Underwater platforms and photographic techniques

Underwater platforms

Robotic vehicles are in use for seafloor surveys aleady since the late 1960's s in deep water archaeology. Submersible technology (human operated vehicles - HOV) such as Alvin and remotely operated vehicles (ROVs) are being used by marine scientistists, military and industrial users for over 40 years.

The first underwater archaeological expedition with the use of underwater vehicle was conducted in 1989 when the Jason ROV (new at that time) investigated an ancient shipwreck in the Mediterranean Sea, between Carthage and Rome (Ballard, 1993). Since then a lot of progress has been made in underwater robotics and a variety underwater vehicles has been used in shallow and deep water for different applications, (from mapping hydrothermal vents to sampling deep sea corals and investigating and excavating deep water wrecks) carrying different payloads and sensors. Since a few years a similar evolution is currently underway as scientists begin adopting AUV technology for the survey of the seafloor.

The process of underwater archaeological investigation through remote sensing is typically a nested process including wide-area survey, target identification, detailed site characterization and (possible) excavation (Mindel & Bingham, 2001).

Nowadays there are a variety of methods to investigate the seafloor including towed systems, HOV, ROV and AUV. Each system has capabilities based on the operating conditions and observation type (Bingham et al, 2012):

- Deep-tow systems require large support vessels and operate with limited survey speed and precision. The hydrodynamics and limited control make it difficult to maintain a fixed altitude and often require maintaining large distances from the seafloor in dynamic terrain. Furthermore, depending on water depth, turns can take many hours decreasing the survey efficiency dramatically
- Submersibles (HOVs) have been used for deep-sea science since the 1960's. With limited bottom time, slow speeds and human pilots, these platforms are much better suited for direct-observation, mapping and sampling than large-area, fine-resolution survey. Because of their untethered configuration they can navigate freely in the underwater environment and are ideal for survey of rough seafloors.
- Remotly operated vehicls (ROVs), using telepresent operators at the surface, eliminate the constraint on bottom time, but require a dynamically positioned support ship which can cost from tens to hundreds of thousands of dollars per day. Furthermore, because of their tethered configuration, executing surveys can be a painstaking process of moving the robot and the surface ship in concert, limiting the efficiency and effectiveness of ROV surveys.
- Compared to ROVs, deep-tow systems and HOVs, AUVs have particular advantages for underwater surveys. They can operate from modest support ships (or from shore) and can survey large areas of seafloor for 24-72 hours without returning to the surface.

Most commonly used sensors mounted on ROVs, HOVs and AUVs include navigation sensors for positioning and guidance (forward looking sonar, transponders, DVL, altimetry sonar), optical (video, photographic, stereoscopic still cameras), sonar sensors for mapping the seafloor and its features (multibeam, side scan sonar, subbottom profiler) and chemical/environmental sensors for quantifying the oceanographic environment.

HOV and ROV performed underwater expeditions have yield spectacular findings on the seafloor and produced high quality results particularly in deep and shallow water geology and archaeology. AUVs have proven their utility as a stable, controlled near-bottom survey platform. AUV platforms are capable of flying precisely controlled fixed-altitude survey lines, making full use of the sonar resolution.

<u>Collection of six underwater vehicles (HOVs, ROVs, AUVs)</u>

Fig.1: ALVIN submersible, 4500m (WHOI)

Fig. 2: THETIS submersible, 610m (HCMR)

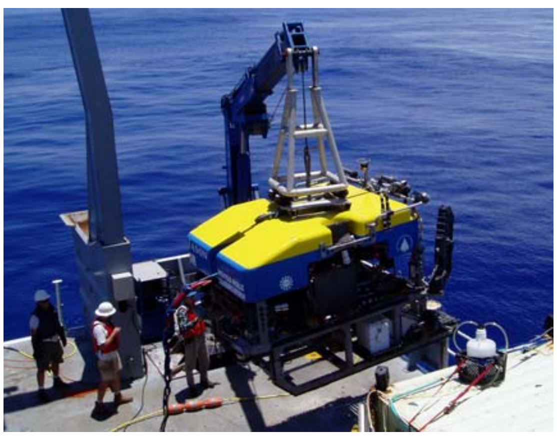

Fig. 3: Jason II ROV (WHOI)

Fig. 4: Super Achilles ROV, 600m (HCMR)

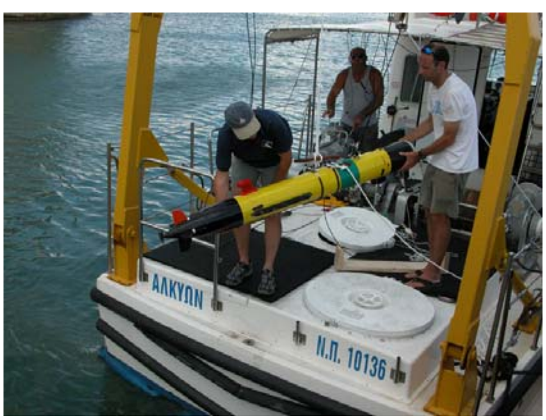

Fig. 5: REMUS 100 AUV (WHOI)

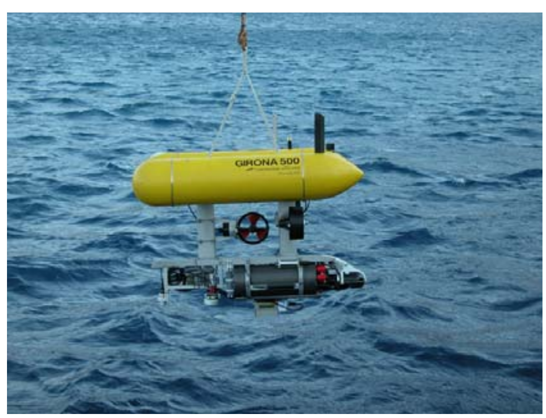

Fig. 6: GIRONA 500 AUV (Girona Univ.)

Photographic techniques

When the first wreck was found in the Skerki Bank in 1988 it was photographically documented with a 35mm film camera from the Jason ROV. The images were fairly representative of what is seen through a video camera mounted on a remotely operated vehicle in deep water: a few artifacts and some of the surrounding ocean. But such images have limitations. They give no sense of the shape and the extent of the site. Video imagery and photography from submersibles and ROVs provide evidence of a find and may even permit identification but are not of archaeological or even geological quality. They do not provide quantitative information about the size, shape and topography of a site.
The aim of photographic techniques is to produce a precise, three-dimensional map and image of the archaeological or geological site in shallow or deep water.

Since 1988 a lot of progress has been made. High precision navigation and vehicle control allows high precision positioning of the acquired photographic data. Photo- and videomosaicing techniques. Photomosaicing and videomosaicing is the technique of combining photographic images with precision positioning.
Most common techniques for automated mosaicing make use of techniques adapted from the field of simultaneous localization and mapping (SLAM), augmented with techniques from computer vision and photogrammetry, to create a consistent set of image transformations (Singh et al, 2000; Pizarro et al., 2009; Bingham et al, 2010). These techniques enable automated generation of strip mosaics, using data association between sequential images to produce a mosaic representing a single pass over the sight. Extending automated mosaicing to multiple transects in a variety of directions makes it possible to constrain the growth of positioning uncertainty through the use of vision-based constraints (Eustice et al, 2008); however, this use of the image data is still an active area of research.

The latest advance in underwater photographic techniques is the creation of 3D reconstructions in parallel with generation of the qualitative 2D photomosaic (Pizarro et al, 2009) and the development of visually augmented navigation (VAN) (Eustice et al, 2008). These techniques extract three-dimensional bathymetry estimates for the entire site based on only the collected photographic images. The VAN method employs camera-derived relative-pose measurements and provide spatial constraints, which enforce trajectory consistency and also serve as a mechanism for loop closure. This vision-based SLAM framework makes use of the relative navigation information between successive images to arrive at both a vehicle trajectory with bounded uncertainty and, simultaneously, an estimate of the bathymetry of the imaged seafloor (Bingham et al, 2010).

Most of the above improvements in underwater navigation and 2D and 3D imagery are rlated with the use of autonomous underwater vehicles, since AUVs have been proved very stable platforms in respect to ROVs and HOVs and are capable to fly at constant altitude and speed above the seafloor.
One of the few applications of seafloor imagery performed by AUV for mapping submerged landscape features took place recently close to the drowned Pavlopetri city in Southern Greece. A shallow water Iver2 AUV in photo-mapping configuration performed the survey of three bands of submerged beach rocks at depths between 2m and 5 m. The navigation data together with the stereo imagery was combined using a form of Simultaneous Localization and Mapping (SLAM) (Pizarro et al, 2012).

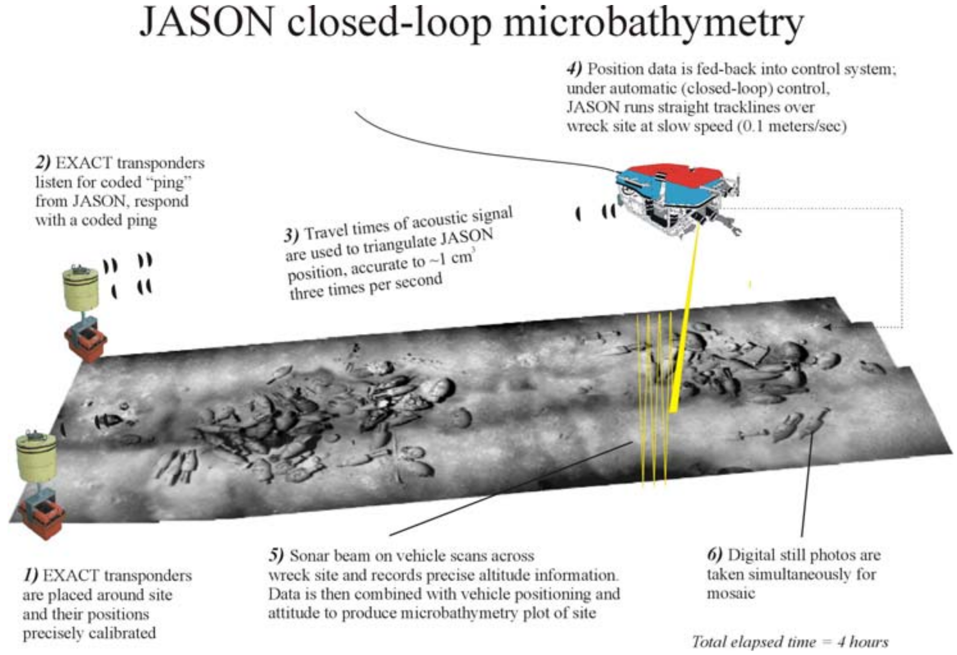

Fig. 7: Jason ROV conducting photographic survey ("closed loop control") above Wreck D in Skerki Bank in 1997 (drawing by D. Mindel from Oleson & Adams, 2004)

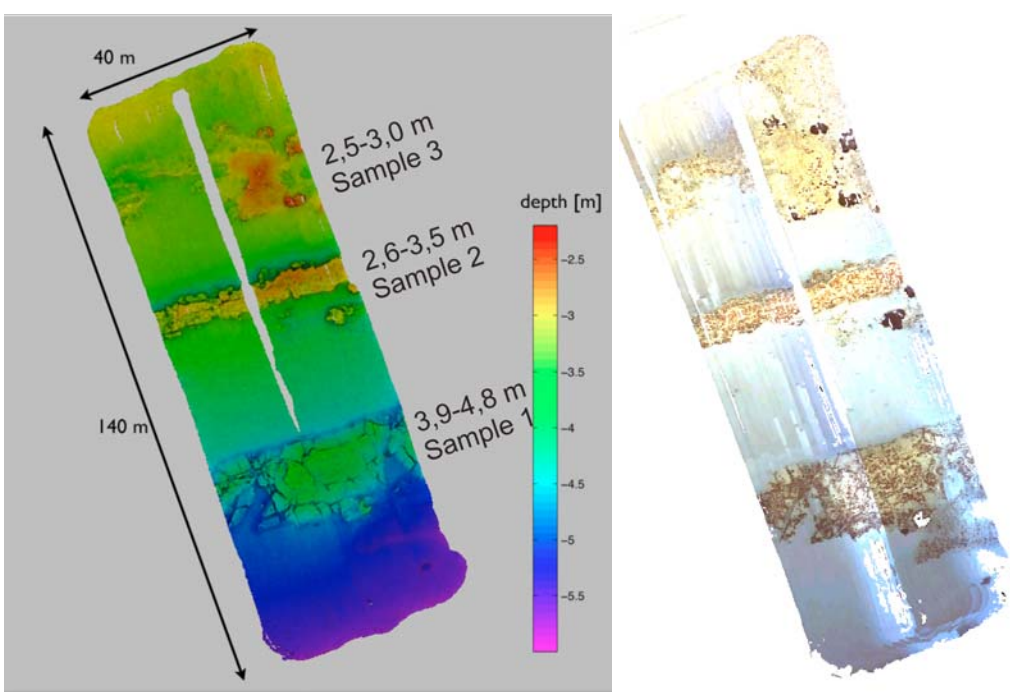

Figure 8: Two views of the 3D reconstruction from AUV-conducted optical imagery, Vatika Bay, SE Peloponnese, Greece. 3D structure shaded by depth (left) and with the optical images projected back onto the 3D surface (right) to form a 3D mosaic. The three bands of beach-rock are clearly visible. Core samples depths are indicated (above left) (Pizarro et al, 2012).

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