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# UAVs for the visualization, preservation, and sharing of “lost” eighteenth century fortified system on Monte Urpino hill in Cagliari (Italy).

During the eighteenth century the Piedmontese government strengthens the walls of the city of Cagliari through a series of pentagonal bastions, horn works, ravelins and a series of minor buildings located in the hills that characterize the landscape context. Some of these buildings are designed by military engineers on the hill of Mount Urpino which is about 2 km from the walled city. The project involves the construction of some small forts well described in eighteenth and nineteenth century historical maps; this document are very interesting because they allow the architectural and dimensional analysis of the project. Some portions of these works are in an area of the urban park of Mount Urpino that has undergone major changes as a result of an intense quarry activity that continued until the middle of the last century. A photogrammetric survey with UAVs made it possible to identify some traces of the Piedmontese works, some of which are difficult to access due to the conformation of the site. Following an analysis of historical maps, a surface prospecting and a reconnaissance with the drone it was possible to develop some digital models of the southern sector of the hill and propose a first reconstructive hypothesis of the historical structures. These results are described through a selection of axonometric and zenith views, environmental and orthophoto sections. The investigation has therefore allowed to define a first step of research aimed at the knowledge, protection, and enhancement of the historical military landscape. Starting from these results it is possible to design further analysis using geophysical methods, (the latter being useful for identifying structures located below ground level), and also to define a project to enhance a cultural itinerary that connects the identified structures located in panoramic places.

Keywords:
UAV application; 3d modelling; representation; Historic military landscape; Cagliari.


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## DIGITAL SURVEY FOR VISUALIZATION, PRESERVATION, AND SHARING OF THE HISTORIC MILITARY LANDSCAPE.

The knowledge of the military historical heritage is the preliminary necessary step to identify the correct protection and valorisation strategies. Once the analysis of the archival documents is completed, this aim can be achieved through a graphical and informative documentation capable of representing the complexity of the investigated system. This complexity now can be managed thanks to computer technologies that make possible the production of a digital database of high scientific value. The results of data elaboration have the task to transmit, through a graphic language at the same time technical and easy to understand, not only the problems related to the site and its recovery, but also those shared cultural values that arouse an indispensable attention to its protection. The achievement of this objective requires the definition of documentation strategies that, integrating traditional and digital techniques, select the most suitable instruments and procedures for survey and representation. When working on the historical military landscape one of the main problems to cope with is the frequent lack of graphic documentation or accessibility to architecture, often degraded and located in places difficult to reach with surveys instruments. This constitutes an important obstacle not only in the process of analysis of the assets but also in the formulation of programs designed to preserve or manage the assets itself. Furthermore, it is not unusual for some fields of application to be devoid of truly valid intervention protocols for the documentation and safeguarding of historic heritage. A fundamental tool for the data acquisition, analysis, and communication of information in this sense is the 3D survey that allows, through three-dimensional databases, to represent the heritage maintaining its morphological characteristics, and offering a precious instrument to design its reuse and valorisation. However, the analysis would be incomplete if limited to the single emergency, decontextualized from its natural environment. In addition to this, there is also the need to study realities that belong to the different scale levels and to identify the relationships between different architectural objects and between the objects and the landscape context that hosts them. There are many examples of research that underlie the geographical and typological identification of the sites; not infrequently, there has also been the involvement of subjects belonging to different social and cultural realities, such as the case of the UNESCO's World Heritage List which is recognized as a real reference for identifying the characters to be preserved (Rao 2010). The identification and classification phases are therefore the bases on which to define the actions of monitoring and cataloguing of the information. In this regard, the digital survey allows an ever more in-depth understanding of the heritage by offering not only the possibility of carring out not only the study of the actual state of the architectures but also that of being able to carry out simulations on the hypothesis of reuse creation of cultural itineraries (Parrinello et al. 2019b), both in terms of performances and uses. Field operations need the surveying object to be reachable, a condition not always guaranteed. In fact, the artefacts to be surveyed may reside in areas that are difficult for men to reach, especially if you decide to use instruments whose overall dimensions are an obstacle to the mobility of the operators. In other cases, despite having sufficient physical accessibility, the site may present risk factors for people, making it practically impractical (e.g. areas affected by instability, degradation of structures or unsuitable environmental and sanitary conditions); furthermore it can happen that the study area has an extension that makes difficult to employ traditional methods, which would require high timing both in the survey phase and in subsequent analyses. Therefore, it is essential to define documentation strategies that select the most suitable procedures and instruments, planning the different operating phases and the different levels of information and analysis. Analyses that are aimed at producing a graphic and informative documentation functional to build a database capable of reading (Cianci, Molinari 2019) and representing the complexity of the investigated system. The result of this process is a multidisciplinary and implementable 3D information system functional for the management, maintenance of architectural and landscape heritage and the development of valorisation projects.

Concerning digital surveying, it is well known that each technology has its own advantages and disadvantages (Baltsavias 1999) in terms of cost, transport and usage, safety for the surveyors, data processing and accuracy in data measurement. The possibility to combine the use of different tools allows to offset the individual weaknesses, by exploiting the strengths of each technique (Barba et al. 2020) and to achieve a high-quality result. In particular, the integration of Terrestrial Laser Scanning (TLS) and digital photogrammetry using Unmanned Aerial Vehicle (UAV) offers the potentials of both active and passive sensors, enabling terrestrial and aerial acquisitions for a complete documentation and digital reconstruction of the investigated object (Liang et al. 2018). Both methods, Terrestrial Laser Scanning and digital photogrammetry, "excluding direct contact with the wall surface or

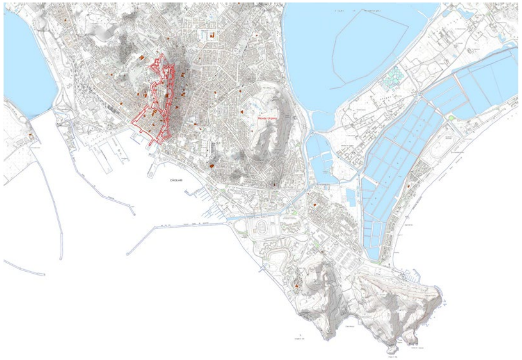

Fig. 1 - The park of Monte Urpino, the eighteenth-century city walls, and the urban landscape context of Cagliari represented on a recent digital map (graphic elaboration by Andrea Pirinu and Sergio Mocci).


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reducing it to the minimum, are the most effective techniques for non-invasive diagnostics of risk assets” (Remondino 2011). A methodology that is increasingly being used is photogrammetry using drones; the technological advancement of drones today makes them tools that, while maintaining relatively high-performance levels, allow to contain costs (Fernández-Hernandez et al. 2015, Brumana et al. 2013), if compared with equipment such as laser scanners. The high mobility allows drones to have access to areas that are difficult or inaccessible to humans, both in physical and environmental terms (Westoby et al. 2012); moreover, the possibility of shooting at altitude makes it extremely easy to work on very large areas, as well as individual emergencies. This is combined with the possibility of flight programming and the high mobility of the cameras mounted on drones, making them instruments of exceptional flexibility of use (Aicardi et al. 2016). The fields of use are definitely manifold with the possibility of moving from the architectural to the territorial scale (Ebolese et al. 2019); among these the stratigraphic documentation, static and structural analysis (Fiorillo et al. 2013), the project of urban regeneration interventions in areas affected by the landslide (Conte, Bixio 2022), the reconstruction of defensive systems starting from the identification of fragments. This last condition characterizes the historical military architectures that almost always are part of a defense system on a territorial scale. The database acquired through the UAV photogrammetric survey can also be supported by GPS references and other survey methods, as direct measurement or TLS, and integrated by shots taken from the ground; in this way it is possible to acquire information on the dimensional and material characteristics inside and outside the architectures. This choice mainly depends on the scientific objectives of the survey. Another important step is sharing the results of the research. The digital models thus obtained through the processing of the data provide drawings characterized by different levels of detail and a high complexity which must be “communicated and shared”. An interesting application is represented by the research on the fortress of Portobello in which “the goal was to structure a multimedia output that can be explored through interactive platform, a drawing that shows the environmental complexity and is able to enhance the fort by explaining the relation system that it entertains with the surrounding context” (Parrinello, Picchio 2019). In this case study the research group, using integrated survey and hybrid representation techniques, represents and communicates with great clarity the architectural and landscape values of the military historical heritage.

## THE “LOST” EIGHTEENTH CENTURY FORTIFIED SYSTEM ON MONTE URPINO HILL IN CAGLIARI. TOWARDS ITS REDISCOVERY AND PROTECTION

A photogrammetric survey with the use of the drone is been applied in the study of the historical military landscape of Cagliari and of its disappeared architectures whose traces are preserved in the current urban context; it is possible to identify original position, consistency and elaborate a digital representation of these works thanks to a methodology structured on the following several phases: analysis and comparison of historical maps and study of other archival documents, integrated digital survey with UAV’s application supported by field verification of traces detected, elaboration of the digital model from which to extrapolate 2D and 3D drawings useful for further analysis and hypothesis, representation and dissemination of the results. The first step starts with examination of the eighteenth and nineteenth century maps. These documents are very interesting because offer numerous elements for a reconstruction and a representation of the historical landscape, in areas that have undergone major changes since the end of the nineteenth century. This is the case of the system of small forts [1] planned in the seventeenth century (Pirinu, Schirru 2022) during the Spanish Kingdom, designed and realized at the end of the eighteenth century by Piedmontese engineers on the “Monte Urpino” hill (Montaldo 2003), an area of great landscape value (fig.1) located 2 km far from the historic city

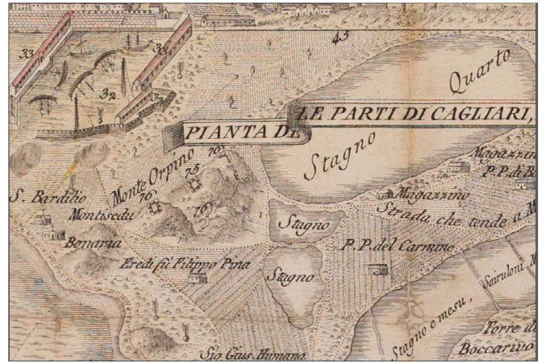



Fig. 2 - Detail of the map of 1793 that identifies with the number 75 and the number 76 the defensive positions placed on the “Monte Orpino” and the paths that lead to the city through the “pass” between the hill of “Montisedu” and the hill of “Monte Orpino”.

Fig. 3 - “Piano militare della fortificazione di Cagliari e posizioni circonvicine misurato a passi ordinari, calcolati a quatro il trabuc[c]o da Giuseppe Verani tenente nello stato generale d’armata di s.s.r.m. il re di Sardegna li 25 agosto 1813” (ASTo, Sezione Corte, Carte topografiche e disegni, Carte topografiche segrete, Cagliari C 1 Nero).


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and nowadays interested by a project of valorisation [2]. Said area has undergone important transformations due to recent times to military use and mining activities.
The eighteenth century (fig.2) map intitled "Dimostrazione delli fatti d'arme dei giorni 24,27,28 gennaio, e 13,14,15 e 16 febbraio 1793. Seguiti tra l'armata sarda equella della nazione francese. Prospetto delle Parti assediate e nuove Fortificazioni di Cagliari. Prospetto delle Parti del Disimbarco ed accampamenti di Quarto" (Demonstration of the military events of 24,27,28 January, and 13,14,15 and 16 February 1793 between the Sardinian army and that of the French nation. Prospectus of the besieged parts and new fortifications of Cagliari. Prospectus of the landing areas and military camps of Quarto) describes the defensive project and the territorial system of Cagliari in which the military works are represented with simple graphic models [3], unlike the nineteenth century maps (fig. 3) intitled "Piano militare della fortificazione di Cagliari e posizioni circonvicine misurato a passi ordinari, calcolati a quatro il trabuc[c]o da Giuseppe Verani tenente nello stato generale d'armata di s.s.r.m. il re di Sardegna li 25 agosto 1813" (Military plan of the fortification of Cagliari and nearby positions measured in ordinary steps, calculated by Giuseppe Verani lieutenant in the general armed state of the king of Sardinia li 25 August 1813) supported by a view (fig.4) and a map (fig.5) intitled "Pianta topografica di montixedu ed una parte di monturpino" (Topographical map of montixedu and part of monturpino). This map shows with major detail the surrounding landscape of monte Urpino hill [4] and the dimensional/geometric/functional choices clarified thanks to a metric scale in "trabucchi" [5], the latter a useful reference for a virtual reconstruction of the forts; this map, made by expert Piedmont surveyors [6], it also describes the design of the individual forts [7] of which it is possible to recognize the artillery posts, the different levels that connect the sectors, low flanks and ditches provided for further defense. The project area is limited to the hill of Monte Urpino and Montixeddu and described with considerable precision that facilitates the identification of traces of the works made and still present within the current urban landscape, directing the next steps of field operation. This step of recognition is possible through the comparison in CAD environment between the nineteenth-century map and the most recent digital maps appropriately selected (fig.6). A study also favored by the recognition of some well-described natural and anthropic elements, such as the main paths and the morphology of the places, shared by all the documents; for this purpose, the choice of aerial views falls on a recent photo (RAS 2008) and a B/W photo of the 40s of the twentieth century, the latter of considerable interest because it shows the obvious signs of quarrying that has characterized the area for a long time (Smith 1828).
The second step is an integrated survey designed at a different level of detail and dividing the study area into two sectors. To this aim, the survey through UAVs becomes helpful support for the reconnaissance of a broad context and the observation of places through a privileged vision (overall and detailed), often according to visual angles not practicable from the ground; in the present case, this latter possibility allows to identify some traces of the fort of "Sant'Ignazio" and minor works connected to it (figg.7-11). Field operations required a photographic survey at different flight heights to construct a broad model of the study context and detailed models of some areas of interest. The shots were taken with a low-cost DJI MINI 2 drone with 249-grams MTOM, equipped with a 1/2.3" sensor camera with a resolution of 4000x3000 pixels, 12.4 MPX, on a 4:3 aspect ratio. It is combined with a prime lens with a FOV (Field-of-View) of 83°, equivalent to 24mm compared to the 35mm format and a focus range from 1 m to ∞. The photographs were taken at maximum resolution in *.jpg and *.dng (RAW) format, the camera set to timed release, and the exposure set to mode "A" with ISO100. The project's goal is to realize of different models: one larger on a territorial scale, and the other on an architectural scale. The airspace involved in the operations is near the Cagliari-Elmas airport, classified as CAGLIARI CTR, for which a

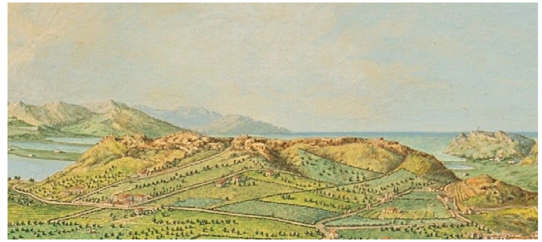

Fig. 4 - Monte Urpino hill with its system of forts. Detail of the view "Disegnata da sovra un terrazzo del R. Palazzo di Cagliari da Giuseppe Verani nel mese di Maggio 1815 - Drawn from above a terrace of the Royal Palace of Cagliari by Giuseppe Verani in May 1815" (from Ladogana 2015).

Fig. 5 - "Pianta topografica di Montixedu ed una parte di montorpino" (Archivio di Stato di Torino, Sezione Corte, Carte topografiche e disegni, Carte topografiche segrete, Cagliari 6 C I Rosso). The document, accurate and detailed, is equipped with a metric scale in "trebuchets" and "steps" that contributes to the correct placement of military works on the recent digital surveys.

Fig. 6 - Localization of the eighteenth-century works on aerial photos dated 1940 (in which quarry activity is clearly identified) and 2008 (source: https://www.sardegnageoportale.it/webgis2/sardegnafotoaeree/): 1-fort of Sant'Ignazio and 2- other additional works.


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maximum flight altitude of 25 meters is permitted. This condition limited the flight operations for the joint survey to 25 meters. The survey on a territorial scale [8] was divided into two phases to overcome the technical limitations of the instrument; for this purpose, a first survey was carried out in the North sector, followed by a survey in the South sector. Later, separate low-altitude flights were planned to reproduce of architectural scale models of the individual structures identified during the first survey. The framing flights were set on a cross-mesh trajectory at a maximum of 50 meters above ground distance, taking advantage of the maximum flight altitude allowed concerning to the take-off point explicitly chosen at the summit of the promontory, which guaranteed a GSD (Ground Sample Distance) of 1.7cm/pix. As a result, a distance between the strips of 23 meters and a cruising speed of 4.5 m/s was maintained with a shutter speed interval of 4 seconds, resulting in an overlap of at least 65% both longitudinally and laterally. The flight plans for the northern part and the southern part have been programmed, in order to be able to align the two elaborates in post-production. The following flights for the survey of the structures were set with orbit and irregular trajectory and camera facing the structures, shooting images at different altitudes and distances between 15 and 30 meters. The drone, in this case, was controlled with a manual flight due to the irregularity of the terrain and numerous obstacles. For the survey of the extended area, a total of 400 photos were taken for the northern area and 400 for the southern area. Close flights, they acquired: 99 Images of the S1 Structure and 65 Images of the S3 Structure. Once the helpful photographic documentation for the construction

Fig. 7 - Wide view (1) and traces of the fort of Sant'Ignazio identified during the UAVs survey. Among these a portion of the trench that housed the positions for artillery (2), masonry structures (3) and a stretch of a connecting path between different levels occupied by the works (4).

Fig. 8 - Additional works of the fort of Sant'Ignazio. Views of additional dated 2022 and 1996 (Montaldo 2003).

Fig. 9 - Fort of Sant'Ignazio. Signs of instability of the rocky slope and of the historical military structures.

Fig. 10 - Wide views captured with drone flight and detail captured from the ground of the portion of a vertical connecting structure (R1 in figures 19-22) positioned between the fort of "Sant'Ignazio" and some additional works designed to control the route located between the hill of "Monte Orpino" and the hill of "Montisedu".

Fig. 11 - Masonry structures (S3) located in the south area of Monte Urpino hill. It is possible to recognize the inclined shape of the upper part of the parapet.


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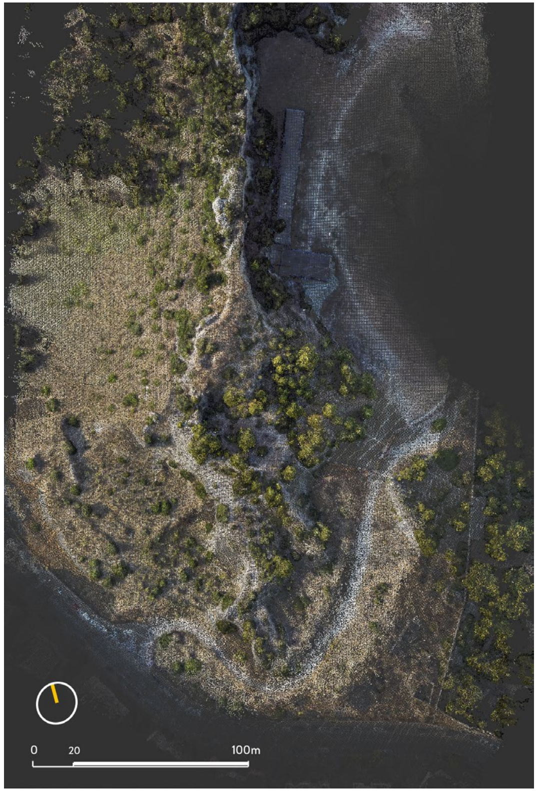
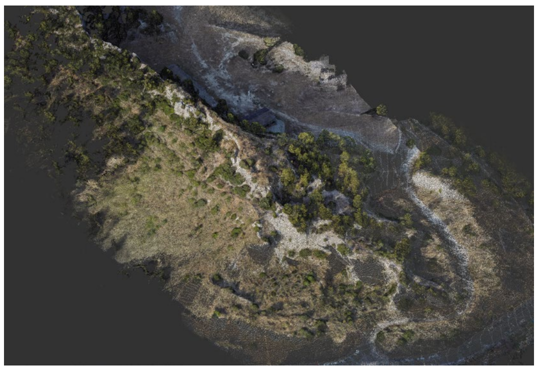


of the model was acquired, the images were processed through an SfM algorithm process, managed with the Agisoft Metashape Professional software. In this phase the high amount of data acquired has directed towards the processing of the survey on two different "Chunks" to reduce the workload caused by the high number of photographs taken and aligned successively with markers placed on the common spaces. The first step is Estimate image quality (Agisoft 2022), a quick image quality assessment process that returns a rating coefficient to elaborate only on those without imperfections and exclude photographs with imperfections and blurry ones and those with incorrect exposure. The second phase is aligning photos process, which generates a sparse cloud. This cloud has been cleaned of outlier's points and projected in the wrong position, and optimization has been performed, reducing the error. The next step is Build Dense Cloud through which a dense point cloud is returned; these are cleaned of excess points, and at the end the following technical specifications resulted:

- Territorial survey. Chunk 01 (north sector): 44.229.000 points, Chunk 02 (south sector): 41.786.000 points, Chunk 03 (focus depression close to the fort of Sant'Ignazio) 8.049.000 points and size 5.50x6.00 m.
- Structure S1 (collapsing wall) 15.513.000 points
- Structure S3 (existing structures) 21.068.000 points

The next stage is drawing the digital model from which to extrapolate 2D and 3D representation. The redrawing of the small forts, represented in

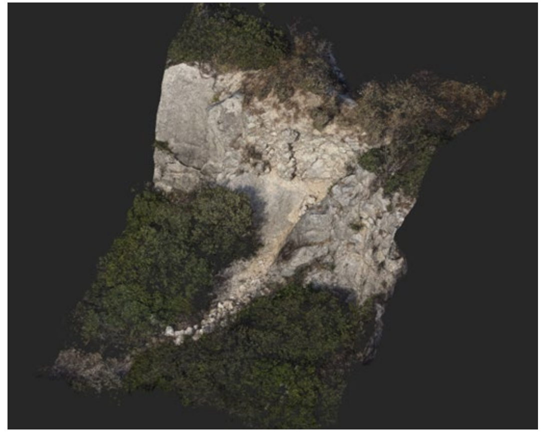
Fig. 12 - Digital survey (orthophoto) of the study area (point cloud model).

Fig. 13 - Digital survey (axonometric view) of the study area (point cloud model).

Fig. 14 - Point cloud model of the collapsing wall (structure S1 in figures 19-22).

Fig. 15 - Fort of Sant'Ignazio. Portion of the trench that housed the positions for artillery (hypothesis). Close-up view in which S1 (in figures 19-22) indicates the collapsing wall.

Fig. 16 - Fort of Sant'Ignazio. Portion of the trench that housed the positions for artillery Close-up (axonometric) view.



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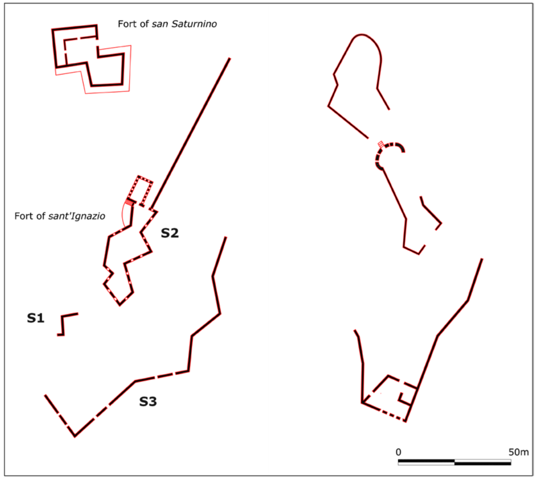
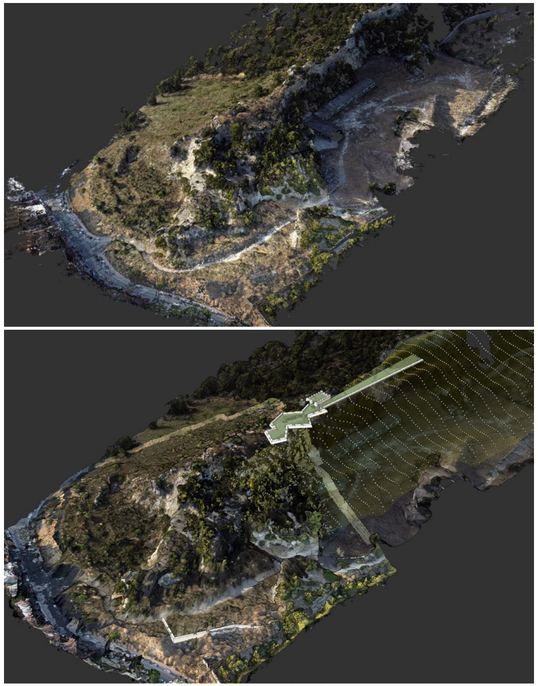
the nineteenth-century map through two-dimensional schemes, requires support from the knowledge of the eighteenth-century fortifications [9], its design techniques and the dimensional and formal characteristics indicated in the manuals of the time and/or supplemented by the information derived from the survey of existing and contemporary structures of those being studied. Once the necessary choices for interpreting of the graphic diagrams indicated in the historical map have been made, the insertion of the military works into the digital model of the study area becomes a “study model”. At this stage, it is necessary to make a simplification that requires the transition from a “point cloud” model (figg.12-16) to a simplified mesh model with reduced texture to 1.500.000 polygons. The last phase in Metashape is projecting the texture with a resolution of 8000x8000 pixels and exporting the models in *.obj format. The transition from the point cloud to the mesh is a choice that derives from the need to work with a lighter and compatible model and from the function that the same model “mesh” assumes as a study tool on which to perform section operations, manipulation, and insertion of new objects (fig.18). The 3D reconstruction arises from the elaboration of the map intitled “Pianta topografica di Montixedu ed una parte di montorpino” and the surveys in a CAD environment. Rhinoceros 7 software was used; the textured mesh in *.obj format and the historical cartography were imported and aligned, and the volumes were extruded and positioned at ground level. This step may involve a relocation of the single fort compared to what was achieved in the previous elaboration proposed in figure 6; now the scale of observation is more detailed as it has gone from an aerial-based comparison to the study of a detailed model from UAVs survey. Once inserted and, if necessary, relocated the forts in the study model, it is possible to carry out some graphic operations section or orthophotos (Chiabrando e al. 2015) suitably chosen to carefully observe the overall project, the individual military work, the relationship between forts and the changes occurred since the end of the eighteenth century to date (figg.19-22).



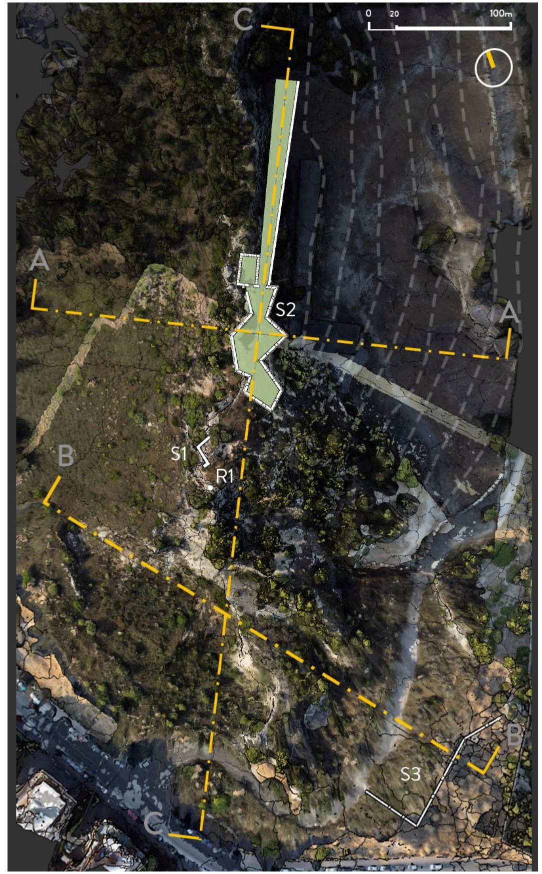



Fig. 17 - Digitalization of the military works represented in the “Pianta topografica di Montixedu ed una parte di montorpino”.

Fig. 18 - Digital reconstruction of the eighteenth-century military landscape. The area affected by the quarry activity is represented in a axonometric view in which a graphic solution simulates the original profile of the slope. This drawing shows how the quarry activity has erased most of the traces of the fort of Sant'Ignazio.

Fig. 19 - Digital reconstruction of the eighteenth-century military landscape: orthophoto with cross section. The area affected by the quarry activity is represented with a graphic solution that simulates, using level curves, the original profiler of the slope.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## CONCLUSIONS, INNOVATIVE AND ORIGINAL ASPECTS

The digital model obtained from UAV's survey allows to measure and represent the places with a great precision and becomes the basis for further insights thanks to the possibility of offering 3D and 2D representations such as detailed orthophotos, zenith views, axonometric views, and environmental sections (figg. 20-22) Each of these are useful for different readings: orthophoto for the stratigraphic analysis of masonry structures, axonometric and zenith views for an overview of existing structures and environmental sections for the study of transformations induced on the profile of Monte Urpino hill by the quarry activity, the latter useful for address a reconstructive hypothesis of military works. The usefulness of UAVs in surveying and of new information technologies for the analysis, representation and sharing of cultural heritage is confirmed. The results, always implementable, allow a progress of research on the eighteenth-century system of forts with the construction of a digital database that may receive information of different formats such as maps [10], images, reports. This methodology, despite several impediments such as dense vegetation, makes possible an effective configuration of integrated, verified and discretized data, from which to structure valid multi-scale and multi-level imaging systems. In addition, in the case study, it offers a survey [11] and representation of existing historical structures (fig.23) integrated by a morphological characteristics of the area, allowing a reconstructive hypothesis of the system of forts and its landscape context and offering useful information for the redevelopment planned in the area.

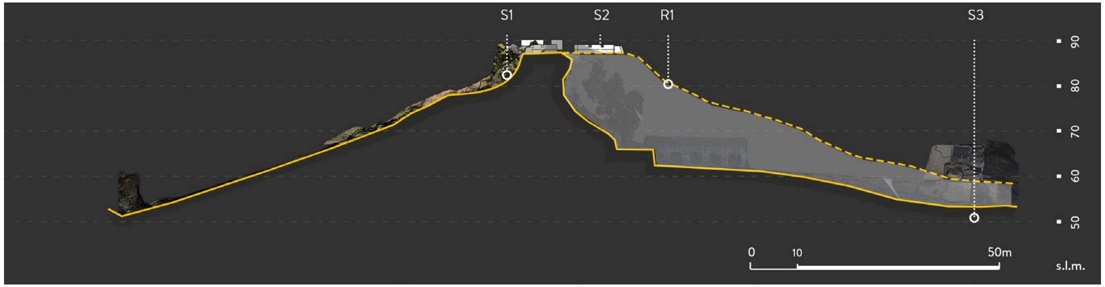


Fig. 20 - Environmental Section A-A showing the structures identified and graphical reconstruction of the slope modified by the quarry activity.

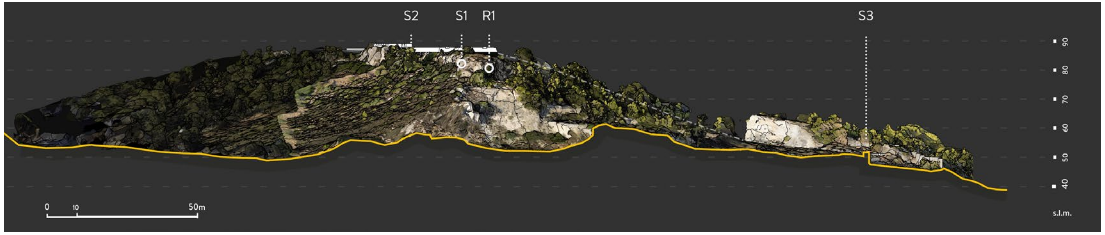


Fig. 21 - Environmental Section B-B showing the structures identified.

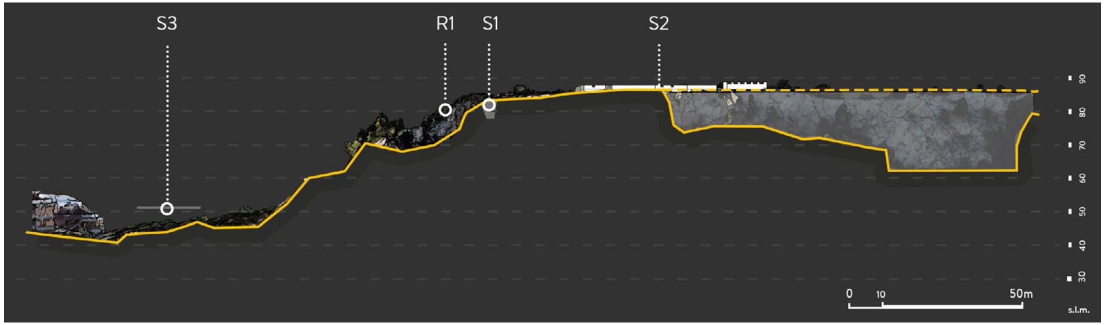


Fig. 22 - Environmental Section C-C showing the modification of the slope because of the quarry activity.

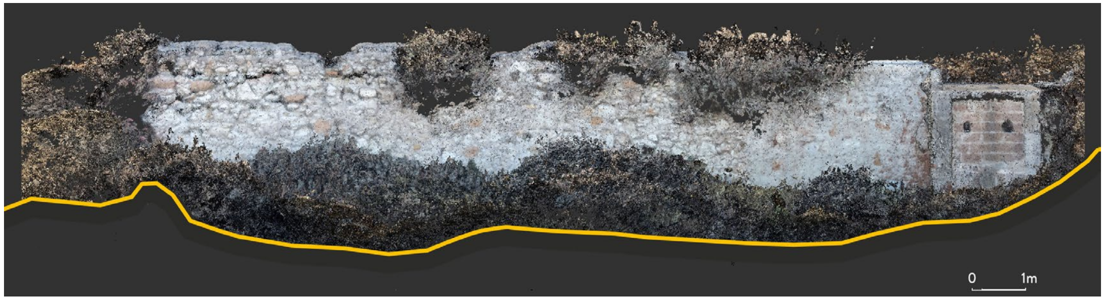


Fig. 23 - Structure S3 (orthophoto of existing and visible masonry structure). It is clearly identified the artillery opening represented in the Verani's map.


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NOTE

[1] These are works of small size due in particular to the morphological conditions of the site and the hardness of the rock as reported in the report di don Manuel Bellejo of 1 August 1707: "En Monte Orpino, q(ue) toda su cumbre es de peña viva, y fuerte por ser muy dilatado, y toda accesible por la parte, q(ue) mira á lluch, y al Estanq(ue) en concideracion de ser muy dificultoso, y aun costoso el poder subir carros de fagina, y tierra, y de no poderse clavar Estaca ni palichon por la duresa de.la peña se podra en su ambito accesible construir unas man posterias á distancias conbenientes de fagina sobra fagina enclavadas entre ellas en la forma (ASCa, Antico Archivio Regio, Reg. P34, cc. 119v-130r).

[2] The project involves securing the profile of the hill modified by the quarry activity, the connection by means of new paths between the different sectors of the park of Monte Urpino and the planting of the area under study. The latter activity involves a cleaning of the area; this operation must be carried out with particular attention in relation to the presence of historical structures not documented and not bound to date. This phase will also be an opportunity for a careful observation of the traces still present.

[3] The simple graphic model could indicate a work of less complexity and importance that has nothing to do with the solutions represented in the following nineteenth-century map. In this regard it is possible to hypothesize a new project to replace existing structures and the realization of a well-articulated defense system that became necessary after the French attack of 1793. Such hypothesis suggests to date the realization of the forts present in the map "Pianta topografica di Montixedu ed una parte di montorpino" and in the "Piano militare della fortificazione di Cagliari e posizioni circonvicine misurato a passi ordinari, calcolati a quatro il trabuc[c]o da Giuseppe Verani tenente nello stato generale d'armata di s.s.r.m. il re di Sardegna li 25 agosto 1813", to the decade 1795-1805.

[4] The map can be attributed to Giuseppe Verani, active in Cagliari in the first half of the nineteenth century and author of the "Pianta topografica di una parte delle campagne di Cagliari" made by G. Verani in 1813 (which describes an area adjacent to that of Monte Urpino with the use of the same graphic codes and the same precision) and of some views (fig.5) made in the years 1814 and 1815 (Ladogana 2015).

[5] Unit of measurement equal to 3,083 meters (Martini 1883).

[6] Giuseppe Maina, a Piedmontese military engineer employed in Sardinia in the second half of the eighteenth century.

[7] The military works represented in the map are 4: from south to north, the fort of Sant'Ignazio in connection with other works located at different altitudes, an unnamed military work on the side that controls the pond of Molentargius and the paths of approach to the city coming from east, the fort of San Saturnino in the west side of the hill and a last defence work indicated as "fortino incominciato/ fort started" in the north of the hill.

[8] The total area measured is 200 x 300 m.

[9] Graphic models of eighteenth-century fortifications in Lepage 2009.

[10] An comparison between the historical maps is guaranteed by the nineteenth-century map that describes with great accuracy the morphological characteristics of the landscape and the positions of the individual forts as demonstrated by the precise insertion of the existing structures within the study model

[11] S1 – 2.00 square meters of masonry; S2 – fort of Sant'Ignazio; S3: height - internal surface m 1.10 /external surface m 3.50, thickness 0.42 cm and length 15.5 m.

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