XXXVIII Jornadas de Automática
https://doi.org/10.17979/spudc.9788497497749.0232

MERBOTS PROJECT: OVERALL DESCRIPTION, MULTISENSORY AUTONOMOUS PERCEPTION AND GRASPING FOR UNDERWATER ROBOTICS INTERVENTIONS

Pedro J. Sanz, Raul Marin, Antonio Penyalver, David Fornas, Diego Centelles
Jaume I University of Castellon
e-mail(sanzp,rmarin,penaalvea,dfornas,centelld AT uji.es)

Resumen

The MERBOTS project is, at the moment of writing the present article, in its third year, and have already obtained most of the expected results, from both lab and sea field trials. The project is being coordinated by the Jaume I University (i.e. IRS Lab), jointly with the University of Girona (i.e. CIRS Lab), and University of Balearic Island (i.e. SRV Group).

Recent results demonstrate the viability to perform semi-autonomous cooperative interventions in underwater scenarios for archaeological applications. In this paper, first of all an overall description of the project is given, and then some results belonging to the UJI subproject are explained in more detail, such as communications and, in a more detailed manner, the autonomous perception and grasping modules

Key Words: Marine Robotics, Autonomous Grasping, Underwater Communications

1 Introduction

The MERBOTS (DPI2014-57746-C3-1-R) coordinated project has been organized into 3 subprojects:

- MERMANIP (DPI2014-57746-C3-1-R), under responsibility of UJI, in charge of the multi-sensory based autonomous manipulation, the multi-modal user interface, and the Sonar/RF communication system for enabling compressed image transmissions between the robots and the human operator.
- ARCHROV (DPI2014-57746-C3-3-R), under responsibility of UdG, assuming the cooperative mobile robotics part, including communications and localization of the mobile robots, sonar-based survey, and path planning, also the construction of a new ASC and the final mechatronics, hardware/software integration will be under their responsibility.

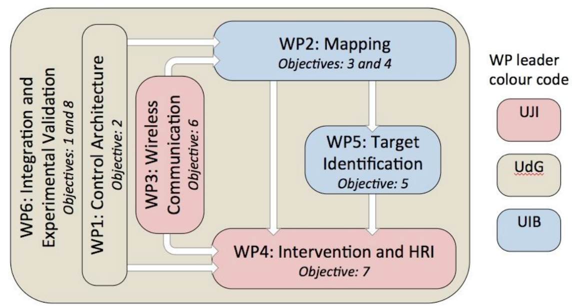

Figure 1: Relationships between Work-packages

- SUPERION (DPI2014-57746-C3-2-R), under responsibility of UIB, in charge of processing the multi-modal sensor data collected during the survey stage to build 3D models of the area of intervention and the target, as well as for searching the target prior to the intervention and tracking the target during the intervention.

In Figure 1 can be appreciated the relationship between the work-packages. In fact, the UJI subproject is focused mainly in the hand-eye coordination for intervention, the Human-Robot Interaction (HRI), and the Wireless Communication, enabling the long term objective of a Wireless H-ROV for underwater archaeological missions.

2 Overall System Description

The robot intervention is performed by using two ordered missions: The first one, cooperative survey (see Figure 2), comprises an autonomous survey of the seabed by means of an AUV assisted by a surface vehicle that provides absolute localization and communication.

Moreover, the second mission (see Figure 3), cooperative intervention, includes a semi-autonomous intervention by means of an HROV assisted by an AUV providing an external view of the intervention. In order to achieve the second mission, the data acquired during the cooperative survey mission has been processed to reconstruct and visualize the scene in the HRI. Wireless image

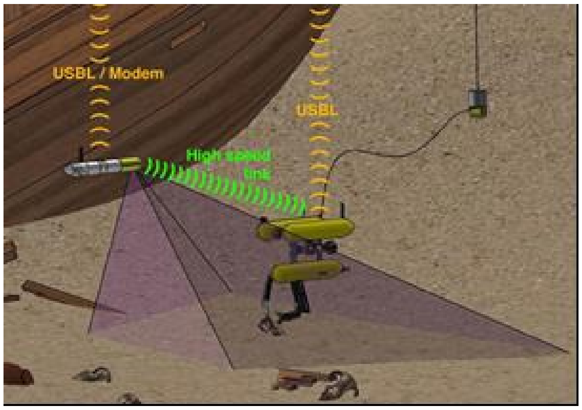

Figure 2: Mission 1: Survey using a surface and an underwater robot

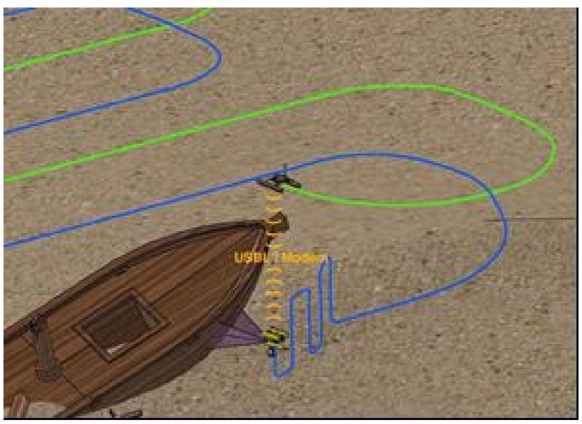

Figure 3: Mission 2: Intervention using a mobile manipulator and a assistant robot for external point of view

transmission and HROV control have been also demonstrated.

3 Background

Only a very short introduction will be addressed in the next to clarify the main reason to move from autonomous intervention systems (I-AUV) to hybrid ones (H-ROV). Bearing in mind that the underlying context is related with the "search and recovery problem" the reviewed works will be focused mainly on this issue. The first object manipulation from a floating vehicle (I-AUV) was achieved in 2009 within the SAUVIM project [4], demonstrating the capability of searching for an object whose position was roughly known a priori. The object was endowed with artificial landmarks and the robot autonomously located it and hooked it with a recovery device while hovering. More recently, the first multipurpose object search and recovery strategy was demonstrated in the TRIDENT project in 2012. First, the object was located using a down-looking camera and photomosaicking techniques. Next, it was demonstrated how to autonomously "hook" the object in a water tank [5]. The experiment was repeated in a harbor environment using a 4 DOF arm [6], and later with a 7DOF arm endowed with a 3 fingered hand [8]. Nevertheless, according to [3] "Long-term AUV vision" the technology for light intervention systems is still immature, but very promising.In summary, MERBOTS aims to bring a team of heterogeneous marine robots (an ASC, an AUV and an HROV) together, tightly cooperating to conduct a multimodal survey (stereo, laser and multibeam) of an unknown, unstructured area with significant 3D relieve (like a shipwreck), where a multifunctional intervention operation must be performed. A mixture of autonomous (ASC and AUV) and task-level teleoperated vehicles (HROV) has been developed. So, MERBOTS has been able to integrate recent and promising technologies to explore the powerful concept of a wireless HROV, in the cutting-edge of technology.

4 Intervention: 3D Grasping Determination and Execution

4.1 Multipurpose/Multisensory-Based Manipulation

This task concerns the semi-autonomous planning of 3D contact points for a given intervention task. First, we will identify the grasp requirements for the tasks of this proposal in terms of the required forces and torques, and constraints in the geometry of contact points. With this info, a 3D grasp planner is developed. It takes as input the multiview target tracking for manipulation (this task has been responsibility of UIB), and computes valid grasps according to the requirements identified in the first step. The 3D grasp planner is integrated in the user interface, thus assisting the user in the specification of the intervention by suggesting possible grasping configurations. The planner has been validated with different grasping tasks.

In the experiment presented in this article, the multi-view laser reconstruction is made using the real system. The robot has an electric manipulator with 4 DoF (Light-weight ARM5E), a lineal green laser for underwater operations (MKIII), and a submarine camera (Luxus Compact Camera). Then, the robotic arm is used for obtaining different points of view of the scene, calculating the 3D Point Cloud (see Figure 4).

Once the 3D Point Cloud is obtained, the RANSAC algoritm is used for segmentation. First of all, a plane-based geometrical model is used to detect the points that belong to the background.

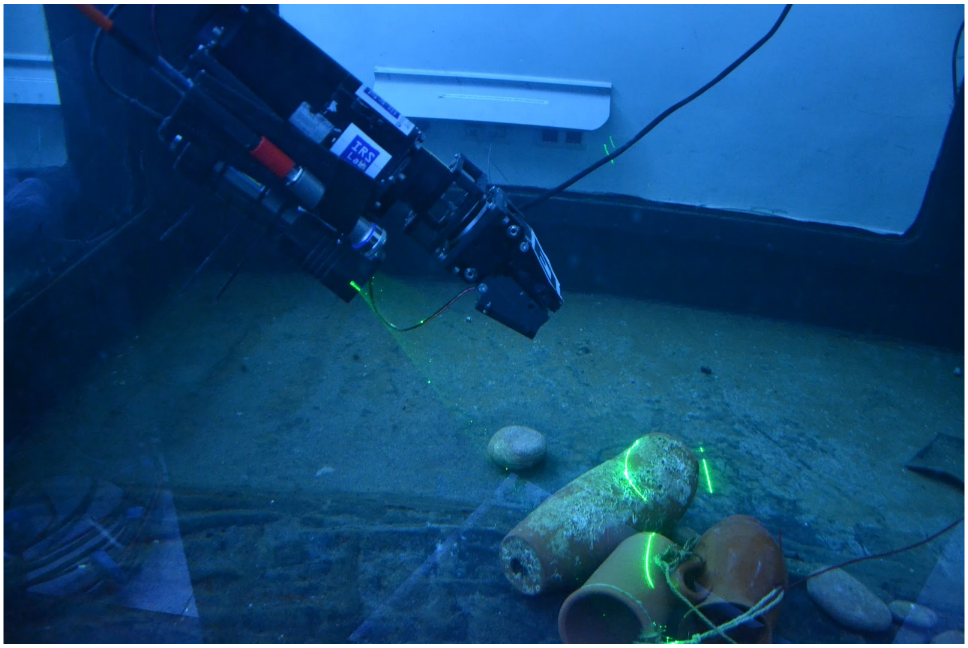

Figure 4: Multiple robot positioning for multi-view scene 3D reconstruction

With this information the depth related to the arm is easily obtained. After that, the interest object is segmented, by using pre-defined models, such as for example cylinders to detect an amphora. This procedure helps to extract the position, center, inertial axis, radio, and height.

4.2 Grasping Determination

The grasping determination procedure starts once the geometrical aspects of the object have been calculated, in order to obtain an appropriate vector to reach the object and grasp it.

For this, some parameters are taken into account: (1) ”T”, translation through the minimun inertia axis, (2) ”R”, rotation respect to the X axis of the object, which permits the grasping execution that facilitates the stability of the robot, and (3) ”D”, which determines the execution of the grasping at a given distance from the object, depending on its radio and the geometrical representation of the gripper.

To validate the grasping determination algorithm a user interface has been designed (see Figure 5), which allows not only evaluate the proposed grapping, but also modify some of its parameters, such as position, rotation, etc. The new grasping specification can be made by two methods: (1) modifying the geometrical parameters (i.e. T, R and D), and (2) by using Interactive Markers.

5 Grasping Execution

As can be seen in Figure 6, once the grasping has been calculated, its corresponding robot position to let the end-effector reach the grasping point is calculated. The joints are moved accordingly to the final position and the gripper is actuated to perform the grasp.

To help in the grasping execution and avoid uncertainties, the force sensor is used, which is installed in the robot wrist.

While the robot-arm is moving the values from the force sensor are analysed, adjusting the movement accordingly, depending on the different kind of possible contacts:

- If the contact has been produced when the end-effector is at a greater distance than 5cm from the final position, it is considered that the hand touched the object. In this case, the hand is elevated and adjusted the grasping execution position, considering which is the finger that actually touched the object, and moving the hand left or right accordingly.
- Otherwise, if the contact has been produced when the distance to the final position is less than 5 cm, it is considered that the robot hand touched the sea floor, adjusting the final grasping height accordingly to make the grasping more stable.

Once the end-effector reached the final grasping position, the gripper is closed. To detect the force

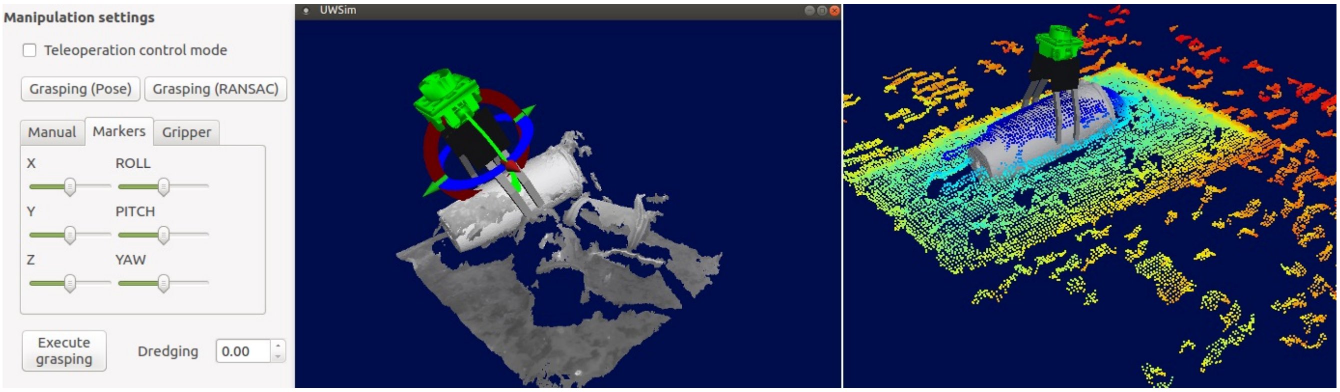

Figure 5: User Interface for human supervision using a real point of cloud (left). Results obtained from simulation (right)

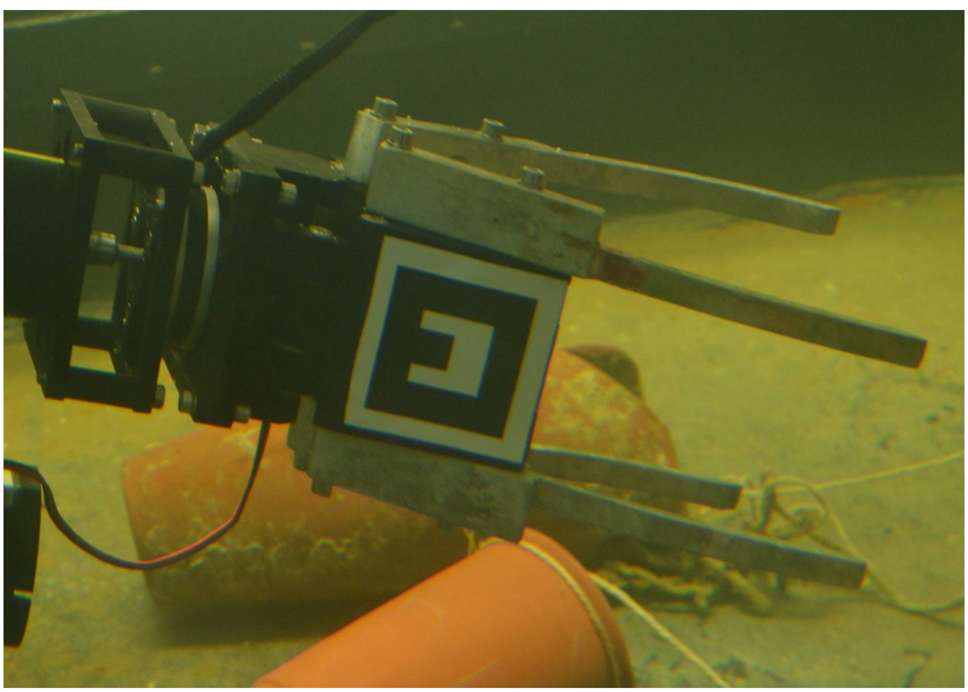

Figure 6: Grasping Execution: Optofoce sensor with 6 degrees of freedom, for underwater applications

that the gripper is applying to the object, a current control is used. Finally, the robot arm comes back to its home position, maintaining the object grasped.

In the following web address a video with one of the experiments is shown: https://youtu.be/1jBZLyjvSLs

6 Underwater Communications

The Merbots project requires the use of wireless communcications to control the robot, if necessary, without using the umbilical.

Several experiments have been performed in this area, using both, Sonar, and Radio-Frecuency modems.

A protocol for multimodal communication has been designed, which includes the possibility to link operator and robot by using different communication media. This protocol has been tested with real acoustics modems in the freshwater pool of the CIRS Lab (University of Girona) facilities, Girona.

In these experiments a pair of acoustic modems manufactured by the Evologics Company have been used. A S2CR 18/34 modem has been used to be the modem of the simulated HROV and a S2CR 18/34 USBL (Ultra Short Base Line) as the operator's modem.

The S2CR 18/34 modems provides data transfer rates up to 13.9 kbps in optimal conditions. These modems implements a data link protocol architecture created by Evologics, named D-MAC, and presented [Kebkal11]. This protocol provides two data delivery algorithms, the one based on sending short instant messages, and the burst mode. The results are very promising, and further work is to control a real underwater robot using radio-frequency modems at sea.

7 Conclusions and Further Work

This paper gives an overview of the current state of MERBOTS projects at UJI, giving an overall description of the project, and focusing on recent results related to multisensory autonomous perception, and grasping. Also, some keypoints related to communications are given. In fact, The system is able to transmit compressed images and telemetry to the user via radio-frequency and sonar techniques, in order to perform a supervised control of the autonomous intervention.

Further work will focus on cooperative manipulation, which includes the necessity of underwater real-time communications, supervised control, and more advanced techniques for perception and grasping

Acknowledgements

This work was partly supported by Spanish Ministry of Economy and Competitiveness under grant DPI2014-57746-C3-1-R (MERMANIP Project), and by Valencian Government under GVA-PROMETEO/2016/066 grant, and Jaume I University (P1-1B2015-68).

References

[1] Pedrycz, W., (1993) Fuzzy setes and fuzzy systems, Research Setudies Press, england.

[2] Zadeh, L., (1965) "Fuzzy logic", *Fuzzy Sets and Systems*, pp 100-106.

Deben estar ordenadas por orden alfabético y justificadas con la sangría correspondiente.

[3] B. Gilmour, G. Niccum and T. O'Donnell, "Field resident AUV systems - Chevron's long-term goal for AUV development," 2012 IEEE/OES Autonomous Underwater Vehicles (AUV), Southampton, 2012, pp. 1-5. doi: 10.1109/AUV.2012.6380718

[4] Marani, G., Choi, S.K., Yuh, J.: Underwater autonomous manipulation for intervention missions AUVs. Ocean Engineering 36(1), 15-23 (2009). DOI 10.1016/j.oceaneng.2008.08.007.

[5] M Prats, D Ribas, N Palomeras, J C GarcÃa, V Nannen,Â·S Wirth, J J FernÃ¡ndez, J P BeltrÃ¡n, R Campos, P Ridao, P J Sanz, G Oliver, M Carreras, N Gracias, R MarÃn, A Ortiz. Reconfigurable AUV for intervention missions: a case study on underwater object recovery. Intelligent Service Robotics, vol 5 (1), pp. 19-31, 2012. DOI: 10.1007/s11370-011-0101-z. Published online 4 October 2011: http://www.springerlink.com/content/d715441x8885527g/

[6] M. Prats, D. Ribas, N. Palomeras, J. Garcia, V. Nannen, S. Wirth, J. J. Fernandez, J. Beltran, R. Campos, P. Ridao, P. Sanz, G. Oliver, M. Carreras, N. Gracias, R. Marin, and A. Ortiz, "Reconfigurable AUV for intervention missions: a case study on underwater object recovery," Intelligent Service Robotics, vol. 5, no. 1, pp. 19-31, 2012. [Online]. Available: http://dx.doi.org/10.1007/s11370-011-0101-z.

[7] Mario Prats, Javier PÃ©rez, J. Javier FernÃ¡ndez, Pedro J. Sanz, "An Open Source

Tool for Simulation and Supervision of Underwater Intervention Missions Proceedings of the 2012 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 2577-2582, October 7-12, 2012. Vilamoura, Algarve, Portugal. 978-1-4673-1735-1/12/S31.00

[8] Pedro Jose Sanz; Raul Marin; Jorge Sales; Gabriel Oliver; Pere Ridao. Recent advances in underwater robotics for intervention missions. Soller harbour experiments. Castellon (Spain): Low Cost Books, 2012. ISBN 978-84-940663-7-5.

[9] O. Kebkal, M. Komar, K. Kebkal, and R. Bannasch, "D-mac: Media access control architecture for underwater acoustic sensor networks,"in OCEANS2011 IEEE-Spain, June 2011, pp.1-8.

[10] N. Palomeras, S. Nagappa, D. Ribas, N. Gracias, and M. Carreras, "Vision-based localization and mapping system for auv intervention,"in 2013 MTS/IEEE OCEANS - Bergen, June 2013, pp.1-7.

[11] E. Rubino, D. Centelles, Jorge Sales , Jose Vicente Marti Aviles, Raul Marin, Pedro Jose Sanz. Image compression with Region of Interest for Underwater Robotic Archaeological Applications. XXXVI Jornadas de Automatica (CEA IFAC 2015). Bilbao (Spain). 02-09-2015. Nacional. Cientific. 2015. Ed. (CEA). ISBN 9788415914129.