POSEIDON Project: Objectives and Preliminary Results

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Abstract

This paper is presenting preliminary results dealing with the ongoing three-year project POSEIDON (imProving underwater cOoperative manipulation by meanS of lEarnIng, augmenteD reality and wIreless cOmmunicatioNs). In fact, this Project is a sub-project inside of a bigger one, COOPERAMOS (COOPErative Resident Robots for Autonomous ManipulatiOn Subsea). The aim and specific objectives of this project are presented, as well as some preliminary results on Simulation, HRI, and communications.

Keywords: Autonomous Underwater Vehicles, Cooperative Robotic Mobile Manipulation in Underwater Scenarios, HRI and Mixed Reality

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Resumen

Este documento presenta los resultados preliminares relacionados con el proyecto POSEIDON (mejora de la manipulación cooperativa subacuática mediante el aprendizaje, la realidad aumentada y las comunicaciones inalámbricas), que tiene una duración de tres años y está en curso. De hecho, este Proyecto es un subproyecto dentro de uno más grande, COOPERAMOS (COOPerativos Residentes de robots para la Manipulación Autónoma Submarina). Se presentan los objetivos de este proyecto, así como algunos resultados preliminares sobre Simulación, HRI y comunicaciones.

Palabras clave: Vehículo Autónomo Submarino, Manipulación Robótica Submarina Cooperativa, HRI, Realidad Mixta

1 INTRODUCTION

In particular, the UJI subproject, POSEIDON, will focus mainly on some of the challenges assumed through COOPERAMOS, according to its expertise. Thus, new progress will be made through the underwater wireless communication context, exploring three different dimensions: Local Area Visual-Light Communications Network; Multimodal underwater wireless communication service (RF, Sonar, VLC); and Semantic image compression and reconstruction. All these subjects of research are under the general objective of COOPERAMOS named “Multimodal Networking”. Moreover, the UJI team will be responsible for all the aspects related to the mission specification by the user and simulation, integrated both through the HRI module. So, Multimodal Human Robot Interface (HRI) and Simulation techniques include Augmented Reality multi-robot task specification; Augmented Reality multi-robot task monitoring and supervision; and Simulation for Hardware in the Loop Experiments.
All these techniques are under the general objective of COOPERAMOS named “HRI and Simulation”. Other research context assumed will be related with robot grasping, concerning the use of different perceptual channels for the guiding of grasping actions, that’s to say Multisensory Grasping Approach. Moreover, some AI techniques will be explored in this context, like Grasping Learning from Experience. UJI is also involved in the experimental validation of cooperative mobile manipulation, focusing on the Cooperative assembly by means of available I-AUV’s. Finally, it is noticeable that the UJI team is Coordinating the bigger project COOPERAMOS.

It is worth mentioning that the starting point was the first of September of 2021, so we have been working on it for eight months so far. So, the results presented here are very preliminary but even so, they are interesting to understand the challenges assumed and the proposed solution paths.

2 Manipulator Integration into the AUV

The first step is the integration of a 6 DoF Mobile Manipulator in the payload of the Girona 500 underwater robot (i.e. G500) [1], in order to start building the required software architecture and design.

The mechanical integration of the arm into the G500 main frame has been done using a specially designed and manufactured part (see Figure 1). This part is made of bent steel, has a wall thickness of 5mm and a geometry that fits perfectly into the lower structure of the robot.

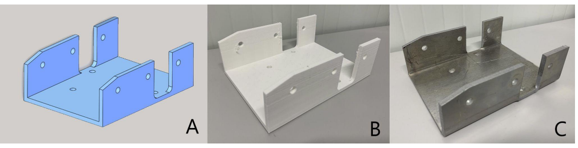

Figure 1: Evolution of the design process. A: 3D modeling, B: PLA prototype using FDM, C: final steel part.

Four M8 screws allow the arm to be attached to the interconnection part, then 6 others M6 screws fix the part to the G500 (see Figure 2).

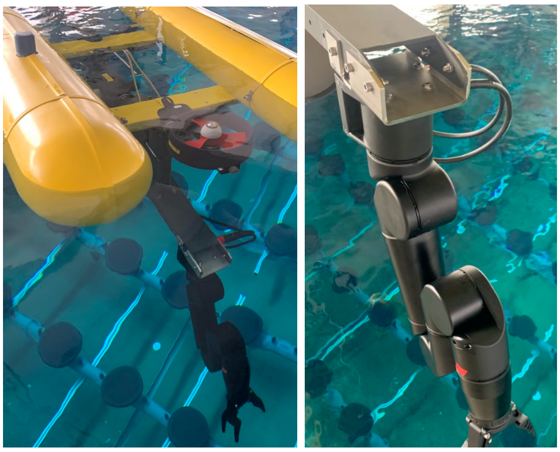

Figure 2: Mechanical integration of the Reach Bravo 7 BluePrint arm (i.e. RB7)[2] in the G500 payload.

The arm is located at the front and farthest place from the center of mass, to contribute positively to weight distribution and to balance the robot. (Figure 3).

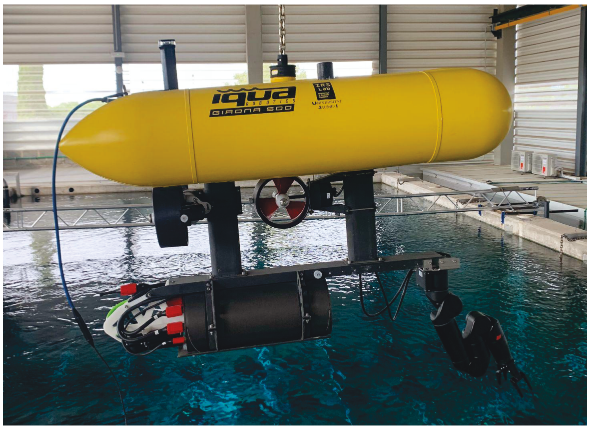

Figure 3. Weight distribution of the G500 with the RB7 arm

The RB7 has two cables: one for power and another one for data transmission. The power cable is internally connected to one of the two 24V step down converters that the G500 provides. The data cable is a cat8 Ethernet cable. However only four of the eight wires are wired into a RJ45 connector. The connector itself is connected into an Ethernet switch. One of the remaining pairs is wired into the serial port of the G500 while the last pair is not connected.

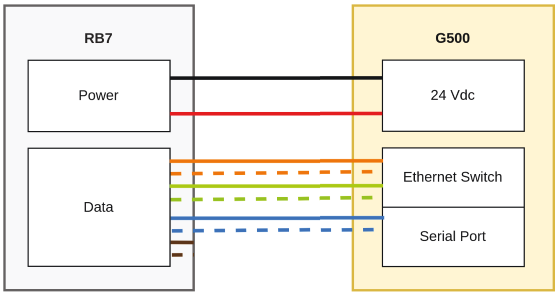

Figure 4: Connections diagram between de RB7 and G500.

Subconn connectors and cables are used in order to provide the manipulator a waterproof connection.

3 Graphical User Interface

3.1 Python GUI

In order to provide a fast prototyping procedure a set of Python widgets have been implemented, so that it is possible to create a simple user interface that enables visualizing the state of the sensors (e.g. cameras), controlling the mobile manipulator, and also adding semi-autonomous behaviors.
In fact, this library has been tested, validated, and transferred to education activities at Master level, which have resulted in a very positive experience.

Besides this, the education activity has helped in order to prepare the subjects related to the EU MIR Master (i.e. Marine and Maritime Intelligent Robotics Master), which combines Robotics and Artificial Intelligence activities.

3.2 3D Mixed Reality GUI

The project also includes the design of a 3D Mixed reality user interface, in order to enable a safer and efficient user experience, specially when having to face the interaction of the mobile manipulator with an object (e.g. valve or screw).

The interface will allow the user to train and preview mission scenarios, which can be found during real interventions, and also gives more information, such as the vehicle depth. It will also allow the user to preview a mission specified via ROS Plan, to anticipate possible issues during the real intervention.

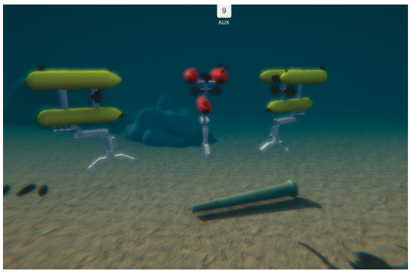

Figure 5. GUI simulation with 3 Girona 500 reaching a pipe

In future work we plan to enhance the GUI by using HoloLens 2 as an AR system, in order to create an immersive experience for the operator. The system will use GPS to position the vehicles and the HoloLens itself to draw a 3D model in the real world to localize the vehicle through AR. Also, it is planned to provide the user the possibility of teleoperating the ROVs with gestures and the AR interface.

Finally, this interface will show the information of multiple sensors over the real world, such as battery level, depth and cameras.

3.3 Mission Plan

In order to let the operator specify cooperative tasks using three similar mobile manipulators, a Mission Plan module will be implemented, which will provide the necessary inputs to the semi-autonomous behaviors.

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4 Wireless Communications

Cooperative robotics in underwater scenarios, especially when using more than two robots, requires wireless communication. In this section an introduction to the problem with some preliminary results is explained. Also a description of a secondary communication channel, used only on the surface, is described.

4.1 Wireless communication VLC, RF, and Sonar

In underwater wireless communications, there are three possible technologies to be used: sound waves (ultrasound), light (led/laser) and radiofrequency.

SOUND WAVES: This is the technology that was first used for underwater wireless communications. Even sea creatures use it. Sound propagates faster and further in water than in air, but compared to RF communications in air, the available bandwidth and delays due to the low propagation speed prevent the transmission of the amount of data needed for today's applications. In addition, acoustic waves do not cross the boundary between water and air, also making communication between the two media.

LIGHT: For communication by means of a light beam, lasers are usually used, considering that led technology is also available. This technology solves the drawbacks of sound wave communication, but has its own shortcomings, such as limited distance, especially in turbid water, the need for alignment between transmitter and receiver, and absorption of certain colors.

RADIOFREQUENCY: The main problem with this type of communication in underwater environments is the high attenuation of radio signals, especially in salt water [3]. On the other hand, the higher the frequency of the signals, the greater the attenuation, which affects the available bandwidth.

In short, since there is no one method that provides high performance in all aspects under all circumstances it is necessary to choose, between them, the most appropriate for each situation.

Table 1 shows the maximum values for the characteristics of each of the methods considered. It should be noted that some of the parameters shown are dependent, especially in the case of radio frequency, where, since distance and bandwidth are strongly dependent on frequency, the maximum values of both cannot be reached simultaneously.

	SOUND WAVES	LIGHT	RADIO FREQUENCY
RANGE	20 Km	10 m	100 m
BANDWIDTH	30K bit/s	20 Mbit/s	300 Mbit/s
PROPAGATION	12 s	3.3 e-9 ms/m	3.3 e-9 ms/m

Table 1. Characteristics of the methods considered

Within the scope of the project, the following devices have been considered for each of the above methods:

- Sound waves: EvoLogics S2C R 18/34 WiSE, modelo S2C-510-18-C.
- Light: Hydromea LUMA.
- Radiofrequency: WFS S100 RF.

Table 2 shows their respective performances, where it can be seen that sound wave and radio frequency devices offer similar performance, with a clear advantage in favor of radio frequency in terms of delay and propagation speed, while laser provides a much wider bandwidth with the disadvantage of having to align the receiver with the transmitter and the drastic reduction of range in unclear waters.

	Evologics [4]	Hydromea [5]	WFS [4]
Bandwidth	13.9 Kbit/s	10 Mbit/s	16 Kbit/s
Range	3500 m	50 m	5 m
Intrinsic delay	450 ms	UNKNOWN	85 ms
Propagation	0.67 ms/m	3.3 e-9 ms/m	3.3 e-9 ms/m

Table 2: Performance of the devices under the water

4.2 Secondary Communication Link on Surface by means of LORAWAN

To increase reliability in case of failure of the main communication system, a secondary surface communication channel has been adopted. Instead of using the same technology of the primary communication channel, LoRaWAN [6] has been chosen as it shows a very low power consumption, reliable communications, great penetrability and long range capabilities. The bandwidth of this technology ranges from 250 bps to 11,000 bps as seen in Table 3, LoRaWAN will be used in the 868MHz band as it is the one available in the EU. Geolocation is also possible through LoRaWAN, it is based on Time Difference of Arrival, TDoA, the only requirement being three gateways with fine timestamps.

Data Rate	Modulation	SF	BW (kHz)	bit/s

0	LoRa	12	125	250
1	LoRa	11	125	440
2	LoRa	10	125	980
3	LoRa	9	125	1760
4	LoRa	8	125	3125
5	LoRa	7	125	5470
6	LoRa	7	250	11000

Table 3. LoRaWAN Data rates

We have designed a PCB to allocate a RAK3172 module, based on STM32WLE5CC MCU, see Figure 6. The PCB is connected to the main board of the G500 and communicates using AT commands through a Serial connection.

Figure 6: PCB with RAK3172 module.

In future work we would present some results on how LoRaWAN geolocation performs compared with GPS in outside scenarios. Furthermore, a study on how to transmit images through LoRaWAN will be made as this presents a bandwidth challenge due the low bandwidth of the communications, the images will be compressed in JPEG2000 format.

5 Software Architecture

In order to facilitate the development and adaptability of the system to different missions, a modular software architecture has been created. This architecture has been developed mainly in ROS [7], as its node structure allows elements to be easily added or removed as required for each mission. Figure 7 shows the proposed structure.

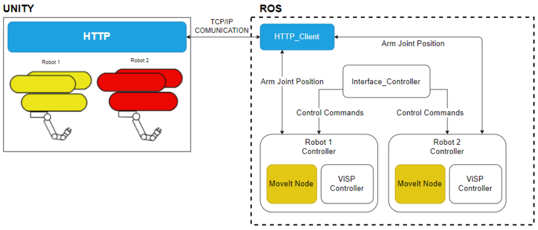

Figure 7: Software architecture

The central node of the ROS architecture is the control interface. This node creates a graphic user interface (GUI) from which the operator can send different movement controls (both to the Girona 500 and to the RB7 integrated manipulator), activate and deactivate the different control nodes and represent the images from the cameras captured by the robots.

Thanks to the modular structure of ROS, it is possible to add and remove different control nodes as required for the mission and to communicate them easily with the control interface thanks to different topics. The MoveIt control node (created with the MoveIt framework [8]) facilitates the calculation of trajectories for the robotic manipulators attached to the AUVs. This allows the operator to indicate the final position of the manipulator in different reference systems and for the trajectories to be executed avoiding known obstacles.

On the other hand, the VISP [9] control node applies visual servo control to guide the robot's movement towards the reference target.

Both the actions and positions calculated by the various controllers and the individual actions set by the control interface are sent to the robot via the communication node. In this case, a communication node has been created with a TCP-IP protocol to send the various instructions to a realistic simulator built in UNITY (Using Unity Robotic Hub Technology [10]).

This simulator will receive the actions calculated by the ROS control architecture via HTTP commands and execute them. This allows the different control algorithms to be tested before being taken to the real world. In addition, the simulator will send to the communication node the information extracted from the different simulated sensors.

6 Conclusions and Further Work

In this paper a summary of the challenges to face in the POSEIDON project has been presented, including some preliminary results and the description of the design of the main modules, including the mechatronics integration, the GUI, underwater

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wireless communications, surface secondary wireless link, and software architecture for cooperative behaviors. Some of these techniques have already been tested and validated in education for Master students.

Concerning the user interaction, it is worth mentioning that currently, the HRI interfaces that exist for the control of multiple robots, in a cooperative way, are mainly focused on planning missions going through different states until reaching the final result through command strings indexed in files similar to XML. Our interface would allow, as a starting point, given a situation at the origin of the mission, to visually generate and send these files to the robots so that they can execute said mission. During the execution of the mission, the user will be able to visualize its status and give the go-ahead to the different points of the same, so that the robots can advance in a supervised manner until completing it. Another future objective is dealing with the use of augmented reality functionalities that allow an expansion of the information received by the interface of the different sensors of the robots.

Next steps will focus on the implementation of a 3D simulator to start implementing autonomous skills, the design of the cooperative Mission Plan, and the implementation of more advanced network protocols to support the wireless multimodal communication requirements of the project.

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References

[1] https://iquarobotics.com/girona-500-auv

[2]https://blueprintlab.com/products/manipulators/reach-bravo/

[3] Tahir M. Underwater Wireless Communication Using EM Waves. Microwave Journal. 2020 Oct.

[4] Centelles 2018 – “Mejoras en la Teleoperación Inalámbrica de ROV's”. Trabajo de Introducción a la Investigación. Universitat Jaume I, 2018.

[5] https://www.hydromea.com/underwater-wireless-communication

[6] https://lora-alliance.org/about-lorawan/

[7] http://www.ros.org/

[8] S. Chitta, I. Sucan y S. Cousins, «MoveIt!,» IEEE ROBOTICS & AUTOMATION MAGAZINE, pp. 18-19, Octubre 2012.

[9] F. Chaumette, E. Marchand y F. Spindler, «ViSP for visual servoing: a generic software platform with a wide class of robot control skills,» IEEE Robotics & Automation Magazine, vol. 12, nº 4, pp. 40-52, 22 Enero 2005.

[10] Unity-Technologies, «Github,» Microsoft, 20 Mayo 2020. [En línea]. Available: https://github.com/Unity-Technologies/Unity-Robotics-Hub. [Último acceso: 4 Octubre 2021].

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