Geophysical Surveying with Marine Networked Mobile Robotic Systems: The WiMUST Project

[Extended Abstract] *

Giovanni Indiveri
Dipartimento Ingegneria Innovazione
Università del Salento, Lecce, Italy
giovanni.indiveri@unisalento.it

João Gomes
Institute for Systems and Robotics
Instituto Superior Técnico
Universidade de Lisboa, Portugal
jpg@isr.ist.utl.pt

ABSTRACT

The WiMUST proposal (Widely scalable Mobile Underwater Sonar Technology) has been favorably evaluated by the European Commission and the project is expected to kick off in the near future. It aims at expanding and improving the functionalities of current cooperative marine robotic systems, effectively enabling distributed acoustic array technologies for geophysical surveying. This paper describes the main features of the envisaged developments, with a focus on communication and networking issues.

1. INTRODUCTION

Characterization of the upper sub-bottom layer is a prerequisite for any type of underwater construction, from peers and oil rigs to cables and pipelines, with the intent of identifying any possible geo-hazard, steep slope, escarpment, or wreck. Geo-seismic surveys are also routinely performed during all stages of exploration and development of oil and gas sub-bottom reservoirs, and for monitoring the conditions of offshore critical structures and pipelines. Traditionally, seismic reflection surveying is performed by towed streamers of hydrophones acquiring reflected acoustic signals generated by acoustic sources (either towed or onboard the same vessel). These sets of linear arrays are long, extremely cumbersome to operate, and difficult to steer accurately along desired paths (Fig. 1).

Recent developments have shown that there is a vast potential for groups of marine robots acting in cooperation to drastically improve the toolbox available for ocean exploration and exploitation. The vision underlying the WiMUST proposal is that of developing advanced cooperative and networked control/navigation systems to enable a large number (tens) of marine robots, both on the surface and submerged, to interact by sharing information as a coordinated team. Such teams of autonomous robots equipped with acoustic sensors can replace conventional streamers, thus physically decoupling the acoustic source from the receivers and enabling them to follow desired paths more accurately, in the presence of external environmental disturbances. By allowing the group of (surface and submerged) vehicles to change their geometrical configuration, the geometry of the "distributed streamer" trailing the emitter may be adjusted with great flexibility, something that has hitherto not been achieved in practice and holds much potential for ocean surveying.

*See also "additional authors" section before the references.

WUWNet '14, November 12–14, Rome, Italy

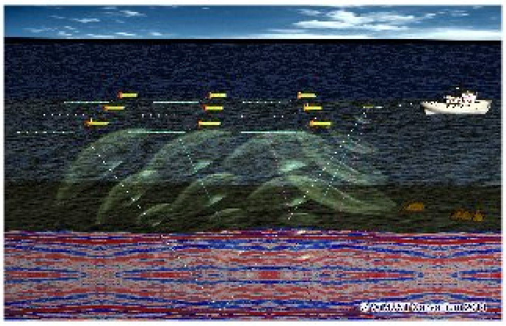
Figure 1: Conventional geophysical surveying using long lines of towed streamers

The project brings to the core of the proposed R&D effort a group of research institutions, geophysical surveying companies and SMEs with a well proven track record in a vast number of areas that include autonomous adaptive and robust systems, communications, networked cooperative control and navigation, and marine robot design and fabrication (See affiliations in "additional authors" section).

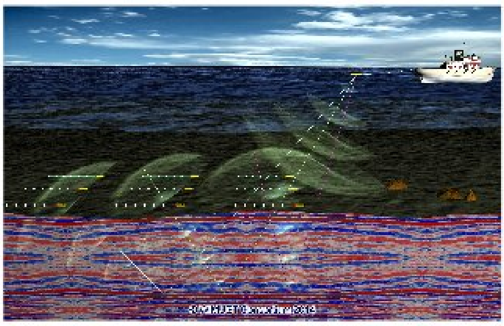
2. CONCEPT AND APPROACH

The overall objectives of WiMUST are pursued with a dual-step procedure to tackle the underlying technical and methodological problems, namely, by considering 2D and a 3D operative scenarios, with an increasing level of complexity.

In 2D, acoustic acquisition is performed by a formation of cooperating autonomous surface vehicles, each one towing a relatively short streamer with hydrophones. From the



(a)



(b)

Figure 2: Geophysical surveying using a team of autonomous vehicles (a) 2D surface configuration (b) 3D submerged configuration

functional point of view, such a scenario is similar to the way geotechnical surveys are currently performed, i.e. with streamers towed, at the surface, by a vessel (Fig. 2a). However, it provides greater flexibility and ease-of-use over conventional systems. In 3D, the sensing nodes will be submerged and towed by a team of autonomous underwater vehicles. Additional network topologies can be obtained, as nodes may be positioned at different depths. Potential performance gains arise, e.g., from reducing the distance of the sensing array to the sea bottom (Fig. 2b).

In the 2D surface scenario, where radio signals are available, vehicles can navigate through GPS and can easily exchange information via broadband wireless radio links. This makes it clearly simpler than the 3D scenario, where acoustic transmission must be used with orders of magnitude lower data rates. Furthermore, in 3D vehicles must control their relative positions and attitude even in the absence of a global positioning information, as it is available only with low rate, either through signals exchanged with surface vehicles, or through surfacing maneuvers to directly obtain GPS fixes.

In 2D the focus will be to develop and validate two fundamental ingredients of the WiMUST system: Distributed acoustic sensor arrays; cooperative marine vehicle navigation and control techniques. In the 3D scenario, where the underwater vehicles shall mainly navigate with traditional equipment such as AHRS, IMU, depth sensors, DVL, as well as communication mechanisms, the research effort will mainly focus on important topics related with: underwater communications; cooperative navigation; marine vehicle motion control.

3. PUSHING THE ENVELOPE

The proposed work is related to several recent international efforts in the areas of underwater robotics and networking. This overview focuses on EU FP7 project MORPH [1], which advances the concept of an underwater robotic *supra-vehicle* composed of a number of collaborating mobile robot-modules, carrying distinct but complementary resources to carry out survey-like missions more effectively than using a single complex monolithic vehicle. These modules operate at short/medium range and are kept in a tightly-coupled formation through a mix of acoustic communication/networking and visual cues [2].

While WiMUST and MORPH share the common objective of endowing underwater robot teams with adaptive and reconfigurable behavior, the WiMUST system will have a localization, navigation and motion control system for the vehicles that is structurally intertwined with the functionality of the geo-surveying sonar. In particular, significantly more precise positioning of vehicles/hydrophones and clock synchronization will be required to attain a level of spatial resolution that is comparable to that of current centralized surveying systems. Compared with MORPH, the number of vehicles will be larger, and they will be operating farther apart. In the 3D scenario this translates into longer propagation delays and more intensive use of the common underwater acoustic channel (for ranging, synchronization, and coordination, as well as generic data transmission). Given the very scarce available bandwidth in acoustic channels, accommodating these more ambitious communication requirements constitutes a major challenge.

4. ACKNOWLEDGMENTS

Preparation of this work was partially supported by the Portuguese Fundação para a Ciência e a Tecnologia (project PEst-OE/EEI/ LA0009/2013) and EU FP7 project MORPH (grant agreement no. 288704).

5. ADDITIONAL AUTHORS

Additional contributing authors in the WiMUST consortium: Gianluca Antonelli (Interuniversity Centre on Integrated Systems for the Marine Environment (ISME) & University of Cassino, Italy), Andrea Caiti (ISME/University of Pisa, Italy), Giuseppe Casalino (ISME/University of Genova, Italy), António Pascoal and Luís Sebastião (ISR-IST/ University of Lisbon, Portugal), Sérgio Jesus (University of Algarve, Portugal), Daniel Polani (University of Hertfordshire, UK), Konstantin Kebkal (EvoLogics GmbH, Germany), Andrea Caffaz (Graal Tech S.r.l., Italy), Habib Al-Khatib (CGG Services SA, France), Ivan Bielic de Jong (Geo Marine Survey Systems B.V., The Netherlands), Henrique Duarte (Geosurveys, Portugal).

6. REFERENCES

[1] J. Kalwa et al. The MORPH concept and its application in marine research. In *Proceedings of MTS/IEEE OCEANS'13*, Bergen, Norway, June 2013.

[2] V. Ludovico, J. Gomes, J. Alves, and T. C. Furfaro. Joint localization of underwater vehicle formations based on range difference measurements. In *Proceedings of the 2nd Underwater Communications Conference (UCOMMS'14)*, Sestri Levante, Italy, September 2014.