“Marine Autonomous Observing Systems: Scientific Requirements and Technological Opportunities” Workshop

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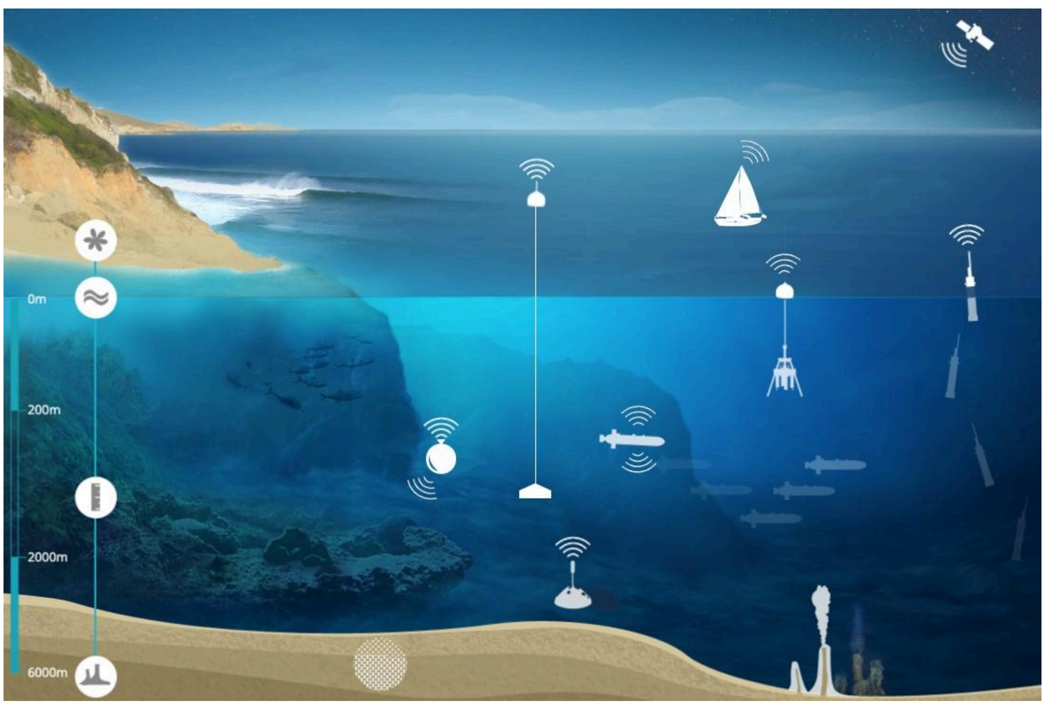
White Paper

Communication and positioning



Guidelines:

- **Coordinator / Contact:** Olivier Soubigou, Séverine Martini
  Please send email to coordinators to notify your interest for this section
- **Objective:** report on SMA2M “table ronde” and highlight technological opportunities and prospects.
- **Length (soft limit)**: 4 to 6 pages, figures included
- **Structure**: each subsection (e.g. “Energy and reliability”, ...) should adopt the following structure:
  - Background / introduction
  - Item 1 (e.g. “Fixed-point observatories”):
    - Background
    - Description of relevant opportunities with expected outcomes
  - Item 2…
- **Highlighting opportunities:** opportunities should be highlighted with **bold, red fonts**
- **Table:** fill the sheet entitled “technological opportunities” in the following spreadsheet:
  - https://docs.google.com/spreadsheets/d/1aIDtzbTsZqSEzydYGZsivjrf-04ci0UOyyGddkv6e_M/edit?usp=sharing
  - The data will be used to assemble a visual synthesis of these sections
- **List contributors:** early in the document
- **References:** provide pointers/links toward relevant papers, projects, efforts.
- **Keywords:** each subsection should have a list of keywords related to either autonomous platforms relevant features, characteristics.

discussion / general comments:
(please identify yourself)

1.1. Communications et Positionnements

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Keywords :

Positionnement, communications par ondes radio, communication acoustique, communication optique, communication surface Vs sous-marine

Introduction

Les systèmes de positionnement et communication présentent de nombreuses similarités et interactions dans le domaine des Systèmes de Mesures Autonomes. En effet, les technologies utilisées se basent sur l'acoustique, l'optique ou les ondes radio pour répondre aux besoins fonctionnels des systèmes déployés dans le but d'observer le milieu marin.Avec l'avènement de nouvelles technologies d'engins, le système de positionnement de ces véhicules marins est très important pour déployer les systèmes de mesure sur les sites visés par l'étude scientifique, que ce système soit statique ou mobile. La position précise des mesures réalisées par le système autonome permettra l'interprétation des données acquises.

Le choix d'un système de communication, qui permettra non seulement de récupérer les données d'un système autonome mais également de le maintenir en condition opérationnelle, est lié à sa position et son bon fonctionnement en dépend souvent.

1. Le besoin scientifique / utilisateur face aux technologies disponibles actuellement

1.1. Introduction / background

1.2. The use of satellite data from the surface to the seafloor. Information transfer on a long range underwater and with very high resolution. Valerie Ballu

Being able to map deformations under water is absolutely essential in geofor us, to understand the phenomena but also if we have real time, to be able to issue alerts in the long term. What we are looking for are deformations of the order of a cm or displacement speeds of the order of a cm/year.

The challenge is great... The ideal would be to be able to do what we do on land with GNSS (or GPS) and position points on the bottom in a global system. The problem is that the electromagnetic waves used in GPS are not transmitted underwater and we have to combine surface GPS and underwater acoustics with a surface relay platform, boat, drone or buoy.

With acoustics, we see the very direct link between communication and positioning…. we use the same kind of waves! with common issues of range, resolution, multiples, signal analysis….

We could add that even when the measurement is done differently, for example with pressure sensors for vertical deformation, there is a need for bottom-surface communication if we want to monitor in real time or almost.

Specialized in marine geophysics, I am particularly interested in the measurement of deformations at the bottom of the sea as indicators of processes that take place at depth, in connection with earthquakes or volcanoes for example. Plate tectonics, crustal deformation.

Description of relevant opportunities with expected outcomes

1.3. Radio communication between moorings. Communication at air/water interface, issues with small sensors up to 5-10m depth underwater. Alain Gaugue

1.4. Swarm of drones, for hundreds of robots (underwater or surface drones). Radio or acoustic telecommunication. Thomas Le Mezo, Christophe Laot

The development of new types of autonomous underwater robots that use marine currents in an opportunistic way to travel long distances while consuming a minimum of energy. These robots are intended to be used in packs and require new innovative control algorithms. Robotics applications are moving towards the use of packs of sometimes heterogeneous robots that collaborate with each other (several submarines with a surface robot for example). This requires coordinating them, locating them and ensuring a link between them and with a command center (C2) to ensure the proper conduct of the mission, safety and quality of the data collected.

https://www.youtube.com/watch?v=9xGeTaG2exk

For positioning, these robots use satellite positioning signals (RTK, conventional GNSS) and sometimes underwater positioning systems (USBL). While for communication we are mainly working with satellite communication system (Iridium), sometimes commercial systems (3G/4G), Wifi type connection and Lora type network.

This swarm of drones is more designed to be a proof of concept and not a finished product. The questions of energy autonomy are generally less important, even if the increase in the duration of the missions sometimes poses a problem. Generally speaking, we are often constrained by the size of the equipment to be integrated since we are aiming at applications with robots in packs which are therefore often small (size of antennas, signal processing boxes, etc.). The cost of the technologies is often an obstacle since we are targeting applications where several hundred robots must be equipped. Finally, for a large part of the applications, the localization (mainly acoustic) and communication technologies are reaching their performance limits and are for the most part not designed to work with a pack of robots or to use their possibilities.

There is currently a fundamental movement towards miniaturization of the systems to be integrated. The hardware is therefore evolving in the right direction, and prices are starting to be more affordable. However, still too few solutions take advantage of the use of a pack of robots. This is the case for example for acoustic systems. In the lab, we are designing localization methods and algorithms to overcome some of these problems: more interest from the industry towards these methods and new challenges would be useful.

1.5. Developpement for systems of biologging (seals, turtles, birds..) and deployments away from shores, short transmission time at the surface.

Christophe Guinet

Biologging (i.e. deployment of behavioral and environmental recorders on animals to study their ecology, physiology and/or environment) and biotelemetry (radio transmission of recorded and previously reduced data) approaches allow to study the ecology of marine mammals at sea in relation to the oceanographic context. One example is the elephant seal ecology and bio-acquisition of physical (temperature, salinity, light), biogeochemical (chlorophyll-a, dissolved oxygen) and biological (bioluminescence, assessment of intermediate trophic levels by active and passive acoustics...) parameters. Elephant seals have thus become a major source of information on the Southern Ocean.

For this purpose, there is a need to develop and implement numerous sensors that are integrated into recorders and/or Argos tags. Indeed, the Argos technology and more recently the GPS technologies (Fast-loc approach with post-calculation of the position) allows an acquisition of satellite constellations in view in a few milliseconds.

The Argos system (alone or coupled with GPS) is the only one we can use on animals that we are not able to re-capture. However, this system does not allow for extremely accurate positioning of the animal (unless coupled with GPS).High frequency GPS positioning requires the recovery of the recorder.

One improvement would be a reactive and robust Argos tracking thanks to the KINEÏS constellation (25 nanosatellites) and the implementation of upward and downward communication to optimize data transmission and minimize energy consumption by the beacons and thus their lifespan (each Argos transmission from the beacon is then efficient, which is not currently the case).

1.6. Argos / Iridium: what is the maturity of these technological systems? Few evolution sfor the last few years. Michel Calzas

2. **Les opportunités technologiques : Les technologies en rupture**

2.1. Introduction / background

2.2. Tomorrow's tools / opportunities / technological breakthrough. What are the solutions studied and in disruption of technologies in underwater communication systems?

2.3. Satellite technologies. Positioning and communication accuracy. Jean-Luc Issler

Multi GNSS system positioning of the surface drones, boats, drone, buoy and animals provide more accuracy and robustness. GALILEO is presently the most accurate system among GPS, GLONASS, BEIDOU and GALILEO. Alternatively to RTK, the Precise Point Positioning, in particular when using undifferentiated integer carrier phase ambiguity resolution techniques, allows very high precision in real time. The more accurate PPP techniques are presented in the following websites:

http://www.ppp-wizard.net/

http://www.geoflex.fr/

Future improvements of GNSS high accuracy positioning can be expected from the combination of MEO (Medium Earth Orbit) and LEO (Low Earth Orbit) GNSS constellations. This combination should bring cm real time absolute positioning accuracies with a very short convergence time, everywhere and anytime (which is not the case for the MEO GNSS constellation alone).

ARGOS and KINEIS (25 LEO satellites provided with ARGOS-like payloads, and also AIS payloads for a part of the satellites) are and will be also good means for animal tracking, and other trackings. The KINEIS constellation, with its 25 satellites to be launched soon, will provide an important reactivity, to know the trackings, without significant delay.

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2.4. Last developments of acoustic communications. Christophe Laot

Télémétrie (lien de contrôle et mesure) et positionnement

Bas débit (<100bps) – longue distance (>10km)

Haut débit (>10kbps) – faible et moyenne distance (<2km)

Modélisation / caractérisation du canal

Protocoles réseaux – Multiples utilisateurs

Acoustics is the only way to transmit information underwater at distances of several hundred meters and in an omnidirectional manner, a technique well adapted to underwater drones. Several acoustic communication systems (modems) are available on the market offering different data rates and ranges for shallow and deep water transmissions. These communications systems can be used to transmit data (text, images, etc.) or telemetry information. However, the vast majority of these communication systems fail when the mobiles move at speeds greater than a few knots. Moreover, these systems are extremely sensitive to acceleration, engine noise, etc. From an academic point of view, it is a challenge to establish robust and secure communications. This requires the implementation of advanced techniques in signal processing and experiments at sea to validate the proposed concepts

The limits are related to the physical parameters of the propagation channel: time, frequency and space selective channel, wave speed in water (high propagation time), attenuation depending on the wave frequency and distance, impulsive noise, … We can also note material and operational constraints: cost of transducers, limited bandwidth of projectors, complex experiments at sea and subject to administrative restrictions, ...

In the future, such technologies require innovations such as low cost and easily deployable applications, feedback from sea trials, self-adapting systems to the environment, image or video transmission.

2.5. Use of magnetism and electromagnetism to transmit information.
Radio-transmissions in the maritime environment for remote control

of drones and real time monitoring of the coastline. Alain Gaugue

2.6. Increasing development of optical communication. Ali Khalighi

Optical wireless transmissions are based on the characterization and modeling of the aquatic "channel", data transmission (coding, modulation, etc.), solutions to increase the range and throughput of these links. It also involves the development of techniques to improve link robustness against pointing errors. One of the main developments in the last 20 years is the laser communication systems (FSO: Free-space optics). Optical wireless also includes LoRa and 3G/4G/5G networks.

The strongest constraints concern the limited range (also related to energy consumption), and the limited accuracy of localization in the water of the nodes/drones (thus, pointing errors).

The current and future applications and improvements are techniques to achieve robust, long-range, and very high-speed optical links. There is also a strong interest in air-sea links and interconnections with other terrestrial/satellite networks.

3. Les opportunités technologiques : Les difficultés

3.1. Introduction / background

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3.3. Environmental impacts Ali Khalighi, Alain Gaugue

3.4. Software interface Michel Calzas

4. References

Keywords :

Positioning, radio wave communication, acoustic communication, optical communication, surface Vs underwater communication

Introduction

Positioning and communication systems present many similarities and interactions in the field of Autonomous Measurement Systems.

The technologies used are based on acoustics, optics or radio waves to meet the functional needs of systems deployed to observe the marine environment.

The positioning system of a marine vehicle is very important to deploy the measurement systems on the sites targeted by the scientific study, whether this system is static or mobile. The precise position of the measurements made by the autonomous system will allow their interpretation.

The choice of a communication system, which will allow not only to recover the data of an autonomous system but also to maintain it in operational condition, is linked to its position and its good functioning often depends on it.

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8. **References**