The sunrise summer school: An innovative learning-by-doing experience for the documentation of archaeological heritage

THE SUNRISE SUMMER SCHOOL: AN INNOVATIVE LEARNING-BY-DOING EXPERIENCE FOR THE DOCUMENTATION OF ARCHAEOLOGICAL HERITAGE

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ABSTRACT:

The first edition of the SUNRISE (Seashore and UNderwater documentation of aRchaeological herItage palimpSests and Environment) summer school was carried out in Marina di Ragusa in Sicily (Italy) from 3rd to 9th September 2022. It was jointly organized by Politecnico di Torino, IUAV, University of Sassari, FBK, University of Udine and the University of Modena and Reggio Emilia with the support of SIFET, ISPRS Student Consortium, private companies (Images, Microgeo, Stonex, Leica and Geomax) and the municipality of Santa Croce Camerina.The five days of summer school were attended by 20 students from Europe, Asia and USA. After the first day of lectures focused on the theoretical basis of surveying, photogrammetry, LiDAR, and SLAM, the field activities took place in a submerged and terrestrial scenario. The underwater surveying involved a submerged amphora, and the terrestrial activity was focused on the Arab bath of Mezzagnone, a 6th-century AD building that has been fully preserved until today. The paper deal with this experience and underline the followed approach. Finally some results achieved by the students are reported.

1. INTRODUCTION

In the last decade, a substantial revolution in the photogrammetric and surveying fields is the democratization of mapping with affordable devices. Today's consumer mobile devices have the potential to obtain geospatial information and 3D models, as well as being everywhere around us. However, these affordable sensors cannot perform digitalization without the help of automatic software able to convert this data into meaningful and accurate information. This automatic process entails however some risks, such as the lack of critical awareness of the final quality of the outputs.

According to these limitations, a rigorous education about the pro and cons of reality-based digitization by photogrammetric techniques is required to spread procedures and methods for the correct use of this technology. Nowadays, a correct pedagogical approach needs the use of innovative teaching strategies for smart education (Van den Broek, 2012; Uskov et al., 2018; Shi et al., 2019) including Active Learning (AL), Game-based learning (GBL), Learning-By-Doing (LBD), Challenge-based learning (CBL), Massive Open Online Courses (MOOC), Collaborative Learning (CL), Crowdsourcing-based Learning (CWL), Flipped Classroom (FC), Learning through Augmented and Virtual Reality (LAVR), and others. All these approaches can extensively benefit from the use of advanced technologies to produce enhanced learning materials supporting smart education.

In this paper, the authors describe the *learning-by-doing* strategy applied to a summer school on 3D documentation of archaeological heritage able to:

- improve the didactic impacts on students using practical experiences linked with rigorous theoretical concepts;
- share the learning experience with students with different level of initial knowledge (professionals, surveyors, Bachelor and Master of Science students, PhD students);
- stimulate the multidisciplinary approach required in the documentation of archaeological heritage using team works for data acquisition and processing.

2. THE SUNRISE EXPERIENCE

The first edition of the SUNRISE (Seashore and UNderwater documentation of aRchaeological herItage palimpSests and Environment) summer school was carried out in Marina di Ragusa in Sicily (Italy) from the 3rd to the 9th of September 2022. Politecnico di Torino jointly organized it with IUAV, the University of Sassari, FBK, the University of Udine and the University of Modena and Reggio Emilia with the support of SIFET (Italian Society of Photogrammetry and Topography), ISPRS Student Consortium, private surveying companies (Images, Microgeo, Stonex, Leica and Geomax) and the municipality of Santa Croce Camerina.

The five days of summer school were attended by 20 students (selected from 41 applications) from Europe, Asia and the USA, divided into 4 groups led by 17 tutors (Figure 1).

The schedule of the course was organized in:

- 1 day of theoretical lectures;

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- 2 days of “in field” data acquisition;
- 2 days of data processing;
- final presentation of achieved final products.

Figure 1. Students and Tutors.

2.1 Theorectical and multidisciplinar lectures

The theoretical lectures (Figure 2, above) were carried out on the first day according to the following structure:

- 5 hours of theoretical lectures on instruments, techniques and methods for 3D model generation, focused on the theoretical basis of surveying, photogrammetry, LiDAR and SLAM;
- 2 hours of lectures of archaeologists from “Soprintendenza del Mare” and “Soprintendenza per i Beni Culturali ed Ambientali” of Ragusa, dedicated to the historical description of the Ragusa area, some examples of terrestrial and underwater surveying of archaeological objects in Sicily;
- 1 hours of a simulation of underwater acquisition in a swimming-pool (Figure 2, below).

Figure 2. Theoretical lectures (above) and simulation of the underwater acquisitions in the swimming pool (below)

3. DATA ACQUISITION

3.1 The terrestrial surveying

The terrestrial activity was focused on the Arab bath of Mezzagnone (Figure 4), a 6th-century AD building that has been fully preserved until today. In the test areas, the tutors and the five private companies (Images, Microgeo, Stonex, Leica and Geomax) operationally showed the most advanced technologies for multi-sensor surveying (Figure 3).

Figure 3. Instruments used in the survey of terrestrial case

The site has been prepared locating the vertexes of reference network and positioning some horizontal markers for aerial image acquisition and some checkerboard targets on the surfaces of the archaeologic asset (Figure 5).

The reference network vertexes and the Ground Control Points (GCPs) have been measured using an integrated survey of GNSS receivers-total station techniques (Figure 6 and Figure 7). On four points (A, D, E, V) of the network, GNSS geodetic receivers were positioned by storing static measures.

Figure 4. The location of Arab Bath of Mezzagnone.

The acquired data are summarized in the following list with an amount of 200 Gb:

- Aerial photogrammetry by drones: DJI Matrice 300 (about 200 images), DJI Mini Mavic (about 230 images);
- Terrestrial photogrammetry: Sony Alpha7R (about 130 images);
- Aerial LiDAR: DJI Zenmuse L1 (10 Mpoints, BLK2Fly (10 Mpoints);
- Terrestrial LiDAR: Polaris (250 Mpoints in 6 scans), Faro Focus Premium (300 Mpoints in 10 scans), Stonex X150 (400 Mpoints in 20 scans)
- Handheld Mobile Mapping System: Geoslam ZEB Horizon RT (180 Mpoints in 2 scans), BLK2GO (210 Mpoints in 2 scans).

Figure 5. Site preparation: position of the marker for UAV (above) and terrestrial acquisition (below)

Furthermore, the images to create two time-lapses were acquired during the two survey days to document the activities with 360° cameras and action cameras.
Students were separated in smaller teams to permit the use of all the proposed instruments and methods.

Figure 6. “in the field” data acquisition.

At the end of the survey activities, the acquired data were stored in a cloud location: tutors analysed and discussed with all the students to highlight the main characteristics in terms of integration, quality, time, and issues encountered.

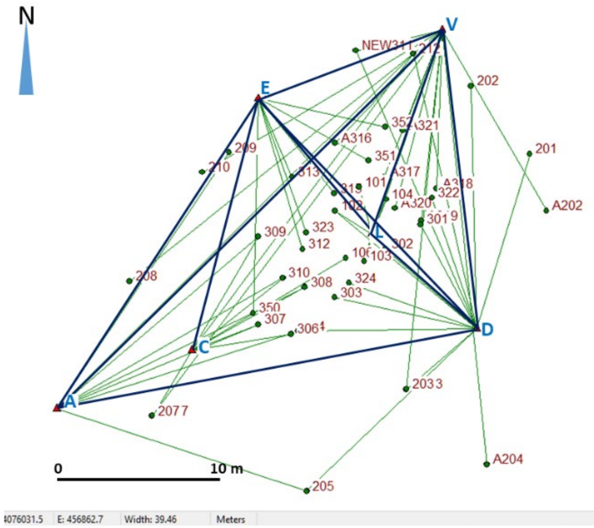

Figure 7. The network (blue) and GCPs (green) topographic schema.

3.2 The underwater surveying

The underwater survey scenario involved a submerged amphora in shallow water (max depth of the underwater site about 4m) in the area of Punta Secca, close to Marina di Ragusa (Figure 8). Due to the reduced depth, the amphora is covered in plants, algae, and other organisms making its shape not easily recognizable.
The site surrounding the amphora was prepared by distributing some coded markers (Figure 10), used for camera calibration, and nine uncoded targets (in orange in Figure 10), to be measured with GNSS. A panel for image quality assessment was positioned close to the archaeological object (Figure 9): the radiometric quality of images can be thus evaluated and eventually corrected using this set of calibrated colors, and the resolution check panel can be used to estimate the metrical quality of images and verify that the acquired images meet the planned ground sample distance (GSD).

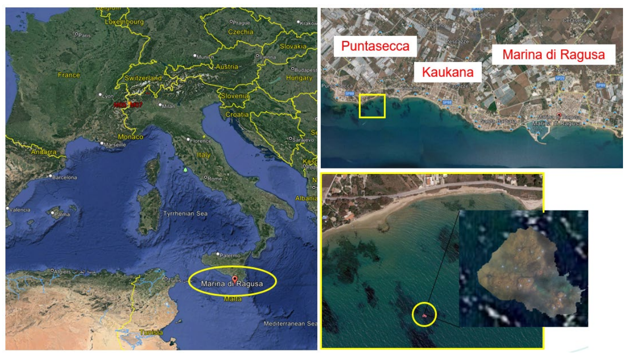

Figure 8. The site of underwater survey

During the underwater survey, scuba divers and snorkel students cooperated to:

- Realize direct measurements (distances and pressure);
- Acquire images of the amphora using an OLYMPUS E-M1 Mark II in its underwater case equipped with a dome port (about 440 images, an example is shown in Figure 11);
- Survey the control points (about 9 uncoded conical orange points, about 15 coded markers) via GNSS RTK (Figure

12). A geodetic receiver (GS18 by Leica geosystem with tilt compensation) has been used with a pole of 5 m length.

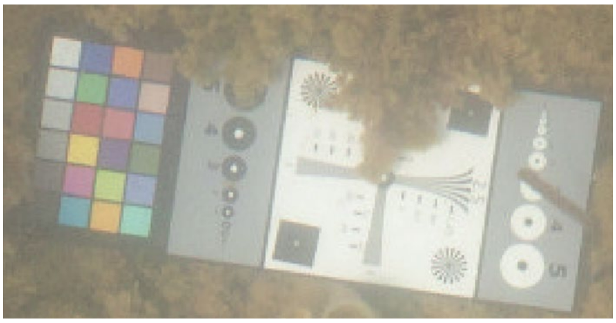

Figure 9. Acquired data for image quality analysis

Figure 10. Site preparation

Figure 11. An example of underwater images showing the amphora covered in algae, plants and other organisms.

Figure 12. GCPs Survey.

Also for the underwater activities, at the end of the survey day, the acquired data were analysed and discussed with all the students to highlight the main characteristics in terms of quality, time, and problems.

4. DATA PROCESSING

The data processing phase started with 2 hours of demonstration of different software tools and methods realized by the different companies.
Some tutors adjusted the reference network survey using the least square method and StarNet software tool of MicroSurvey. This procedure has been described in a practical lecture showing processing configuration and discussing the final results in terms of accuracy, precision, and reliability.
The semiaxes of standard error ellipsoids (95% of probability) of network vertexes are always less than 10 mm (enlarged 100 times in Figure 13), showing the correctness of the topographic work.

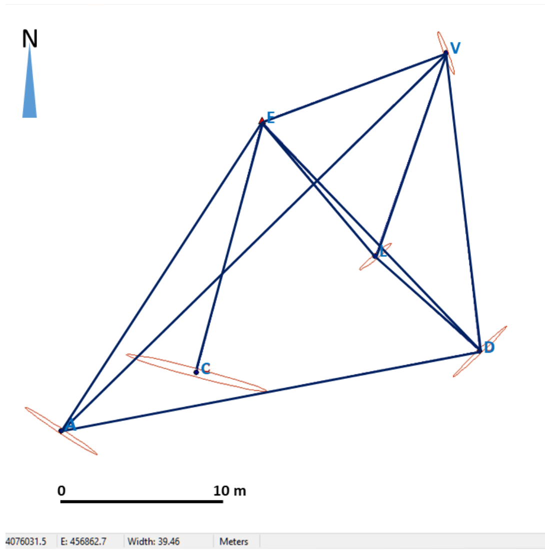

Figure 13. The result of reference network adjustment.

Then, the students were separated into four teams of 5 members to develop the data processing and the generation of final results of the two cases: terrestrial and underwater survey. Each team was guided by 2-3 tutors (Figure 14) who helped the processing procedures, suggesting the setting up of used algorithms and stimulating a critical approach to autonomous evaluation of software results.

Figure 14. Data processing phase in the didactic room.

The final objective of the activities is the production of verified and accurate 3D models in the form of point clouds, texturized meshes, digital terrain and surface models, 2D sections, and other plan representations (orthophotos, …).

4.1 Terrestrial and UAV data processing

Each of the four teams of students was involved in terrestrial data processing, i.e. in processing data acquired with laser scanning and SLAM tools and in plotting terrestrial and drone photogrammetric blocks.
The laser scanning scans and the SLAM clouds were processed in proprietary software and georeferenced in the topographic reference system. The students also proceeded with comparing the clouds obtained with the different technologies (TLS and SLAM) in CloudCompare to evaluate the application areas.
The photogrammetric data were processed in Agisoft Metashape, building separate chunks for terrestrial and drone photogrammetry (Figure 15). The models were oriented in the same reference system using the targets detected with the total station as GCPs. In this way, all the photogrammetric blocks were merged obtaining a very dense cloud of points as the first model of the Arab Bath.

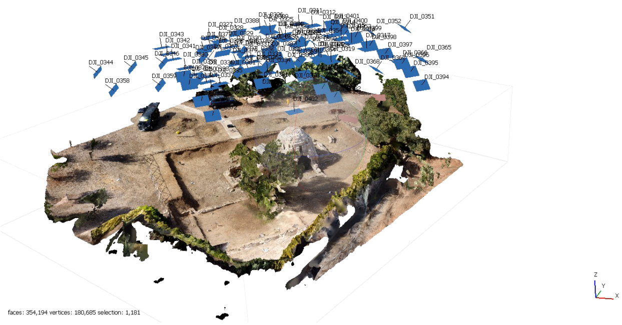

Figure 15. An example of photogrammetric processing

Figure 16. An example of an achieved 3D model

Students elaborate the data to produce three-dimensional models (textured mesh, Figure 16) and bi-dimensional drawings (plans, prospects, and sections, Figure 17). The representation scale settled was 1:50, normally adopted in the architectural and archaeological fields and also in consideration of the accuracies obtained by the different instruments (from 0,4 cm to 1 cm).
Subsequently, they proceeded with the rendering in orthogonal projection of the main architectural fronts through the creation of orthophotos at a scale of 1:50 and with the extraction of profiles (Figure 17) for the drawing of vertical, longitudinal and transversal sections, which also described the internal spaces of the monument, according to the canonical models of architectural representation. The aim of this phase of the school was not only to inform about the existence of these methodologies, but even to highlight the positive aspects and the limits, and focalize the attention on metrological fundamentals that, nowadays, are often disregarded as we frequently rely on automatisms and the greater ease of use of the tools (Achille et al., 2028). The rigorous processing of data has underlined how knowing the possible means and their type of products can also allow better communication between the different professionals who have to work on Cultural Heritage, such us aerial Orthoimages and DSM (Digital Surface models), Terrestrial orthoimages and sections (Figure 17)

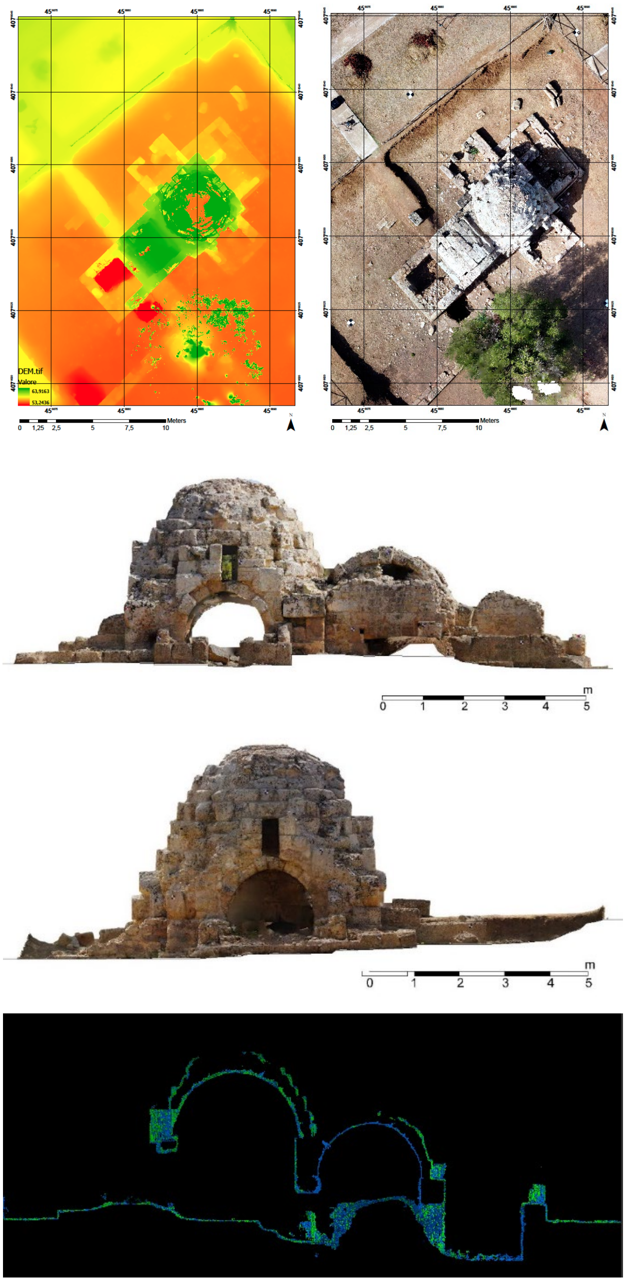

Figure 17. Some examples of final products (DSM,Orthophotos of facades, sections, etc.)

4.2 Underwater data processing

Each student group processed an underwater imagery set. As for the terrestrial case study, the images were processed in Agisoft

Metashape. The process entailed a classic photogrammetric workflow for archeological investigations (Balletti et al, 2016; Capra et al, 2015), from the image orientation step following a self-calibrating bundle adjustment (Menna et al., 2017) to the generation of mesh and DSM of the surveyed area and the production of an orthophoto (Figure 18).

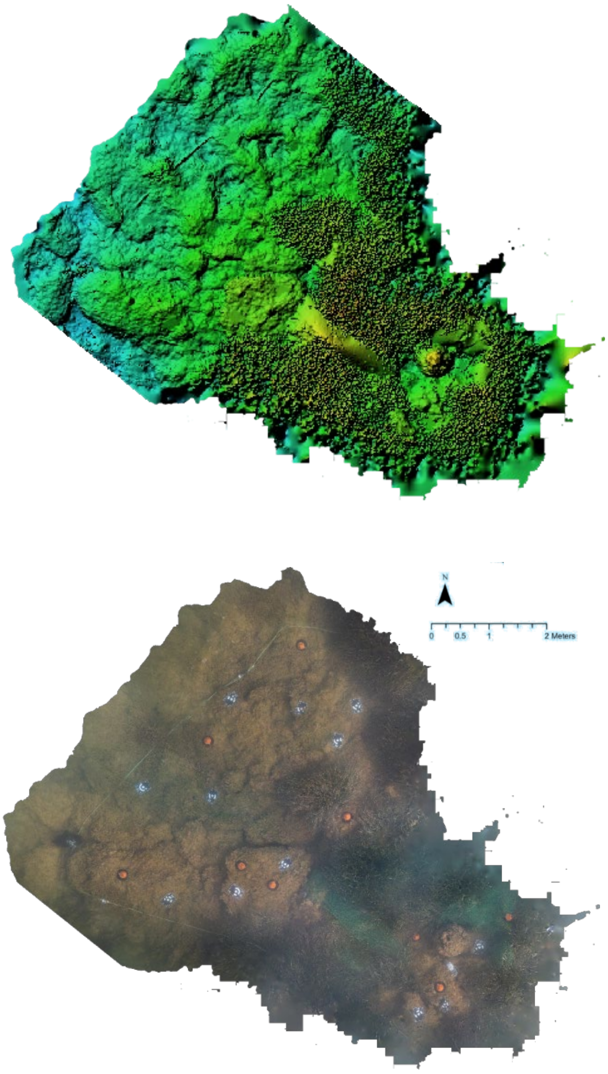

Figure 18. Example of the DSM (above) and the final orthophoto of the underwater site.

The coordinates of the nine GNSS control points were included in a weighted bundle adjustment to georeference the underwater photogrammetric survey. The spatial residuals on the coded targets were also used as quality check of the results. A detailed 3D model of the amphora (Figure 19) was created to simulate advanced analysis, such as, for example, the calculation of the necessary buoyancy in case it had to be recovered from the sea (Figure 21).
The students had the opportunity to challenge themselves with the difficulties of a standard underwater survey: low visibility, color degradation, moving elements and background (seagrass meadows or Posidonia oceanica).

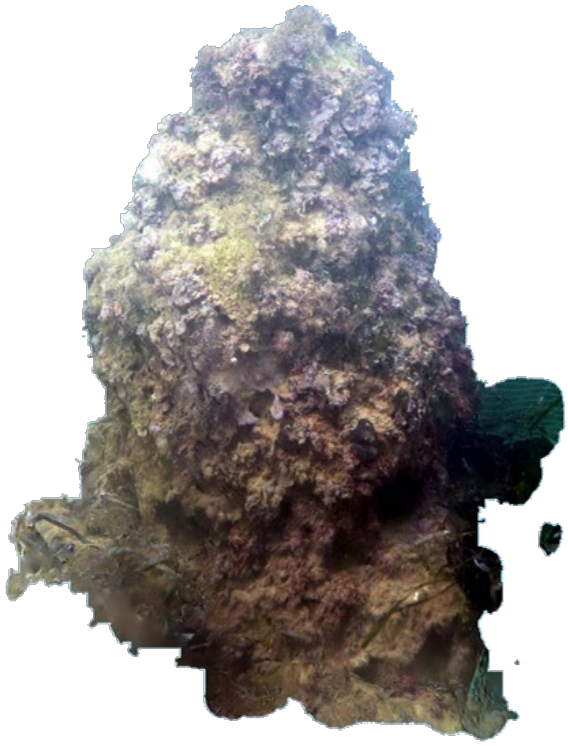

Figure 19. Example of mesh model of the submerged amphora.

4.3 Underwater color correction

As it is well known, going deeper, there is a loss of colour associated with the theoretical distance light penetrates underwater, according to its wavelength (Agrafiotis et al., 2017). However, being that the amphora site is, at its deepest point, at 3 m below the surface (with images acquired at about 1.5 m from the surface), no advanced radiometric correction was performed and the colours were adjusted via a color checker object (Xrite test chart) and images have been pre-processed by minimizing the color difference of measured and reference colors using the CIE76 standard.

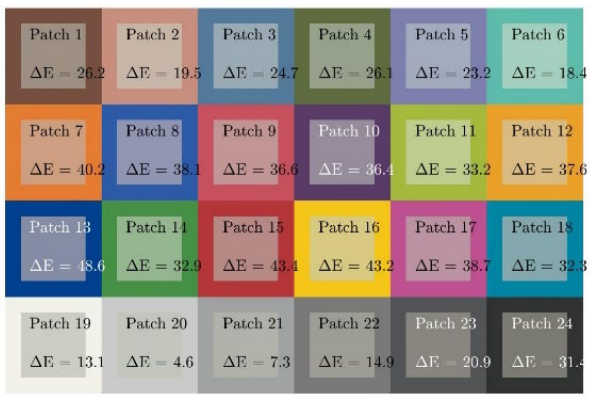

Figure 20. A color patch diagram displays the measured (inner squares) and reference (outer contours) colors with the corresponding CIE color difference superimposed on each patch.

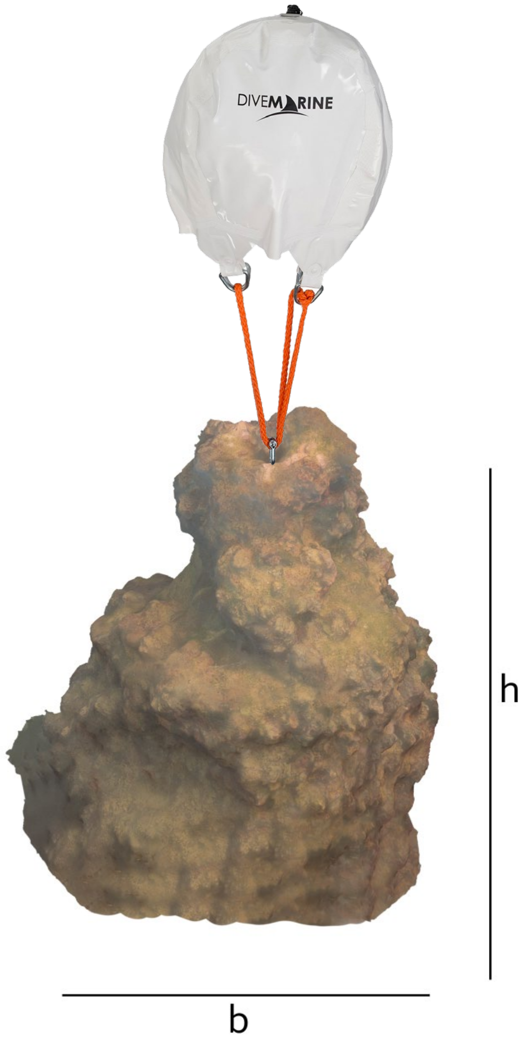

Figure 21. Illustrative sketch showing an underwater lifting bag used to recover the amphora from the sea

The approach followed the use of a Matlab function[1] that measures colors on a test chart and calculates the color difference between measured and reference colors using the CIE76 standard.
Following this step, the original images have been color corrected in the linear RGB color space using a Matlab script[2] and therefore used for the subsequent orthoimage and texture generation of the 3D model.

5. SHARING

The overall work was then officially presented during the final dissemination day with excellent feedback from citizens, local municipalities, and public offices (Soprintendenza per i Beni Culturali e Ambientali di Ragusa) Soprintendenza del Mare della Sicilia).
In fact, the different groups presented the results through presentations divided between the phases of acquisition, processing, and graphic restitution of the digital models (Figure 22 above). Each group detailed some specific aspects to provide an organic and complete overview of the whole work. In particular, some students have deepened the radiometric calibration of the underwater images, others have made hypotheses about the shape, size, and effective volume of the surveyed amphora (Figure 22 below), and finally, others made comparisons between the various SLAM and TLS systems tested on the field.
This dissemination activity allowed to explain to both the citizens and the public administration the benefits that could derive from the geomatics disciplines, the potential of integration with other fields, and the ability to support projects with disparate purposes.

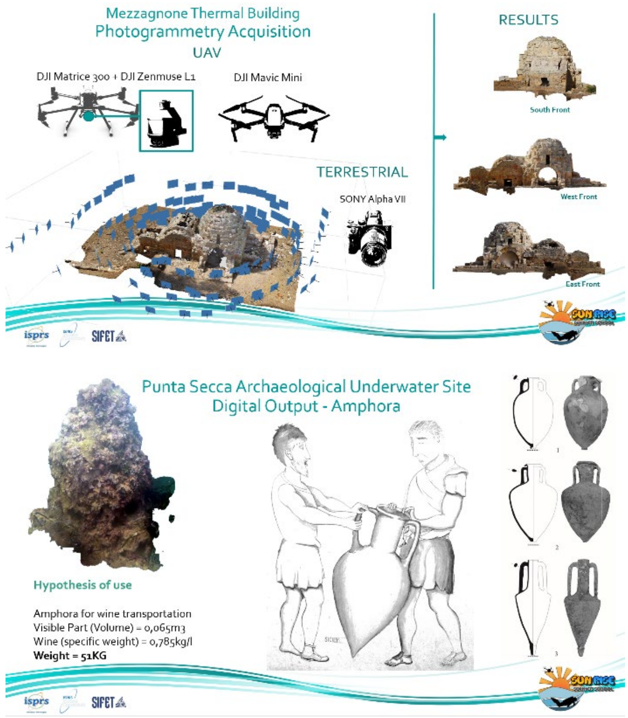

Figure 22. Two slides extracted from the team presentations on data processing and results of the terrestrial site (above) and the shape hypothesis of the surveyed amphora (below).

6. CONCLUSION

In conclusion, after the achieved experience is possible to state that attending the summer school program was a valuable and enriching experience for students of all ages and origins. Summer schools provide a unique opportunity to learn new skills, gain new knowledge, and explore different fields of study in a fun and interactive environment. This is exactly what happened during the SUNRISE Summer School; the students were helped to improve their knowledge in the Geomatics fields using the well-known learning-by-doing approach. The results shown in the present paper are very interesting and demonstrate that in one week is possible to extract important information for improving the knowledge of a specific Cultural Heritage in the terrestrial and underwater environment.
Behind the final results and the week of the summer school is essential to have a qualified team that works well together. This happened during the school organization and on-the-field activities in Sicily; thanks to the SIFET society, a complete and knowledgeable team was established and will be ready for a new

[1] https://www.mathworks.com/help/images/ref/esfrchart.measurecolor.html

[2] https://www.mathworks.com/help/images/correct-colors-using-color-correction-matrix.html

Summer school that will be held in the summer 2024. In the meantime, the possibility offered by the Geomatics companies that allow the students and tutors to work with the more advanced instruments available on the market offers a very important opportunity.

After the summer school a follow up questionnaire was sent to the attendee, the questions of the on line survey covered several aspects of the overall organization of the event, from the opening of the call for participants to post-evet take-home lessons.

Participants were asked how they come to know about the summer school if all the preliminary information provided in the different communication channels were sufficient, what suggestions they had to improve future editions of SUNRISE, if what they learned during the one-week experience met their expectations and any other comments that they might have.

The answer we received from the participants confirmed once again the great impact that a well-structured Learning-By-Doing approach could have on the learning curve of new pieces of knowledge or the improvement of specific skills; especially if working in small groups. The majority of the involved participants treasured the experience gained both from the theoretical lessons and above all the practical experiences of data acquisition in the field, processing, and analysis.

In conclusion, according to the answer and to the achieved experience is possible to state that the experience was very positive and the authors hope that the days spent during the summer schools were helpful for developing new skills and knowledge and to making lifelong connections. SUNRISE can be a transformational experience that can help students achieve their academic, personal and professionals goals.

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