Wireless RF Camera Monitoring for Underwater Cooperative Robotic Archaeological Applications

Diego Centelles, Eduardo M. Rubino, Jorge Sales, José V. Martí, Raúl Marín, Pedro J. Sanz
Computer Science and Engineering Department
University of Jaume-I
Av.Sos Baynat, s/n
12071 Castellón de la Plana, Spain
{al132071, rubino, salesj, vmarti, rmarin, sanzp}@uji.es

Abstract *- The increasing demand for underwater robotic intervention systems around the world in several application domains requires of more versatile and inexpensive systems. One example of such applications is the archaeology, where experimented divers study and reconstruct the history, recovering key objects in order to classify and preserve them properly. Moreover, this task is especially dangerous at deeps over 50 meters, where the archaeologist needs more sophisticated diving equipment and degree of experience due to high risk to which it is exposed caused by possible decompression situations. In addition, some archaeological remains coming from shipwrecks are at deeps where divers cannot access in any way. Remote operated vehicles (ROVs) can navigate deeper but they are expensive, as they require a surface vessel and well-trained operators. To tackle this issue, the use of supervised semi-autonomous robots can help to this task. To achieve this goal, a wireless communication system can provide freedom of movements to the robot and, at the same time, will allow the operator to get camera feedback and supervise the intervention. This paper presents the roadmap to follow in the context of the MERBOTS research project, in particular, the objective to provide a wireless communication link to the robot so that it can be remotely supervised.*

Keywords **-** Underwater Robotics Intervention, Autonomy, Wireless Communications, Image Compression, Image Transmission.

I. INTRODUCTION

In the context of the MERBOTS research project, a three-year coordinated project funded by the Spanish government for the period 2015-2017 under grant DPI2014-57746-C3 [1], one of the roles of our research group inside the MERMANIP subproject is to build a wireless communication system that can provide freedom of movements to the underwater robot and, at the same time, to allow the operator to get feedback and supervise the intervention (see Figure 1). This wireless communication system is based on radio-frequency (RF) and will allow compressed image transmissions between the robots and the human operator.

MERBOTS represents the natural continuation of several research national and international projects in the last years in the field of underwater robotic intervention (i.e. RAUVI [2], TRITON [3] and TRIDENT [4]). One of the objectives of MERMANIP is to provide different communication technologies that will be used for allowing the operation of a vehicle without any physical connection to the surface operators, which are supervising and controlling an intervention task. Our research team is in charge of the design of a wireless communication underwater system that is able to transmit telemetry data as well as compressed low-resolution images, allowing the implementation of cooperative intervention missions.

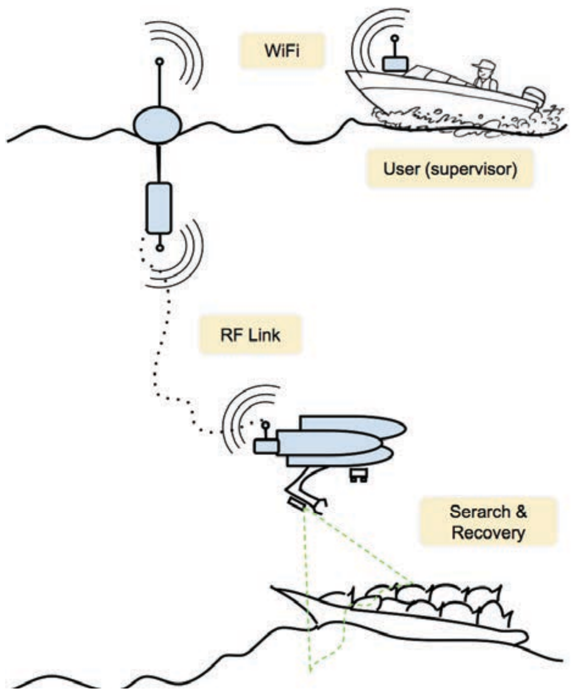

Fig. 1: Search and Recovery in the context of archaeology. A wireless RF link provides feedback to the user that is supervising the intervention.

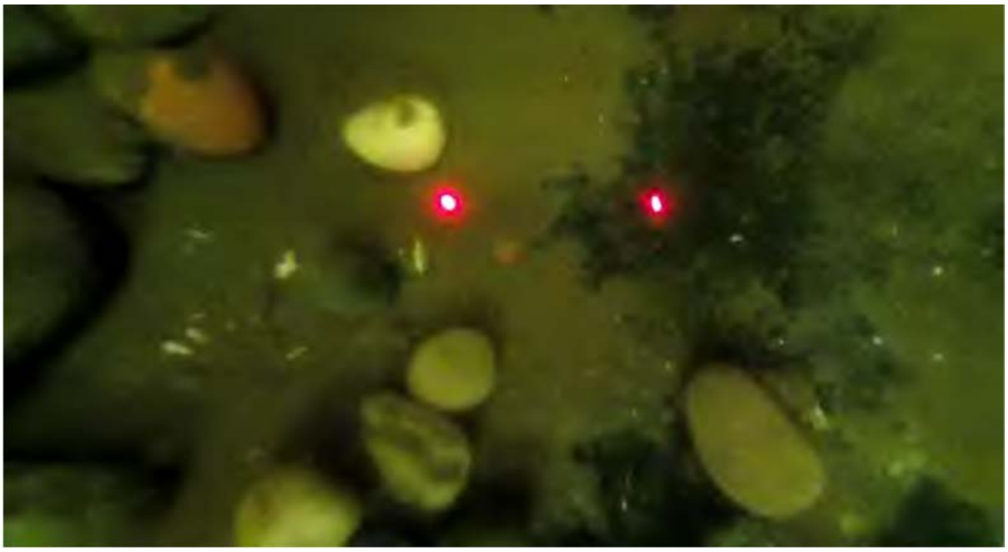

Fig. 2: Image compression experiments conducted at IRSLab-UJI laboratory in water tank conditions. Images with a resolution of 1200x650 pixels have been compressed and transmitted through a 868Mhz radio channel at 1 fps.

II. UNDERWATER RF COMMUNICATIONS

RF based solutions are not as affected by the typical problems of acoustic and optical methods, and are much cheaper. Moreover, RF signals can propagate easier from a medium to another, allowing the establishment of a communication link to an underwater transducer from the surface. The first problem of the RF is the high attenuation that it suffers when the waves go through the water. However, different studies [5-9] indicate that, with the necessary antennas, at lower frequencies and using the best modulation methods, it is possible to set up a communication link up to several tens of meters through the water.

The objective now is to explore the new possibilities to provide a point-to-point underwater radio frequency networking system able to transmit telemetry data as well as compressed low-resolution images. A range of different frequencies (e.g. 433MHz, 868MHz, etc.) has already been explored to guarantee the communication service [10,11]. The next step will be the design of an adaptable networking protocol to enhance the cooperative underwater manipulation mission.

To allow the system to perform robotic underwater interventions, the use of video cameras input is crucial, allowing the robust storage, compression and transmission of well-synchronized video on both, through the umbilical (wired) and on the Radio Frequency channel (unwired robot). Moreover, due to the fact that the available network will present a dynamic behaviour due to the specific location of the robots at each moment, as well as the interferences, the communications protocol must be well integrated with the video compression and transmission algorithms. In fact, depending on the actual services offered by the network (i.e. latency, bandwidth), the video compression and networking parameters could be adjusted accordingly to improve the general behaviour of the whole system, always guaranteeing the efficient storage and transmission of the mission video input.

Thanks to communications improvements, the system will be able to operate with or without umbilical cable in a robust way. A preliminary wireless communication system based on radio-frequency (RF) has already been tested in water tank conditions, and will allow compressed image transmissions between the robots and the human operator (see Fig. 2). This duality will enable the exploration of new possibilities of the so-called hybrid intervention systems (i.e. HROV's), where the system can work in standalone or teleoperated mode, as appropriate.

III. THE PROPOSED COMMUNICATION SYSTEM

The proposed communication system will connect the surface with the intervention vehicle (see Figure 1), allowing the access to the network through a wireless Wi-Fi channel at 5 GHz (<10Km), and connecting this device to a second one, which will establish a radio connection with the first one by using two channels, one for sending and one for receiving. Through these channels, the compressed images, the feedback from the sensors and the control commands will be sent to the vehicle. The system will include a specific communications protocol that will adjust in real time the compression ratio depending on the available bandwidth at each time, thus guaranteeing a minimum quality to allow proper monitoring of the intervention by the expert operator. It is also considered the objective of improving the compression system, allowing the quality adjustment of the scene by regions, when the user requires higher image quality in a specific area (e.g. around the manipulator arm).

IV. CONCLUSION

In this paper, the problem of controlling and supervising underwater vehicles for intervention in real-time and the need to send information to allow a fully supervised control and camera monitoring has been introduced. Communication is a crucial subsystem in any robotic application, specially the ones that permit the user to interact remotely with the system. For that, image compression and transmission is necessary in order to send the required information at the lowest time-delay and without compromising the network and the whole system. In the physical layer, a RF based solution is not as affected by the typical problems of acoustic and optical methods, and are much cheaper. In this sense, our research group is working in the design of a wireless communication underwater system that is able to transmit telemetry data as well as compressed low-resolution images, allowing the implementation of cooperative intervention missions. According to previous preliminary results, we can conclude that an underwater communication system based on RF to transmit visual compressed data could be viable in a range of, at least, 6 meters in freshwater. This wireless communication link will provide freedom of movements to the robot and at the same time will permit to perform archaeological supervised interventions in a safe and reliable manner.

ACKNOWLEDGEMENT

This work was partly supported by Spanish Ministry under grant DPI2014-57746-C3 (MERBOTS Project), by Universitat Jaume I grants PID2010-12, E-2015-24, PREDOC/2012/47 and PREDOC/2013/46, and by Generalitat Valenciana grant ACIF/2014/298.

REFERENCES

[1] P. J. Sanz, A. Peñalver, J. Sales, J. J. Fernández, J. Pérez, D. Fornas, J.C. García, and R. Marin, “Multipurpose Underwater Manipulation for Archaeological Intervention”, Sixth International Workshop on Marine Technology (MARTECH'15), Cartagena, Spain, 15-16 September 2015.

[2] P.J. Sanz, M. Prats, P. Ridao, D. Ribas, G. Oliver and A. Ortiz, "Recent progress in the RAUVI Project. A reconfigurable Autonomous Underwater Vehicle for Intervention", 52th International Symposium ELMAR-2010, pp. 471-474, Zadar, Croatia, Sept-2010.

[3] P. J. Sanz, A. Peñalver, J. Sales, D. Fornas, J. J. Fernández, J. Pérez, J. Bernabé, "GRASPER: A Multisensory Based Manipulation System for Underwater Operations", IEEE International Conference on Systems, Man, and Cybernetics (SMC'13), Manchester, UK, 13-16 October 2013, IEEE Computer Society, pp. 4036-4041, ISBN: 978-1-4799-0652-9

[4] P. J. Sanz, P. Ridao, G. Oliver, G. Casalino, Y. Petillot, C. Silvestre, C. Melchiorri, and A. Turetta, “TRIDENT: An european project targeted to increase the autonomy levels for underwater intervention missions,” in OCEANS’13 MTS/IEEE conference. Proceedings, San Diego, CA, 2013.

[5] H. Zhang and F. Meng, “Exploiting the skin effect using radio frequency communication in underwater communication,” in Industrial Control and Electronics Engineering (ICICEE), 2012 International Conference on, Aug 2012, pp. 1150–1153.

[6] Siegel, M. and King, R.W.P., “Electromagnetic propagation between antennas submerged in the ocean”. Antennas and Propagation, IEEE Transactions on, 21(4), 1973, 507–513. doi:10.1109/TAP.1973.1140525.

[7] Shaw, A., Al-Shamma’a, A., Wylie, S., and Toal, D., "Experimental investigations of electromagnetic wave propagation in seawater". In 36th European Microwave Conference, 2006, 572–575.

[8] Shen, L., King, R., and Sorbello, R., “Measured field of a directional antenna submerged in a lake”. Antennas and Propagation, IEEE Transactions on, 24(6), pp. 891– 894. 1976, doi:10.1109/TAP.1976.1141448.

[9] Guarnizo Mendez, H., Gac, C., Le Pennec, F., and Person, C. “High performance underwater UHF radio antenna development”. In OCEANS, 2011 IEEE - Spain, 1–5. 2011, doi:10.1109/Oceans-Spain.2011.6003480.

[10] E. Moscoso, D. Centelles, J. Sales, J.V. Marti, R. Marin, P.J. Sanz, “Wireless Image Compression and Transmission for Underwater Robotic Applications”, IFAC Workshop on Navigation, Guidance and Control of Underwater Vehicles (NGCUV’2015), 28th – 30th April 2015, Girona (Spain).

[11] D. Centelles, E. Rubino, M. Soler, J.V. Martí, J. Sales, R. Marin, P. J. Sanz, “Underwater Radio Frequency based localization and image transmission system, including specific compression techniques, for autonomous manipulation”, in MTS/IEEE OCEANS'15, Genova (Italy), 18-21 May 2015.