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Antonio Vasilijević, Đula Nađ, Nikola Stilinović, Nikola Mišković, Zoran Vukić
University of Zagreb, Faculty of Electrical Engineering and Computing

Application of an ASV for Coastal Underwater Archaeology

Abstract

Coastal underwater archaeological sites are by nature dynamic, and often subject to disturbance from the action of waves, currents, sediment, and human activity. The need to document such sites comprehensively, accurately, and quickly has been the driving force behind technological advances in predisturbance site mapping since the 1960s. Certain challenges remain constant: the need for technology to be affordable and robust, with efficient post-processing as well as data acquisition times. Non-engineers must be able to interpret the results and publish them according to archaeological conventions. Large ancient shallow water port sites, submerged settlements, and landscape surveys present additional difficulties because of the volume of data generated. In this paper we present results of two expeditions to map the submerged Herodian structures at Caesarea Maritima, Israel, using a robotic vehicle, the Autonomous Surface Vehicle (ASV) Pladypos, which was developed to address these challenges. This vehicle carries high-resolution imaging and remote-sensing tools to produce photomosaics and microbathymetry maps of the seafloor, as well as performing precise geo-referencing. The results were later integrated into a GIS.

Keywords: coastal underwater archaeology, Autonomous Surface Vehicle (ASV), remote sensing, geo-referencing

1. Introduction

As much as archaeologists are eager to trade the laborious work of manual recording for more efficient methods [1] [2] [3], no single technology has demonstrated enough clear advantages for it to be widely adopted or accepted as the new standard for digital site recording. Issues of cost, accuracy, reliability, and post-processing time are usually paramount. The ability to integrate point clouds and photomosaics to produce archaeologically useful diagrams and publication quality maps is also a concern for archaeologists who typically lack the training to process the data themselves.

Although in a shallow water marine robots are not faced with the technical difficulty of operations in deep water, they ultimately need to provide fast, accurate, reliable and low-cost operation. When the area to be surveyed gets larger, or the time available for field operations becomes shorter the advantage of robotic vehicles with the ability to take thousands of instant measurements and photos along precisely georeferenced survey lines becomes clear.

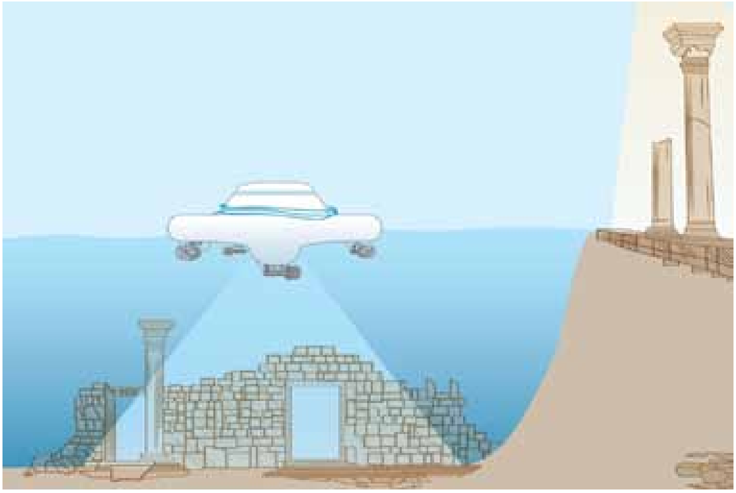

Fig. 1: Illustration of the ASV Pladypos mapping system.

The use of surface vehicles relying on a combination of RTK GPS, inertial and acoustic sensors for accurate localisation and navigation resolve the most difficult problem in underwater vehicle development. A surface vehicle also offers a fast wireless communication link with the base, unlike the slow acoustic communication channel required underwater. Fig. 1 illustrates the ASV Pladypos, an autonomous PLAtform for DYnamic POSitioning that utilizes these advantages in a new approach to map submerged coastal archaeological landscapes.

2. Experimental site and resources

2.1. Caesarea Maritima

The construction of Caesarea Maritima in the last decade of the first century BCE was described as ”triumph over nature”. The new city’s most notable feature was a large artificial harbour encompassing an area over 200,000 square meters [4]. It included massive artificial breakwaters built up from the seafloor using hydraulic cement foundations. The city itself grew to be five times the size of Jerusalem. Today Caesarea’s ruins are the centrepiece of a national park adjacent to the modern town of Qesarya. The sunken foundations of the breakwaters and quays are buried in sand and scattered afar, presenting a challenging puzzle for archaeologists trying to reconstruct harbour’s original plan.

At the time of writing, however, our map of the port is at best an incomplete patchwork. There has been no effective large-scale integration of the available bathymetric, archaeological, and sub-surface data with information from excavations and coring over the last 60 years. Moreover, the movement of sea and sand is constantly transforming the visible site, and any recording strategies must take this into account.

Until recently, however, there has not been an appropriate vehicle for conducting such a large-scale systematic underwater survey at Caesarea with the appropriate level of precision. In summer 2014 and 2015, the autonomous surface vehicle Pladypos began the first merged multibeam and photographic imaging of the sunken port structures. The goal of this ongoing project is to create the first full-scale fully-georeferenced underwater site map of Caesarea with a level of accuracy and detail normally only seen in small-scale underwater excavations.

2.2. Autonomous surface vehicle

The Pladypos is a highly manoeuvrable ASV that can be deployed with a variety of payloads for seafloor imaging and remote-sensing within conventional scuba-diving depths. During the sea trials in Israel, we tasked the Pladypos with collecting data for a complete georeferenced archaeological site map of Caesarea Maritima, an operation that could have taken years to complete with human divers.

The ASV platform PlaDyPos was developed at the University of Zagreb Faculty of Electrical Engineering and Computing, at the Laboratory for Underwater Systems and Technologies (LABUST) [5] [6]. The Pladypos is over-actuated with 4 thrusters forming an X configuration. This configuration enables motion in the horizontal plane in any direction. The current version of the platform is 0.35 meters high, 0.707 meters wide and long, and it weighs approximately 25kg, without payload. This lightweight design allows the ASV to be easily deployed and recovered. The vehicle was also designed to be quick to program for a desired mission. These features eliminate the labour-intensive mission planning, cranes, winches and research vessels that typically support the operation of larger marine robotic vehicles, making the Pladypos ideal for investigation and monitoring tasks where fast response times and mission flexibility are important.

The vehicle has a ROS based architecture (http://www.ros.org) for control, communication, telemetry and acoustic and optical data logging. The navigation sensors provide a level of localization accuracy within tens of centimetres. Payload for depth sampling in shallow water are the 128-beams Sonar (Aris 3000) or the 4-beam DVL (LinkQuest 600). As an example, at a cruising speed of 1 knot, the sonar produce a non-homogeneous point cloud density of 1200 points per square meter. For documenting an underwater archaeological landscape extending over several square kilometres, this represents extremely detailed coverage. For visual imaging, low light mono camera, the Bosch FLEXIDOME IP starlight 7000 VR, in a custom-made waterproof housing, was used.

3. Experiments and results

The Pladypos field experiments were conducted in Israel in May 2014 and July 2015. When sea conditions allowed it, the Pladypos operated in the outer Ceasarea harbour, where the water depth and reasonable seafloor visibility extends down to 8 meters. When the open sea became too rough, the Pladypos surveyed the ruins of a Roman and Crusader towers in the more sheltered area of the inner harbor, which ranges in depth from 1-3 meters. One of the inner harbor survey areas is depicted in fig. 2.

Fig. 2: ASV surveying the inner harbour of Caesarea Maritima.

During the trials at Caesarea Maritima, two types of data were collected: a georeferenced point cloud of the seabed and archaeological features using the acoustic remote sensing and visual imaging using a low light camera. The georeferenced data was acquired by performing pre-programmed lawn mower missions across the site area. The point cloud data was processed off-line to create a microbathymetry map and a 2.5D digital model of the scanned seabed. Many of Caesarea's structures are semi-buried ruins, not immediately obvious or comprehensible to a swimmer seeing them close-up underwater, where perspective is limited. However, the sand and rubble transform into recognizable architecture when reconstructed as a 2.5D digital image (fig. 3) or the georeferenced microbathymetric map as illustrated in fig. 4. Both figures were created using customized Matlab-based software developed by LABUST.

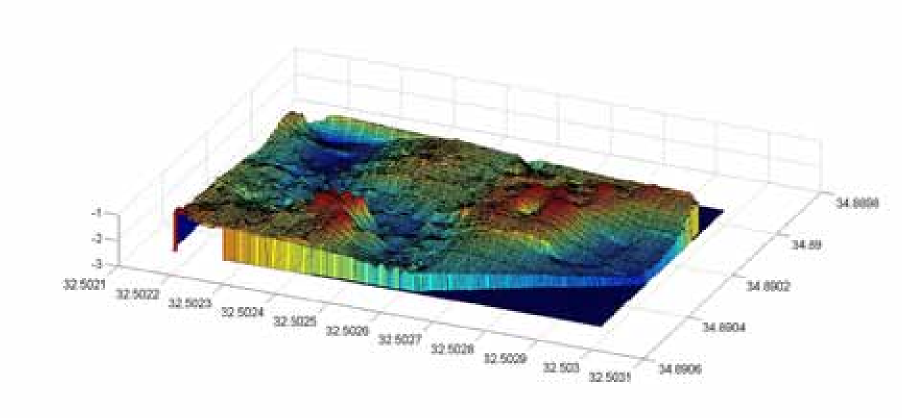

Fig. 3: 2.5D visualization of a Roman and Crusader towers foundations at Caesarea.

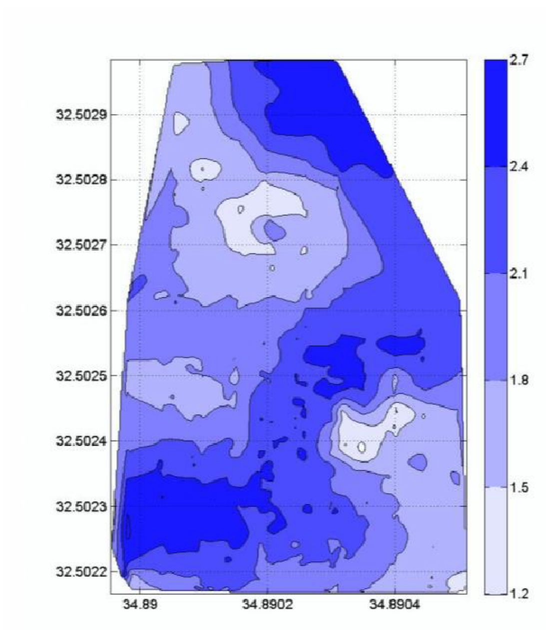

Fig. 4: Bathymetry map of Caesarea's inner harbour, showing the foundations of a round Roman and square Crusader tower.

The optical data was merged with the telemetry data to build photo mosaics or 2.5D models of the scanned transects as shown in fig. 5.

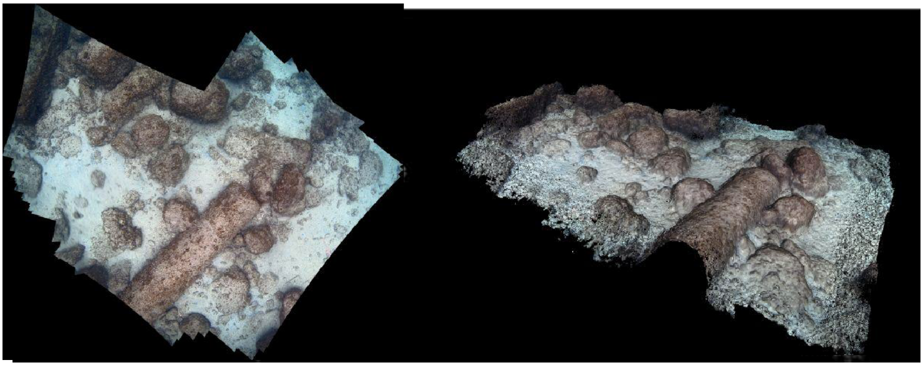

Fig. 5 Left: Photo-mosaic of the area with an ancient pillar. Right: appling the photogrammetry the same images fused with filtered telemetry generates 3D model of the same area.

Preliminary mosaics were produced on site at the land station, providing high resolution images and real-time information to the archaeologists in the field, illustrated in fig.6.

Fig. 6 Data provided to the team in the field. Preliminary visual, navigation and bathymetry data are shown respectively.

For image stitching we have tested freely available software such as Microsoft ICE and for 2.5 modelling commercial software such as Agisoft. On the final large-scale site map produced from this process, information such as the absolute positions of underwater objects and features and their dimensions can be determined within a range of centimeters.

4. Conclusion

Our expeditions demonstrated that when equipped with an appropriate remote-sensing payload, the ASV Pladypos was an efficient and effective tool for mapping a submerged coastal archaeological landscapes. The point cloud generated by acoustic sensors, DVL or sonar, was good enough for the production of local microbathymetry maps and 2.5D visualization of the seabed. Optical data, on the other hand, was processed into georeferenced photomosaics.

This interdisciplinary collaboration helped us move towards long—term goal, development of the first universal standard robot customized for underwater archaeology, versatile, robust, and affordable. The sea trials helped us to identify and address technical and application issues for future work, and experience first-hand a real archaeological mission environment. The mission itself helped to build mutual understanding of the needs of specialists in two very different fields, as well as improving their ability to communicate productively and work together towards common goals.

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Antonio Vasilijević, Đula Nađ, Nikola Stilinović, Nikola Mišković, Zoran Vukić

Primjena ASV-a za mapiranje obalnih arheoloških lokaliteta

Sažetak

Obalni podvodni arheološki lokaliteti su po prirodi dinamični usljed djelovanja valova, struja, pomjeranja sedimenta i ljudskih aktivnosti. Upravo velika potreba da se takvi lokaliteti dokumentiraju sustavno, brzo i točno potaknula je ozbiljan pokušaj primjene morskih tehnologija još od 60tih godina. Zahtjevi poput cijene i robusnosti opreme, mogućnosti brzog prikupljanja podataka i njihove učinkovite obrade i danas predstavljaju ozbiljan tehnološki izazov. Na kraju krajeva, korištenje tehnologije i interpretacija rezultata mora biti pogodna i za struke koje nisu tehničke. Članak prezentira rezlutate sa dvije ekspedicije mapiranja potopljenih dijelova Herodove luke "Caesarea Maritima" u Izraelu, korištenjem autonomnog površinskog plovila (ASV) Pladypos. Plovilo je bilo opremljeno sa optičkim i akutičkim senzorima za osjet na daljinu visoke rezolucije. Cilj je bio kreirati fotomozaike i mikro-batimetrijske karte dna potopljene luke. Točnim geo-referenciranjem prikupljenih i obrađenih podataka rezultati su na kraju integrirani u GIS.

Ključne riječi: obalna podvodna arheologija, Autonomno površinsko vozilo (ASV), senzor za osjet na daljinu, georeferenciranje