in "Poisson Surface Reconstruction" in CloudCompare.

Fig. 8: Hulot. "Reconstitution" of the ancient town of Selinunte: bird's-eye perspective taken from the sea, © Beaux-Arts de Paris, Dist. RMN - Grand Palais.

representation demand a perfect overlap between the reconstructive models and the ruins visible on the site.

If the elaboration had been based only on Hulot's surveys and restorations, without the support of a laser scanning, or similar, survey of the site, the alignment discrepancies would have affected the match between real and virtual data.

This is why digital reconstruction models have been built in a CAD environment starting from the mesh models of the existing ruins. Some areas featured a perfect match between the morphology of the site, the ruins and Hulot's drawings; in these areas the digital models built after the French architect's reconstructions could be directly placed on site.

In the areas where discrepancies were more relevant, the morphology fixed in Hulot's drawings was modified to ensure the best overlapping of 3D models with the site and the ruins.

The following step addressed the chromatic characterization of digital models; this process was performed with Blender; the textures were created through the extraction of specific areas from Hulot's watercolour drawings and the subsequent re-elaboration was developed with raster and vector image processing software. Starting from this texture, specific shaders have been created to define the physical features of the materials.

The following step aimed at enriching the chromatic information with specific auxiliary textures that represent the decay of stone surfaces due to ageing, as reported in Hulot's drawings.

These complex shaders, and the textures associated, applied to the models with mapping processes, underwent a process of render to texture (texture baking), a procedure that allows to transfer precalculated rendering effects and to merge the information deriving from multiple overlapping textures into a single image. Texture baking was a mandatory step for the use of these models with the real-time rendering engines used by augmented reality applications.

3. *3D Camera tracking and Digital compositing*

The ancient city of Selinunte occupied a vast area that stretched from the promontory of the acropolis to a hinterland plain area and to the eastern hill: no point of view from the ground allows the visualization of the entire site. This is probably the reason why Hulot, aiming at rendering the whole extent of the ancient town, chose a suggestive bird's-eye perspective taken from the sea.

The development of UAVs allows today to easily take aerial images and videos of a site; in this study UAVs have been used to shoot footages of the site, later processed with 3D camera tracking and image compositing techniques.

The concept of the video footage plays a fundamental a role in this research work, both for the questions related to storytelling and for those inherent to the technical features of tracking, composition, and post processing techniques. Several footages were taken with a drone equipped with a stabilized camera, using Fly over and Orbital shooting modes. In Fly over mode, a specific area or one building is framed from a certain distance and remains in the frame for the entire duration of the clip, as the drone approaches and then flies over them; this shooting mode allows to contextualize the architectural artefacts and understand their dimension. The Orbital shooting mode allows shooting a building from different points of view, with a fluid and slow rotation movement around it.

In this study the 3D camera tracking was processed with Blender; the software uses a workflow that allows the creation of a virtual copy of the camera that shot the footage. This process reconstructs in a virtual space the movement of the camera during the shooting and, at the same time, allows the calculation of camera's intrinsic parameters, i.e., the focal length and the lens' distortions.

3D camera tracking workflow follows two steps: camera solving and scene solving. Camera solving uses the parallax effect and structure from motion techniques to estimate the position in space of elements and features that appear in a structured sequence of two-dimensional images. The procedure tracks characteristic points identifiable in a long sequence of frames.

The software detects points characterized by contrast conditions and performs an automatic feature identification process. Further points can be created through the manual identification of natural or materialized points *in situ*.

These points, named markers, are tracked by the software and their position in each single frame of the footage is calculated. This automatic process can evaluate errors and the operator can manually adjust or remove the markers that, during the tracing process, are mis-traced due to various factors, such as sudden lighting and contrast changes or occlusion caused by other elements in the scene.

Once intrinsic and position parameters of the camera have been calculated, the workflow proceeds with Scene Solving, i.e. the orientation and scaling of the 3D scene. This procedure demands the identification of three markers for the definition of a vertical or horizontal reference plane, an origin, and a direction for the orientation of the coordinate system; finally, the distance between two points allows to scale the scene.

Fig. 8: Frame from the video of Hermocrates fortifications, made with 3D camera tracking and digital compositing techniques.

If the points used for the orientation and scaling are extracted from a survey of the site, the footage scene and the 3D models will be referred to the same coordinate system.

This process allows the accurate integration of the 3D models in the footage, that stands in the background. In order to produce a realistic effect, the lights that illuminate the 3D model have been set according to the daylight conditions of the footage. The following step addressed the rendering of the 3D model animation that follows the camera path. Finally, through compositing processes, the two video sequences have been combined and some adjustments have been made on colour correction, transparency effects and overlapping modes.

Fig. 9: Frame from video, made with 3D camera tracking and digital compositing techniques, of the Temple C.

4. *Augmented reality*

As mentioned above, 3D reconstruction models have been used for the development of an augmented reality application as well. The application was conceived to offer people visiting the archaeological park a virtual window that shows the Selinunte of Hulot from different points of view. The information panels mounted on site will act as keys to enter and start the AR application.

It is well known that augmented reality is a computer technique that allows, in real time, to enrich a scene, viewed with the aid of a mobile device (smartphones or tablets), with digital contents.

Motion tracking solutions allow devices to understand and constantly check their position and orientation in the scene, using simultaneous visual location and mapping (SLAM) algorithms.

These algorithms allow the real time calculation of the position of the point of view and the orientation of the axis of view; these parameters are applied to the 3D model visualization, thus producing a perspective of the virtual model that is coherently superimposed, in real time, to the video stream taken by the device's camera.

The main problem of the tracking technology is the impossibility to define a reference system persistent in time. The orientation of the system's coordinates is set according to the initial position of the device in a given environment and cannot be retrieved by other devices. In the field of cultural heritage, where the superimposition between real scenes and virtual objects is a fundamental requisite, the accuracy in the orientation process and the possibility of reusing a pre-calculated orientation are relevant questions.

For this reason, in recent years, several research works have focused the development of solutions capable of offering time-persistent AR experiences (Guo, Canberk, Murphy, Monroy-Hernández, & Vaish, 2019).

Fig.10: Augmented reality App

The augmented reality application dedicated to the visualization of Hulot's Selinunte was developed using Google ARCore platform and Persistent Cloud Anchor technology. The use of anchors is a strategy adopted by many AR platforms to ensure that a virtual object is "anchored" in a precise position in the environment.

Anchors allow to link the virtual object to the scene; the system is capable of understanding the environment and refine the pose of the device inside the scene; changes in the orientation of the reference system will not affect the position of the 3D model in the scene.

Anchors can be temporarily stored while using the app, or saved in the cloud; it is therefore possible that multiple users share the same orientation or the reuse of a calculated orientation at a later time. Persistent Cloud Anchor technology, therefore, allows observing the virtual reconstructions perfectly superimposed to the ruins, both to several users at the same time and to users experiencing the AR application at a later stage.

In this study two AR applications were developed with Unity 3D software: the first one is dedicated to the developer, the second one to the users. The first application allows to position the reconstructive models, using the position data extracted from surveying information and to position the information panels mounted on site in the surveyed scene. This app allows to store on the cloud the position of the anchors that are close to the information panels.

The app dedicated to users allows to "resolve the anchors": when the user frames the information panels, the application recognizes the area and retrieves the associated anchors from the cloud. This simple procedure will allow multiple visitors to view the 3D model of Hulot's Selinunte superimposed to the ruins on site at the same time, leaving them free to move and observe the reconstruction from any point of view.

5. *Conclusion*

Digital representation techniques allow the investigation of new solutions for the communication and the visual experience of architecture.

In particular, VFX techniques and augmented reality offer the possibility of effectively transmitting, to a wide audience, knowledge and studies on archaeological and historical architecture.

The investigated case study allowed the definition and verification of a workflow dedicated to the creation of digital models to be used for the construction of different media that offer multiple displaying experiences.

The development of augmented reality tools has remarkably improved motion tracking, image stability and referencing calculations.

Nonetheless, during the test of the augmented reality App some critical issues in the interaction between the user and the context emerged.

In wide and open archaeological areas, it is necessary to provide solutions that delimit the area of action of users. For example, in order to ensure the safety of users, the AR experience should be interrupted if the user moves away far from the origin and exits the boundary of a determined circle. These features, related to the issues of user experience, demand proper investigations addressed to allow the diffusion of augmented reality visual experiences.

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