Autonomous Geotechnical Surveys with Autonomous Marine Vehicles: the WiMUST project

Enrico Simetti, Giovanni Indiveri, and Giuseppe Casalino
DIBRIS & ISME
University of Genova
Genova, Italy
enrico.simetti@unige.it, giovanni.indiveri@unige.it, giuseppe.casalino@unige.it

***Abstract*—This extended abstract presents the main results of the H2020 WiMUST project, whose goal was the development of an autonomous system to execute geotechnical surveys in shallow water.**

***Index Terms*—autonomous surface vehicles, autonomous underwater vehicles, autonomous marine vehicles, geotechnical surveying, geotechnical surveys**

I. Introduction

Marine robotics is developing faster than ever, as confirmed by several innovative works in perception, navigation and control. Among the new applications enabled recently (see for example the survey [1] for more insights), the characterization of the subbottom has received great attention, as demonstrated by a recent Japanese project in multi-stage seismic surveys with AUVs, with a particular focus on the exploration and mapping of seafloor massive sulphides [2].

Seismic surveying was also the focus of the H2020 funded WiMUST (Widely scalable Mobile Underwater Sonar Technology) project [3]. Conventional seismic surveys are conducted with a large manned vessels towing both the acoustic sources and kilometers of streamers with hydrophones. The methodology of acquiring a so-called seismic image is based on the fact that the acoustic wave generated by one of the source propagates in the water, reaches the seafloor, and then bounces off sub-bottom formations. The so reflected acoustic waves travel back toward the surface, where they are recorded by the hydrophones installed within the streamers. Given that both the sources and the hydrophones are physically connected and controlled from the ship, their signals can be accurately time synchronized, allowing data to be post-processed to create the aforementioned seismic images. Experts can then analyze these images to infer on the contents of the layer underneath the seabottom.

The key idea of the WiMUST project was to entirely substitute the role performed by the manned vessel with multiple smaller robots, allowing these type of surveys to be executed in shallow water with much more flexibility. In particular, Autonomous Underwater Vehicles (AUVs) had the role to tow the streamers with the hydrophones. Of course, given their towing capability certainly much more limited than of a manned ship, each AUV was towing a short streamer, with a limited number of hydrophones. Therefore, multiple AUVs were employed to enable for a sufficient coverage of the seafloor. The acoustic sources (sparkers in the WiMUST project) were instead carried by Autonomous Surface Vehicles (ASVs), which were also providing localization data to the AUVs. The major advantages that the approach pursued in WiMUST has are recalled in the following:

- the need of a large manned vessel is lifted;
- shallow water operations are easier to be executed, due to the limited logistic requirements;
- the distributed acoustic antenna can be reconfigured on line, a unique feature of the WiMUST approach over the conventional one;
- the antenna can fly very close to the seafloor, while conventional survey have the hydrophones located always in the proximity of the surface. The flexibility of placing the streamers anywhere on the water column allows for new antenna geometric configurations, while having the streamers near the bottom could deliver improved signal to noise ratios;
- the risk of a fault is spread on many AUVs, whereas in traditional methods everything is towed by the ship and when one equipment has a fault, the survey itself is stopped.

II. Major Challenges

Despite the attractive features highlighted in the introduction, replacing a manned vessel with surface and underwater robots does not come without costs. Several challenges need to be solved to put such a system in place.

A. Navigation

AUVs do not have access to GNSS signals, therefore to be able to maintain their relative positioning while following the acoustic sources, a framework for their localization must be setup. Furthermore, AUVs can communicate between them and to the surface vehicles only through the acoustic channel, which allows only limited amounts of information to be sent and received in a time-shared fashion. The WiMUST project solved this challenge by equipping the surface vehicles carrying the sources also with two acoustic modems, one at high-frequency (HF) and one at medium-frequency (MF). The

This work was supported by the EU through the Horizon 2020 Research and Innovation Programme under grant agreement n. 645141 (WiMUST project).

MF one was dedicated to the navigation task, i.e., it was used by the ASVs to periodically broadcast their GNSS position, therefore acting as moving beacons of a long baseline navigation solution. Note that, to have a scalable system, AUVs were silent on this channel, with only the ASVs periodically transmitting in preallocated time slots. However, to allow AUVs to compute ranges to the ASVs without resorting to time-wise expensive (and not scalable) two ways localization technique, another challenge needed to be solved, i.e., accurate synchronization.

B. Synchronization

Clock synchronization was another key issue of the WiMUST project. In conventional seismic surveying, data collected by the hydrophones can be precisely correlated to the time instant of the acoustic emission as everything comes from the same centralized system. To solve this issue, the WiMUST project integrated Clock Scale Atomic Clocks (CSAC) into the acoustic modems electronics. This also allowed the modems to be able to precisely compute the time instant of arrival of any incoming packets, allowing to compute the range from the source, knowing the time division scheme and assuming straight propagation of acoustic waves. The latter assumption was fine in the WiMUST context, as AUVs were distant only tenths of meters from the ASVs. Detailed results on the precision and time drift of the WiMUST solution are reported in [4].

C. Control

Managing 3 surface vehicles and 4 underwater vehicles at sea is no easy feat. The control of the WiMUST fleet made use of three different control techniques during each deployment. First, all the vehicles are deployed at sea, and put into a hold state. Then, a “go-to-formation” planner computes trajectories to be tracked by the fleet, allowing them to reach the initial formation at the same time. At this point, the AUVs can dive underwater, while the surface vehicles cooperatively follow the mission’s path, using a technique called “Cooperative Path Following” (CFP) maneuver. The AUVs, now underwater, start receiving navigation information from ASVs and perform and they track the leader of the surface formation using a “Coordinated Trajectory Tracking” (CTT) algorithm, indirectly maintaining their relative position in the formation.

III. Experimental Results and Conclusions

To reach the ambitious goal of the WiMUST project, several integration campaigns at sea were necessary. A first, week long, full scale integration campaign was held in November 2016, in Sines, Portugal. A second, two-weeks long integration campaign was held in Sines, Portugal in July 2017. The major result of this integration campaign was that the acoustic sources were successfully installed, along with their power supplies and generators, on top of the two ASVs used in the project. To the best of our knowledge, this was the first time when a small scale seismic survey was carried with acoustic

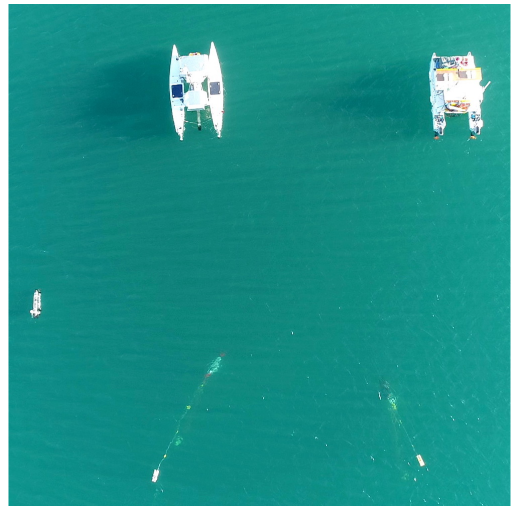

Fig. 1. Aerial view of one of the WiMUST experiments

sources carried by autonomous surface vehicles. Three further major field campaigns were necessary to complete the WiMUST system integration.

The final demonstration survey took place in in the Atlatic Ocean, just outside of the Sines, Portugal harbor. The final experiment consisted of a 2 hours and 15 minutes long survey in open sea, covering an area of approximately 100 m x 200 m. From a seismic user point of view, the main results are the seismic images published in [3], which cover the survey area of approximately 20000 m^2 and have a 1 meter bin size and up to 10 ms two way time penetration below the seabed [3]. The images are a clear proof that the main requirements to collect valid seismic images were met by the WiMUST system, as any major problem would have corrupted and compromised the image in a clear manner.

Acknowledgment

WiMUST was an outstanding research and development cooperative effort involving many institutions and researchers in Europe. Our sincere thanks go to all the members of the WiMUST consortium for their tireless commitment, and contributions to the project.

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