REX 2014 – Robotic Exercises 2014 Multi-robot field trials

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Abstract *– Today there are different teams specializing in different areas such as shipwrecked rescue, searching for mines, environmental monitoring, border surveillance, traffic control, search and rescue and harbor protecting.*
Robotic systems and unmanned vehicles can provide additional capabilities and new innovative solutions that contribute to these applications.
This paper presents the Robotic Exercises 2014 (REX'14) and the lessons learned with various field experiments performed with multiple unnamed systems in the context of the Portuguese Navy concept of operations.
During the REX'2014 multiple experiments and systems were operated. Autonomy and environment characterization and assessment missions were performed with autonomous surface vehicles such as the ROAZ autonomous surface vehicle or with autonomous underwater vehicle MARES. Autonomy and system validation was performed for fast water jet propelled surface systems such as the SWIFT autonomous surface vehicle and the ICARUS unmanned rescue capsule, wind propulsion tests were also performed with unnamed surface vehicles and new maritime wireless communication protocols were tested.

Keywords— Unmanned Vehicles; Sidescan Sonar; Search and Rescue

I. INTRODUCTION

Portugal has the 20th largest Exclusive Economic Zone (EEZ) in the world and the 5th largest amongst the European countries. The Portugal Maritime Rescue Coordination Centre is also responsible for the 15th largest SAR (Search and Rescue) area in the world and the 2nd largest in the North Atlantic [1].

Moreover, the engagement of manned resources into patrolling this entire area constitutes a problem that translates into high costs and deficient coverage unmanned systems could be solution for this problem.

The ICARUS (Integrated Components for Assisted Rescue and Unmanned Search operations) project is a large European FP7 research project with 24 partners from 10 European countries. It addresses large scale mass rescue scenarios and has as two main demonstration test cases, one for Urban (Land) Search and Rescue and another for large scale maritime disasters in REX'14 we have trials that were a good test for the final demonstration in 2015.

The paper is organized as follows. In Section II, we present the Portuguese navy mission and requirements. In Section III, we describe the tests performed by ROAZ autonomous surface vehicle (ASV). Section IV presents the tests realized by MARES autonomous underwater vehicle (AUV). In section V we show the tests performed by ASV wind propulsion vehicle. Section VI shows the preliminary tests done by the SWIFT ASV. In section VII is present the ICARUS maritime scenario, the unmanned capsule robotic transporter (UCAP) deployment and the experiments in victim detection on the water and integration tests. Finally we present some conclusions.

II. PORTUGUESE NAVY MISSION AND REQUIREMENTS

The Navy's mission is to cooperate in an integrated way, the military defense of the Republic, by conducting naval operations and missions under the international commitments and public interest missions.
Increasing the personal safety and diminishing the costs are the main benefits of use autonomous unmanned systems in the Navy missions.

With these systems it is possible to scan wide maritime areas at a very low cost which are really useful in terms of environmental protection and SAR.

The risk that some teams are subjected in certain types of missions of surveillance and recognition can be reduced or even terminated for sending a robot to these areas of risk it will capture images in which after a team can analyze in a safe place without running any risk. The success of all naval

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missions largely depends on the safety of all people involved and so this is also a very important benefit.

The realization of these exercises is very important for the Portuguese Navy for all the reasons above and to strengthen ties and protocols and creating new partnerships with other businesses and projects.

There's no doubt of the importance of such exercises for both Portugal as for the Navy and thus will then be presented all projects that will carry out tests and demonstrations.

Fig. 1 – Multi-robot systems in operation

III. ROAZ Autonomous Surface Vehicle tests

The ROAZ ASV [2] is an ocean capable twin hull surface robot with onboard computational capabilities and a vast set of sensors suitable for multiple missions. The 4.2m twin hull vehicle has 2 electrical motors for propulsion and can operate for up to 8hr of continuous operation and up to 10 knots of maximum speed. It has a high precision L1/L2 GPS receiver with RTK allowing for precise georeferencing of acquired data. In underwater bathymetry and target detection tasks it can use information from an Imagenex Delta T multibeam sonar and Sportscan side scan.

Fig. 2 – ROAZ Autonomous Surface Vehicle

For 3D above surface modeling and obstacle detection purposes it has a Velodyne HDL32 scanning LIDAR, a Lowrance broadband RADAR and can also use the high precision 3D scanning LIDAR FARO Focus seen in Figure 2.

In addition vision and thermal cameras are also available. All these sensory information can be processed onboard allowing for complex autonomous behaviors and reduced requirements in terms of communications.

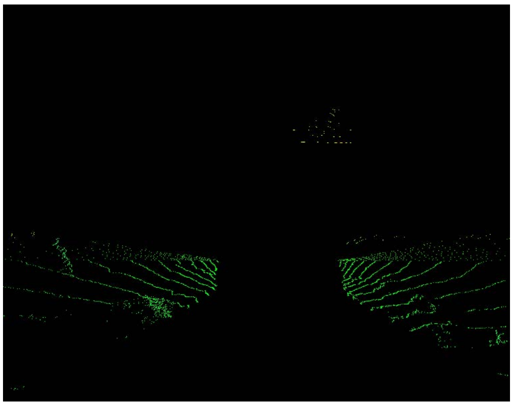

Fig. 3 – USV detection with LIDAR Scan

The ROAZ ASV performed autonomous bathymetry and bottom characterization missions. Both multibeam sonar and sidescan sonar were used. The estuary bottom is largely flat with mud bottom and without relevant points of interest. Due to the vicinity of the naval base and general marine traffic in in the area it was possible to identity visible wrecks in the sidecan data. The navigation channel in the operations area was also characterized.

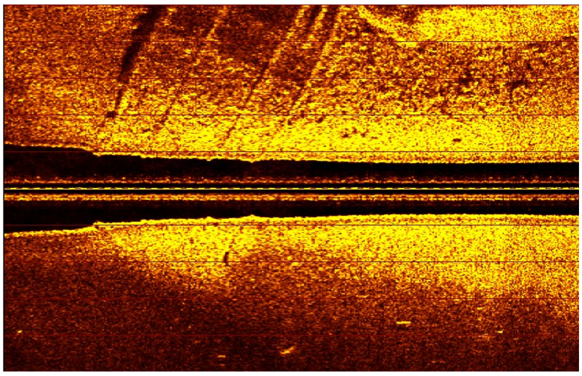

Fig. 4 – Sidescan sonar imagery from the ROAZ survey with a wreck visible

IV. Autonomous Underwater Vehicle tests

The MARES AUV [3] is a 2m long autonomous vehicle with hovering and high maneuverability capabilities. A set of sonar systems can be used for seabed characterization and target identification (single beam echo sounder and side scan sonar). The vehicle can operate up to 200m of depth, 4knots of maximum speed and has 4 electrical thrusters (two longitudinal and two vertical) allowing for direct pitch control and bottom following motion.

Experiments in navigation in the extreme shallow water environment of the operations were performed with the AUV.

The vehicle uses long baseline navigation and in the operation area defined for the REX trials the depth is small (with large areas of less than 3m) and with a high mixture of salt and fresh water. This introduces problems in the acoustic signal propagation.

Experiments to test and characterize the onboard image gathering and processing capabilities of the AUV in the difficult scenario were performed.

As expected, due to the bottom characteristics and low depth, the water visibility was found to be very low, rendering almost impossible the use of image for inspection and target detection with the AUV in the REX scenario.

V. Autonomous surface vehicle Wind propulsion tests

The integration of wind propulsion in the Zarco ASV [4] was tested. The Zarco USV is a small size electrical powered autonomous surface. In its original design it is a 1.5m length vehicle, weighting approximately 50kg and propelled by two independent electrical thrusters with a maximum speed of 4 knots.

Zarco has a catamaran configuration, assembled from a set of T-Slot aluminum structural profiles, supported in a couple of COTS flotation pontoons, one meter apart. To allow enough room for the sails, the original structure was extended from 1.5 to 2.5meters and the pontoons replaced by longer, thinner versions, resulting in a larger configuration but with a similar weight and buoyancy. This extra length also helps in compensating any torque induced by the resulting force on the sail (affecting roll and pitch). Each sail angle can be controlled by a waterproof servo, commanded byte the main CPU using a simple servo motor controller. In order to measure the windspeed and direction, we've installed an Airmar 150WX weather station that outputs NMEA sentences into a CPU serial port. Figure 5 shows the configuration of Zarco .with a wing sail at the stern, during initial testing.

Fig. 5 – Rigid sail propulsion experiments

VI. SWIFT Autonomous surface vehicle Preliminary tests

The SWIFT ASV [5] is a waterjet based small unmanned vehicle designed for coastal waters and surf zone operation.

It has a 1.2m x 0.4 fiberglass hull with a pack of LiFePo4 batteries powering a 1700W brushless motor providing the propulsion through a 50mm waterjet impeller.

The robot control is performed by a dual CPU system, with a low level autopilot (based on the PX4 firmware on an ARM Cortex M3 microcontroller) and a high level main CPU (based on and embedded SBC board such as the Odroid XU).

The autopilot is capable of direct control of the vehicle and performing waypoint based missions and the main computer is responsible for the vehicle supervision and overall control. This architecture allows both for simple control and mission programing either with direct interface with the onboard autopilot form a host computer and for development of more complex and sensor based control missions due to the flexibility provided by the main CPU. This runs a Linux based operating system with the ROS (Robotic Operating System) middleware providing easy integration of components and functionalities and interoperability capabilities.

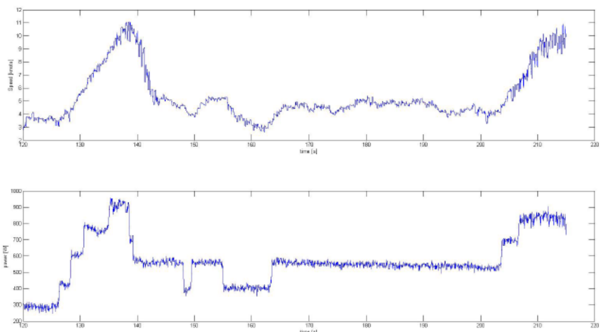

Fig. 6– SWIFT ASV propulsion tests (top – speed, bottom – power)

Propulsion and basic navigation tests were performed. The SWIFT vehicle with a 8Kg payload cargo was able to reach 11knots with an instantaneous power consumption of

900 W. Although at this speed with the standard battery configuration the autonomy is limited to about 30 min at a lower speed (2-4 knots) the vehicle is able to operate for multiple hours.

VII. ICARUS SEARCH AND RESCUE EXPERIMENTS

The ICARUS (Integrated Components for Assisted Rescue and Unmanned Search operations) project [6], [7] is a large European FP7 research project with 24 partners from 10 European countries. It addresses large scale mass rescue scenarios and has as two main demonstration test cases, one for Urban (Land) Search and Rescue and another for large scale maritime disasters.

The location of the REX' 14 exercises at Arsenal do Alfeite was chosen for the ICARUS maritime scenario final demonstration. In this context, one of the main focus of the exercises was dedicated to ICARUS related tests and preparation for the final demo.

A. ICARUS marine scenario

One of the scenarios addressed by ICARUS is the large scale disaster maritime one. This search and rescue problem differs from the more common problem in the sea were the number of potential victims is rather limited, here the posed scenario is an accident with a passenger ship were the number of people in the water is potentially large leading to additional problems in the tracking and rescue.

The ICARUS perspective is not to substitute the human search and rescue dispositive with a robotic one but to integrate robotic tools in the operations. To accomplish this task, a common C2C is necessary for multiple and heterogeneous robotic tools. This is also object of research and development in the project along with its integration capabilities with the human decision support systems. Here of primordial relevance is the aggregation and presentation of all the relevant information provided by the robot systems to the human devisors and integration in the human based command structure.

The ICARUS use of robotic tools to address the scenario entails four types of robots. Upon the accident is signalized a fixed wing long endurance UAV is used to provide initial coarse mapping and victim detection. Unmanned Surface vehicles such as the ROAZ ASV or the Calzoni's U-Ranger (also from a project partner) are used to transport assets to the area and provide support. These USV's also carry short range robotic rescue capsules (UCAP) [8] that are deployed in the area and then approach the victims in the water carrying inflatable life rafts. The UCAPs can be either programed to assists victims or cluster of victims at a known location or guided from the carrying USVs or with the help of shorter range VTOL UAVs. These, will provide detailed aerial coverage and precise victim localization. This information integrated in the C2C and them used either by robotic systems or the manned vessels.

B. Unmanned capsule robotic transponder deployment

The UCAP is a small short range ASV carrying a 4 person inflatable life-raft. It has a water jet based propulsion and carries an on-board small SBC providing navigation and interface to the ICARUS C2C infrastructure. A WiFi link (both operating in standard infrastructure mode and with a custom designed Ad-hoc with QOS control mode.) in the 2.4GHz band provides communication to the capsule.

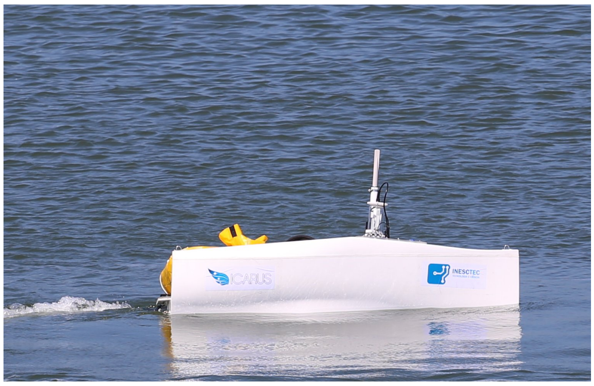

Fig. 7 – UCAP robotic rescue capsule

The UCAP is deployed either from the larger ASVs or from a manned vessel. From the ASVs it is deployed by gravity in a platform that can be mounted in the vehicles. Upon performing the designated mission (predefined waypoints or direct control) the UCAP inflates the life-raft at the designated point.

Propulsion, navigation and launch system tests were performed with the UCAPs, either being deployed from shore and also validating the autonomous deploy from the ROAZ ASV.

C. Vicitm on the water detection experiments

In the context of ICARUS, field experiments for the detection of human victims on the water by an USV were performed.

Fig. 8 – Victim on the water experiments

Human victims were deployed in the water carrying a small GPS logger in order to provide ground-truth for their localization.

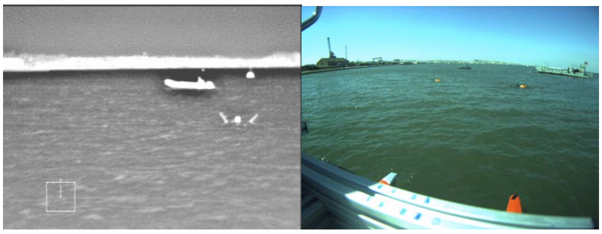

Fig. 9 – Victim on the water in the infrared and visible spectrum cameras

On the ROAZ ASV both thermographic camera and a visible spectrum one were used to detect the victims [9]. The main victim detection candidates are detected in the IR image and then verified in the visible spectrum one.

Logistical aspects concerning the deployment of the victims for the final demonstration were also addressed.

D. Preliminary ICARUS C2C integration tests

The tests were also useful for the validation of the preliminary C2C infrastructure [7] with some of the marine robotic assets (the ones from INESC TEC, ROAZ and UCAPs in particular).

The ICARUS interoperability middleware is based in JAUS and a set of bridge modules were developed to interface the common infrastructure to the various robotic platforms. In particular for the INESC TEC robotic ones, the integration of the ICARUS middleware was tested with the UCAP communication system (and the proprietary communication protocol) allowing for telemetry data from the UCAPs to be provided in the ICARUS C2C and also to issue commands and missions for the UCAP.

For the ROAZ ASV image stream data and telemetry information such as the vehicle position, attitude and other status information were integrated in the C2C.

VIII. CONCLUSIONS

In Portugal in 2013 we had 184 accidents at a sea and with the systems talk in the previous sections will be easier to patrol, detect and rescue the victims at sea.

During the REX'2014 the trials were a success and with this acknowledge will be easier to have good performance in the final tests of ICARUS trials in 2105.

The vehicles ROAZ ASV, Zarco ASV, SWIFT USV MARES AUV and the ICARUS UCAP have a good perform in this exercise and realized all the tasks that was planned at this stage for this vehicles.

These robotic exercise allows the realization of tests to a large variety of robotic systems and to assess their capabilities in realistic scenarios applications under the Portuguese Navy requirements is the main goal of REX'14. It is also an opportunity to the main companies, universities and project developers to be all in one place trading experiences and opinions and, helping each other to fulfil a gap in our world that persist among the past years that is the international cooperation.

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