STRONG MAR

Strengthening Maritime Technology Research Center

The STRONGMAR project is funded by the European Commission under the H2020 EU Framework Programme for Research and Innovation (H2020-TWINN-2015, 692427).

WELCOME

Dear all participants, welcome to the first STRONG**MAR** summer school.

The aim of the STRONG**MAR** project is to create solid and productive links in the global field of marine science and technology between INESC TEC and established leading research European institutions, capable of enhancing the scientific and technological capacity of INESC TEC and linked institutions, helping raising its staff's research profile and its recognition as a European maritime research center of excellence.

The training strategy of the STRONG**MAR** project is based on sessions touching multidisciplinary aspects, followed by sessions focused on specific fields of expertise, allowing researchers to improve their knowledge and preparing them for the research and implementation challenges in the sea harsh environment. The training strategy targets not only theoretical training but also hands-on training, enabling direct application of the knowledge acquired and improve their understanding of the actual requirements of the stakeholders, allowing them to design solutions with higher economic potential.

Interchange and interaction among different fields of expertise is fundamental to address the ocean challenges, due to the multidisciplinary nature of the application area. Cross-fertilization among fields of expertise is also key to stimulate the design of better specific solutions.

This summer school (***Introduction to advanced marine technologies***) will cover the following broad topics: knowledge-transfer and technology-based entrepreneurship, underwater archaeology, visual and acoustic perception, underwater acoustics, underwater sensing, optical sensing and multi-target tracking.

After this general introduction to advanced marine technologies, hands-on training on visual and acoustic seabed mapping with the SPARUS II Autonomous Underwater Vehicle (AUV) will be provided by the Girona Underwater Vision and Robotics (CIRS) of the University of Girona (Spain). This will teach how to program and operate an AUV to cover an area near the shore with side scan sonar. Once the area is covered, the AUV will be programmed to check visually several interesting points of the acoustic map. Real experiments will be performed at the sea (close to underwater archaeological spots), and at the Robotics EXercise 2016 (REX16).

The STRONG**MAR** team.

VENUE

The summer school will take place at the ***Base Naval de Lisboa*** (Lisbon Navy Base) – a military base of the Portuguese Navy – which is located at the city of Almada (Portugal). A short description is available here: www.marinha.pt/pt-pt/meios-operacoes/comando-apoio/bases/Paginas/Base-Naval-Lisboa.aspx (in Portuguese).

Photo of the *Base Naval de Lisboa* (© Marinha Portuguesa).

The lectures will take place at the ***Escola Naval*** (Navy School), which is located inside the campus of the *Base Naval de Lisboa.*

The main contact inside the *Base Naval de Lisboa*, related with the summer school, is **Commander Cordeiro Salgado** (cordeiro.salgado@marinha.pt). The main general contacts are the following:

Base Naval de Lisboa

Alfeite
2810-001 Almada
Portugal

Phone: +351 212 728 000
URL: http://tinyurl.com/pb6afgh

Escola Naval

Alfeite
2810-001 Almada
Portugal

Phone: +351 210 902 000
URL: http://escolanaval.marinha.pt

In case of emergency, please contact: +351 210 902 073 or +351 917 554 654.

The campus of the *Base Naval de Lisboa* is very large and comprises several buildings and facilities, in particular, the *Escola Naval* and the *Arsenal do Alfeite*. The following map locates the buildings related with the summer school inside the campus:

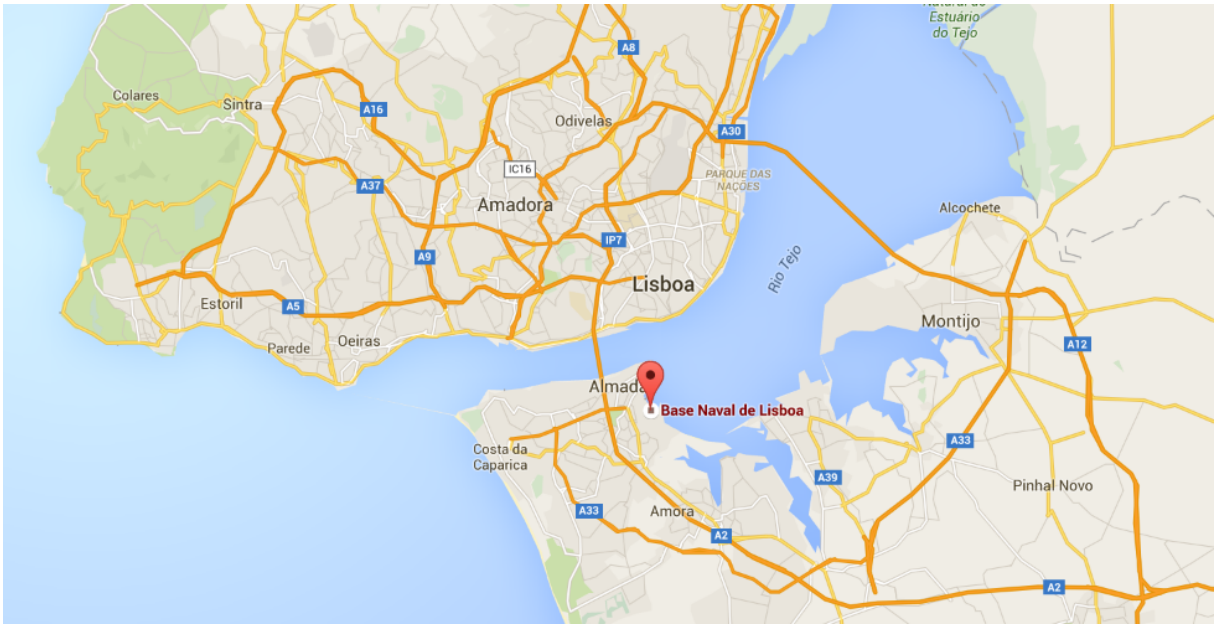
- **Portão Verde BNL** – Entrance to the *Base Naval de Lisboa*
- **Edifício escolar** – School building at the *Escola Naval*, where lectures will take place
- **Refeitório** – Canteen at the *Escola Naval*, where breakfast, lunch and dinner will be served
- **Messe Residêncial** – Hotel
- **REX16** – Location of the Robotics EXercise 2016 (REX16) activities at the *Arsenal do Alfeite*

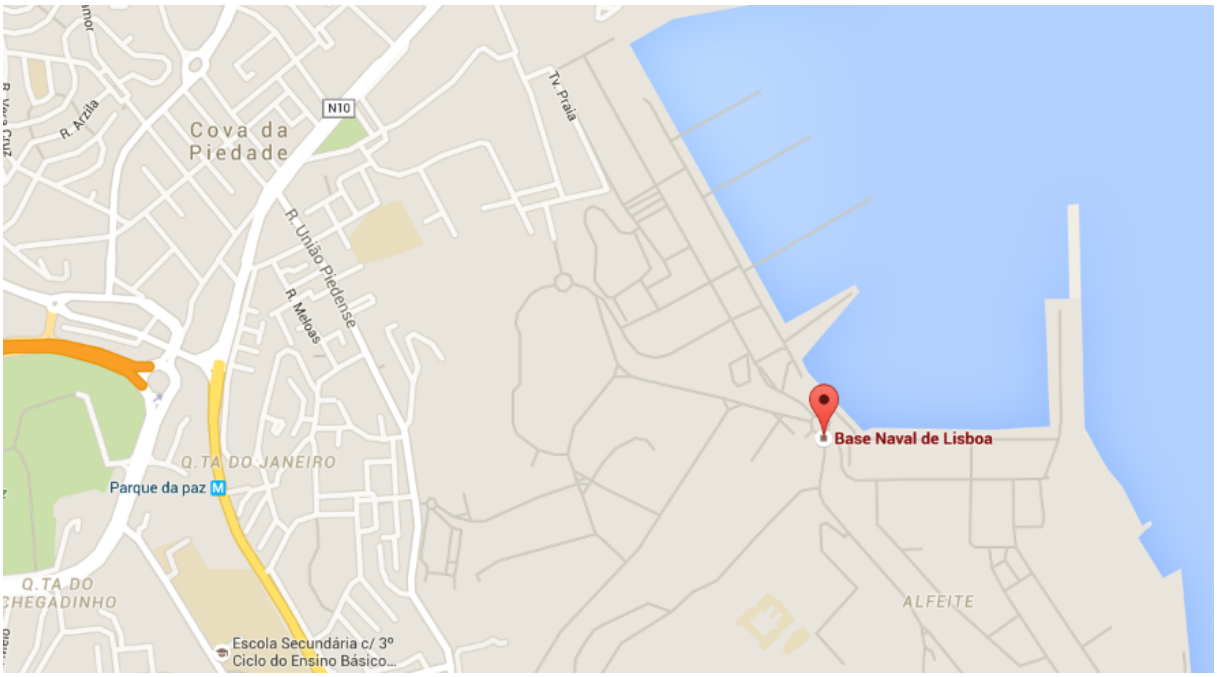
Map of the *Base Naval de Lisboa*.

Please note that you are inside a military campus, with several restrictions for civilians and external visitors, in particular, in terms of mobility. You must not walk away from the authorized areas or enter any building (apart from the ones identified above) and you should always obey to any instructions provided by the military staff.

How to arrive?

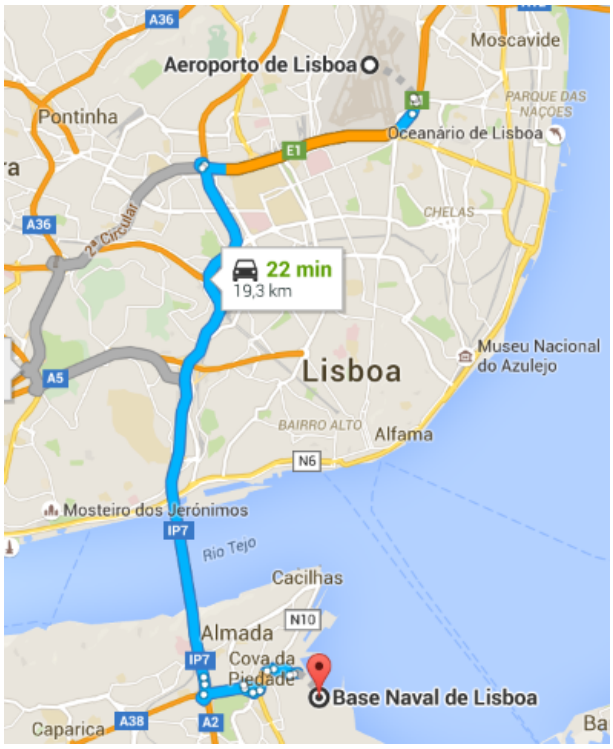
The *Base Naval de Lisboa* is located at the left side of the Tagus River (Rio Tejo), in the **city of Almada**. The address is: Base Naval de Lisboa, Alfeite, 2810-001 Almada, Portugal.





Base Naval de Lisboa at Google Maps (http://tinyurl.com/zna9k3w).

The Lisbon Airport (LIS) is 30 minutes away from the Base Naval de Lisboa.



Directions from the Lisbon airport (LIS) to the *Base Naval de Lisboa* (http://tinyurl.com/gmcmsjc).

The entrance to the *Base Naval de Lisboa* is made at Rua José Carlos de Melo (Laranjeiro, Almada), which is the *Portão Verde BNL* identified at the map of the *Base Naval de Lisboa*:

- GPS coordinates: 38°39'30.9"N 9°09'15.4"W
- Online map: http://tinyurl.com/haaqqqw

Entrance to the *Base Naval de Lisboa* at Rua José Carlos de Melo (Laranjeiro, Almada).

GENERAL OVERVIEW

	27-06-2016 Monday	28-06-2016 Tuesday	29-06-2016 Wednesday	30-06-2016 Thursday	01-07-2016 Friday	02-07-2016 Saturday	03-07-2016 Sunday	04-07-2016 Monday	05-07-2016 Tuesday	06-07-2016 Wednesday	07-07-2016 Thursday	08-07-2016 Friday
08:00 09:00	NA	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)
09:00 10:30 10:50 12:20	Arrival	**Alves Salgado** [CINAV]	**António Silva** [CINTAL]	**Daniel Clark Yan Pailhas** [HWU]	REX16 (Arsenal do Alfeite)	Free	Free	REX16 (Arsenal do Alfeite)	Sea training [UdG]	Sea training [UdG]	Sea training [UdG]	REX16 (Arsenal do Alfeite)
12:20 14:00	Lunch (Escola Naval)	Lunch (Escola Naval)	Lunch (Escola Naval)	Lunch (Escola Naval)	Lunch (Escola Naval)			Lunch (Catamaran)	Lunch (Catamaran)	Lunch (Catamaran)	Lunch (Catamaran)	Lunch (Catamaran)
14:00 15:30 15:50 17:30	**Victor Lobo** [CINAV] **Joseta Roca** [UdG]	**Matias Valdenegro** [HWU]	**Paulo Santos** [CINTAL]	**John Watson** [UNIABDN]	REX16 (Arsenal do Alfeite)			REX16 (Arsenal do Alfeite) and Equipment set-up (Escola Naval)	Sea training [UdG]	Sea training [UdG]	Sea training [UdG]	REX16 (Arsenal do Alfeite)
19:30 21:00	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	NA

Week One

	27-06-2016 Monday	28-06-2016 Tuesday	29-06-2016 Wednesday	30-06-2016 Thursday	01-07-2016 Friday
08:00 09:00	NA	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)
09:00 10:30 10:50 12:20	Arrival	**Alves Salgado** [CINAV]	**António Silva** [CINTAL]	**Daniel Clark Yan Pailhas** [HWU]	REX16 (Arsenal do Alfeite)
12:20 14:00	Lunch (Escola Naval)	Lunch (Escola Naval)	Lunch (Escola Naval)	Lunch (Escola Naval)	Lunch (Escola Naval)
14:00 15:30 15:50 17:30	**Victor Lobo** [CINAV] **Joseta Roca** [UdG]	**Matias Valdenegro** [HWU]	**Paulo Santos** [CINTAL]	**John Watson** [UNIABDN]	REX16 (Arsenal do Alfeite)
19:30 21:00	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)

Week Two

	04-07-2016 Monday	05-07-2016 Tuesday	06-07-2016 Wednesday	07-07-2016 Thursday	08-07-2016 Friday
08:00 09:00	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)	Breakfast (Escola Naval)
09:00 10:30 10:50 12:20	REX16 (Arsenal do Alfeite)	Sea training [UdG]	Sea training [UdG]	Sea training [UdG]	REX16 (Arsenal do Alfeite)
12:20 14:00	Lunch (Catamaran)	Lunch (Catamaran)	Lunch (Catamaran)	Lunch (Catamaran)	Lunch (Catamaran)
14:00 15:30 15:50 17:30	REX16 (Arsenal do Alfeite) and Equipment set-up (Escola Naval)	Sea training [UdG]	Sea training [UdG]	Sea training [UdG]	REX16 (Arsenal do Alfeite)
19:30 21:00	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	Dinner (Escola Naval)	NA

LECTURES

Lecture 1: "R&D activities at the Portuguese Navy"

Victor Lobo, CINAV

27th of June 2016 – 14:00

SPEAKER'S BIO

Victor Lobo

Prof. Dr. Victor Sousa Lobo has a 5-year degree in Electrical and Computer Engineering at the Technical University of Lisbon, a MSc degree in Computer Engineering (computer science) at the New University of Lisbon, and a PhD also in Computer Engineering at the New University of Lisbon. In 2007 he was given the "agregação" degree (roughly equivalent to the French "Habilitation") by the Statistics and Information Management Institute of the New University of Lisbon. He served as an officer in the Portuguese Navy from 1989 to 1991, and has been a civilian professor at the Portuguese Naval Academy since 1993, where he is currently Associate Professor. He is also deputy director of the Portuguese Navy Research Center since February 2010. He was faculty adjunct at San Diego State University during several short periods from 1997 to 2002, and invited professor at the French Naval Academy during the fall semester of 2008. He was invited professor for a semester at the Faculty of Science and Technology of the New University of Lisbon, and at ISCTE, and has been invited professor at the Statistics and Information Management Institute of the New University of Lisbon since 2003, where he currently heads the Research Center for Statistics and Information Management. He is author of over 90 papers in scientific journals, proceedings of international conferences, and proceedings of national conferences. He has participated in various research projects, and been principal investigator in two of them.

DESCRIPTION OF THE INSTITUTION

Centro de Investigação Naval

Centro de Investigação Naval is the Portuguese Navy's Research Centre. It was created in 2010 to coordinate the various research projects in which the Navy participates, and to support the research conducted by the faculty of the Naval Academy, where CINAV has its offices. It currently has 7 research lines, in the following areas: Signal Processing, Decision Support Systems, Mobile Robotics, Maintenance Engineering and Management, Maritime History, Maritime Strategy, and Naval Health. It has 10 permanent members that hold PhDs (mainly faculty from the academy), and over 30 associate members (mainly naval officers involved in research projects), besides several colaborators. It's research projects cover a wide range of areas, and go from theoretical research funded mainly by the Portuguese Science Foundation, to more applied research funded by the European Union, to very applied research funded by the Navy itself. The Portuguese Naval Academy, where CINAV has its offices is one of the oldest higher education institutions for naval officers in the world, having been founded in 1779 as "Royal Academy of the Navy", but heir to the "Royal Cosmographer's Class", founded in 1559, where Naval Officers received their formal education.

Lecture 2: "Knowledge transfer: the story of our underwater technology"

Joseta Roca, University of Girona

27th of June 2016 – 15:30

ABSTRACT

Girona Underwater Vision and Robotics research lab has a strong experience in the design and development of hovering AUV prototypes for different applications going from inspection to intervention. Several AUV prototypes have been designed during the last 10 years, all of them having a different conceptual design, and being GIRONA 500 AUV and SPARUS II AUV the currently operative platforms.

Besides its technical expertise, one of the core competences of the lab is its internal organization in terms of project management and general organizational issues. The talk aims to share the experiences of the UdG with INESC TEC and try to identify possible collaboration points as well as a general advice on the topic of knowledge transfer through the experience of the lab in the technology licensing and spin out experience.

SPEAKER'S BIO

Joseta Roca

Girona (1983). Studied Business Administration at the University of Girona, along her studies she was Erasmus Student at FH Joanneum in Austria, where she had the chance to participate in a very industrial oriented studies programme. After two years working in the retail sector as a marketing manager, she started her master studies on Business Innovation and Technology Management at the University of Girona. She defended her master thesis on the topic "Key Success Factors for technology management" and since then she works at Computer Vision and Robotics Research Institute where she combines project management tasks with technology transfer management and business development. She currently leads a team of the people focused on the general management of the research and communication of the institute.

DESCRIPTION OF THE INSTITUTION

GIRONA UNDERWATER VISION AND ROBOTICS

Girona Underwater Vision and Robotics research lab, as part of the Institute, has a strong experience in the design and development of hovering AUV prototypes with high--resolution image mapping capabilities. 5 AUV prototypes have been designed during the last 10 years, all of them having a different conceptual design. Being GIRONA 500 AUV and SPARUS II AUV the currently operative platforms. During the last years the team has worked on the development of advanced image processing techniques for the 2D and 3D mapping of the seafloor, as well as with the fusion of these techniques with navigation data coming from state of the art navigation sensors (DVL, gyros,

USBL) together with global optimization techniques to face large--scale maps. Map based navigation and SLAM of underwater robots using both acoustics and/or video images is currently one of the main topics of research. VICOROB has also a long experience in intelligent control architectures and has contributed in mission control systems, behaviour--based architectures, robot learning and path planning for AUVs. Finally, the group has expertise in mechatronics and software integration. Recently, 4 Sparus II AUVs have been developed to be delivered to external research institutions, three of them participating in the EU--funded euRathlon underwater competition. UdG has consistently shown in the past that it can afford young and senior researchers the proper intellectual setting for training in the interdisciplinary field of cooperative autonomous robotics. After 20 years doing research, the team has become a benchmark in Europe for the design and construction of autonomous underwater vehicles, and the development of cutting edge software for the processing of visual and acoustic data. The team is also a member of TECNIO network of Excellence in technology transfer in Catalonia region. We are located in Scientific and Technological Park of the UdG.

Lecture 3: "Underwater Archaeology"

Alves Salgado, CINAV

28th of June 2016 – 9:00

ABSTRACT

Maritime History is one of the research lines of CINAV. Within that line of research, created HistArC: a Research Program about Maritime History and Archaeology of the Conflicts, that aims the study Maritime study of the XX century, on its Military, Merchant and Fishing areas, in both dimensions: Archaeology and History, added of the Maritime Landscape approach, on a multidisplinary level, not only by consider different areas of human sciences, but also with sciences as biology, chemistry, geophysics and robotics.

We will try to show students how and how much this multidisplinary and multi-science approach is considered of critical importance at HistArC, but also the historic and geographic context where the practical activities will be developed, in order to familiarize students with the patrimonial "targets" we proposed, and how the data they shall collect, can greatly assist our work.

SPEAKER'S BIO

Alves Salgado

Captain Augusto Salgado was born in 1965 and graduated from the Portuguese Naval Academy in 1983. He has a PhD in Maritime History by the *Faculdade de Letras*, in Lisbon, since 2011. He is a researcher at CINAV - PT Naval Research Centre, member of the Academia de Marinha and of the Portuguese Military History Commission. His field of study is the Portuguese Naval History, mainly sixteen century onward and has published 3 books on this subject, plus several papers. In 2011 he won the award *Prémio do Mar - Rei D. Carlos* 2011 (Cascais).

He is also a keen underwater archaeologist enthusiast since 1996 and underwater photographer for over 30 years. Currently he is the co-coordinator of the project "The U-35 operations in the Algarve" that won the National Archaeology Society (UK) award "Adopt a Wreck Award 2015".

DESCRIPTION OF THE INSTITUTION

Centro de Investigação Naval

Centro de Investigação Naval is the Portuguese Navy's Research Centre. It was created in 2010 to coordinate the various research projects in which the Navy participates, and to support the research conducted by the faculty of the Naval Academy, where CINAV has its offices. It currently has 7 research lines, in the following areas: Signal Processing, Decision Support Systems, Mobile Robotics, Maintenance Engineering and Management, Maritime History, Maritime Strategy, and Naval Health. It has 10 permanent members that hold PhDs (mainly faculty from the academy), and over 30 associate members (mainly naval officers involved in research projects), besides several

colaborators. It's research projects cover a wide range of areas, and go from theoretical research funded mainly by the Portuguese Science Foundation, to more applied research funded by the European Union, to very applied research funded by the Navy itself. The Portuguese Naval Academy, where CINAV has its offices is one of the oldest higher education institutions for naval officers in the world, having been founded in 1779 as "Royal Academy of the Navy", but heir to the "Royal Cosmographer's Class", founded in 1559, where Naval Officers received their formal education.

Lecture 4: "Visual and Acoustic Perception with Deep Neural Networks"

Matias Valdenegro, Heriot Watt University

28th of June 2016 – 14:00

ABSTRACT

Deep Learning has revolutionized the field of computer vision by learning features directly from data. This kind of algorithm achieves human-level performance in object recognition on optical images, and has enabled many advanced applications, like automatic image classification, face recognition and autonomous driving. Companies like Facebook, Google and Car manufacturers are using it to develop new products.

The core of Deep Learning is the Convolutional Neural Network, and while it is not a new technique, the availability of large scale datasets combined with Graphics Processing Units has allowed us to train networks with large number of layers that can generalize very well on unseen data.

In this talk we will present a detailed introduction to Convolutional Neural Networks and their applications for different tasks in Underwater domain and Autonomous Underwater Vehicles. We will discuss how they are normally applied to optical imaging as well as how they can be used with acoustic data from Forward-Looking Sonars. We will also discuss code examples in Python.

SPEAKER'S BIO

Matias Valdenegro

Chile (1984). Studied Computer Science and Engineering at Universidad Tecnologica Metropolitana in Santiago (Chile), and received a Master of Science in Autonomous Systems from Bonn-Rhein-Sieg University of Applied Sciences in Sankt Augustin (Germany). He did his Master thesis about text detection in road scenes at the Fraunhofer Institute for Intelligent Analysis and Information Systems (IAIS). His Master thesis research has received the 1st place in the AFCEA Bonn e.V. Studientpreis 2015 and the Preis der Förderer der Hochschule Bonn-Rhein-Sieg e.V.

He is currently a PhD student at Heriot-Watt University and Early Stage Researcher in the ROBOCADEMY Marie Curie Initial Training Network. Matias' doctoral research is about detection and recognition of submerged garbage using Deep and Convolutional Neural Networks on Sonar and Optical images.

DESCRIPTION OF THE INSTITUTION

The Ocean Systems Laboratory is a multidisciplinary science and engineering research centre that innovates, applies and teaches world class advances in autonomous systems, sensor modelling/processing, and underwater acoustic

system theory/design for offshore, marine science, renewable energy and security applications. We are a key member of the Joint Research Institute in Signal and Image Processing in partnership with Edinburgh university. We have also recently joined forces with Edinburgh Institute for Perception Action and Behaviour (IPAB) to create the Edinburgh Alliance in Robotics and Autonomous Systems (EDU-RAS). EDU-RAS harnesses the potential of over 50 world leading investigators from 16 cross disciplinary research groups and Institutes across the School of Engineering & Physical Sciences and The Department of Computer Science at Heriot-Watt University and the School of Informatics at the University of Edinburgh. It's research and training focus is on the broad classes of physical and cognitive interactions between robots, people, environments and autonomous systems. With £7.2M of capital equipment in 2013, it is establishing ROBOTARIUM, a unique integrated facility including humanoids, interactive spaces, field robots, 3D printing and sintering, micro sensor assembly and micromaterial processing for fabrication with state of the art multi-core computing accelerators.

Our research covers three main areas:

• Autonomous Systems

In Autonomous Systems, our fundamental work has developed novel planning, obstacle avoidance, world modelling, operator dialog and visual servoing methods for Autonomous Underwater Vehicles and integrated them within open system architectures.

• Sensor modeling and analysis

In Sensor modeling and analysis, novel navigation algorithms have been developed sharing information from multiple sensors. Model-based detection and classification algorithms have been successfully developed and trialed seeking mine like objects, seabed trawling impact and marine mammals in acoustic and video data.

• Experimental Validation

Our approach has always been to approach research problems by a triangle linking theoretical analysis, software simulations and experimental validation. Our tank facilities and vehicles enable us to validate the theory and simulation findings in real experiments.

Lecture 5: "Generic introduction to underwater acoustics. Underwater acoustic sensors"

Antonio Silva, CINTAL

29th of June 2016 – 9:00

ABSTRACT

The following topics will be addressed in the presentation:

- The technologies for observing, measuring and monitoring, in space and time.
- Tools: numerical models, remote sensing, in situ sensors (bottom, water column, surface and air), observation platforms… and sound.
- Why is sound so different from the other tools?
- Usage of acoustics in the ocean: sound propagation in the ocean, sound velocity, transmission loss and ocean noise (man made, environmental and biological).
- Applications and live examples

The objective of this module is to provide a basic understanding of underwater acoustic ocean sensors and systems for engineering and scientific applications. The module comprises the presentation of the physical processes, which are behind the acoustic sensors operation, its transduction to electrical signals and the sensors integration in electronic systems. Moreover, the operation of active/passive and in situ/remote sensor systems will be presented. At the end of the module the students will be able to understand ocean acoustic sensors operation and its usefulness in ocean monitoring.

SPEAKER'S BIO

Antonio Silva

António Silva received his PhD. degree in Electrical Engineering by Instituto Superior Técnico in 2009 with the topic "Environmental based underwater communications"; currently he is Adjoint Professor of the Department of Electrical Engineering of the University of Algarve where, among others, he teaches digital systems, microcontrollers and instrumentation; he also collaborates with the teaching of the discipline Ocean Acoustic Technologies for Ocean Science students. His main interests are related to underwater communications, equalization systems, mode invariants, time reversal mirrors and oceanic acoustic sensors. He has participated in several Portuguese and European projects.

DESCRIPTION OF THE INSTITUTION

The Centro de Investigação Tecnológica do Algarve (CINTAL) is a no-profit research organization founded in 1990 with the objective of providing a link within the innovation chain between fundamental research as a source of knowledge and practical application as the use of knowledge which can be commercially exploited. CINTAL is located at the University of Algarve, Faro, Portugal with which has particular and permanent scientific cooperation ties including personnel exchange and collaboration agreements in various projects. CINTAL is actually formed by three laboratories, among which, the Signal Processing Laboratory - SiPLAB, which emphasis is on underwater acoustic signal processing, ocean acoustics and underwater communications. SiPLAB has approximately 15 researchers: 5 professors, 2 senior scientist, 1 postdoc, 4 PhD students and 2 engineers. CINTAL/SiPLAB participated or coordinated a number of technological oriented projects at national, European and international level.

CINTAL activities in underwater acoustics cover hardware development of sea going prototypes to support its research projects, methods and techniques for array signal processing and data analysis that directly exploit the developed hardware and at sea testing during international experiments. SiPLAB organizes and participates in approximately 1 or 2 sea trials per year in collaboration with its research partners. SiPLAB's main achievements encompass a record of publications of over 150 international papers both in journals and conference proceedings and the development of the Acoustic - Oceanographic Buoy (AOB) concept for network shallow water tomography. CINTAL is expertise in the areas of on underwater acoustic signal processing, system prototype integration, ocean acoustics and underwater communications.

CINTAL has recently coordinated two european FP7 projects: OAEx - Ocean Acoustic Exploration (2009-2012) and UAN - Underwater Acoustic Network (2008-2011), providing a good basis for experience on administrative and technical management of European projects. Currently coordinates some projects at national as European level.

Lecture 6: "Acoustics for underwater sensing"

Paulo Santos, CINTAL

29th of June 2016 – 14:00

ABSTRACT

Acoustics can be used to obtain relevant parameters for underwater applications. This presentation is divided in two main parts in order to show how the ocean parameters are estimated depending on the underwater application. The first part is dedicated to provide basic concepts of signal processing
applied for underwater acoustic, to obtain the impulse response of the underwater acoustic channel and to achieve the travel time for range estimation. It will be discussed the fundamental issues of time and frequency response introducing acoustic propagation models. The second part is dedicated to array data processing techniques. First of all, the principle of beamforming, where the data acquired at different sensors (an array) are delayed, weighted and summed in order to obtain a pattern, whose maximum gives the estimation of directional of arrival (DOA). Several examples of different array configurations will be presented including the Vector Sensor Array. Then, the concept of beamforming will be extended for the estimation of other parameters and a generalized beamformer will be introduced – Matched-field Processing.

SPEAKER'S BIO

Paulo Santos

Paulo Santos received his PhD degree in Electronics and Telecommunications Engineering by University of Algarve in 2012 with the topic "Ocean Parameter Estimation with High-frequency signals using a vector sensor array". Currently he is Adjoint Professor of the Department of Electrotechnical Engineering from the "Instituto Superior de Engenharia", where, among others, he teaches Measurements and Instrumentation and Industrial Instrumentation. His main interests are related to underwater acoustics propagation, directional of arrival estimation and vector sensors. He is a specialist on 3D array beamforming and source localization, and he is working on the recent field of vector sensor array processing for geoacoustic inversion. He has participated in several Portuguese and European projects.

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Lecture 7: "Multi-target tracking algorithms and applications"

Daniel Clark, HERIOT WATT UNIVERSITY

30th of June 2016 – 9:00

ABSTRACT

It is becoming increasingly important to be able to accurately model and track a large number of objects for a range of different applications. For example, advanced surveillance capabilities are needed to be able to identify and monitor activities in earth's orbit. It is critically important to these surveillance activities to be able to detect, estimate, and track multiple potential threats across a variety of platforms with different sensing characteristics. Multiple-target tracking algorithms have been developed since the 1970s, yet these methods can suffer from systematic failure due to heuristics introduced for track management. A radically different approach to multiple-target tracking has attracted a lot of attention in recent years, called Finite Set Statistics, considers the multi-sensor multi-target tracking problem in a unified way. Estimating target populations holistically enables operators to estimate the correct number of targets in challenging environments where there may be many false alarms and the targets are not always observed. This approach led to principled low computational cost solutions that can be deployed on real-time systems, known as multi-object filters. This talk will describe the statistical methodology used to develop multi-object filters and show how it can be used to address a range of problems. The methods will be illustrated on a range of applications including space surveillance, maritime surveillance, autonomous robotics, and cell biology. The talk will highlight the unique challenges in multi-sensor fusion for space situational awareness and outline a strategy for addressing them.

SPEAKER'S BIO

Daniel Clark

Daniel Clark is an Associate Professor in Sensors and Systems at Heriot-Watt University, UK. His research interests are in the development of the theory and applications of multi-object estimation algorithms for sensor fusion problems. He has made a number of key contributions to the field of multiple-object filtering that span the development of novel algorithms and methodology for multi-object tracking to the deployment and demonstration for commercial applications. He has collaborated closely with defence organisations internationally on a range of projects in multitarget tracking spanning theoretical algorithm development to practical deployment in collaboration with Dstl, BAE Systems, Finnmechanica, Thales, DCNS (France), SAGEM Defense (France), DST (Australia) and the USAF. His algorithms have been deployed on a commercial Autonomous Underwater Vehicle which played a primary role in the inspection of oil pipeline in a commercial venture with BP, which helped achieve a world record in autonomous navigation for the length of pipeline tracked on an autonomous underwater vehicle. His algorithms have been demonstrated in trials with BAE

Systems for maritime trials, where they tracked ships in the Solent from live feed from radar and electro-optic sensors.

DESCRIPTION OF THE INSTITUTION

The Ocean Systems Laboratory is a multidisciplinary science and engineering research centre that innovates, applies and teaches world class advances in autonomous systems, sensor modelling/processing, and underwater acoustic system theory/design for offshore, marine science, renewable energy and security applications. We are a key member of the Joint Research Institute in Signal and Image Processing in partnership with Edinburgh university. We have also recently joined forces with Edinburgh Institute for Perception Action and Behaviour (IPAB) to create the Edinburgh Alliance in Robotics and Autonomous Systems (EDU-RAS). EDU-RAS harnesses the potential of over 50 world leading investigators from 16 cross disciplinary research groups and Institutes across the School of Engineering & Physical Sciences and The Department of Computer Science at Heriot-Watt University and the School of Informatics at the University of Edinburgh. It's research and training focus is on the broad classes of physical and cognitive interactions between robots, people, environments and autonomous systems. With £7.2M of capital equipment in 2013, it is establishing ROBOTARIUM, a unique integrated facility including humanoids, interactive spaces, field robots, 3D printing and sintering, micro sensor assembly and micromaterial processing for fabrication with state of the art multi-core computing accelerators.

Our research covers three main areas:

• Autonomous Systems

In Autonomous Systems, our fundamental work has developed novel planning, obstacle avoidance, world modelling, operator dialog and visual servoing methods for Autonomous Underwater Vehicles and integrated them within open system architectures.

• Sensor modeling and analysis

In Sensor modeling and analysis, novel navigation algorithms have been developed sharing information from multiple sensors. Model-based detection and classification algorithms have been successfully developed and trialed seeking mine like objects, seabed trawling impact and marine mammals in acoustic and video data.

• Experimental Validation

Our approach has always been to approach research problems by a triangle linking theoretical analysis, software simulations and experimental validation. Our tank facilities and vehicles enable us to validate the theory and simulation findings in real experiments.

Lecture 8: "Underwater Acoustics: understanding the environment to increase autonomy"

Yan Pailhas, HERIOT WATT UNIVERSITY

30th of June 2016 – 10:30

ABSTRACT

The deep sea exploration and exploitation is one of the biggest challenges of the next century. Military, oil & gas, offshore wind farming, underwater mining, oceanography are some of the actors interested in this field. The engineering and technical challenges to perform any tasks underwater are great but the most crucial element in any underwater systems has to be the sensors. In air numerous sensor systems have been developed: optic cameras, laser scanner or radar systems. Unfortunately, electromagnetic waves propagate poorly in water, therefore acoustic sensors are a much preferred tool then optical ones. This keynote is an introduction to underwater acoustics. We will show why the sensor design and the signal/image processing associated with it play a key role on understanding the underwater environment and can help on the forthcoming challenges.

SPEAKER'S BIO

Yan Pailhas

Dr. Yan Pailhas is a research fellow at the Ocean Systems Laboratory in the School of Engineering and Physical Sciences, Heriot-Watt University. where he is currently carrying out research activities in bioacoustic signals and sensors, signal processing for detection and classification, and numerical simulations. His researches focus on the understanding of the interaction between wideband ultrasonic wave and solid objects. He is currently working on the development of novel wideband signalling systems, detailed analysis and simulation of wideband target echoes for classification and identification from sonar returns, and on the implementation of a low power wideband sonar system for AUVs.

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Lecture 9: "An introduction to Optical Sensing and Measurement Techniques and their application in the offshore environment"

John Watson, University of Aberdeen

30th of June 2016 – 14:00

ABSTRACT

Subsea sensing in its widest sense is growing in importance and application in our study and exploitation of the oceans and its environment. This is particularly true of optical sensing, which is finding application from high-resolution imaging to communications; from spectroscopic measurement of ocean constituents to monitoring of stress and strain in offshore structures. In this presentation we will present an overview of some of the most important types of optical sensing and their application, including holography for measurement of plankton and other marine organisms, laser-induced breakdown spectroscopy (LIBS) for measurement of rare-earths on the ocean floor, Raman spectroscopy of constituents of the oceans and fibre-sensing for use on offshore platforms.

SPEAKER'S BIO

Professor Emeritus John Watson

Emeritus Chair of Electrical and Optical Engineering,

School of Engineering, College of Physical Sciences, University of Aberdeen, Scotland, United Kingdom

Professor Watson holds an Emeritus Chair of Electrical and Optical Engineering at the University of Aberdeen, Scotland. Since starting a PhD, on laser microspectral analysis of steels, in 1973 at the University of St Andrews, Scotland, his professional career has been dominated by research in laser applications and optical engineering. After five years (from 1976) with the UK Atomic Energy Authority in Caithness, Scotland, on the development of scientific instrumentation for fuel reprocessing plant inspection, before turning to the application of holography and laser-based spectroscopy to plant inspection. In 1981, he returned to the academic world at Robert Gordon's Institute of Technology (now The Robert Gordon University) in Aberdeen before moving to the School of Engineering at the University of Aberdeen, in 1984, becoming Professor of Optical Engineering (2004) before taking up the Established Chair of Electrical Engineering in 2007. During this time his research activities centred on optoelectronics and optical engineering; with a particular emphasis on underwater optics. The research group which he established acquired an international reputation in underwater holography and digital holography. The group developed two unique subsea holographic cameras (HoloMar and eHoloCam) to image and analyse plankton. The first, HoloMar, was based on classical holography

on photographic plates; and the second, eHoloCam, is an electronic (digital) underwater holographic camera. Both have been deployed extensively in Scottish sea lochs and in the North Sea. Other specialisms include work on 3DTV, subsea laser welding, laser microspectral analysis, optical image processing, display and colour holography. The group was the first to demonstrate laser welding in water to a simulated depth of 500 m.

Joint research has been undertaken with laboratories in the UK, Europe, USA, China and Russia. The work of his group work has been supported by DSTL, EPSRC, NERC, DTI, the EC, The Royal Society and industry. Prof Watson has published extensively in learned journals and conference proceedings, and has published textbooks on "Optoelectronics", "Subsea Optics" and "Digital Holography and Wavefront Sensing". He has presented several invited papers and guest lectures at Universities and Institutions around the world. He is a member of the Editorial Board of the European Optical Society JEOS and has served as a member of the Editorial Boards of *Optics and Laser Technology* and the *Journal of Holography and Speckle* and was formerly Book Editor of *Optics and Lasers in Engineering*. He was Editor-in-Chief of a series on *Lasers and Optical Engineering* (Academic Press UK).

He is a senior member of IEEE, and a Fellow of the (UK) Institute of Physics (IOP) and the Institution of Engineering and Technology (IET) in 2001 and is a Chartered Engineer and Chartered Physicist. He has chaired several International Conferences in Aberdeen including the Annual Meeting of EOS, Blue Photonics and IEEE OCEANS. Prof Watson was Executive Chair of IEEE/OES OCEANS'07 in Aberdeen on its first visit to the UK and will repeat the exercise when OCEANS makes its return to Aberdeen in 2017. He serves on various committees of the IEEE Oceanic Engineering Society.

DESCRIPTION OF THE INSTITUTION

The **Power Systems, Communications and Optics Research Group** seeks to advance fundamental knowledge and promote applications across the whole spectrum of activities in topics relating to electrical and electronics. This spans the development of new semiconductor devices and laser components for applications such as holographic cameras to techniques for high power DC transmission; novel circuit design; design of algorithms for sensor networks with applications ranging from subsea to solar-power video monitoring of the natural environment; and the engineering of new Internet transport mechanisms.

The Power Systems, Communications and Optics Research Group enjoys an international reputation and profile for its activities with substantial support from industry – both local and international. Projects span the range from individual student scholarships to large multinational projects, with topics from modelling of new experiments techniques to evaluation of the deployment of prototype technologies. At a European level, the group successfully participate in the EC Framework programme, and European Space Agency ARTES programmes.

HANDS-ON TRAINING

Robotics EXercise 2016 (REX16)

CINAV and Portuguese Navy

1st, 4th and 8th of July 2016

ABSTRACT

The Portuguese Navy's mission is to cooperate in an integrated way, which includes the military defence of the Portuguese Republic, and also the conduction of 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 using autonomous unmanned systems in the Navy's 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), by sending a robot to these areas of risk, as it will capture images that a team can analyse in a safe place without running any risk. The success of all naval missions largely depends on the safety of all people involved and so this is also a very important benefit.

Today, there are diverse teams specializing in different areas such as shipwrecked rescue, searching for mines, environmental monitoring, border surveillance, traffic control, search and rescue and harbour protecting. Robotic systems and unmanned vehicles can provide additional capabilities and new innovative solutions that contribute to these applications.

The Robotics EXercise 2016 (REX16) aims to run a set of field experiments performed with multiple unnamed systems in the context of the Portuguese Navy concept of operations. During the REX16, multiple experiments and systems will be operated. Autonomy and environment characterization and assessment missions will be performed with autonomous vehicles such as the ROAZ II autonomous surface vehicle (ASV) and the MARES autonomous underwater vehicle (AUV). Recent developments related to the acoustic navigation and new maritime wireless communication protocols will also be tested.

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.

The Robotics EXercise 2016 is organized by CINAV – Centro de Investigação Naval (Research Centre of the Portuguese Navy) and the Portuguese Navy, and takes place at *Arsenal do Alfeite*, inside the campus of *Base Naval de Lisboa*, close to the *Rio Tejo* (Tagus River).

Photos of exercises within the REX14 at the Tagus River.

EQUIPMENT USED

MARES – Autonomous underwater vehicle (AUV)

MARES (Modular Autonomous Robot for Environment Sampling) is an autonomous underwater vehicle (AUV) used in underwater operations. This robot can be easily configured and its modular structure allows it to carry a large variety of sensor packages. MARES can be used for different applications such as environment monitoring, underwater inspection and mapping, and surveillance. An acoustic positioning system makes it possible to georeference collected data. This device has been used regularly since 2007 in environmental monitoring operations.

Typical sensors include CTD, sonar, turbidity, fluorescence and video camera.

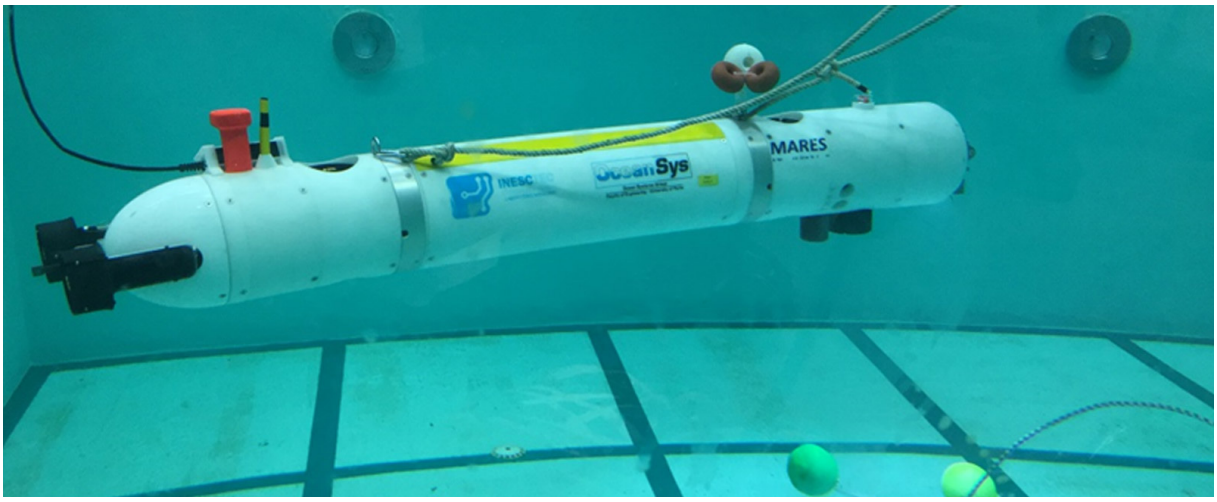


Photo of the MARES autonomous underwater vehicle (AUV).

ROAZ II – Autonomous surface vehicle (ASV)

ROAZ II is an autonomous surface vehicle (ASV) designed for aquatic environment monitoring, bathymetry, data collection and oceanography, security and search and rescue missions. With on-board sensor processing and high precision navigation it is capable of operating autonomously in the ocean environment. The robot has a wide range of sensors and advanced on-board controls allowing its use in efficient precision environmental modelling (oceanographic, 3D sea floor modelling), automated intrusion detection, target tracking, identification, area patrol, communications relay in multi-vehicle scenarios and surface support to underwater assets. On-board ROV in coordinated missions makes it a suitable surface platform for underwater inspection and data collection tasks. This vehicle has already taken part in various operational missions.

ROAZ II is equipped with RTK GPS and FOG INS for precision navigation, uses Radar/laser and vision (visible and thermographic) for collision detection, uses several underwater sonars/sensors for bathymetry and underwater characterization. It can operate in several modes: maned, teleoperation, autonomous waypoint following, station keeping and adaptative autonomous mission.

It is not a close off-the-shelf system and is continuously adapting to different projects and missions. At the moment, it is equipped with: MBES Imagenex Delta T, Tritech SubBottom Profiler, Teledyne explorer DVL, evologics USBL/modems, Altimeter and Tritech DST, Sportscan Sidescan Sonar and a Reson SVP.

Photo of the ROAZ II autonomous surface vehicle (ASV).

SPARUS II AUV: "Sea hands-on training"

University of Girona

5-7th of July 2016

ABSTRACT

During the STRONGMAR summer school the University of Girona (UdG) will introduce the Sparus II AUV (see Fig. 1) and the methodology to operate it and post process the data gathered in field trials.

Three practical sessions are scheduled on board a catamaran in which the students and the UdG researchers will complete the following goals:

- Define autonomous missions using a geographic information system (GIS) over areas of interest (see Fig.2). Missions can be focused to obtain multibeam data, in order to build high resolution bathymetries, or to gather image data from the sea bottom.
- Configure and understand the main AUV parameters (i.e., navigation, safety, control, ...) as well as the sensors used for the mission at hand (i.e., multibeam sonar, camera, side scan sonar, ...).
- Deploy and recover the AUV and execute the previously defined mission.
- Monitor the AUV mission execution using acoustic communications.
- Postprocess the data gathered in order to build bathymetry maps (see Fig.3) or underwater mosaics (see Fig.4) using the pipelines developed in the UdG. Obtained bathymetries and mosaics will be georeferenced and used in the GIS software to define new missions.

Trials will be performed with the Sparus II AUV and the ROAZ II autonomous surface vehicle (ASV) (see Fig.5) that will provide position updates and localization to the AUV through an ultrashort base-line (USBL) device.

Fig. 1: Sparus II AUV

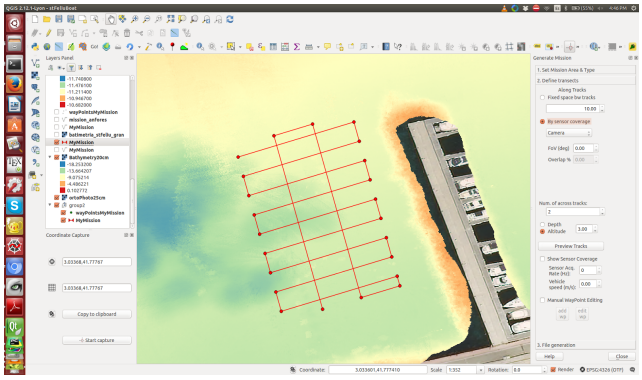


Fig.2: QGIS Mission definition environment

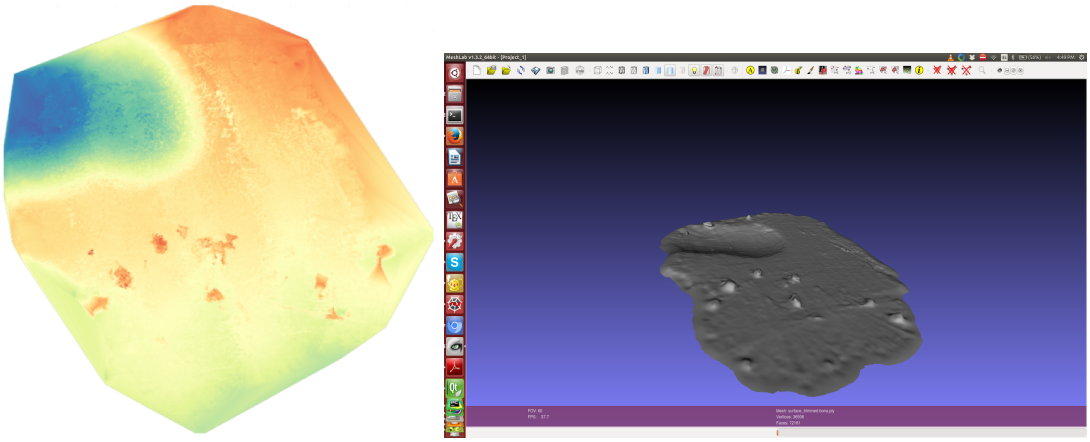


Fig.3 Bathymetric maps and reconstructions

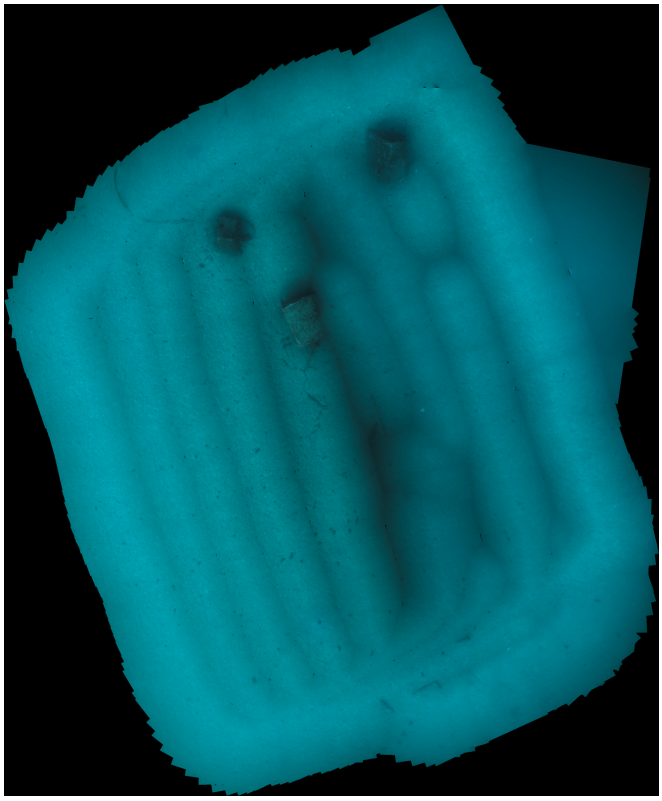


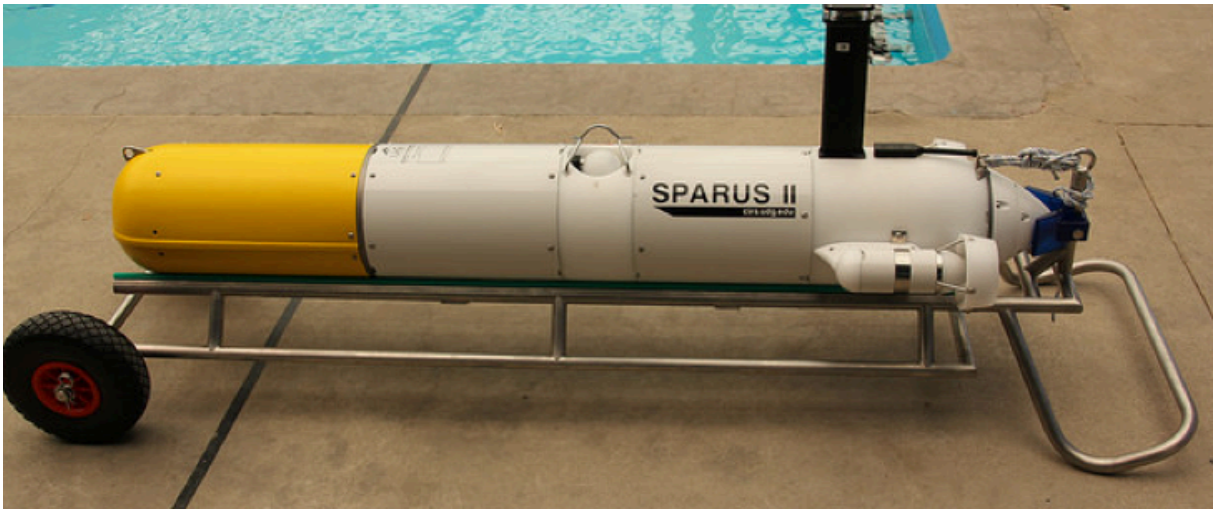
Fig.4 Underwater photo mosaic

Fig.5 ROAZ II ASV

EQUIPMENT USED

SPARUS II AUV

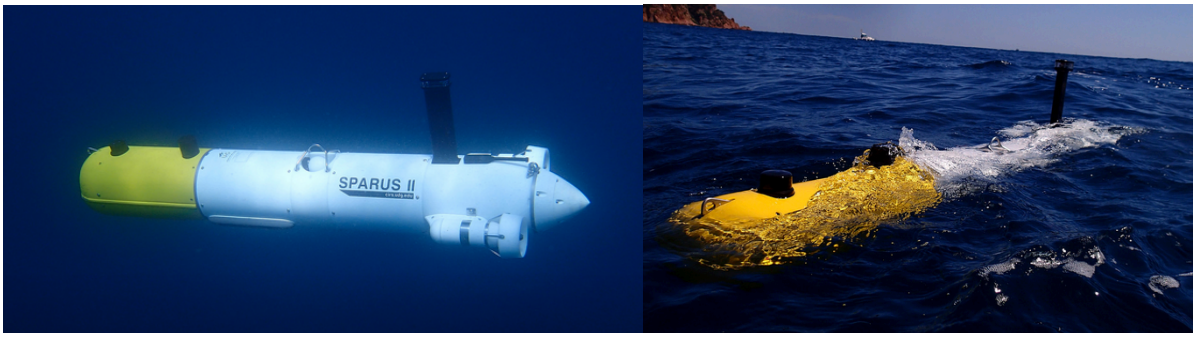
The SPARUS Autonomous Underwater Vehicle (AUV) was conceived in the Underwater Robotics Research Centre (CIRS) of the University of Girona (Spain). The first version was designed in 2010 to participate in the European Student AUV competition, organized by CMRE in La Spezia (Italy). The robot won the competition and, since then, it has collaborated in several research projects. In 2013, a new version of the robot, SPARUS II AUV, was finished and is now being commercialized.



SPARUS II AUV is a lightweight hovering vehicle with mission-specific payload area and efficient hydrodynamics for long autonomy in shallow water (200 meters). It combines torpedo-shape performance with hovering capability. It is easy to deploy and to operate. The payload area can be customized by the end user and it uses an open software architecture, based on ROS, for mission programming. Its flexibility, easy operation and openness makes the SPARUS II AUV a multipurpose platform that can adapt to industrial, scientific and academic applications.

Key points:

★TORPEDO-SHAPE MOVEMENT: EFFICIENT HYDRODYNAMICS AND LONG AUTONOMY
★HOVERING: HIGH MANEUVERABILITY
★LIGHTWEIGHT: GLIDER LIKE SIZE AND WEIGHT
★EASY OPERATION: BY 2 PEOPLE FROM ANY BOAT
★MISSION SPECIFIC PAYLOAD: OPEN HARDWARE FOR EQUIPMENT INTEGRATION
★SOFTWARE ARCHITECTURE BASED ON ROS: OPEN SOFTWARE AVAILABLE FOR DOWNLOAD
★LOW COST



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SPEAKER'S BIO

Marc Carreras

Marc Carreras (MSc 1998, PhD 2003) is Associate Professor in the Computer Engineering Department at UdG, and member of the VICOROB group working in the CIRS laboratory. He holds a B.S. degree in Industrial Engineering (1998) and PhD in Computer Engineering (2003, Best PhD award) from the University of Girona. Since 1999, he has participated in 14 research projects (6 European and 8 National), he is author of more than 80 publications, and he has directed 3 PhDs thesis (3 more under direction). His research activity is mainly focused on underwater robotics in research topics such as intelligent control architectures, robot learning, path planning, AUV design, modelling and identification.

Narcís Palomeras

Narcís Palomeras (MSc 2004, PhD 2011) is a Postdoctoral Fellow in the Department of Computer Engineering of University of Girona (UdG), and a member of the Underwater Robotics Laboratory in the Computer Vision and Robotics Group (VICOROB). He holds a B.S. degree in Computer Science (2004) and a PhD in Computer Engineering (2011) from the University of Girona. He has participated in several research projects (both national and European) related with underwater robotics and has taken part in several European AUV competitions. His research activity is mainly focused on underwater robotics in research topics such as intelligent control architectures and mission control.

Tali Hurtós

Natàlia Hurtós is a postdoctoral researcher in the Underwater Robotics Laboratory (CIRS) of the Computer Vision and Robotics Group (VICOROB) of University of Girona (UdG). She holds a B.S. degree in Computer Science (2007), an European Master in Computer Vision and Robotics (VIBOT, 2009) and a PhD in Computer Engineering (2014). Since 2006 she has participated in several research

projects (both national and European) and contributed to various STEM dissemination activities carried out at CIRS. Her research interests are mainly focused on underwater robotics and more particularly in mapping of underwater environments using sonar data.

Carles Candela

Carles Candela finished the electronics degree in the University of Girona in 2011 and joined the Research Center in Underwater Robotics (CIRS) of the same university. During his final degree project he designed a fins actuator and the low level control of the SPARUS AUV. Since then he has worked in the development of the SPARUS II AUV, various payloads and other underwater equipment for robotics.

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