Localization and control of a chain of underwater robots in confined underwater environments

SUPERVISION

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SUBJECT

Although autonomous submarines are now able to perform image mosaicing in open water environments, the exploration of confined environments (cenotes, caves, wrecks, mines, ...) remains a challenge for underwater robotics. The exploration of submerged mines has been the subject of several recent H2020 projects [1] [2] whose objectives included assessing the integrity of structures in order to prevent their collapse and estimating the quantity of ore resources, but none of these projects have focused on the management of the cable that connects the robot to the surface.

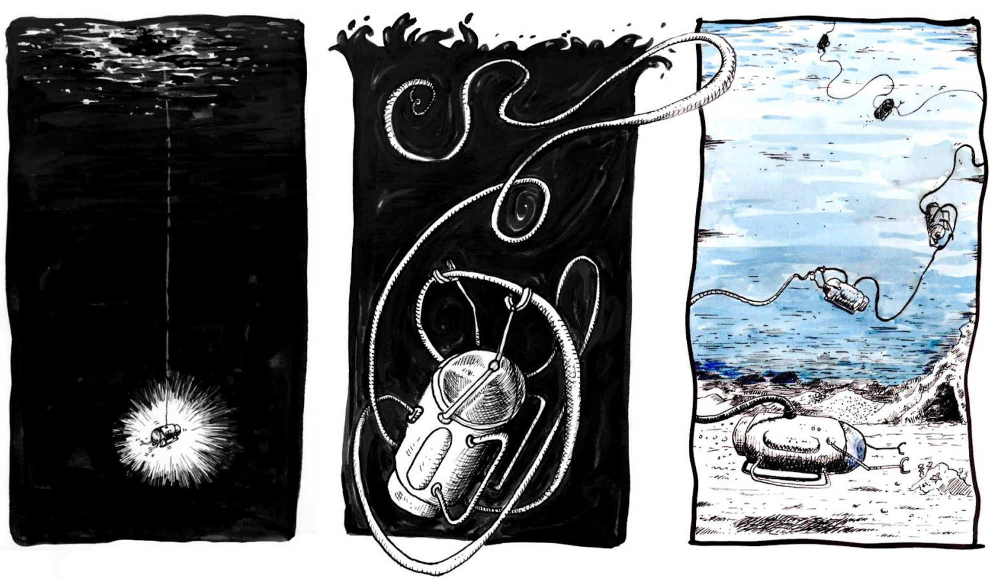

Figure 1: In underwater robotics, electromagnetic waves are absorbed in the first few meters, isolating the robots from the surface vessel. The only way to maintain high-speed communication in real time is to use an umbilical. 2. This cable, deployed over a long distance, can disturb the robot's control. 3. We propose to add intermediate mini-submarines regularly spaced on the cable to control its shape, this is the CHAIN OF ROBOTS concept.

[1] https://www.unexmin.eu/ 2016-2019 An autonomous underwater explorer for flooded mines, qui sera suivi par unexup à partir de 2020

[2] http://vamos-project.eu/ Viable Alternative Mine Operating System

The exploration of confined underwater environments requires long dive times and permanent adaptation of movements according to the environment discovered. Only remotely operated vehicles (ROVs) combine these two skills. Indeed, divers have relatively short dive times and can only access limited depths. As for the AUVs (autonomous underwater vehicles), without umbilicals, and despite advances in artificial intelligence and energy storage, they are still very limited in terms of dive time and decision making. ROVs benefit from an unlimited energy supply and the support of a teleoperator who co-analyses the sensory data transmitted in real time via the cable.

Far from being a disadvantage, the cable acts as a backup in allowing to mechanically retrieve the robot and can be used as a breadcrumb trail to find the exit of the explored network. However, to deploy a cable system in a confined environment, a method must be developed to control the position of the cable to prevent it from becoming entangled or jammed. Automatic cable management is a problem that has received little or no attention so far (for ROV operation, a second operator supervises cable deployment).

We propose to control the cable by adding winding systems and intermediary mini-robots evenly distributed over the cable run. We have named this concept ROBOT CHAINING.

This project is one of the research axes of the Cosmer laboratory which has already received support via two theses. In a first thesis [Laranjeira2017, Laranjeira2018, Laranjeira2019, Laranjeira2020], we have demonstrated that it is possible to control a pair of robots linked by a heavy cable using the image of this cable filmed by the cameras embedded in the system. A second thesis, currently undergoing, focuses on the physical modeling of a cable and aims at developing a dynamic tension control system through the design of an active reel [Tortorici 2020].

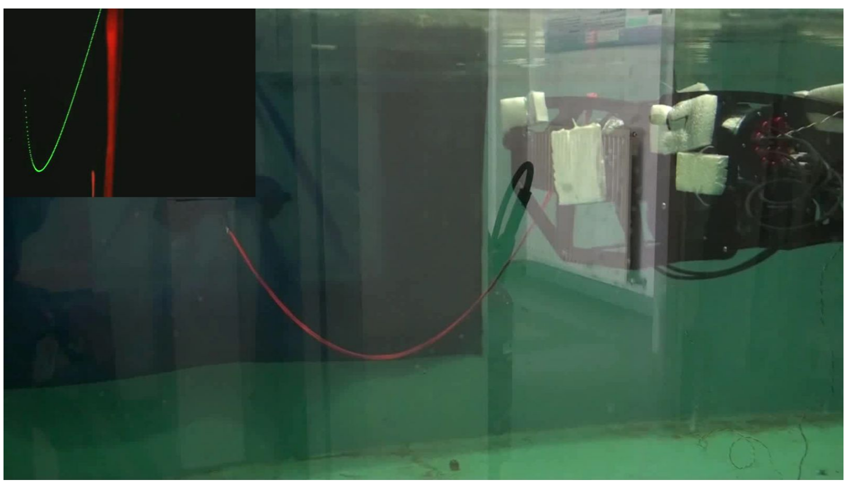

Figure 2 : Control of an underwater robot (main view) based on images of its mooring (top left view).

The subject of the thesis is an extension of Matheus Laranjeira's thesis. **The objective is to control a chain of robots in order to explore and map confined submerged spaces:**

1. **SLAM: Mapping of the environment and simultaneous estimation of the position of a subsea robot:** the first work consists in evaluating and adapting algorithms for simultaneous mapping and localization for marine environments [Vidal2017, Weidner2017, Meilland2013, Mahe2019, Rahman2019]. Terrestrial localization techniques can be applied to the underwater environment but require adaptations. Indeed, they are developed for structured and static environments, such as city streets or the interiors of buildings. In an underwater environment, much of the scene is in motion and, in the case of natural environments, there are fewer structured contours.

What's more, the imaging pattern differs in water: absorption and backscattering parameters are added to the usual pattern of light wave propagation in air. This part will be based on an adaptation of Andrew Comport's work for aerial cameras.

2. **T-SLAM: Simultaneous Co-construction of the map and estimation of the chain parameters:** the second step is to simultaneously deploy the underwater SLAM on all the modules evenly distributed on the robots chain. The sensors (cameras, inertial units, depth gauges) are distributed along the cable and thus constrained by its shape. They allow us to co-construct a map of the environment and to estimate the parameters of a model of the complete system. The constraints imposed by the shape of the cable and its length can be merged with the information acquired by the sensors to refine the resulting map: T-SLAM (Tethered Simultaneous Localisation and Mapping) [McGarey2017]. This second part will be based on the results obtained at the COSMER laboratory on the modelling of an umbilical [Laranjeira2020, Tortorici 2020].

3. **Path planning and control of a robot rope in a confined environment:** in the chain of robots, if the leader is controlled by an operator, the movements of the intermediate robots and the cable must be automated. It is then necessary to control a mixed cable-robots dynamic system including a dynamic model of the cable and the management of platooning effects (accordion effects due to delays in the reactions of each module, equivalent to the effects observed in vehicle trains). This part will be based on the first results of the control of a string of two vehicles obtained during Matheus Laranjeira's thesis [Laranjeira2020] and on the maps made in points 1 and 2.

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SOFTWARES & EQUIPMENTS

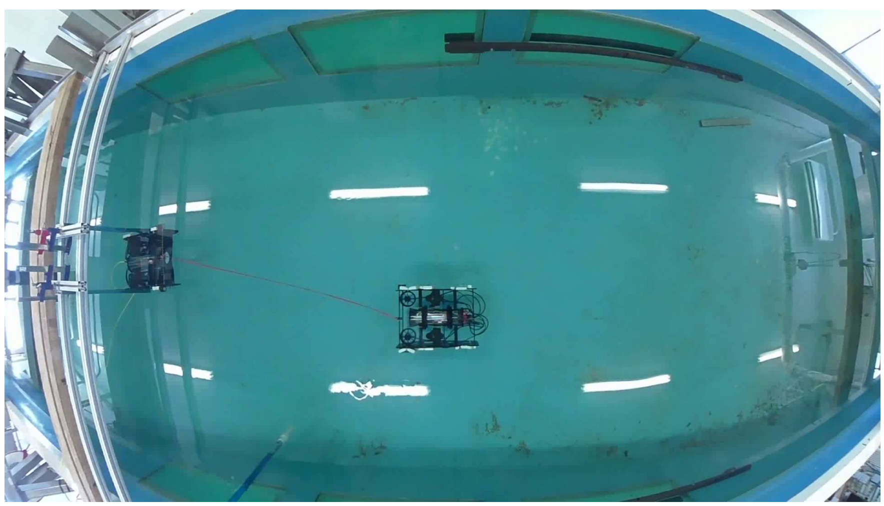

Figure 3 : Two BlueRov mini underwater robots roped up in the wave pool of the University of Toulon [Laranjeira2020].

- Simulation tools for robotics, marine environment and cables (VORTEX licenses, URDF model of a string of robots, Matlab license,...)
- Terrestrial mobile robots and small roped-up subsea robots
- Test pools (inner wave basin, Ifremer basins) and sea front.

APPLICANT'S PROFILE

- Master 2 degree or equivalent in computer vision, robotics or a related field;
- Strong skills in mathematics, programming (python, C/C++, shell script, matlab, ROS);
- Advanced skills in electronics, automation and image processing will be appreciated;
- A very good level of English is a definite asset for this recruitment.

HOW TO APPLY?

Deadline for application: April, the 30th, 2020

Applications should be sent to Vincent Hugel (vincent.hugel@univ-tln.fr), Claire Dune (claire.dune@univ-tln.fr), and Andrew Comport (Andrew.Comport@cnrs.fr).

It must contain :

- An up-to-date CV, no more than two pages long;
- A cover letter demonstrating the adequacy of your profile to the subject of your thesis;
- The grades obtained in the master's program and the rank in the promotion;
- A letter of recommendation from the person in charge of the master's degree or the supervisor of the end-of-study internship;
- The name and contact details of a referent (master's supervisor or supervisor of the end-of-study internship) that we can contact.