2^{ND} FIELD TRAINING WORKSHOP ON UNDERWATER ROBOTICS INTERVENTION

PORT DE SÓLLER (SPAIN), 1^{ST}-5^{TH} OCTOBER 2012

Organized by the TRIDENT project team, the 2nd I-AUV field training workshop took place in Port de Sóller (Mallorca) from the 1st to the 5th of October 2012. During five days the project consortium prepared and made the final field experiments to demonstrate the TRIDENT objectives achievement. All the project Mechatronic's was successfully integrated and extensively tested in sea conditions. In addition, during the first two days, the workshop was open to the scientific community and some invited lectures and demo sessions were given. The open days program was partially co-funded by the Spanish Research Network AUTOMAR and by the IEEE-Oceanic Engineering Society.

DELFIM (IST)

Nessie-VI (HWU) endowed with USBL (IST)

FUGU (UIB)

SLOCUM Glider from SOCIB

Girona 500 (UdG) equipped with the TRIDENT payload

ECOMAPPER from UTM-CSIC

Sparus AUV (UdG)

Open Days: AUTOMAR and IEEE-OES Meeting — **TRIDENT Experimental Sessions**

Monday	Tuesday	Wednesday	Thursday	Friday
LECTURES TRIDENT Project Workpackages presented by their responsibles	DEMO 1: Gliders SOCIB DEMO 2: Ecomapper UTM DEMO 3: Sparus UdG	TRIDENT FIELD EXPERIMENTS	TRIDENT FIELD EXPERIMENTS	TRIDENT FIELD EXPERIMENTS
LECTURE ARTIFICIAL INTELLIGENCE IN UNDERWATER MANIPULATION Peter Kampmann DFKI, Germany	LECTURE DEALING WITH AIRCRAFT ACCIDENTS AT SEA Hubert Thomas ACSA-ALCEN, France	TRIDENT FIELD EXPERIMENTS	TRIDENT FIELD EXPERIMENTS	TRIDENT FIELD EXPERIMENTS
LECTURE INTRODUCTION TO MODELING AND CONTROL OF UNDERWATER VEHICLE-MANIPULATOR SYSTEMS Gianluca Antonelli Univ. Studi di Cassino, Italy	TRIDENT FIELD EXPERIMENTS			
DEMO PRESENTATIONS SOCIB - UTM - UdG				

Lectures & Demos

Few activities were programmed to present recent progress of TRIDENT and related projects to the scientific community, combining formal

Port de Sóller (Mallorca)

INVITED LECTURES

ARTIFICIAL INTELLIGENCE IN UNDERWATER MANIPULATION

Abstract: Off-the-shelf underwater manipulators lack the motor and sensor capabilities their counterparts on land or in space have. Efforts to reduce this haven been undertaken in several projects at the DFKI Robotics Innovation Center in Bremen (Germany). The motivation towards intelligence in underwater intervention tasks as well as the results from the C-Manipulator project and the SeeGrip project are presented in this talk.

About the speaker: **Peter Kampmann** holds a Bachelor and a Master in Computer Science. In 2007, he joined the German Research Center for Artificial Intelligence, and in 2009 became the SeeGrip project Leader ,which has the goal of developing a fine manipulation deep-sea manipulator with tactile feedback.

INTRODUCTION TO MODELING AND CONTROL OF UNDERWATER VEHICLE-MANIPULATOR SYSTEMS

Abstract: This talk gives the basics mathematical and control concepts for Underwater Vehicle-Manipulator Systems (UVMSs). The mathematical model is first presented by discussing the main physical effects that affect the motion of an underwater vehicle carrying a serial-link manipulator. After a brief review of inverse kinematics techniques, kinematic control strategies for UVMSs are discussed. The talk is "shaped" at entry-level for an audience with university knowledge of mathematics, physics and basic control and robotics.

About the speaker: **Gianluca Antonelli** is an Associate Professor at the University of Cassino and Southern Lazio, Italy. His research interests include marine and industrial robotics, multi-agent systems and identification. He has published 30 international journal papers and more than 80 conference papers, he is author of the book *Underwater Robots* (Springer-Verlag, 2003, 2006) and co-authored the chapter 'Underwater Robotics' for the Springer Handbook of Robotics, (Springer-Verlag, 2008). He has been scientific responsible of the STREP Co3AUVs, Associate Editor for the IP project ECHORD and researcher for the IP ARCAS. He has served both as an independent expert and reviewer for the European FP calls several times since 2006. He is chair of the IEEE RAS Chapter of the IEEE-Italy section, he has been Chair of the IEEE Robotics and Automation Society (RAS) Technical Committee in Marine Robotics. He served in the Editorial Board of the IEEE Transactions on Robotics, IEEE Transactions on Control Systems Technology, Springer Journal of Intelligent Service Robotics. He is Editor for the RAS Conference Editorial Board.

DEALING WITH AIRCRAFT ACCIDENTS AT SEA: EFFICIENT CRISIS MANAGEMENT

Mr. Thomas presented his experience of three major aircraft accidents at sea he has dealt with in the past. Among other issues, his talk covered the following topics: Alert procedure and accident type; Rescue operations organization; Search and recovery operations steps; Black boxes detection and localization; Discussion about real operations; Recovery issues; Return gained on experience and place to innovations.

About the speaker: **Hubert Thomas is** an expert in underwater intervention. He has been working more than 40 years in this field either at sea or in R&D activities. After 4 years spent at Paris Physics and Chemistry Engineers school, he specialized in Dynamic Oceanography. In 1976, he joined the French Navy deep submergence group as a research engineer, working on deep-water decompression tables. Two years later, he joined INTERSUB, a manned submersibles operations company working in the North Sea, as Survey and Technical Manager. In 1980 he founded SBS, a company involved in integrated navigation and mapping software. In 1995, he founded ACSA Underwater GPS, an underwater positioning equipment manufacturer. After developing the technology and the market worldwide, he sold the company to ALCEN's Group in July 2012. Mr. THOMAS is today consultant promoting innovations. He is also technical manager of MANOPY, a company newly created by Noel Forgeard, previous EADS CEO, to offer services for sunken aircraft black boxes relocation and recovery.

OPEN DAYS

Members of SOCIB during the demo

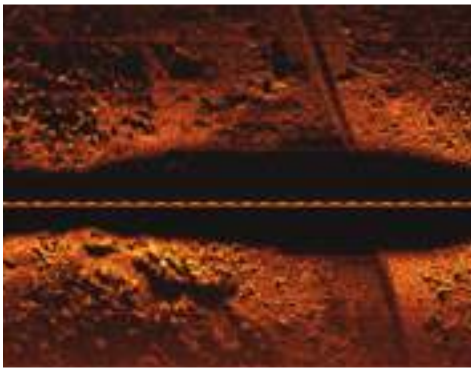
DEMOS

TECHNICAL AND OPERATIONAL ISSUES OF SOCIB GLIDERS

Members of the Balearic Islands Coastal Observing and Forecasting System (SOCIB) presented the scientific activity and the facilities of the institution, which include different Observing Platforms -fixed stations, buoys, vessels and gliders, among others-, Modeling and Forecasting applications as well as Data Centers. After the talk, a demonstration of a coastal glider operation was given including a mission programing process, launching and recovering steps and data downloading.

Simó Cusí holds a Master's degree in Mechanical and Aerospace Engineering from the Illinois Institute of Technology (IIT-MMAE) and one in Industrial Eng. from the Technical University of Catalonia (UPC). He is specialist in mechanical design and helped with the design and construction of Sparus AUV at UdG-VICOROB. Since 2010, he is part of SOCIB's glider team dealing with its operation and maintenance.

Marc Torner achieved a Bachelor's degree in Telecommunications by the University of the Balearic Islands and a Master's degree at the Technical University of Catalonia. Since 2010, Mr Torner is part of the SOCIB's staff dedicated to the operation and management of a fleet of seven gliders.



SIDESCAN SONAR AND IMAGE SURVEYING WITH AN AUV

The Unidad Técnica Marina (UTM - CSIC) owns two survey AUVs, based on the Oceanserver Iver2-580-EP, as part of the research platforms available to the scientific community. These vehicles can perform missions completely autonomous and collect oceanographic data during a time frame of 8 to 10 hrs, depending on the payload. The maximum reachable depth is 200 m. The vehicle used for the demos in Sóller is configured to collect still images and video data and sidescan sonar as well as current data with a HF Doppler Current Profiler, but it can also integrate additional sensors. At the workshop, the vehicle was used to demonstrate its operation during different survey missions, as well as the planning and data processing. Few transect were executed inside the Sóller Bay, launching the vehicle from the coast and from an auxiliary boat.

Pablo Rodríguez is the Technical Manager of the Autonomous Vehicles Laboratory of the Unidad de Tecnología Marina (Spanish Research Council). With a Telecommunications Engineering degree he has worked with acoustical and geophysical instrumentation for 15 years before moving to the AUV world.

SEAFLOOR MOSAICKING WITH THE SPARUS AUV

SPARUS is a small and low-cost AUV developed by the University of Girona, designed as a torpedo shape vehicle with hovering capabilities. It has 3 thrusters and 2 fins for moving in surge, heave, pitch and yaw DOF. It has a complete navigation system based on DVL, IMU, pressure sensor and GPS. Additionally, the vehicle allows an easy integration of other underwater equipment such as a camera, an imaging sonar or a CTD. The vehicle has on-board computer, electronics and Li-Ion batteries for moving autonomously following predefined missions, with an autonomy of 5 hours. The maximum velocity of the vehicle is 2 knots and the maximum depth is 100m. The size and light weight (40 Kg) allow the operation of the AUV by 2 persons, and it can be launched or recovered from a small boat. The demo included the description of the robot and its operation. The robot was programmed to perform a coverage mission of the seabed at 2 meters altitude for image acquisition and photo-mosaic generation.

Marc Carreras got a degree in Industrial Engineering and a PhD in Computer Engineering. He is currently an Associate Professor at the Computer Engineering Department at the University of Girona. He is member of the Computer Vision and Robotics research group, working in the Underwater Robotics Research Centre (CIRS).

O P E N   D A Y S

T R I D E N T   P A R T N E R S   R O L E

TRIDENT proposes a new methodology for multipurpose underwater intervention tasks with diverse potential applications like underwater archaeology,oceanography and offshore industries, and goes beyond present-day methods typically based on manned and / or purpose-built systems. Trident is based on new forms of cooperation between an Autonomous Surface Craft and an Intervention Autonomous Underwater Vehicle. These methodology splits the mission in two consecutive steps. Firs the I-AUV performs a path following survey, where it gathers optical and / or acoustic data from the seafloor, whilst an ASC provides geo-referenced navigation data and communications with the end user. The motion of the ASC is coordinated with that of the I-AUV for precise Ultra Short Base Line positioning and reliable acoustic communications. After the survey, the I-AUV docks with the ASC and sends the data back to a ground station where a map is set up and a target object is identified by the end user. Then, the second step starts and the ASC navigates towards a waypoint near the intervention area to search for the object. When the target object has been found, the I-AUV switches to free floating navigation mode. The manipulation of the object takes place through a dextrous hand attached to a redundant robot arm and assisted with proper perception. Particular emphasis is put on the research of the vehicle's intelligent control architecture to provide the embedded knowledge representation framework and the high level reasoning agents required to enable a high degree of autonomy and on-board decision making of the platform. The new methodology allows the user to specify an intervention task to be undertaken with regards to a particular target object, but after that the object is automatically recognized and manipulated by the robot in a completely autonomous way.

Universitat Jaume I de Castellón (Spain)
Dr. Pedro J. Sanz
Multisensory Based Manipulation Architecture

Universitat de Girona (Spain)
Dr. Pere Ridao
Navigation and Mapping

Universitat de les Illes Balears (Spain)
Dr. Gabriel Oliver
Visual/Acoustic Image Processing

Università di Bologna (Italy)
Dr. Claudio Melchiorri
Mechatronics System and Control

Università di Genova (Italy)
Prof. Giuseppe Casalino
Floating Manipulation

Instituto Superior Técnico (Portugal)
Dr. Carlos Silvestre
Single and Multiple Vehicles Control

Heriot Watt University (United Kingdom)
Dr. Yvan Petillot
Vehicles Intelligent Control Architecture

Graal Tech (Italy)
MSc. Andrea Caffaz.
Electromechanical design of the arm

WP1: Navigation and Mapping, leaded by Pere Ridao from Universitat de Girona, is responsible for endowing the team of robots with two fundamental capabilities: building multimodal maps of the environment and geo-referencing the robot position within the application scenario.

WP2: Single and Multiple Vehicles Control is responsible for the development and testing of the Single and Multiple Vehicles Control strategies. The WP is responsibility of Carlos Silvestre, from the Instituto Superior Técnico in Lisbon.

WP3: Intelligent Control Architecture, under the direction of Yvan Petillot, from Heriot-Watt University, this WP provides the embedded knowledge representation framework and the high-level reasoning agents required to enable autonomy and on-board decision making of the platform.

WP4: Visual and Acoustic Image Processing. Processing the incoming optical and acoustical images and providing the other modules of the system with the relevant information of the environment is the main responsibility of WP4, which is leaded by Gabriel Oliver, from the Universitat de les Illes Balears.

WP5: Floating Manipulation. Directed by Giuseppe Casalino, from the Università di Genova, this WP is responsible for guaranteeing the maximum of dexterity during the execution of intervention tasks to be performed by part of the hand-arm system acting within the floating conditions exhibited by the supporting base, represented by the vehicle itself.

WP6: Hand-Arm Mechatronics, System and Control. This WP is in charge for the design and development of the manipulation device for the underwater vehicle, composed of a redundant arm with 7 DOF and a dexterous robotic hand with three articulated fingers able for advanced grasping and manipulation tasks. This WP is mainly carried out at the Università de Bologna, directed by Claudio Melchiorri, developers of the hand, and in cooperation with Graal Tech, implementing the 7DOF arm.

WP7: Multisensory Based Manipulation Architecture. Pedro Sanz, from Universitat Jaume I de Castellón is the leader of this WP, as well as the Project Coordinator. This WP is centered on ensuring that suitable manipulation actions are performed during the final intervention mission gathering information from all the sensorial equipment of the system.

The TRIDENT Project was launched on March 2010 and ends on February 2013. The field experiments made during the Sóller Workshop were the final integrated project achievements demonstrations.

Cooperative navigation and control of single and multiple vehicles


The Autonomous Underwater Vehicle Nessie VI, from HWU, with the USBL from IST and part of the team

COOPERATIVE NAVIGATION

The Ultra-Short Baseline (USBL) acoustic positioning system, designed by Instituto Superior Técnico (IST), was integrated in the AUV Nessie VI, provided by Heriot-Watt University (HWU), and operated with the ASC Delfim, property of IST. Together with the instruments installed on-board Nessie VI, and using communications with the navigation system of Delfim, a sensor-based cooperative navigation system was successfully integrated and validated at sea.

INTEGRATION OF MARITIME CAPABILITIES FOR UNDERWATER INTERVENTION

A computer simulation of a capability-based planner was shown. Capabilities are provided by services so the planner supports a Service-Oriented Architecture (SOA). The automated planning mechanism combines sequential and parallel tasks based on the services provided by the maritime capabilities (i.e. navigation, vision, path following, manipulation, etc.) available in the platform (ASC, AUV, IAUV). Some configurations of missions were successfully demonstrated (e.g. seabed surveys), including missions in which maritime services were not available where the planner responded as expected by dealing with such a lack of capability.

SINGLE VEHICLE CONTROL

Using the USBL-based cooperative navigation system, both homing and docking integrated control strategies were tested with Nessie VI, whereas Delfim played the role of base station. The tests revealed smooth and effective trajectories, adequate for the problems at hand.

MULTIPLE VEHICLE CONTROL

The tests in Sóller ultimately allowed to validate a leader-following controller based on the USBL sensing device. Delfim described several surveying trajectories in the working area, at surface, while Nessie VI performed leader-following at 1.5 m depth, keeping a close distance to Delfim. The distance was so small (about 3 m) that collision seemed eminent as seen from shore. The excitement of all project members was noteworthy.

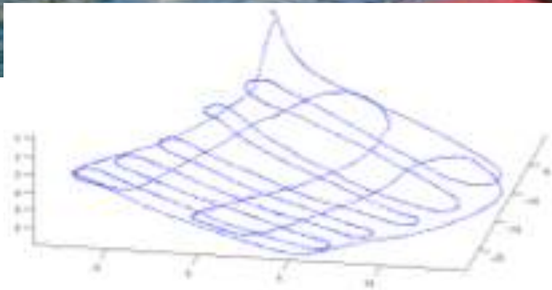

The Autonomous Surface Craft Delfim, from IST

Autonomous Intervention: Black box recovery

I.- HARDWARE & SOFTWARE INTEGRATION

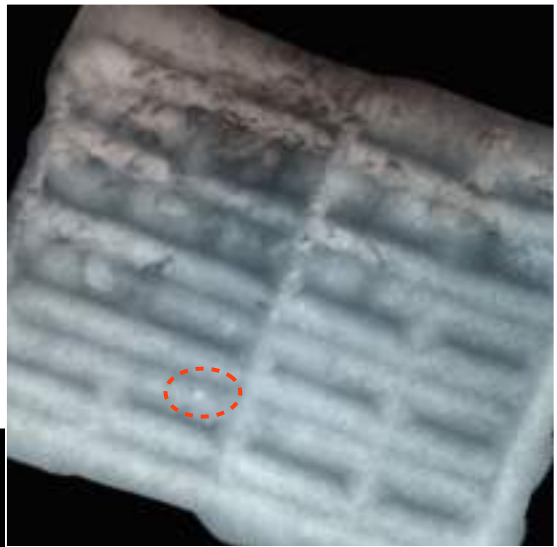
During the 1st week of September 2012 (from 3rd to 7th), several partners joined at CIRS facilities in Girona to do some preliminary hardware & software integration of the following systems: (1) a 7DOF arm from Graal Tech, (2) the stereo vision system from UIB, including both the stereo camera and the dedicated computer for 3D recognition, and (3) the UJI's Control PC, which includes the free-floating module (from UNIGE) and the grasping software control (from UJI). These systems were integrated into the Girona500 underwater vehicle developed by UdG and visually-guided free-floating manipulation tests were performed in the CIRS pool. Afterwards, from 17th to 21th, the TRIDENT consortium met again at CIRS to test the intervention stage and to solve the last hardware & software integration details. The vision system allowing 3D reconstruction, the free floating controller, the planner, the multisensory dexterous hand from UNIBO and the grasp planning module were tested and fine-tuned. After this preliminary integration, the team did the integration again in Sóller to perform the field experiments.

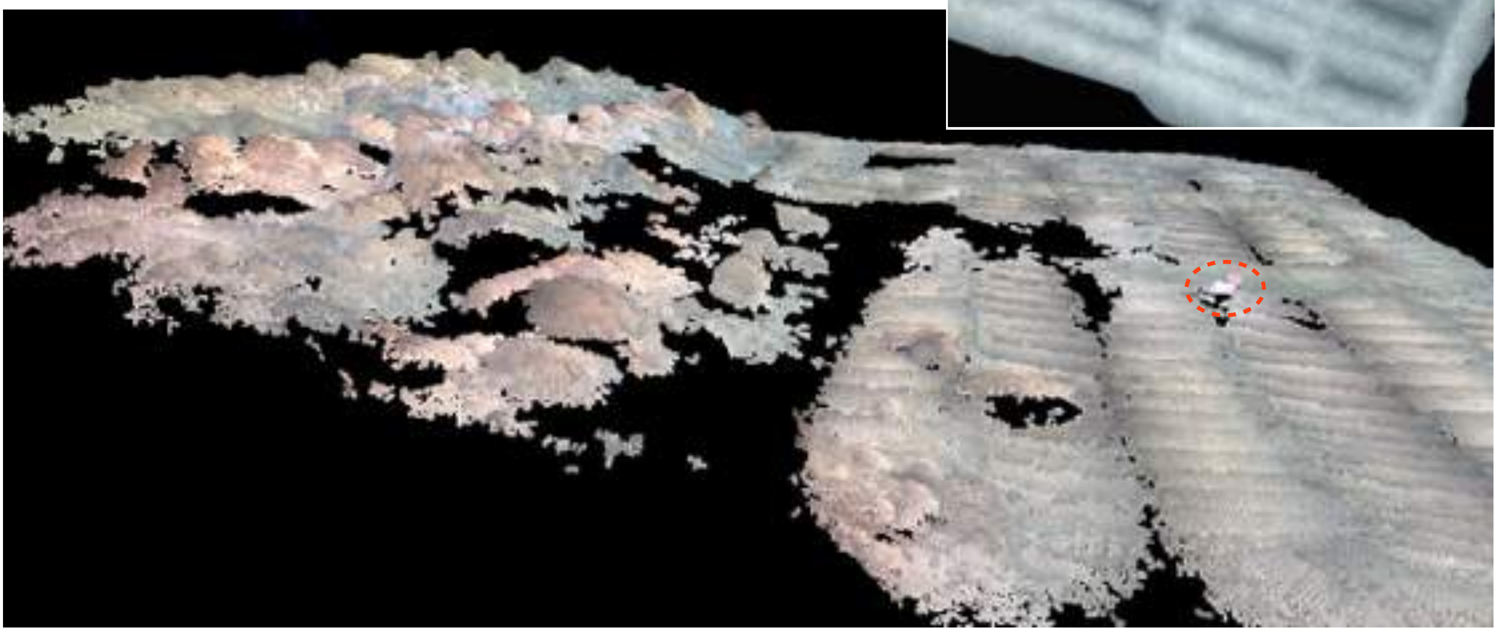
Autonomous Intervention: Black box recovery



II.- SURVEY AND MOSAICING OF THE INTERVENTION AREA

The first step for the Autonomous Intervention experiment that took place during the first week of October 2012 in Port de Sóller's harbour (Mallorca) was the surveying and mosaicing of the area where the target was suposed to be. The goal was to autonomously perform a survey trajectory under difficult harbor conditions (bad visibility, large rocks and steep slopes) with the purpose of building an image mosaic with sufficient quality to identify a target of interest, a mock-up black-box, for a subsequent intervention. The Girona500 AUV was equipped with several navigation sensors during the experiment: a Doppler Velocity Log (DVL) to measure the velocity, an Attitude and Heading Reference System (AHRS) to measure the angular position, a Sound Velocity Sensor (SVS) with an embedded pressure sensor which makes possible to estimate depth, and an echosounder to provide more reliable altitude measurements than the DVL ones. In addition, the vehicle was also equipped with a down-looking HD stereo color video camera to capture images for building the mosaic and characterize the target. The vehicle performed a grid trajectory of aproximately 25x20m, with parallel swaths along the larger dimension of the harbour, flying at approximately 1.5m from the seabed. The trajectory plotted from the estimate of the vehicle navigation system and the resulting mosaic after composing all the images can be seen in the figures to the right. The black box can be identified in the mosaic image and in the 3D point cloud map (image below) obtained combining the navigation estimated by the vehicle and the point cloud created from the stereo camera system.

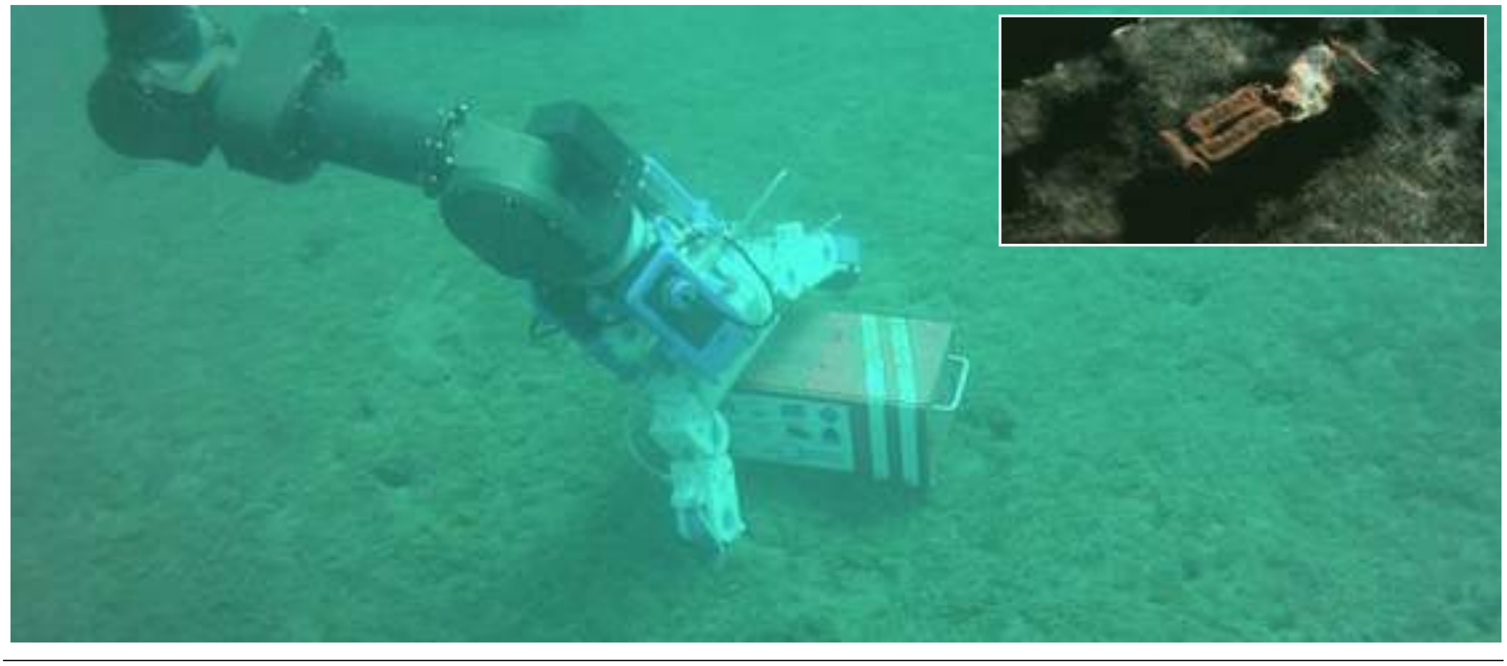




Autonomous Intervention: Black box recovery

III.- DETECTION, GRASPING AND RECOVERY

The autonomous intervention stage consisted on a black box detection, grasping and recovery from the seafloor, previously launched from a boat in a random point of the harbor area. At this time, the team had to solve some onboard computer and mechatronic problems, but thanks to the redundancy of the system, the situation was properly managed to guarantee the experiments success. After getting the seafloor mosaic, the robot did autonomous target detection. Once the black box was detected, the grasp was specified by the human operator using a specially designed user interface. Then, again with the aid of the vision system, the black box recovery stage was autonomously initiated by the system. The vision system of the robot is robust enough to allow working both in 2D and 3D (using in this case a stereo camera and a specially developed software modules). Once the box was properly grabbed by the multisensory dexterous 3-fingered hand, the vehicle brought it to the surface. The success of the experiment was observed by the TRIDENT team from the quay, thanks to the images provided by the onboard cameras of the AUV, and with the help of divers that recorded the experiment.



ACKNOWLEDGEMENTS

SEVENTH FRAMEWORK PROGRAMME

Universitat de les Illes Balears

MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

MINISTERIO DE DEFENSA

UTM Unidad de Tecnología Marina

SOCIB Balearic Islands Coastal Observing and Forecasting System

automar

CSIC Consejo Superior de Investigaciones Científicas

Govern de les Illes Balears

OES Oceanic Engineering Society

RED ELÉCTRICA DE ESPAÑA

Palma Mallorca aquarium

MEDIA IMPACT

diariodemallorca.es

ELMUNDO.es

Ultima Hora