Methodological Approaches and ICT Solutions for Smart Cities

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Abstract: This paper illustrates some results obtained by the ITLab (Information Technologies Lab of IBAM CNR Institute) within two PON (National Operational Program) projects called: "DiCet" and "Siracusa Energia", both financed by national funds. These two projects pursue the objective of defining and producing innovative models, processes, and tools for the sustainable development of a smart territory by capitalizing on its cultural assets and environmental resources, to promote their tourism offer. From this standpoint, some procedures were developed to compile technical models for an efficient management of 3D and 2D resources, and to define best practices and methodical protocols for quality certification and process standardization, capable of fostering cross-sector dialogue. The sites were identified as a function of a supply-and-demand analysis with regard to a placement on the market of innovative models and services based on the creation of hyper-realistic digital models and virtual scenarios. Particular attention was given to those uses that permit greater visibility, protection, and conservation of cultural assets characterized by difficult access, vulnerability, seismic risk, hydro-geological risk, etc. In view of this, innovative models and tools were designed and developed for capitalizing on and exploiting cultural heritage, understood as an integrated and complex system conceived as a holistic model strongly based on the use of ICT technologies. Virtual enjoyment is understood here as a form of representing reality that accelerates and strengthens cognitive capacities, which is to say it becomes capable of generating extremely sensitive, “virtuous virtual” learning processes based on metaphors of the real world, and thus easy to use and understand. Operationally, our working group has made some Augmented Reality solutions available; these enable the interactive display – directly in situ and especially on mobile devices – of archaeological monuments integrated within the urban fabric. A simple solution allows the user to display an interactive 3D reconstruction directly on the real site, using the latest-generation gyroscope function. In addition to this, certain inaccessible monuments of the cities of Lecce and Siracusa have been virtualized, chiefly using image-based technologies and ultra-realistic laser scanning, to allow them to be visited remotely both via smartphone and on large virtual theatres.

Keywords: Smart Cities, augmented reality, virtual reconstruction, laser scanner

Introduction

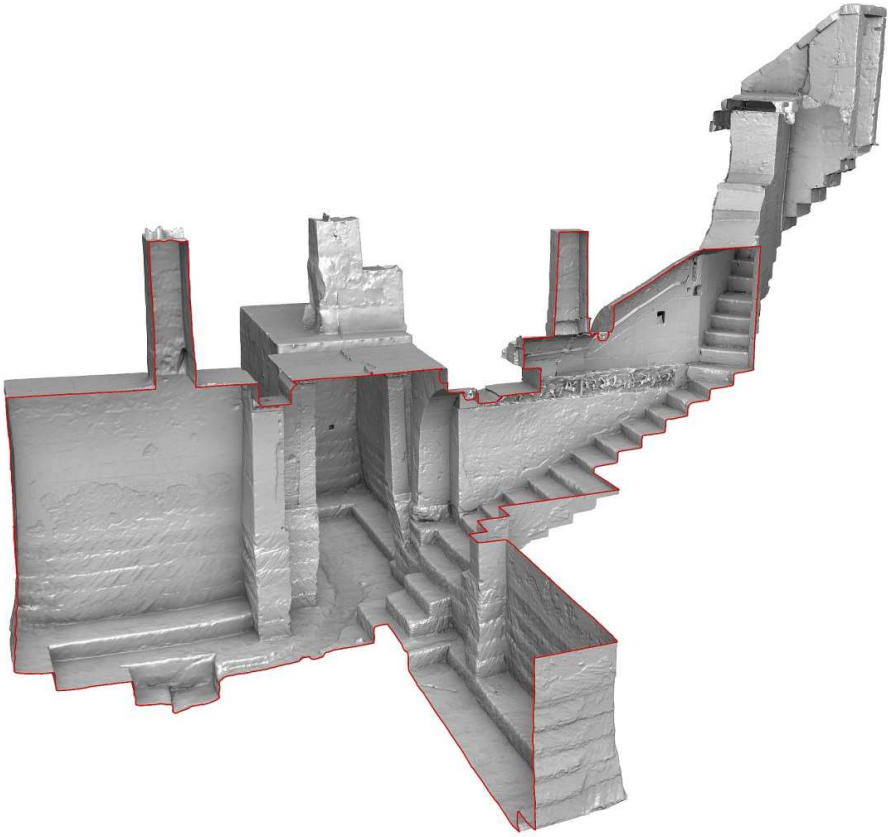
The project Energy from renewable resources and ICT for Sustainable Energy (in short, Siracusa Energia) intends to analyze and to test a system of innovative solutions to make cities sustainable from an energetic and environmental point of view. This objective can be reached using pervasively renewable energy sources and ICT in order to make the services of the towns demand-adaptive (thus improving the energy efficiency) and commensurate to the availability of renewable energy resources.

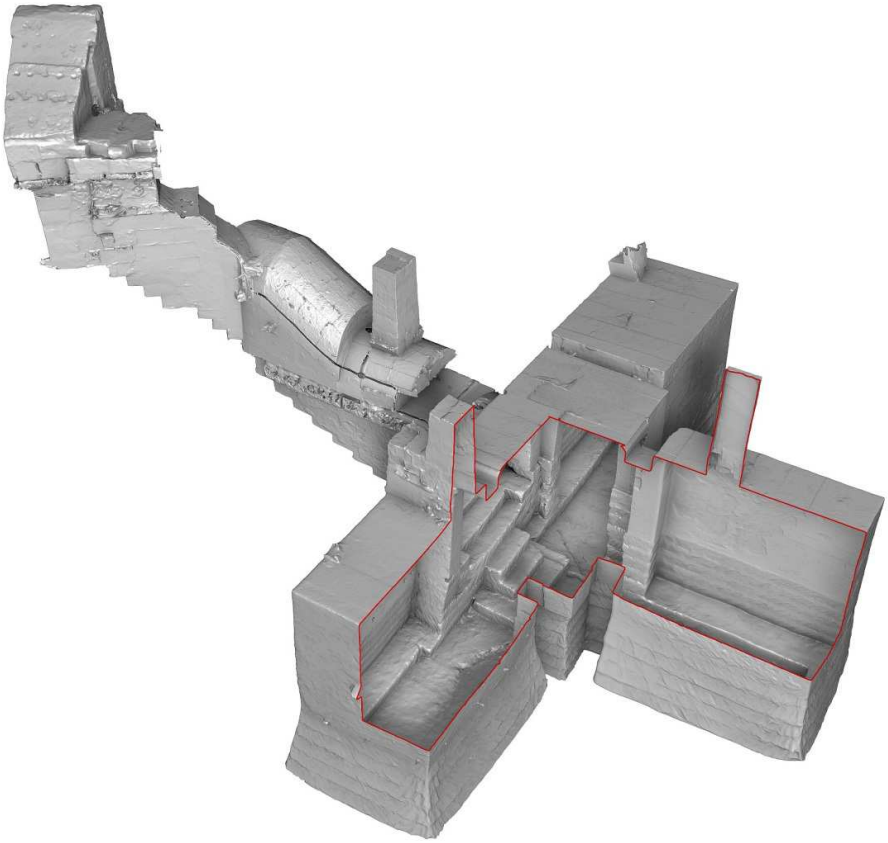
The DiCet project purses the objective of creating a platform enabling the processes of sustainable development for a smart city, based on the spread of knowledge and on an innovative model for the correct use and enhancement of the cultural heritage.
The project uses an open platform with intelligent services for the capitalization of cultural heritage, to strengthen social inclusion and to encourage the formation of virtuous places, real or digital. Here you can create, develop and share information to improve new forms of businesses in a desirable framework of social and economic growth.
DiCeT is based on a social innovation approach, where the services are co-created involving all actors of an ecosystem oriented towards smart culture and tourism (companies, research, public authorities, final users). The project analyzes and builds innovative solutions for the elements that constitute the cultural offer: namely the knowledge of cultural heritage to offer to the users (tourists, citizens, curators, researchers, etc.); its use; its conservation and preservation. With regard to the use, we want to implement (by extending and improving open source technologies already built in the past) a smart system capable of enabling the concept of exploration (increased usage) of cultural heritage: information, narratives, relevant and pertinent stories that enrich its vision; tracing the life of cultural assets; manipulating and/or moving virtually within them; documenting and sharing their use.
Both projects are carried out by the means of mobile services that integrate automated systems characterized by multimodal user interfaces and new interaction metaphors. In order to obtain an immersive environment, the DiCet project provides the integration of mobile solutions with large fixed displays within the Living Lab Museum, a new room of the MUST Museum (Museo Storico della città) in Lecce. This can be done by means of virtual and augmented reality tools and new forms of interaction (adaptive storytelling: personalized multimedia narratives constructed on-the -fly). This article discusses some of the achieved results concerning the 3D reconstruction of some monuments of Siracusa and Lecce, their reconstructive study and the digital solutions adopted for their on-site use.

Augmented Reality for the on-site visit. The case study of Lecce

The first case study we intend to explain, regards the 3D survey of the Hypogeum Palmieri, a monumental chamber tomb located in the center of Lecce (south Italy), which currently can't be opened to tourists visit. This monument is located in a private residence and is therefore part of a larger research objective of the IBAM ITLab, aimed to use 3D-based digital technologies to allow the virtual tour of inaccessible places.
In the survey of the Hypogeum Palmieri the technique of "Camera Mapping" was used in order to obtain a realistic and metrically accurate 3D model. The survey was executed by an indirect active method, with the use of a laser scanner Leica ScanStation 2. The 3D survey involved both the entrance corridor, characterized by an illustrated frieze running on the right and left hand side of the entrance stairs, plus four spaces that are radially distributed downstairs. During the same survey campaign, all the photographic shots required for a documentation of the conditions of the spaces and for further texture mapping tasks of 3D models have been taken. Each picture has been conveniently treated with PTLens software of Tom Niemann. In this way, the distortions induced by the lenses have been filtered out. The 3D model has been

subsequently optimized in order to achieve an advanced texture mapping, adopting some camera projection methodologies on multiple patches experimented on purpose and documented by our laboratory.
The correct mapping of the three-dimensional model acquired through laser scanning is usually one of the most problematic issues in order to process the data and offer a verisimilar restitution of the artifact under test. The results of this method (F. GABELLONE et alii 2012) are visible in the attached images, but the real utility of this technique in this project is related to the possibility of obtaining a unique mesh with only three large textures applied in UVW mode. This has allowed an easy porting of the 3D model and an efficient management of high resolution textures (10000x10000 pixels) with classical LOD systems. Thanks to the availability of this model, and with the fundamental contribution of the ISTI CNR of Pisa, one of the components has been tested for the creation of interactive multimedia presentations, aimed at allowing the use of the monument on the web.
The 3DHOP application is available at the URL: http://vcg.isti.cnr.it/palmieri/.
The central component of the 3DHOP allows the navigation of the 3D model with the movement restricted on a path: in practice we can imagine the camera fixed on a rail. Navigation's hotspots have been added moving the camera operated by the user within the 3D model of the Hypogeum, with the result of a optimal real-time navigation of the 3D data.





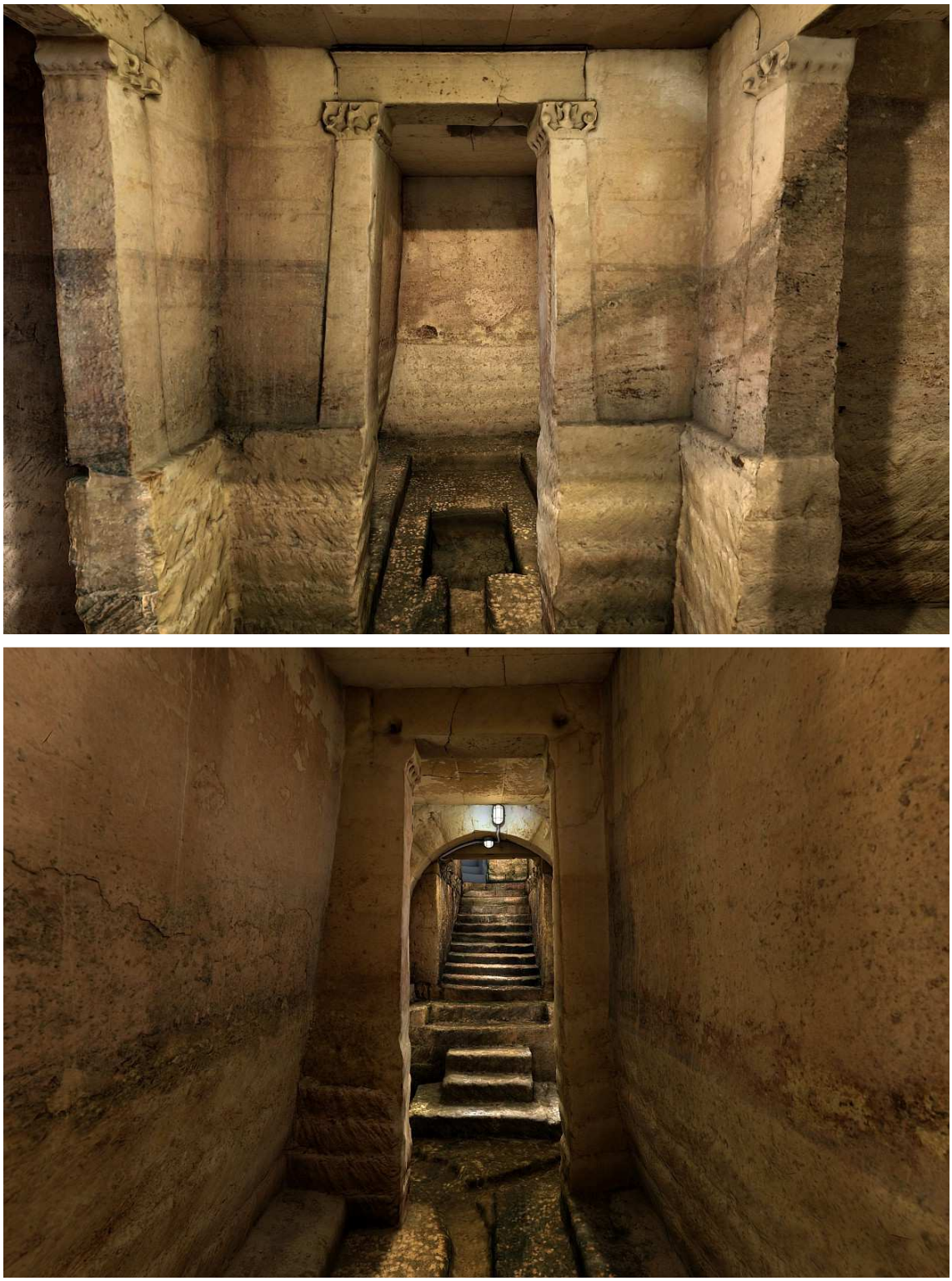
Figs. 1, 2 – Hypogeum Palmieri, 3d survey with laser scanner

In addition to the web application, a native application for iOS has been implemented. This application displays in real time the Hypogeum Palmieri, using an interface based on the mobile iPad Air sensors. In particular, it uses the gyroscope for the virtual camera orientation and a touch interface for the movement within the 3D model. For the movement, a component was developed to implement a camera with a rail system, similar to the one previously added to 3DHOP, but optimized for the iOS. As previously said, this application is understood as 3D mode for the virtual tour of inaccessible contexts, possible nowadays with the latest generation devices. Moreover, in addition to this way of visiting, we experienced other forms of use, much more simple, which do not require special hardware equipment. In these applications, that could be called “semi augmented reality” and that are based on observable panoramas, the innovative element is the ability to connect the virtual reconstruction on the real context, with an immediate dimensional and spatial feedback. More details will be provided later on.

Fig. 3 – The final 3D model with UVW texturing, using the camera projection method

Semi-augmented Reality for on-site visit. The case study of Syracuse

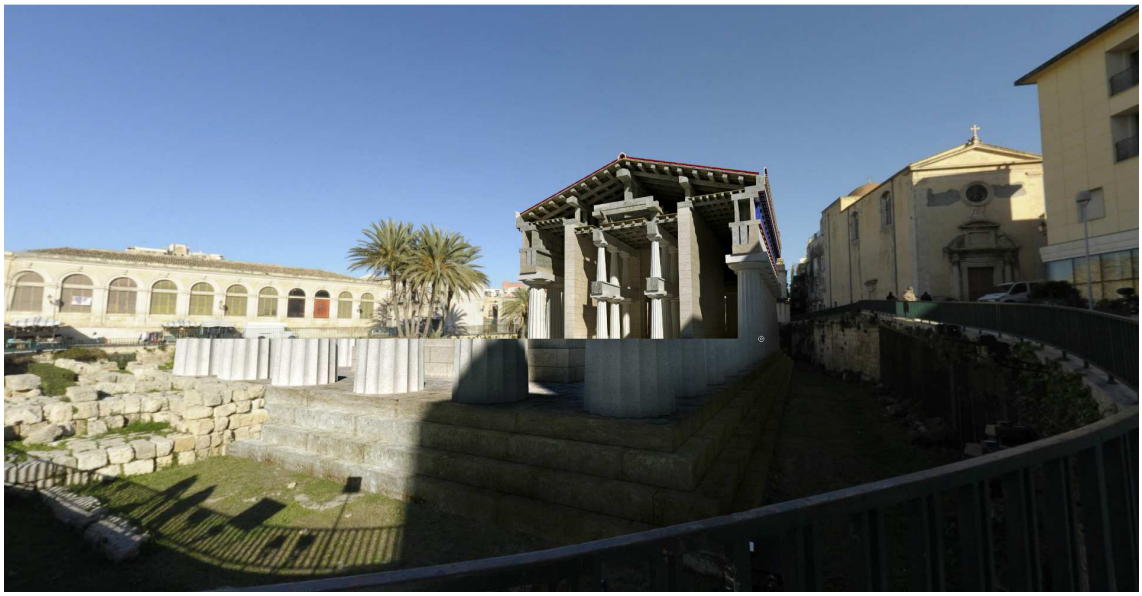
In the last decade, Syracuse has been assuming an important role, where the urban planning starts from a several initiatives for smart development and growth, derived from an active collaboration with different subjects, public and private. The “PON Energia Smart City” project intends to create knowledge paths in a comprehensive framework of energy efficiency on urban basis that uses information kiosks for digital signage, high-speed Wi–Fi, and multimedia systems based on mobile-App for accessing on-site contents. In this context, we have implemented visualization outputs for mobile devices, mainly focusing on logic of efficient use on-site, thanks to the adoption of technologies based on the Augmented Reality (AR).



Figs. 4, 5 – Hypogeum Palmieri, realistic 3D representation

These technologies allow creating an overlap between the real experience and the virtual information (multimedia information, geo-located data, analytical data, and so on) in an environment wherein the multimedia elements “increasing” information on reality can be progressively added, superimposed and displayed through a “direct vision” approach. There are several ways to view in AR mode. The most classic form presents a simple superimposition of information directly displayed on the framed object. Texts, images

and other information appear directly on the framed object, but in some implementations of graphics libraries it is possible to overlap simplified three-dimensional models that help to understand the archaeological structures within the urban fabric. The idea of linking 3D models in the real environment has been experienced for a long time now, even in the manufacturing industry, in automotive, in fashion. Moreover, many research groups have developed solutions that allow to contextualize 3D objects directly on a smartphone. The use of these libraries, however, is strongly affected by the limitations of the various computational devices, compromising, as a matter of fact, the fruition of many poorly performing equipment. One solution to this limitation is given by a hybrid mode of AR, in which ultra-realistic three-dimensional reconstructions are mixed with high-resolution spherical VR panoramas. Many skeptics and lovers of performing technologies lose sight of these old solutions, well supported in HTML5, where the aspiration to technicality generates a communicative effectiveness, easiness of use and quality of yield. The basic idea of this solution is very simple. The three-dimensional model of the old building is placed in the center of the spherical panorama, taking care of finalizing this process to the linking of the attachment points to the points detected on the ground and reported in the 3D scene. These attachment points must exactly match those in the landscape. Therefore, they have to rotate accordingly to the camera when this one focuses on the center of gravity of the VR panorama. In this way, we can show the 3D object perfectly anchored to the real scene. Within this process, special attention has been devoted to the lighting of the scene and to the implementation of a set-up that recreates the same environmental conditions present in the actual scenario, in order to provide a convincing result, that can be perfectly superimposed to the site. This solution allows to view the various monuments in their original context, in an "optimized" and efficient management, even in particularly complex scenarios. Specifically, this happens to old buildings stacked in urbanized environments, where the adoption of a simplified 3D model, without shadows, without radiosity and with low texture resolution would provide a poor integration and an unacceptable quality of the final result, not to say about the meaningful problem of the items located at various depths, which partially obliterate the reconstruction and are partially obliterated by the reconstruction in turn. In one AR scene, a 3D object should solve all these problems, plus the problems related to the real time restitution. In the solution shown in these pages, the reconstructed three-dimensional model is integrated into the urban fabric by means of a simple masking that considers various objects placed in depth, the global illumination and, last but not least, the point of view of the observer.



Figs. 6, 7, 8 – The Temple of Apollo in Syracuse, the reconstruction over the modern city. Image-capture from semi-AR application.

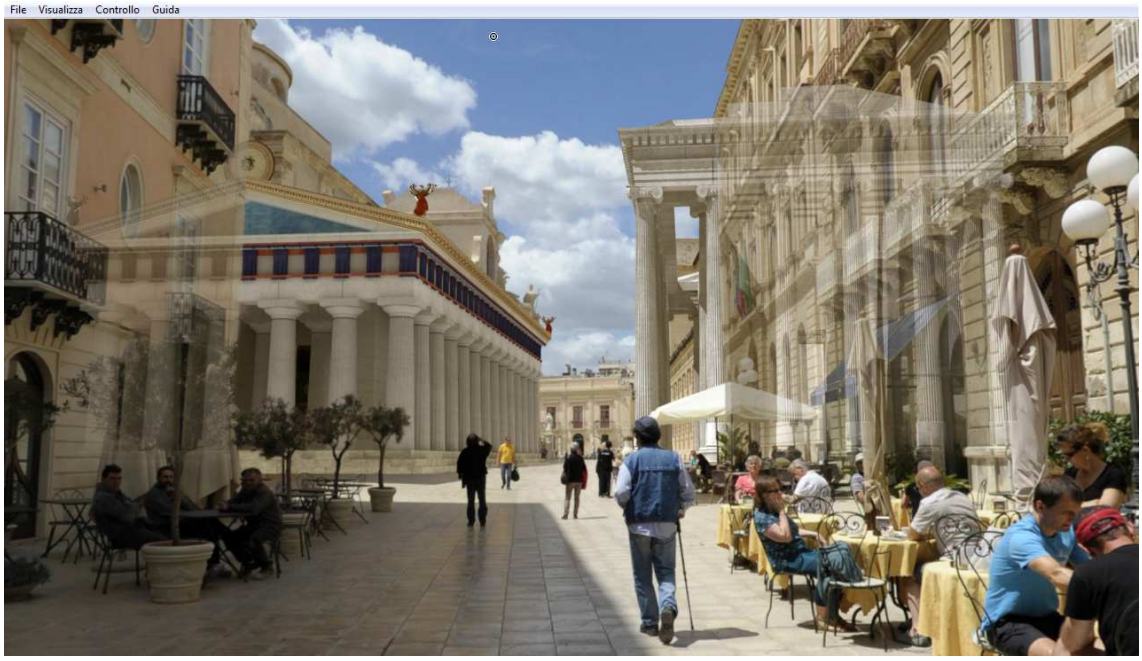


Fig. 9 – The temples of Piazza Duomo over the modern city.

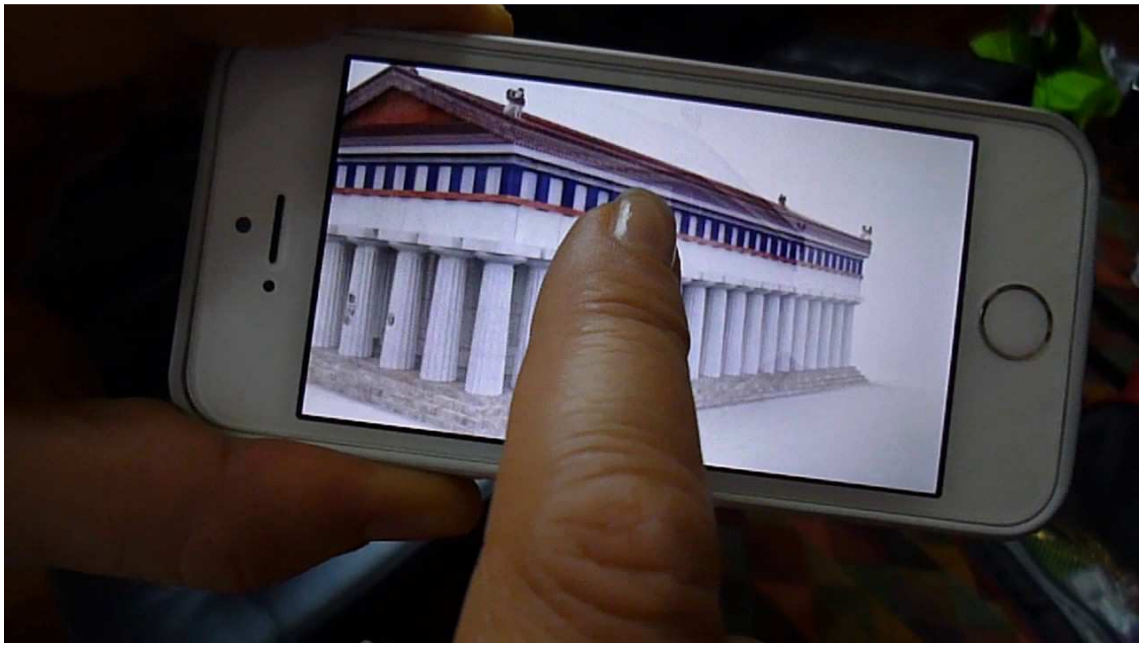


Fig. 10 – Temple of Apollo, interactive navigation

The Greek theater of Syracuse

In the archaeological district of Neapolis, the work has been focused on the Greek theater and mainly on the reconstruction of its Hellenistic scene. The structures of the scene of the great theater built by Hieron II are almost entirely disappeared, except some fragments of sculptures and architectural. On the rock level for the edification of the scene, today different cuts and holes are visible today, but their exact chronology is difficult to be established. Although an extensive and tormented literature has dealt with the Greek theater of Syracuse – that is one of the most famous in the world- we can say that until now a graphic rendering of the

scene based on scientific data has never been attempted. The reconstructive hypothesis that we propose is based on previous studies on Sicilian minor theaters, best preserved and probably inspired by the great theater of Syracuse. So, probably the proskenion was characterized by revolving walls spaced by pillars and the scene included two orders, Doric in the lower part, Ionic in the upper part, with walls punctuated by doors and windows. In the two foreparts on the sides of the scene, called *paraskenia*, the precious architectural sculptures recovered in ancient and now preserved in the archaeological museum Paolo Orsi in Syracuse have been virtually reconstructed and positioned. Two pairs of Satyr-Telamons have been placed in the lower part of *paraskenia* on the side of the gates that used to allow the access to the Orchestra, following the example of neighboring and coeval altar of Hieron II. The other preserved sculpture is the upper part of a Maenad- Caryatid, sculpted all around. Consequently, unlike the Satyr-Telamon, we cannot presume that this Maenad- Caryatid was set very close to a wall. The most reasonable solution was to imagine a loggia crowning of *paraskenia* where a pair of maenads in line with the underlying Satyrs was placed, although this represents an inedited solution in this kind of monuments.

Image-based restitution and virtual reconstruction of the sculptural elements of theatre

Until a short time ago, one of the most critical phases of the reconstructive process of ancient monument was constituted by the practical difficulties linked to the restitution of its sculptural elements. Of course, there are no particular problems of indirect reproduction of these objects, because nowadays it is a routine process. The real problem is instead linked to the cost, the availability of old equipment, and the achieving of the permissions needed to complete the work within a reasonable time. Quite often, in fact, the idea to submit fragile artifacts to the harmless light of a laser scanner in class 1 discourages some museum directors. Moreover, sometimes a pathological form of possessive jealousy of the artifact can lead to overextend the waiting time, with easily imaginable results. In recent years, however, many research groups in the field of archeology have found in the virtual image-based technologies a new way to get an efficient and low-cost relief. This constitutes a real revolution that solves the problem of reproducibility of fast three-dimensional objects, despite some limit due to the precision of the measurements. In the present project this need has occurred several times, e.g. with regard to the reconstruction of the angular acroteria of the temple of Athena and, above all, with regard to the sculptures of the scene of the Greek theater. In fact, a plausible reconstruction of the scene of the Greek theater of Syracuse has been possible thanks to the importance given to the sculptural elements inserted within the complex and debated architectural articulation of the entire scene. This is the case of the two busts of caryatids and fragments of Telamons found during excavations and now preserved in the Archaeological Museum Paolo Orsi. Their fragmentary state, the lack of characterization physiognomic and the bad state of preservation do not allow a full understanding of the sculptures. Therefore, from a preliminary study supported by relevant stylistic comparisons, virtual reconstructions of the lost parts have been proposed, so presenting a complete vision that enables us to read them in their original context. In order to retrieve the 3D relief of the sculptural fragment, we have made use of image-based and low-cost techniques that can produce digital models with a high level of detail, a good geometric accuracy, photorealism and portability. As already mentioned, this choice is enormously flexible and easy to use when compared to an acquisition by laser scanners, which is known to be not very fast, to involve complex procedures for the data processing and to need a relatively weighty equipment.

These problems are even more evident with the latest generation scanners, that produce a large amount of points in a short time. This is a major technological breakthrough, which could easily stall also the computationally stronger computers. In this work, the whole process of 3D restitution of sculptural fragments (the biggest approximately 160x80x50 cm) has required only a photographic campaign performed with a high resolution reflex camera (Canon 5D Mark II, 24 Mpx). In the shots we have maintained a constant focal length (24 mm) and a constant sampling step, so as to cover the entire surface of the objects and ensure a sufficient overlapping of the images (about 70-80%): a fundamental condition to obtain the tracking points in space and their consequent position in 3D. The frames (a total of 60 shots for sculpture) have been processed with the software PhotoScan of Agisoft, proceeding with the alignment of the shoot, the creation of the point cloud, the meshing and the processing of the textures. The software uses flexible algorithms that ensure the orientation of the photos even in the absence of the classic procedures of digital photogrammetry, then even without previously calibrating the camera and without any substantial contribution by the human operator. All operations have been then automated, leaving the possibility to set the parameters according to the desired quality by defining the number of polygons and the size of the textures. The 3D models obtained have been optimized with respect to the number of needed polygons (approximately faces 2.000.000) without any meaningful loss of resolution of the textures to be imported into the modeling software. For the restoration of the missing parts, in a first phase techniques of polygonal modeling point-to-point and subdivision surfaces have been used in order to precisely control the process of creation. Afterward, techniques of advanced digital sculpting for the characterization of surfaces have been applied, especially for the restitution of the drapery present on one of the two caryatids. The texturing of surfaces has been achieved with digital painting techniques for the creation of UV-maps able to realistically simulate the materials and the original colors.

Conclusion

The development of applications for mobile devices requires technological solutions easy to use and good portability on hardware with media power. For these reasons the results gained under the auspices of this projects, as mentioned, are based on simple approaches (interactive VR pano's, passive video, HTML5, etc.). However they contain important issues on interdisciplinary study about methods for an integrated survey, linked to several problems related to the reconstructive study. This approach was made possible by the integration of virtual tour of ancient monuments over the actual city, in accordance with 3D CG narratives that facilitate the dissemination and better understanding of cultural message.

Acknowledgements

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Fig. 11 – Virtual reconstruction of **The Greek theatre of Syracuse**

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