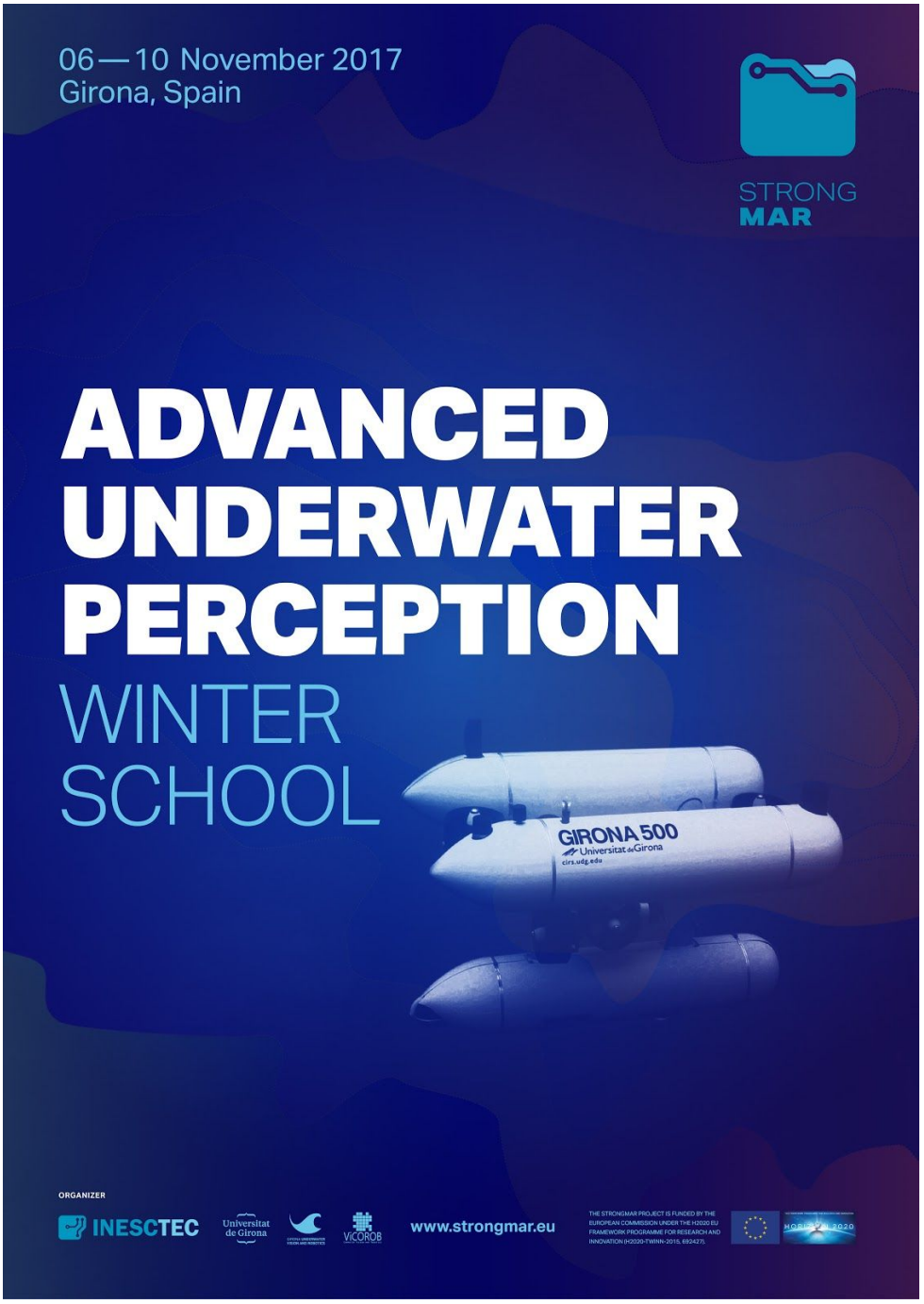
STRONG
MAR

Strengthening Maritime Technology
Research Center



"Winter School on Intervention Autonomous Underwater Vehicles"

University of Girona, Spain

6 to 10th November 2017

WELCOME

Dear all participants, welcome to the first STRONG**MAR** winter 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 winter school (**Intervention Autonomous Underwater Vehicles**) will cover the following broad topics: Kinematics of Underwater Vehicle Manipulator Systems, Task priority framework for the kinematic control of an IAUV, and MoveIt!, together with hands on training on ROS IAUV programming.

The STRONG**MAR** team.

VENUE

The winter school will take place in the city of Girona, at the Science and Technology Park, located in the outskirts of the city.

How to arrive to Girona?

Girona city is only 65 km / 40 mi from the French border (100 km / 62 mi from Perpignan) and 100 km / 62 mi from Barcelona, the easiest way to arrive is fly either to:

Girona-Costa Brava Airport

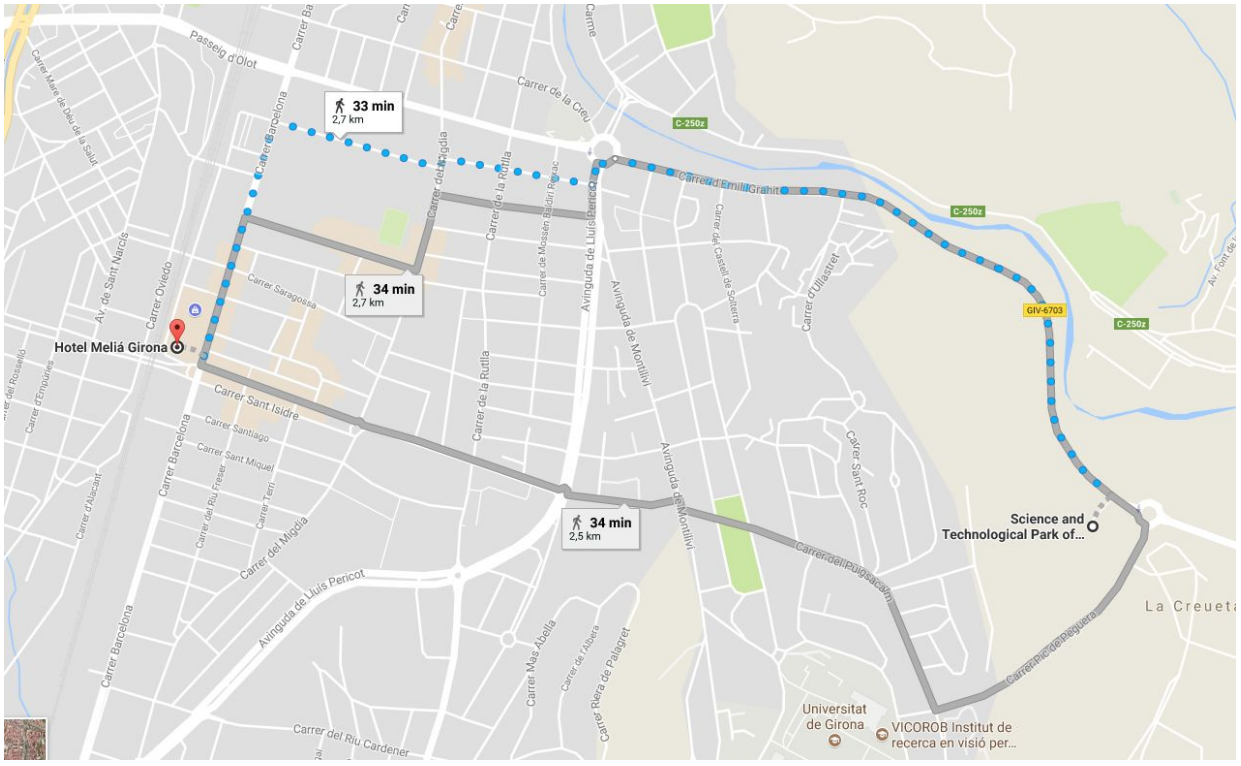
Girona-Costa Brava Airport has regular flights from cities in Europe and other parts of Spain. The airport is located about 12 km / 7 mi outside Girona, with good road connections to the city centre by car, coach or taxi. Road access into Girona city is by the N-II main road or the AP-7 motorway (taxi may cost you around 20 €). There is also a coach service into Girona bus station every 30'.

Barcelona-El Prat Airport

Barcelona-El Prat international airport receives regular European and intercontinental flights. Just 110 km / 68 mi away, there is direct access to Girona by motorway (taxi may cost you around 160 € and will take around 1h and 20 minutes to arrive) or train (you need to take the Barcelona area train to reach Barcelona-Sants train station and then pick the high speed train to Girona, the whole process will take you around 2 hours).

How to arrive to Science and Technology Park?

The Science and Technology Park is in the outskirts of the city. You can easily arrive walking (it will take you a 30-minute promenade around the river from the city centre), take a taxi (may take you 5 minutes and can cost you around 8 €) or take the bus L8 from the train station to Science and Technology Park stop (it leaves every 30 minutes and will cost you around 2 €/way).



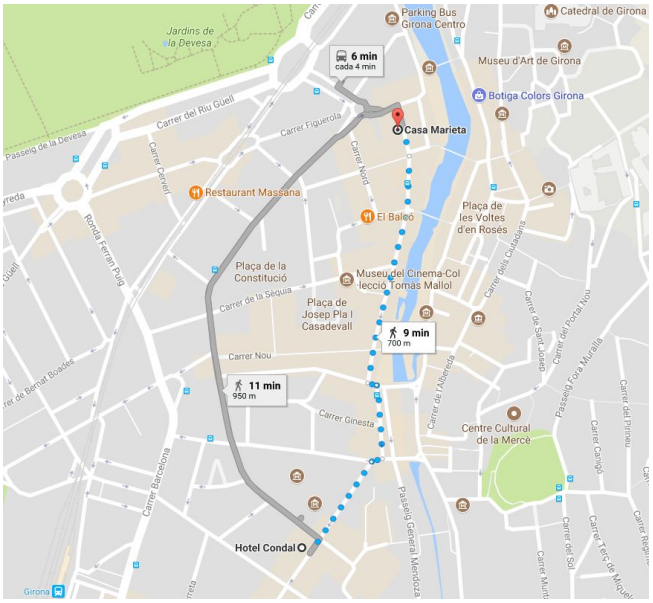
The training will take place at: **"Aulari 5" of Giroemprèn Building**. **Access B**, end of the corridor, on your right hand side.

Invited Dinner

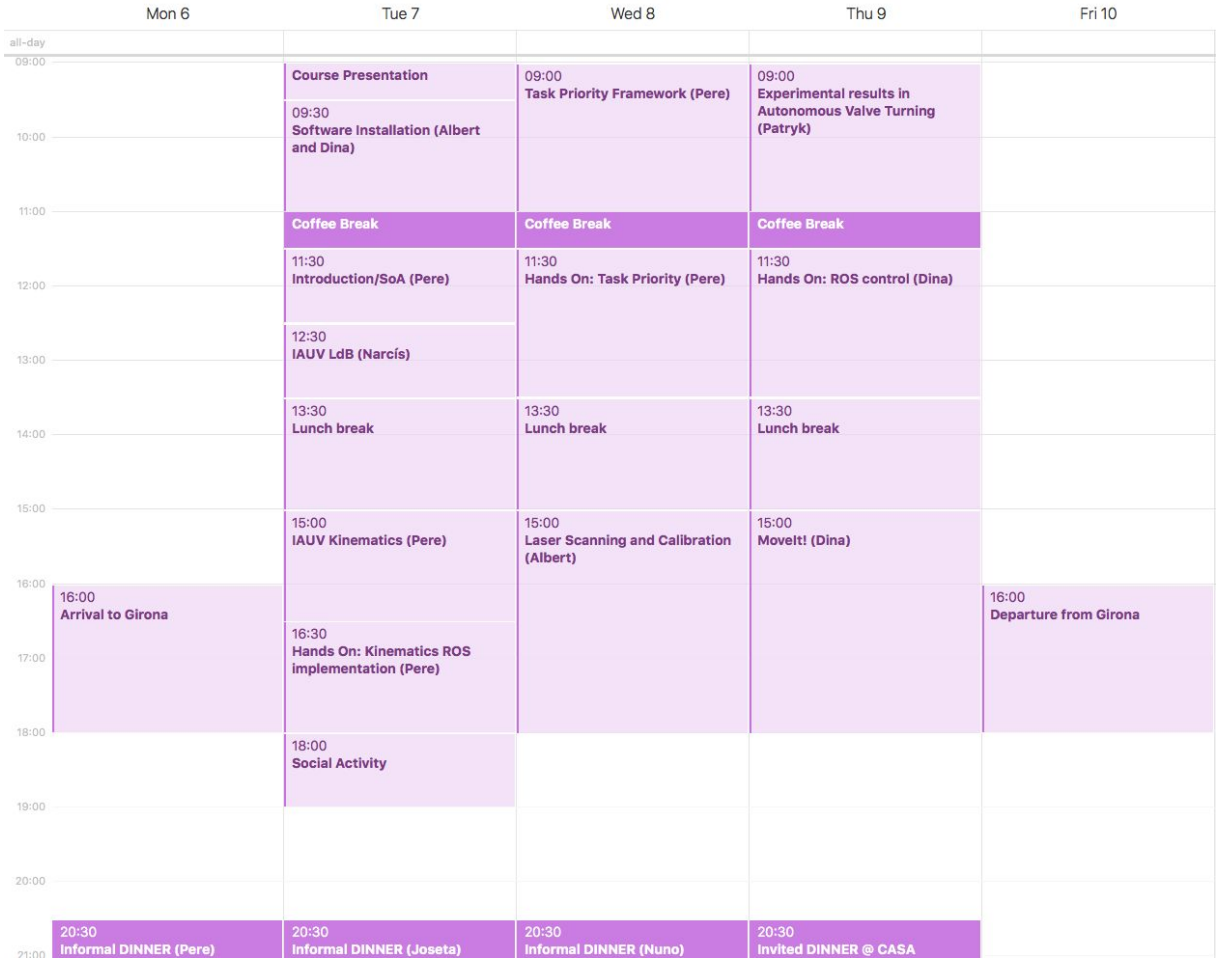
On Thursday evening there will be an invited dinner at **restaurant Casa Marieta**, in the city centre. **We will meet there at 20:30**.

RESTAURANT
Casa Marieta
CASA CENTENÀRIA DE GIRONA

Restaurant Casa Marieta
Plaça Independència, 5-6
17001 Girona
https://goo.gl/maps/SDJzk9MJdTB2



SYLLABUS



Lectures

Tuesday the 7th of November

Introduction: State of the Art by Pere Ridao. While commercially available AUVs are routinely used in survey missions, a new set of applications exists which clearly demand intervention capabilities. The maintenance of: permanent observatories underwater; submerged oil wells; cabled sensor networks; pipes; and the deployment and recovery of benthic stations are but a few of them. These tasks are addressed nowadays using manned submersibles or work-class ROVs, equipped with teleoperated arms under human supervision. Although researchers have recently opened the door to future I-AUVs, a long path is still necessary to pave the way to underwater intervention applications performed in an autonomous way. This talk reviews the evolution timeline

in autonomous underwater intervention systems. Milestone projects in the state of the art will be reviewed, highlighting their principal contributions to the field. Next, GIRONA 500 Intervention AUV will be presented and its software architecture discussed. Recent results in different scenarios will be reported: 1) Valve turning and connector plugging/unplugging while docked, 2) Free floating valve turning and connection plugging/unplugging , 3) Free floating multipurpose multisensory based object recovery and 4) manipulation in the presence of obstacles. The talk will end with a discussion about the lessons learnt and the future directions for research.

IAUV LdB by Narcís Palomeras. In this lecture, a flexible framework for I-AUVs using learning by demonstration (LbD) algorithms will be explained. This method allows an expert to transfer a skill or knowledge to the I-AUV using a natural and intuitive form: a set of demonstrations. This system speeds up and simplifies the way in which new tasks can be programmed giving the robot the ability to perform multiple tasks with minimal effort.

Kinematics by Pere Ridao. This lecture will present the position/velocity kinematics of an I-AUV. The GIRONA500 AUV (4DOF) equipped with a 4 DOF ECA micro-arm, will be used as example. After developing the equations, it will be shown how to take profit of already existing ROS libraries to solve the forward/inverse kinematics of an I-AUV, as well as how to use the inverse Jacobian for its kinematic control. The lecture will include 'hands on' exercises in python to test the presented concepts.

Wednesday the 8th of November

Task Priority Framework by Pere Ridao. This lecture will present the Task priority framework used for the kinematic control of a redundant IAUVs. Starting from the definition of the IAUV Jacobian already introduced in the previous lecture, it will be presented how to use its pseudo-inverse to control the end effector motion in the workspace. The concept of singularities will also be introduced. Next, it will be presented how to define and implement a control task, as well as how to run simultaneously several task to exploit the redundancy of the system. The lecture will be illustrated with several examples and real code.

Laser Scanning & Calibration by Albert Palomer.
This lecture will start by presenting a method to calibrate a camera, base of any laser scanning system, with a robotic arm to allow interaction between both. This lecture will then review the different laser scanners available in the literature for underwater applications. Then, a ray casting model will be presented to assess the laser distortions that appear because of the refraction that the laser suffers when passing through the viewport and into the water. Based on this distortion, a new surface for triangulation will be studied so better and faster results can be achieved with

underwater laser scanners. Finally, a basic calibration procedure for a laser-camera system where there is no relative motion will be explained as well as solved with a hands-on by the attendants.

Thursday the 9th of November

Experimental Results in Autonomous Valve Turning by Patryk Cieślak. This lecture will present a controller for the GIRONA500 Underwater Vehicle Manipulator System and report experimental results for an autonomous floating-base valve-turning manipulation application. The selected method is based on kinematic control, avoiding the need for a complex, and difficult to obtain, hydrodynamic model. The method relies on the decoupled control of the vehicle and manipulator velocities using a combination of the task priority redundancy resolution and the task concurrence approaches. The talk discusses the manipulation tasks needed, their hierarchical organisation, and a set of strategies that were needed to complement the `standard' task-priority approach to successfully solve the floating-base manipulation problem in water tank experimental conditions.

ROS Control by Dina Youakim. This lecture will introduce the audience to the ROS control software package which is used to help robot developers to set up robot controllers without the need to reinvent the wheel. After a brief description of the main concepts, a 'hands on' approach will be followed. The students will follow a tutorial to set-up a simple controller for a virtual I-AUV, taking profit of possible already existing controllers offered by the hardware (which in this case will be simulated).

Moveit! Based IAUV by Dina Youakim. The work reported in the literature on underwater free floating manipulation is based either on variations of the task priority framework or the use of learning by demonstration. Although there have been significant advances toward fully autonomous underwater intervention, today's technology is still far from having the capabilities already demonstrated by terrestrial robots, in which motion planning techniques have been extensively introduced. There are no reported results in the literature on seamlessly integrating motion planning, manipulation, three dimensional(3-D) perception, kinematics, control, and navigation technologies to control UVMSs to perform manipulation tasks while moving in the presence of obstacles. This is the case even though obstacle-avoidance skills are necessary to safely operate in submerged infrastructures. MoveIt! mobile manipulation software, a framework integrating all of these technologies, has been successfully applied to industrial, single/dual arms, mobile manipulators, and humanoid robots, and recently to intervention AUVs (I-AUVs). The main focus of this talk is the evaluation of the use of MoveIt! motion planning capabilities to control a UVMS and demonstrate beyond-state-of-the-art tasks, including valve turning in the presence of obstacles and connector plug/unplug, both on a free-floating base for the first time.

PREPARING YOUR LAPTOPS

Prerequisites from participants:

It is required to have a computer with UBUNTU 16.04 LTS and ROS Kinetic already installed to not loose time preparing the system. To follow the course it will be also necessary to install the UWSim simulator and the COLA2 software architecture:

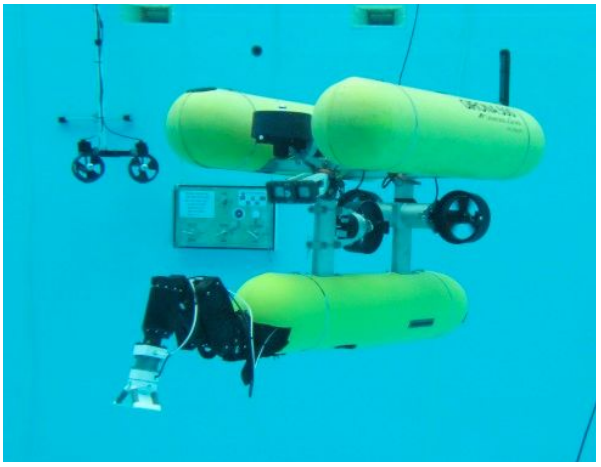
- To install UBUNTU 16.04
  http://releases.ubuntu.com/16.04/
- To install ROS kinetic
  http://wiki.ros.org/kinetic/Installation
- To install UWSim:
  sudo apt-get install ros-jade-uwsim
  Once done, run UWSim for the first time. It will download some extra content.
  roscore & rosrun uwsim uwsim
- To install COLA2 architecture:
  Once your system is ready (UBUNTU and ROS installed), you have to create a catkin workspace (http://wiki.ros.org/ROS/Tutorials/InstallingandConfiguringROSEnvironment) to install the packages that form the COLA2 control architecture. Next, install de follow packages:
  cd ~/catkin_ws/src/
  git clone https://bitbucket.org/udg_cirs/auv_msgs.git
  git clone https://bitbucket.org/udg_cirs/cola2_core.git
  git clone https://bitbucket.org/udg_cirs/cola2_g500.git
- Install ROS control & its dependencies: sudo apt-get install ros-kinetic-ros-control ros-kinetic-ros-controllers ros-kinetic-control-toolbox ros-kinetic-rosparam-shortcuts
- Install MoveIt! sudo apt-get install ros-kinetic-moveit

To check that everything has been correctly installed do:
cd ~/catkin_ws/
catkin_make

Further software will be installed on site. Any inquires in the installation process, please contact: albert.palo@gmail.com

Meet University of Girona team

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.



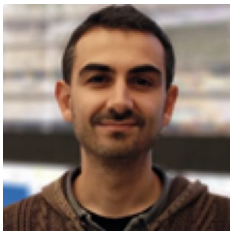
VICOROB has also a long experience in intelligent control architectures and has contributed in mission control systems, behaviour-based architectures, robot learning and path planning for AUVs. Finally, the group has expertise in mechatronics and software integration. Recently, 4 Sparus II AUVs have 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.

Pere Ridao

Dr. Pere Ridao who received the Ms.C. degree in computer science in 1993 from the Technical University of Catalonia, Barcelona, Spain, and the Ph.D. degree in computer engineering in 2001 from the University of Girona, Spain. His research activity is mainly focused on underwater robotics in research topics such as intelligent control architectures, UUV modelling and identification, simulation, navigation and mapping, Mission Control and real-time systems. He joined the Institute of Informatics and Applications, University of Girona, in September 1995. Currently, he is an associate professor with the Department of Computer Engineering of the University of Girona. Currently he is involved in national projects (RAUVI or ARCHROV) and European projects (FP7 STREP TRIDENT, PANDORA, MORPH, EUROFLEETS 2, amongst others) about underwater robotics and some technology transference projects (INSPECSUB). Dr. Ridao is the chair of the IFAC's Technical Committee on Marine Systems and member of the editorial board of Springer's Intelligent Service Robotics journal.

Patryk Cieślak

Patryk Cieślak acquired his Doctoral degree at the Department of Robotics and Mechatronics (2016), faculty of Mechanical Engineering and Robotics, at the AGH University of Science and Technology in Krakow, Poland. His main research interests focus around control system design for mobile, under-actuated and underwater robots. His experience in this area ranges from the mechanical engineering, choice of sensors/electronics, design of electronic circuits and implementation of firmware/software on microcontroller and PC platforms. During his research stay at UdG in 2014, he lead the development and implementation of a control system for an autonomous underwater vehicle-manipulator system (AUVMS) composed of the Girona500 AUV and a 4-DOF manipulator. This work included mathematical modelling, control design based on kinematic control, with some original ideas, and implementation on the real robot, in a ROS-based architecture. It lead to a successful realisation of an autonomous underwater valve-turning task in a test tank, yielding rarely seen experimental results. Recently he has been awarded a Marie Curie Individual Fellowship to work as a Postdoc at CIRS-UdG, developing control strategies for I-AUVs.



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.

Albert Palomer

Albert Palomer received his Masters degree in 2013 from the University of Girona. He is now in the final year of his Ph.D. Since the master thesis Albert has been working in the Underwater Robotics Research Center (CIRS) under the supervision of Dr. Pere Ridao. His research has focused on mapping and 3D perception. His first part of the Ph.D. as well as the master thesis were dedicated to multibeam mapping using underwater robots. During this part, he stayed four month at the University of Rhode Island (Narragansett, Rhode Island, USA) under the supervision of Dr. Christopher Roman for improving his bathymetric SLAM algorithm. The second part has been focused in developing a new underwater laser scanner for high resolution and dense 3D underwater perception. During this second part he spent two months at the Heriot Watt University (Edinburgh, Scotland, UK) in the Oceans Systems Laboratory along with his supervisor Dr. Ridao. There they worked in underwater object detection and manipulation.

Dina Youakim

She received her Master degree in Computer Vision and Robotics from the UdG in 2015, where she also received the best Master student award. She joined the Underwater Robotics Research Center (CIRS) as a PhD candidate under the supervision of Dr.Pere Ridao. Her research interests are focused on autonomous motion planning for manipulation. Before studying her master, she has worked on various multinational IT companies, where she gained a wide experience in software development for automotive and medical applications. Moreover, she has worked as a researcher in LITIS, Rouen - France, implementing a SLAM solution for indoor navigation.

LIST OF PARTICIPANTS

SPEAKERS AND TRAINERS

#	Name	Institution		E-mail
1	Pere Ridao	UdG	CIRS	pere.ridao@udg.edu
2	Patryck Cieslak	UdG	CIRS	patryk.cieslak@udg.edu
3	Narcís Palomeras	UdG	CIRS	narcis.palomeras@udg.edu
4	Albert Palomer	UdG	CIRS	albert.palomer@udg.edu
5	Dina Youakim	UdG	CIRS	dina.isaac@udg.edu

STUDENTS

#	Name	Institution		E-mail
1		INESC TEC		
2		INESC TEC		
3		INESC TEC		
4		INESC TEC		
5		INESC TEC		
6		INESC TEC		
7		INESC TEC		
8		INESC TEC		
9		INESC TEC		
10		INESC TEC		
11		INESC TEC		
12		INESC TEC		
13		INESC TEC		
14		INESC TEC		

For logistics along your stay, please contact Joseta Roca, either by email **joseta@eia.udg.edu** or on the phone **+34 601 235 106**