proceedings

Proceeding Paper

Integrated Digital Survey: The Roman Amphitheater of *Suasa* (Castelleone di Suasa, AN) †

Francesca Bindelli [1,*] and Alessandro Campedelli [2,*]

1 Department of History and Cultures—DISCI, University of Bologna, 40124 Bologna, Italy
2 Department of Cultural Heritage—DBC, University of Bologna, 48121 Ravenna, Italy
* Correspondence: francesca.bindelli2@studio.unibo.it (F.B.); alessandr.campedell2@unibo.it (A.C.)
† Presented at the Una Quantum 2022: Open Source Technologies for Cultural Heritage, Cultural Activities and Tourism, Rome, Italy, 15–16 December 2022.

Abstract: This paper discusses an experience developed as part of the 2021 Topographic Survey Workshop, organized by the Department of Cultural Heritage of Ravenna (University of Bologna) in the Roman city of *Suasa* (Castelleone di Suasa, AN), during which the potential of integrating photogrammetric and laser scanner surveys was explored in order to geometrically and morphologically characterize the remains of the Roman amphitheater.

Keywords: topographic survey; photogrammetry; laser scanning

check for updates

Citation: Bindelli, F.; Campedelli, A. Integrated Digital Survey: The Roman Amphitheater of *Suasa* (Castelleone di Suasa, AN). *Proceedings* **2024**, *96*, 5. https://doi.org/10.3390/proceedings2024096005

Academic Editors: Gabriele Ciccone and Giuseppe Guarino

Published: 13 March 2024

1. Introduction

In the last twenty years, digital technologies in the field of cultural heritage have experienced strong activity, obtaining numerous accomplishments in different fields of application and useful results both for the study and monitoring of cultural heritage, and in terms of wider access to the same. Regardless of the final purpose, the starting point is always represented by the responsible use of the tools for acquiring dimensional data and by a set of operations aimed at the digital representation of the study context.

The developments of photogrammetric systems combined with the workflow of terrestrial laser scanning have significantly contributed to the creation of more comprehensive and accurate point clouds, and this advancement has led to an increasingly prevalent use of these techniques for the digitization of cultural heritage. In this paper, we want to present a brief account of the objectives, the method, and the preliminary results obtained following the integrated survey activity carried out at the Roman amphitheater of *Suasa* (see Figure 1).

Figure 1. View of the Archaeological Park of the Roman city of Suasa (authors' photo).

The University of Bologna has been using photogrammetric surveys and laser scanning for many years in order to integrate the graphic documentation of the contexts investigated and collect new information useful for the study and dissemination of its activities.

2. *Suasa* Roman Amphitheater

2.1. Research Aim

The case study presented in this work concerns the application of the integrated survey technique for the digital restitution of the Roman amphitheater of *Suasa* [1]. The archaeological remains of this monument occupy the eastern limit of the Roman city, located about 30 km west of Senigallia (Marche, Italy). This work is part of a larger study project of this building, also comprising its virtual reconstruction (see Figure 2).

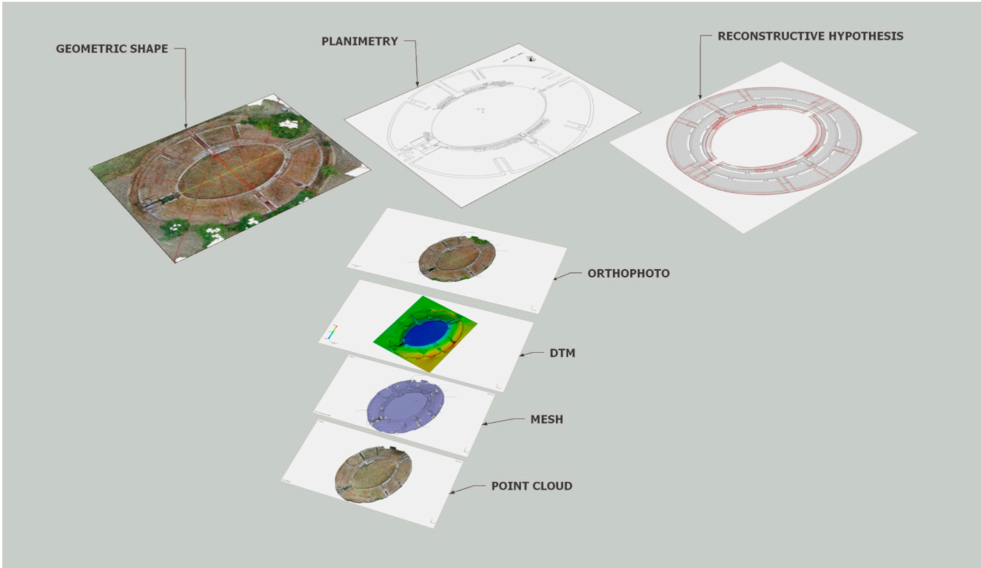

Figure 2. Summary scheme of the results of the processing carried out.

2.2. Archaeological Research in Suasa: The Amphiteater

The development of the center of *Suasa* fits into the historical framework of the intense colonization of the region at the beginning of the clash between the Romans and a coalition of Umbrians, Etruscans, and Samnites [2]. The city began as a *praefectura* and became a *municipium* during the second half of the 1st century BC and experienced a slow and progressive decline from the end of the 3rd century AD [3]. Starting from the middle of the 20th century, a series of archaeological investigations aimed at restoring legibility and accessibility to the Suasan amphitheater, planned by the Soprintendenza Archeologica of the Marche region, have brought to light the main features of the building: the *arena*, the *vomitoria*, the *podium*, and the *ima cavea* [4,5].

Previous graphic documentation has been limited to a few paper drawings made at different scales of detail, which are not adequate enough for addressing the study of this monument. An essential requirement would be a complete and accurate survey, from which metric data can be extracted to uniquely characterize the architectural–constructive design of the amphitheater, such as dimensions, geometry, and shape.

3. Photogrammetric Survey and Laser Scanning: The 3D Reconstruction Workflow

The first phase of the survey involved the materialization of a network of points, acquired with the differential GNSS (Global Navigation Satellite System) technique in static mode. Subsequently, these were used to georeference the surveys carried out using the Total Station. The creation of this network of points made it possible to determine both the absolute coordinates of the Ground Control Points (GCPs) used for photogrammetry, and the georeferencing and control of the point clouds deriving from laser scanning.

A photogrammetric survey of the area was carried out using UAV (Unmanned Aerial Vehicle) technology, specifically a DJI Mavic Air drone, which was set in order to acquire the external surfaces of the remains of the Roman amphitheater. Afterward, a trajectory suitable for recording information from the inside of the building was created. All frames were processed by Agisoft *Metashape Pro*. The entire data set (1563 images with 4056 × 3040 resolution) was divided into 3 chunks both for hardware reasons and to retain divided sets of images acquired under different lighting conditions. The merging of these chunks was achieved using 18 Ground Control Points (GCPs), distributed over the entire surface of the amphitheater. From a geometric point of view, the obtained point cloud showed an average resolution of the ground texture of 7.91 mm/pixel (see Figure 2).

For what concerns the laser scanning survey, the scans were carried out using the Leica P30 model, a time-of-flight laser scanner with an active sensor. This instrument, exploiting a "hybrid" technology called "Waveform Digitizing" (WFD), has made it possible to maintain extremely high acquisition density, precision, and resolution in the entire distance range, from a minimum of 0.3 m up to a maximum of 120 m. The individual point clouds, for a total of 30 acquisitions, were subsequently aligned, recorded, and georeferenced using the *Leica Cyclone 9.0* proprietary software.

The two point clouds thus obtained, inserted within the same reference system, were easily merged within the *CloudCompare* v2.12.4 software. The same software was also used for the *data cleaning* of the merged point cloud, exploiting the potential offered by some tools such as *Remove duplicate points*, SOR Filter, and Noise Filter, for the elimination of out-of-tolerance or insignificant points. Finally, *CloudCompare* was chosen to extract various envelope profiles of the elements characterizing the amphitheater in .dxf format. The preliminary 3D model resulting from the two point clouds was uploaded on *Sketchfab* to facilitate its accessibility, although the point clouds were severely decimated for the upload on the website [6].

The profiles thus acquired, validated through comparison with polylines drawn directly on the point cloud in *AutoCAD 2022*, formed the starting point for understanding this monument.

4. Discussion and Conclusions

The intense survey activity implemented during the laboratory has allowed us to increase knowledge on various formal aspects of the Suasan building: the real dimensions, the definition of the geometric shape, and the construction typology. Thanks to the dimensional data of the axes of the arena, which were 60.08 m corresponding to 203 Roman feet (major axis) and 38.18 m relating to 129 feet (minor axis), it was possible to determine the ratio between the axes: 1.56 (i.e., 11:7). This information was used to calculate the constructive module of the amphitheater, corresponding to 5.46 m that is equal to 18.5 Roman feet. The calculation of the module made it possible to determine that the shape of the Suasan building was traced on the ground by the *Mensores aedificiorum* by exploiting the advantages offered by the geometric scheme of an oval with four centers (see Figure 3) [7].

The amphitheater of *Suasa* responds to the "construction rule" which sees the axes of the *vomitoria* as radial and intersecting on the axis of major symmetry at two common points. In addition, the four *auditums* open along the wall of the *podium* are positioned almost perfectly in correspondence with the points along which the four circumferences that characterize the geometric figure of the amphitheater are welded. From a typological point of view, however, this building is a full-structure amphitheater built with an auditorium, which is supported by closed embankments divided into compartments. In the Suasan case, on the basis of the geometric scheme adopted, the construction involved the creation of eight large sectors placed side by side and delimited by the walls of the six *vomitoria*. These were also delimited by the two main entrances, which were the *Porta Triumphalis* (north/east) and the *Porta Libitinensis* (south/west) [8].

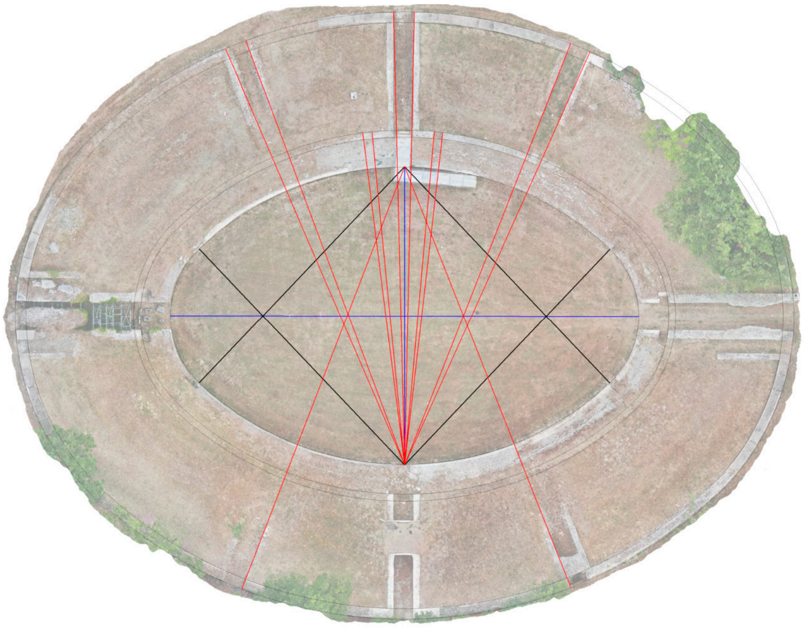

Figure 3. Representation of four-center oval (black), construction lines generated by vertices of circle arcs (red).

This type of construction finds its explanation above all in the choice of the location of the amphitheater, which completely exploits the hillside. Construction activities were carried out through a "simple" operation of relocation of the soil. It was removed from the upper part of the hill and carried over downhill for the preparation of the embankments of the steps of the *cavea*. As in many documented cases, the *cavea* was intended to accommodate the public of the *Suasa* amphitheater and had to be divided into three horizontal sectors (*maeniana*) by means of walkway rings (*praecinctiones*). These rings were delimited and subdivided in turn into vertical sectors (*cunei*) by radial stairways (*scalaria*). The slopes visible in the sections extracted from the digital model show how the first sector (*ima cavea*), built behind the *podium* delimiting the *arena*, was occupied by three medium-sized bleachers covered with limestone slabs. The *media cavea* could have included seven rows of steps smaller than in the *ima cavea* and a *praecinctio*, which separated it from the *summa cavea*. This latter was perhaps made up of a flight of steps (about 14 steps) made of wooden carpentry.

In conclusion, it can be argued that the achievements of this study point out that the use of multiple technologies for the acquisition of metric data represents the most complete way to manage a survey project. The perspectives for the continuation and, hopefully, the conclusion of this study foresee the reconstruction of the amphitheater through the Extended Matrix, which will be made accessible within the ATON *Framework* [9].

Author Contributions: Conceptualization, F.B. and A.C.; methodology, A.C.; software, F.B.; validation, F.B. and A.C.; formal analysis, A.C.; investigation, F.B.; writing—original draft preparation, F.B.; writing—review and editing, A.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets presented in this article are not immediately available because they are part of an ongoing study. Requests for access to the datasets should be addressed to the authors.

Acknowledgments: We sincerely thank the Soprintendenza (SABAP Marche Nord) and I. Venanzoni for granting access and authorization to the site and for allowing the consequent publication. The authors would like to thank E. Giorgi, and C. Manfredi.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Remondino, F. Rilievo e modellazione 3D di siti e architetture complesse. *Disegnarecon* **2011**, *4*, 90–98.
2. Dall'Aglio, P.L.; De Maria, S.; Mariotti, A. *Archeologia Delle valli Marchigiane: Misa, Nevola e Cesano*; Electa Editori Umbri: Perugia, Italy, 1991.
3. Suasa, G.E. Genesi e sviluppo di un municipio romano dell'agro gallico. In *Atlante tematico di topografia antica: ATTA: Rivista di Studi di Topografia Antica*; Gigli, S.Q., Quilici, L., Eds.; L'Erma di Bretschneider: Roma, Italy, 2020; Volume 30, pp. 95–114.
4. Quiri, P. Castellone di *Suasa* (AN): Anfiteatro romano di Suasa. In *Scavi e Ricerche Nelle Marche. Introduzione alla Mostra*; Luni, M., Ed.; Quattro Venti: Urbino, Italy, 1991; pp. 44–45.
5. Quiri, P. Il nuovo programma di lavori nell'anfiteatro di Suasa, in La valorizzazione dei siti archeologici: Obiettivi, strategie e soluzioni. In Proceedings of the XI Borsa Mediterranea del Turismo Archeologico, Paestum, Italy, 13–16 November 2008; MP Mirabilia: Roma, Italy, 2008; pp. 57–59.
6. Sketchfab. Available online: https://sketchfab.com/3d-models/anfiteatro-romano-di-suasa-006ae5b820044dedaf76be25211c12d6 (accessed on 22 February 2024).
7. Trevisan, C. Sullo schema geometrico costruttivo degli anfiteatri romani: Gli esempi del Colosseo e dell'Arena di Verona. *Disegnarecon* **2000**, *18–19*, 117–132.
8. Golvin, J.C. *L'amphitheatre Romain. Essai sur la Théorisation de sa Forme et de ses Fonctions*; Diffusion de Boccard: Parigi, France, 1988.
9. Fanini, B.; Ferdani, D.; Demetrescu, E.; Berto, S.; D'Annibale, E. ATON: An Open-Source Framework for Creating Immersive, Collaborative and Liquid Web-Apps for Cultural Heritage. *Appl. Sci.* **2021**, *11*, 11062. [CrossRef]