Underwater environment, due to difficult accessibility to archaeological sites, represents a complicated and restricted context; technical limits about underwater diving along with protection and conservation issues pose various problems of usability by a wide public not able to dive.

Nowadays, new optical approaches and technologies, as Virtual and Augmented Reality, support studies and documentation of archaeologists and researchers, in order to make available ancient shipwrecks and underwater cultural heritage.

Immersive VR is based on the Real Time Render technology, thanks to which the user can immerse themselves in situations characterised by a simulated reality, with a strong sensation of immersion.

These technologies have been applied on some Sicilian marble cargos, which have been investigated and documented in the last years, also thanks a HFF grant.

The gained experience shows that the actual multi-image digital photogrammetry is an excellent solution to obtain a three-dimensional model of the underwater archaeological sites. In addition to the importance of a virtual artefact for scientific investigation, this kind of representation of archaeological sites has been used to create a polygonal texturized model. We have applied stereoscopic display system as virtual reality headset to the three-dimensional models of the cargos, promoting knowledge of underwater cultural heritage to a wide public.

These technologies give a great potentiality of the interaction, with the possibility to create virtual tours where users can visualise the underwater site in its totality and in a realistic way. Selecting a virtual object, the users can interrogate and consult the historical or archaeological sources (images, photos, written texts, etc.) which describe that object.

Immersive Virtual Reality is going to become a new concept of musealization, in which the museum will be considered an ICT, an information and communication technology, more than a simple container of objects and artefacts.

64. Enhancing Learning and Access to Underwater Cultural Heritage through Digital Technologies: The Case Study of Cala Minnola, Sicily

Fabio Bruno (Università della Calabria, Department of Mechanical Energetic and Management Engineering, Calabria, Italy)

Loris Barbieri (Università della Calabria, Department of Mechanical Energetic and
In the last years, optical and acoustic technologies have evolved fast in maritime archaeology and this evolution has enabled high-quality digital 3D reconstruction of large-scale and complex underwater scenarios. These digital reconstructions are often adopted for archaeological purposes and, in particular for documentation and monitoring activities. Even if these digital representations are already widely and efficiently exploited in the scientific and research field, they present an enormous and partially unexploited potential for the tourism sector in order to make the underwater cultural heritage more accessible and enjoyable for the general public.

This potential has been investigated and leveraged in the VISAS (VIrtual and augmented exploitation of SUbmerged Archaeological Sites) project in order to improve the responsible and sustainable exploitation of the underwater cultural heritage. In particular, new digital technologies have been developed, on the one hand, to promote diving tourism by improving the divers' experience in the underwater site and, on the other hand, to promote the induced tourist activity through the development of an innovative, educative and attractive virtual tour of the site.

For several years now, the Soprintendenza del Mare of Sicily has been actively promoting the Sicilian underwater cultural heritage and, recently, has collaborated with the University of Calabria and the other VISAS partners, to experiment the technologies developed in the VISAS project on the underwater archaeological site of Cala Minnola at a depth of 25-30m. The site consists in the remains of a Roman republican wreck dated to the first century BC and containing wine amphorae (Dressel 1b).

After a brief overview of the 3D reconstruction process, the paper details how 3D bathymetry has been elaborated in order to be enjoyed by the tourists through a virtual reality system that allows them to simulate a diving session. Moreover, the paper describes the tests realized with a tablet based system that guides scuba divers during their visit, showing them the location and a description of the archaeological and biological points of interest.
65. The Evolution of Survey Techniques on the Qaitbay Underwater Site at Alexandria, Egypt

Isabelle Hairy (National Center for Scientific Research (CNRS), Paris, France; Centre for Alexandrian Studies (CEAlex), Alexandria, Egypt)

The underwater site of Qaitbay is situated at the foot of a medieval fort on the eastern extremity of the ancient Island of Pharos where one has traditionally located the Pharos of Alexandria. The underwater site is open to the sea and is composed of more than 3000 ancient blocks spread over a surface area of roughly 1.3ha.

The site has been studied by the CEAlex since 1994. The vast majority of the pieces have been catalogued and the fragments of architecture and of statuary of prime importance have been studied in detail, initially using traditional methods resulting in a 2D drawing. The study of the inscriptions and decoration is particularly challenging in an underwater context, and silicon mouldings have been taken of the texts and decor that are still under the sea. While this technique produces extremely accurate results, it only allows for the reproduction of a part of the block.

In 2009, the CEAlex integrated certain transdisciplinary specialities, including digital humanities. Our motivation sprang from the difficulty of studying underwater the fragments of ancient monuments, given their size and weight, the problems of access and the poor lighting conditions. We needed to find a simple, lightweight, inexpensive, non-polluting method. Photogrammetry was quickly recognised as the solution.

With the support of the Honor Frost Foundation, the CEAlex threw itself into photogrammetry in 2013, mastering the technique and inventing an innovative means of data acquisition in a situation where more modern methods such as side-scan sonar had failed.

Our aim is to develop a methodological approach to submarine photogrammetry that will serve to create, on the one hand, digital doubles of the sunken artefacts, from the smallest object to large architectural blocks or statuary, and, on the other hand, a 3D digital model of the surface of the site.

66. Experiences with Mobile Augmented Reality at Phalasarna. Combining the Present with the Past in situ

Gunnar Liestøl (Department of Media and Communications, University of Oslo, Oslo, Norway)

Elpida Hadjidaki (Former Director of Underwater Antiquities, Athens, Greece)

In this paper we discuss the application of augmented reality for use on mobile devices at the archaeological site of the port of Ancient Phalasarna on West Crete. Currently, traditional mixed reality experience on mobile devices has it obvious limitations in the context of Cultural Heritage mediation. The sensor fusion approach is not accurate enough to provide a graphical match between the live video feed and graphical layer augmenting the present environment, and pattern recognition by means of fiducial markers deployed on objects in the physical environment is not practical on large outdoors cultural heritage sites. The fundamental incompatibility between 2D live video and a dynamic 3D graphics layer also makes these short-lived solutions. While we are
Waiting for real time 3D capture and display on mobile (an eventually wearable) devices it is relevant to find transitional alternatives for these kinds of highly visual interfaces. Thus we have created a static (frozen) 3D version of the current environment, based on photogrammetry, in order to test how it may play a role as an intermediate level between the real present and the reconstructed past. We present the experiences we have gained so far, over several years of exploring different combinations on site, at the Hellenistic site of Phalasarna, from early prototypes to a published application. Finally, we will also present some ideas for how these experiences could be related more specifically to representations of underwater archaeological sites.

67. Numerical Simulation of the Sinking Ship Scenario, Based on the Archaeological Records

Smiljko Rudan (Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Croatia)

Irena Radić Rossi (Department of Archaeology, University of Zadar, Croatia)

The common evidence of the ancient seafaring in the Eastern Adriatic consists in the amphorae cargos from the Greek and Roman period. Although relatively shallow, some of them are still well preserved, allowing the archaeologists to record the intact results of the unfortunate events. During past decade, the photogrammetric recording and virtual 3D modelling evolved in a standard practice in documenting the shipwreck sites. The sets of digital data of satisfying accuracy became a useful tool for studying the sunken ships, their equipment and cargos. Exploiting the same results, we can try to virtually reconstruct the dynamics of the accident that brought to the creation of the archaeological site.

By applying the modern engineering tools, able to include multi-body physics of ship’s damaging, capsizing and/or sinking, we can model and analyse the various possible scenarios of the incident that happened to the ancient merchantman. Subsequently, we can establish a correlation between the characteristics of the actual shipwreck site, and the outcome of the numerical simulation of the presumed scenario. Besides the possibility to understand the real or most probable cause of the sinking of the ship, such a correlation analysis may also provide the clues about the ship’s structure (e.g. the presence of the deck), the organization of the cargo in the ship’s hold etc.

The preliminary numerical analysis, presented in the talk, is performed as the basis for the study of the fourth century BC intact shipwreck site, recently discovered near the island of Žirje in Central Dalmatia.

68. ‘Dive’ in the Past of Ultra Shallow Marine Archaeological Sites in Eastern Mediterranean through Geoinformatics

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Gianluca Cantoro (Laboratory of Geophysical-Satellite Remote Sensing and Archaeoenvironment, IMS-FORTH, Rethymno, Greece)

Theotokis Theodoulou (Ephorate of Underwater Antiquities, Heraklion, Greece)
Nasos Argyriou (Ephorate of Underwater Antiquities, Heraklion, Greece)

Julien Beck (Département des sciences de l'Antiquité, University of Geneva, Geneva, Switzerland)

Geoinformatics, in terms of historical and low altitude (aided by drones) aerial imagery analysis, photogrammetric reconstruction, and geophysical prospection accompanied by RTK-GPS surveys, have been extensively used for the non-destructive mapping of onshore buried antiquities. Thus geoinformatics has a significant contribution on the understanding, management and promotion of cultural heritage. Despite the relatively frequent use of these imaging and mapping approaches in the recovery of archaeological relics from deep marine environments (e.g. shipwrecks), such technologies have only had a minimal contribution towards the understanding of past dynamics in littoral and ultra-shallow offshore environments (up to 3-5m depth).

During the last three years, the GeoSat ReSeArch Lab, in close collaboration with the Greek Ephorate of Underwater Antiquities and foreign institutes, undertook the initiative to explore the resolving capabilities, spatial limitations, and actual applicability of these technologies in mapping submerged cultural assets in shallow depth marine environments where the visibility of the water doesn’t exceed 2m. A combined suite of these approaches was employed in coastal and submerged archaeological sites dating from prehistory to Hellenistic times in Crete (Agioi Theodoroi, ancient Olous, Istron), Peloponnese (Lambayana) and Pafos (harbour), in order to map the submerged built environment and facilities related to port installations.

In all the tested cases, the analysis and integration of the geospatial data allowed us to integrate or unveil the picture of the submerged archaeological environment, and gave us an understanding of how the past landscape was used. Ground-truthing of the measurements, with reference to previous excavations, also helped in completing the palaeoenvironmental picture of the coastal archaeological sites. The results from these integrated surveys, which were systematically employed in Eastern Mediterranean for the first time, can form the basis for similar archaeological investigations in the littoral zone from diverse regions of the world and time periods, and therefore contribute to the best practice of shallow off-shore archaeology.

69. The 3D Technologies for the Archaeology in the Deep Sea: the Danton French Battleship (Cagliari, Italy)

Michel L'Hour (France's Underwater Archaeology Research Department, Marseille, France)
Daniela Peloso (Engineering and research society in oceanography and in underwater archaeology, Marseille, France)
Franca Cibecchini (France's Underwater Archaeology Research Department, Marseille, France)
On the occasion of the centennial commemoration of the First World War, UNESCO has wished to raise public awareness on the importance of its submerged cultural heritage in order to alert on its necessary protection and to promote peace between peoples. In France, studies carried out for many years by the DRASSM (Underwater Archaeology Research Department) made it possible to gradually remove the veil on the underwater heritage too often neglected, if not forgotten, of this great contemporary conflict. The study conducted on the French battleship Danton torpedoed on March 19, 1917 by the German submarine U-64 is emblematic of this work of memory. Its wreck was located on January 18, 2008, by more than 1000m of depth, in the south of Sardinia, during an electronic survey campaign programmed by the company Galsi, prior to the laying of a gas pipeline between Algeria and Italy. A first reconnaissance dive revealed that the site was so well preserved that it posed no threat to identification. Co-financed by the Dassault Foundation, the operation led by Drassm aimed to achieve a 3D restitution of the wreck. The project, which was supported by several research laboratories, including robotic labs, called for the design and development of specific lighting and underwater waterproof housing capable of withstanding very high pressures and providing Images of very high quality. The photogrammetric coverage of the wreck made it possible to carry out a detailed reconstruction of the entire battleship. Useful to the study of the site, this 3D rendering will now allow the public to visit virtually the Danton.

70. The RAM3D Database Project: A Web Portal for the Study of Ancient Mediterranean Warships and Ramming

Study of the physical properties associated with ancient warships of different class designations is challenging. This is primarily because we lack surviving remains from ancient galleys of known classification. As a result, scholars have relied on a mix of indicators comprised of textual (ancient descriptions of warships in action), epigraphical (inventory lists and dedications), iconographic (depictions of galleys) and archaeological evidence (authentic rams and proembolia) in order to develop their theories. In recent years our knowledge has been increased substantially by the discovery and investigation of authentic rams (Athlit, Belgamel, Bremerhaven, Egadi 1-11, Acqualadroni), as well as a number of ‘virtual rams’ from Actium. In order to enable data sharing and communication between researchers working on these ancient artifacts, a web-based platform is being developed at the University of South Florida’s Center for Virtualization and Spatial Technologies (CVAST). This platform will be designed to allow for the display, comparison and sharing of 3D models in various formats, photographic images, and Greek and Latin textual evidence relevant to ramming warfare. This paper will introduce the new
website, explain its usefulness in comparing data from different sites and of different types, in fostering the exchange of ideas, and in helping to standardize ram terminology in different languages. It is hoped that conference attendees will see the usefulness of placing their own and their students’ data on the RAM3D platform in order to advance our study of ancient Mediterranean warships and ramming. The Website is currently under development at this URL: https://cvast.usf.edu/projects/ram3d/

71. The University of Oxford, Research Laboratory for Archaeology Cape Andreas Expeditions 1969-1970, Working with Legacy Data

Jeremy Green (Department of Maritime Archaeology, Western Australian Museum, Fremantle, Australia)

Patrick Baker (Department of Maritime Archaeology, Western Australian Museum, Fremantle, Australia)

In 1969 and 1970, the Research Laboratory for Archaeology conducted two underwater archaeological survey expeditions to Cape Andreas. The expeditions recorded underwater archaeological material including shipwreck sites and anchors. These sites were surveyed, photographed and recorded and were the subject of two publications (Green 1969 and Green 1973). At the time surveying was conducted with horizontal sextants and underwater recording with 35mm cameras. Since the expeditions, the material has lain dormant until the advent of a number of computer-related programs that have enabled a reassessment of this legacy data.

The positions of the sites, although accurately recorded on topographical maps, did not have geographical coordinates, making it almost impossible to relocate them. Using the existing data, it has been possible with the use of Google Earth and the Esri ArcGIS program to precisely locate all the sites and attribute geographical coordinates (latitude and longitude) to them, ensuring the possibility of relocating them in the future.

In addition, these two early expeditions were used to experiment with underwater photogrammetry, which at that time was in its infancy. The expeditions experimented with photomosaic and object recording using the relatively new underwater Nikonos 35mm camera. The photographic data has been reprocessed using PhotoScan and has resulted in some remarkable three-dimensional plans of the sites.

This paper underlines the significance of legacy data as an important source of new information.

72. Seeing is Believing: The Rhetoric of Photogrammetric 3D Digital Models of Underwater Archaeological Sites

Madeline McAllister (Department of Archaeology, The University of Western Australia, Perth, Australia)

If ‘seeing is believing’ and ‘a picture is worth a thousand words’, then what are the deeper impacts and influences of photogrammetric three-dimensional (3D) digital models for the recording and communication of archaeological data? In recent years affordable, user-friendly
software programs enabled archaeologists to undertake complex computing and photogrammetry processes previously only done by skilled specialists. While this provides the opportunity to record underwater archaeological sites with a perceived high level of detail, it also opens the door to a myriad of visualisation approaches and theoretical issues. Visual media are convincing and effective tools for communicating ideas, arguments and theories. Within the discipline of archaeology, imagery and visual media are employed in almost every method of data recording or data production: encompassing journals, field logs, artefact illustrations, photography, site plans, maps, section drawings, reconstructions and the ever growing abilities of 3D digital models.

Critical assessments of the relationship between images, the archaeological process and interpretation are appearing in the discipline of archaeology but, the impact of this discussion has not yet filtered down to photogrammetric 3D digital modelling. This paper seeks to spark discussion and debate over the deeper theoretical aspects of image-based 3D digital modelling of underwater archaeological sites, focusing on ocularcentrism and the rhetoric of imagery. These theoretical issues will further be developed and discussed through the analysis of the following themes: (1) purpose, (2) methodological rigour and transparency, (3) accuracy and authenticity, (4) legacy data, (5) complementarity, (6) sustainability and access and, (7) paradata. These themes are addressed using examples from the results of the authors’ own research of image-based 3D digital modelling of the two case study sites – James Matthews (1841) and Batavia (1629).