

# Deliverable D2.1

## Nine-month report on the progress of know-how exchange 1

Project Acronym:		EXCELLABUST	
Grant Agreement number:		691980	
Project title:		Excelling LABUST in marine robotics	
Funding:		Horizon2020 Twinning	
Call:		H2020-TWINN-2015	
Type of action:		CSA	
Start date of project:		1 <sup>st</sup> January 2016	
Duration:		36 months	
Project website:		<a href="http://excellabust.fer.hr/">http://excellabust.fer.hr/</a>	
Delivery date:		30/09/2016	
Version:		1.0	
Lead participant		UNIVERSITY OF GIRONA	
Dissemination level:			
PU	Public		X
CO	Confidential, only for members of the consortium (including the Commission Services)		



## DELIVERABLE DATA SHEET

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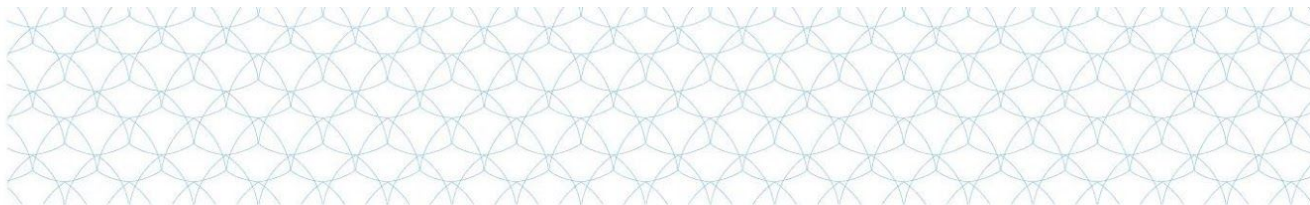
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Work package:		WP2 – Know-how exchange			
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Version log			
Revision no.	Date	Author (Partner)	Change
1	26/09/16	UdG	-
2	28/09/16	UZGR	Suggestions on edition
3	30/09/16	UdG	Final version to be submitted

### Deliverable summary

EXCELLABUST project has as one of its main goals the increase of UNIZG-FER marine robotics scientific excellence and innovation capacity, and raise staff's research profile within the three scientific strategic domains: 1) mapping and perception, 2) advanced NGC, and 3) autonomy and cognition, by implementing strategic measures in the form of staff exchanges, invited talks, on-site trainings and innovation management trainings.

This deliverable covers the activity done within the consortium framework along the first 9 months of project, from January to September 2016.



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## INTRODUCTION

This WP is directly linked to EXCELLABUST **Objective 1: “Increase excellence and innovation capacity”**, specifically:

Increase UNIZG-FER marine robotics scientific excellence and innovation capacity, and raise staff's research profile within the three scientific strategic domains: 1) mapping and perception, 2) advanced NGC, and 3) autonomy and cognition, by implementing strategic measures in the form of staff exchanges, on-site trainings and innovation management trainings that will:

**Ensure S&T knowledge transfer from internationally leading partners to UNIZG-FER (staff exchanges and expert visits),**

**Provide hands-on S&T experience by internationally-leading partners (on-site trainings), and**

**Provide knowledge on innovation management to all involved research institutions (innovation management training)**

WP2 objectives will be achieved through the following main activities:

### 1. Short-term staff exchanges

LABUST staff members visit each partner institution on two occasions, in the duration of 2 months, resulting in a total of 12 months of staff exchanges. Host institutions provide all the administrative assistance for the guest staff members. Researchers at host institutions supervise the guest staff progress and provide them with all the assistance required to ensure high quality know-how transfer. Research topics covered during the short-term staff exchanges are aligned with the defined strategic research domains in which the host institution has expertise. The outcome of these short-term staff exchanges result in joint journal and conference publications.

### 2. Short-term trainings

Each partner will organize one training at their institution along the project: CNR in year 1, UdG in year 2, and UL in year 3. During "Breaking the Surface" summer schools, all partners will organize training events that will include hands-on experience with real marine robotics equipment. Altogether, 12 trainings will be organized, four by each partner.

As a preparation for trainings, trainers will provide agendas and materials required for training events in a timely manner (at least 2 weeks before the training). Each trainer will provide infrastructure required for the execution of trainings. UNIZG-FER will provide the infrastructure for trainings at BtS while trainers will provide the training materials, and personnel and technology resources.

Research topics covered during the short-term trainings will be aligned with the defined strategic research domains in which the host institution has expertise. Training events will be attended by staff from all EXCELLABUST partners in order to increase cohesion between the groups and achieve more interaction and knowledge transfer during the trainings.

The outcome of this task will be transferred hands-on knowledge by trainers from internationally-leading partner institutions to all research staff members involved in EXCELLABUST twinning project.

### 3. Expert visits

Expert visits by each internationally leading partner to UNIZG-FER will be organized twice during the project lifetime. In addition to that, each internationally-leading partner institution will organize an expert visit each year during the BtS workshop. Altogether, this task includes preparation and execution of 15 expert visits to Croatia. Expert visitors will provide lecture materials which will be made public after the completion of the visit. Expert visits will be organized in a form of 2-3 day lecture series with theoretical topics that are aligned with the desired strategic research domains. Tentative titles of the lecture series are given in DoW.

The outcome of expert visits will be transfer of theoretical knowledge, through a series of lectures, in the topics defined by the strategic research domains.

### 4. Participation in innovation management trainings

This task will be devoted to participation in innovation management trainings which are required for efficient and high quality research management. These trainings are organized by professionals, either at partner institutions, or at third sites. Innovation management training will include topics such as proposal writing, project management and implementation, intellectual property protection, patent writing and application, etc. It is expected that young researchers with less innovation management will participate in these trainings. Within this task, research staff members from all EXCELLABUST consortium will participate.

The outcome of innovation management training will be increased level of knowledge in project management, innovation management and IPR issues.



# 1. Short-term staff exchanges

## a. Filip Mandić staff exchange at the University of Girona

During February and March 2016, Filip Mandić was a guest researcher in the Underwater Vision and Robotics Research Centre (CIRS) at the University of Girona (UdG). Around 20 employees are working at the facility which is located in Scientific and Technological Park of the UdG. Their team is composed of: pre-doctoral researchers, engineers, technicians, postdoctoral fellows and permanent staff. They are one of the leading teams in the research and development of Autonomous Underwater Vehicles for accurate seafloor mapping and light intervention. With more than 20 years of experience, they offer research, engineering and field operations experience to companies and institutions. Also, the team is part of the Institute of Computer Vision and Robotics (ViCOROB) and member of TECNIO network of Excellence in Catalonia region.



Figure 1. Scientific and Technological Park of the UdG.

Filip Mandić was working in the field of surface and underwater marine robotics. Specifically, developing algorithms for improving underwater vehicle localization. In February, work on simulation and implementation of algorithms, proposed by research plan written prior to staff exchange, was conducted. All the work was supervised by Dr. Marc Carreras. CIRS lab members, especially Dr. Narcis Palomeras, were very helpful with the introduction of the software and hardware architectures they use in their everyday work. Facilities available at the research centre, like water tank, have proven to be very useful during development and implementation phase. It was possible to quickly test all the hardware and software modifications before setting to open sea for algorithm validation.

Experiments at sea, during which proposed algorithm was tested, were conducted on three separate occasions during March 2016, in Sant Feliu de Guíxols, Spain. The experimental setup consisted of two autonomous underwater vehicles: Girona 500 and Sparus II. Both vehicles were developed at the Underwater Robotics Laboratory of the University of Girona, Spain. Data sets, which show that proposed algorithm for steering beacon vehicle in single range navigation scenario is working in real life-conditions. That was achieved despite acoustic communication constraints and disturbances usually present in real-life conditions. Acquired and analysed results will be presented as a joint conference paper “Mobile beacon control algorithm for maximizing observability in single range navigation” [1].

Major results accomplished during and shortly after staff exchange are:

- Algorithm for improving observability in single range navigation implemented on SPARUS2 and GIORNA 500 vehicles.
- Algorithm tested on sea trials and experiments for data gathering conducted.
- Analysed results will be presented as a joint conference paper “Mobile beacon control algorithm for maximizing observability in single range navigation”



Figure 2. At the sea trials.

[1] Filip Mandic, Nikola Miskovic, Narcis Palomeras, Marc Carreras. Mobile beacon control algorithm for maximizing observability in single range navigation. 10th IFAC Conference on Control Applications in Marine Systems CAMS 2016, Trondheim, Norway

## b. Nadir Kapetanović staff exchange at National Research Council of Italy

Nadir Kapetanović has been a guest researcher during June and July 2016 in Genova at the Institute for research of intelligent systems for automation (ISSIA), which is a part of National Research Council of Italy (CNR). CNR is a public organization founded in 1923, with seven departments and 106 institutes. ISSIA is distributed in three cities in Italy, namely Genova, Bari and Palermo. All three of them have specific research areas in robotics and automation in general.

Department of Field and Interaction Robotics, located in Genova, is composed of 8 researchers, 5 assistant researchers, 1 technologist, and 4 technicians. They have over 20 years of experience in robotics, both in terms of theoretical and applied research. Their research interests include: system modelling and identification, navigation, cooperative guidance, visual odometry, IT and telecommunications.





Figure 3. Presentation of the research plan

Nadir Kapetanović had been involved in research in the field of marine robotics. More precisely, his research goal was to apply model predictive control to line following manoeuvre. Put in a wider perspective, this was the first part of an algorithm which would navigate a marine vehicle (surface and/or underwater) during seabed sonar scanning tasks, in such way that the path along which the vehicle moves is the path along which the most interesting and new information about the seabed is gathered. Motivation and methodology are explained in more detail in the Research plan which Nadir has submitted before his arrival to ISSIA. His work was supervised by dr. Massimo Caccia and dr. Marco Bibuli. Also, Andrea Ranieri introduced him to the software which is being used at ISSIA, in order to integrate his software with ROS (Robotic Operating System) which is widely used in robotics research. Enrica Zereik, Mauro Gaggero, and Cristiano Cervellera helped him a lot with discussions about optimal control, model predictive control and optimization algorithms' complexity and their use in real-time applications.



Figure 4. Working on simulator integration with dr. Andrea Ranieri

The result of this two-month research is a model predictive control framework which uses state-of-the-art optimal control solvers under ACADO toolbox, integrated into ROS environment. The control problem being solved is line following problem with disturbance, i.e. sea current. One goal of this integration was to make this framework as modular as possible, to allow it to be used and tested on various systems, their parameters etc. Another goal was to prepare this framework to be integrated with the simulator and low-level controllers of ISSIA's vehicles, which



can be used in real-life sea experiments. This interface is planned to be implemented in September 2016, so that the real-life experiments on the sea can be carried out in Biograd na Moru during Breaking the Surface workshop in October 2016.

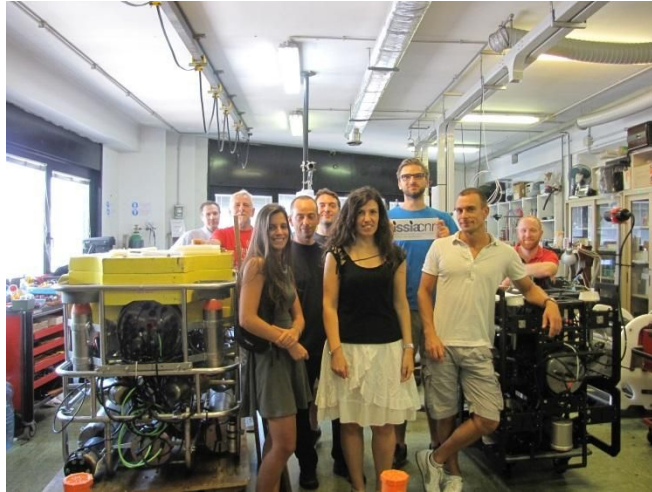


Figure 5. CNR ISSIA team

Major results accomplished during and shortly after staff exchange are:

- Implementation of the proposed MPC framework for the real-time line following manoeuvre without the external disturbance using ACADO toolbox.
- Implementation of MPC framework for the same control problem, but with added disturbance rejection.
- Integration of ACADO toolbox with ROS environment.

## 2. Short-term Trainings

### a. Training at CNR

First S&T training held: Unmanned vehicles - building cooperative control and perception held at CNR, Italy



The *Institute for Research of Intelligent Systems for Automation - ISSIA, National Research Council of Italy - CNR*, organized the first S&T training in the scope of H2020 project "[EXCELLABUST](#) - Excelling [LABUST](#) in marine robotics". The training was held from 19 - 20 June 2016 in Genova, Italy at CNR and was open to all members of the project consortium.

First day was focused on building an Unmanned Marine Vehicle and it covered the following themes:

- Mechanical design and construction,
- Hw/Sw design & implementation,
- Visit to CNR-ISSIA Marine Robotics laboratory,

while, the second day was focused on cooperative control and perception for heterogeneous Unmanned Marine Vehicles with topics on:

- Cooperative guidance and mission control,
- Cooperative perception and environment characterisation,
- Human-robot interaction languages,
- Use of UAVs for ecosystem monitoring.

## SCHEDULE

Day 1: 19 July 2016 (Tuesday) - How to build an Unmanned Marine Vehicle

09:15 - 10:00	<b>Mechanical design and construction</b> by Angelo Odetti
10:00 - 10:45	<b>Hw/Sw design &amp; implementation – part 1</b> by Andrea Ranieri
10:45 - 11:15	BREAK
11:15 - 12:00	<b>Hw/Sw design &amp; implementation – part 2</b> by Andrea Ranieri
12:00 - 14:00	LUNCH BREAK
14:00 - 16:00	<b>Visit to CNR-ISSIA Marine Robotics laboratory</b> Giorgio Bruzzone, Mauro Giacomelli, Edoardo Spirandelli

Day 2: 20 July 2016 (Wednesday) - Cooperative control and perception for heterogeneous Unmanned Marine Vehicles

09:15 - 10:45	<b>Cooperative guidance and mission control</b> by Marco Bibuli, Donato Di Paola, Antonio Petitti
10:45 - 11:15	BREAK
11:15 - 12:45	<b>Cooperative perception and environment characterisation</b> by Annalisa Milella, Rosalia Maglietta
12:45 - 14:15	LUNCH BREAK
14:15 - 15:15	<b>Human-robot interaction languages</b> by Davide Chiarella
15:15 - 15:45	BREAK
15:45 - 16:45	<b>Use of UAVs for ecosystem monitoring</b> by Massimo Ianigro, Roberto Colella

## LECTURE DESCRIPTION

<b>Mechanical design and construction</b>
This lecture will outline the basis of the design of an unmanned marine vehicle from a naval, mechanical and structural point of view. There will be an overview of the existing vehicles and the future ones with their peculiarities and requirements. It will be summarised the process of choice of right components and design of new ones with a specific focus on the choice of propellers and of the adequate propulsion system.
<b>Hw/Sw design &amp; implementation – part 1-2</b>
A brief introduction to the hardware and software design of marine robots will be given in this lecture. The robot's electronic hardware design have a huge impact on the reliability, efficiency and modularity of a marine robotic vehicle. However, the hardware design is an arduous process, often lacking "written rules" where many requirement and conditions must be satisfied at the same time. These requirements are, in turn, often based on the mechanical structure design and the electric design of the vehicle, where space and power constraints greatly reduce the available choices. Again, electronic hardware design reflects on software design, requiring efficiency in choosing the languages, and in designing and writing the code. In the last few years, thanks to the rapid development of fast, cheap, and power-efficient CPUs enclosed in small packages, many of the limiting factors imposed on robot's software by hardware design, have been relaxed. This has given developers some more chances to focus on code modularity and maintainability. Today, using advanced libraries and open-source frameworks developed by the community, is somehow truly possible to implement concepts such as information hiding and software reuse at higher levels, thus really providing an advancement in the world of software development.
<b>Cooperative guidance and mission control</b>
This lecture will be focused on cooperative control of teams of unmanned vehicles, articulated along two dimensions: cooperative guidance and cooperative mission planning and control. In particular for the guidance aspects, the concept of virtual-target based path-following is extended to achieve the task of motion coordination

among a team of unmanned robotic platforms. On the other hand, the cooperative mission planning and control aspects will cover mission re-planning strategies, decentralized task allocation algorithms, and mission execution control methodologies.

#### **Cooperative perception and environment characterisation**

Autonomous driving is a challenging problem, particularly when the domain is unstructured, as in an outdoor setting. Therefore, advanced perception systems are required to sense and understand the surrounding environment in order to recognize artificial and natural structures, topology, vegetation and paths. Due to the variety of situations that may be encountered, no sensor modality exists that can ensure reliable results in every case. Thus, a complementary sensor suite should be used to obtain the best performance.

Cooperative perception from multiple vehicles would further improve the results. This lecture will be focused on perception systems and methods for ambient awareness of mobile robots in field applications. First, an overview of the main sensor devices for autonomous navigation in unstructured environments will be presented, with a special focus on visual sensors. Then, some of the state-of-the-art techniques for robot localization and mapping, and their applications in different contexts will be reviewed. Recent advances from single robot to cooperative perception systems will be presented. Scene understanding has been one of the main goals of computer vision for decades. Recently, the application of machine learning has given rise to new interest in this field, making it possible to capture new environmental properties from highly complex and dynamic scenes. Machine learning techniques enable to turn data into knowledge. Classification problems and some computational and statistical learning theories will be discussed with attention to the computer vision and robotics domains. Statistical methods for image processing, analysis and understanding can result in a final decision of the robot, with the development of fully automatic systems based on the integration of robotics and image analysis.

#### **Human-robot interaction languages**

This lecture will focus on Human–Robot Interaction (HRI) languages. The lecture will describe the different kind of interaction and communication between a human and a robot. In particular, the creation of a gesture-based language for underwater environment, which extends the one already used for diving, will be described: the choice of alphabet, syntax, semantics and communication protocol with error handling will be investigated.

#### **Use of UAVs for ecosystem monitoring**

In this lecture both technological and operational aspects of UAV will be outlined together with the more promising and challenging fields of application. The lecture will give an introductory overview of UAV technologies, with respect to their main components (frame, propellers, flight control unit, power, sensors, flight control unit, communication, safety and regulatory aspects, ground control station, ...).

After this overview, will follow a presentation about the integration of UAV in real-world scenarios, related to projects carried out by the Field and Interaction Robotics Group at ISSIA, together with some of the experimental results achieved, including some aspects related to the marsupial sea-air systems.



## **b. Anja Babić attended European Embedded Control Institute training on adaptive control**



Anja Babić participated in the course Practical adaptive control held by Dr. Anuradha Annaswamy of the Active-adaptive Control Laboratory at MIT and organized as part of the EECI International Graduate School on Control from the 31st of May to the 3rd of June 2016. The lectures covered the following topics:

- Adaptive control theory – first-order plant, states accessible, output feedback
- Adaptive control with closed-loop reference models and solutions to transients
- Robust Adaptive Control
- Examples and case studies from aerospace and automotive systems

### 3. Innovation Management Trainings

#### a. LABUST participates in the workshop on intellectual property



Members of LABUST participated in the workshop "*Fundamentals of the intellectual property for the researchers*" organized by the State Intellectual property office which took place at the Faculty of Electrical Engineering and Computing on the 4th March 2016. The workshop covered the following topics:

- Introduction to Intellectual property
- Intellectual property at FER
- Technology transfer and Intellectual property for research projects
- Patents and patent databases

#### b. UNIZG-FER project managers participated in tutorial on writing and implementing H2020 projects



UNIZG-FER project managers Mirjana Dozan, Ivana Mikolić and Mirjana Stjepanović participated in training *Excellence in Horizon 2020 proposal writing and project implementation training* that was held 15 - 16 April 2016 in Opatija, Croatia. The training was held by [European Training Academy](#).

Focus of the seminar was:

- novelties in Horizon 2020 and priorities for 2016-2017

- project proposal writing
- practical work on development of your project ideas
- evaluation of the proposals
- analyzing H2020 Call for Proposals

## c. Training at CNR

### Innovation management training at CNR "Patent: A tool to promote"



The H2020 project "[EXCELLABUST](#) - Excelling [LABUST](#) in marine robotics" and the National Research Council of Italy (CNR) organized a Innovation management training on the topic of

#### **"Patent: A tool to promote (basic fundamentals)".**

The training was held on 18th June 2016 at CNR in Genova, Italy and attended by researchers and project managers from EXCELLABUST project partners' institutions. [LECTURES DESCRIPTIONS:](#)

1. Presentation and introduction to IPR Training Session by Silvia Cella, Alessia Naso

In this lecture we will give a first glance on Intellectual Property Rights and we will highlight the basic principles of the patent systems and the protection of inventions.

2. Overview on Intellectual Property Rights (IPR) by Silvia Cella, Alessia Naso

We will present an overview of the different forms of Intellectual Property for protecting your research results and for giving value to your ideas. We will briefly introduce the legal rights conferred by patents, trademarks, registered designs, copyright and trade secrets, as well as what they protect and how to obtain them.

3. Patent system: rules and rights by Silvia Cella, Alessia Naso

We will focus our lecture on the main aspect on the Patent system: inventorship and co-ownership, priority date and publication, duration and country validation.

4. Patent procedures @ European Patent Office (EPO) by Silvia Cella, Alessia Naso

This lecture will present the procedures to apply for a European patent application according to the European Patent Convention (EPC) or to apply for an international patent application through the PCT (Patent Co-operation Treaty) way: filing, Search Report and examination, granting and validation.

5. IPR in EU-Projects by Raffaella Beroldo

This lecture will focus on the importance of the IP

## SCHEDULE

Day 1: 18 July 2016 (Monday) - Patent: a tool to promote innovation (basic fundamentals)

09:15 - 09:45	<b>Participant registration. Meet and greet coffee</b>
09:45 - 10:00	<b>Presentation and introduction to IPR Training Session</b> by Silvia Cella, Alessia Naso
10:00 - 10:30	<b>Overview on Intellectual Property Rights (IPR)</b> by Silvia Cella, Alessia Naso
10:30 - 11:00	<b>Patent system: rules and rights</b> by Silvia Cella, Alessia Naso
11:00 - 11:30	<b>Patent requirements: Novelty and Inventive Step</b> by Silvia Cella, Alessia Naso
11:30 - 11:45	<b>BREAK</b>
11:45 - 12:15	<b>Patent procedures @ European Patent Office (EPO)</b> by Silvia Cella, Alessia Naso
12:15 - 12:45	<b>IPR in EU-Projects</b> by Raffaella Beroldo
12:45	<b>LUNCH BREAK</b>

## LECTURE DESCRIPTION:

### **Presentation and introduction to IPR Training Session**

In this lecture we will give a first glance on Intellectual Property Rights and we will highlight the basic principles of the patent systems and the protection of inventions.

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### **IPR in EU-Projects**

This lecture will focus on the importance of the IP Management in Horizon 2020 at the proposal stage.



## d. Invited talk by University of Girona

### INVITED TALK DETAILS

**Date:** 9<sup>th</sup> June 2016  
**Time:** 13:00 – 15:00  
**Location:** On-line talk

**Title:** University of Girona Project Management System – sharing experiences with LABUST laboratory  
**Name:** Joseta Roca  
**Affiliation:** Computer Vision and Robotics Research Institute, University of Girona  
Edifici CIRS, Parc Científic i Tecnològic UdG  
C\ Pic de Peguera 13 (La Creueta)  
17003 Girona, Spain

### 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 FER UNIZGR and try to identify possible collaboration points as well as a general advice on the topic.

**e. EXCELLABUST H2020 project members participating in the lecture on start-ups by Martin Reents (CEO Hetras GmbH): "First 5 Decisions When Founding a Startup"** and in Startup Pitch BoothCamp organized by Centar karijera FER-a, SPOCK



Two times German startup founder award winning, Martin Reents, arrived to University of Zagreb Faculty of Electrical Engineering and Computing on 20th and 21st September to hold lectures on fundamental decisions in founding startup businesses, and on radical changes in hospitality in hotel business.

**Lecture content:**

**Your first 5 decisions when founding a startup**

If you start out on something new you have to take some decisions first. Not all of them are equally important. Some decisions are rather preliminary and can or even have to be changed every once in a while. Startups call that euphemistically a “pivot” and they are proud of their ability to pivot fast whenever needed. Other decisions last for the rest of your life. It’s these choices which are really important and need a solid foundation.

Martin Reents will walk the audience through this process of becoming a founder and entrepreneur. His talk is based on his own experience as a founder of several business startups and his work with social entrepreneurs: “I never started out with the intent just on making money. Rather, I wanted to change the world, make it a better place to live. And the money followed”

## 4. Expert Visits

### Invited talk "Girona Underwater Vision and Robotics lab: AUVs for inspection and intervention"



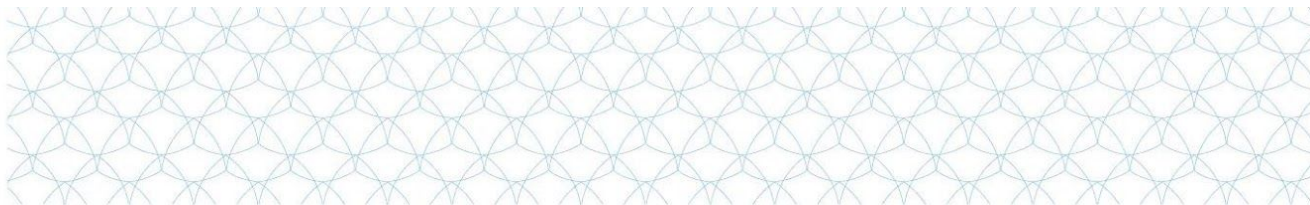
The H2020 project "[EXCELLABUST](#) - Excelling [LABUST](#) in marine robotics" and IEEE Croatia Section, Robotics and Automation Chapter organized the lecture:

#### **"Girona Underwater Vision and Robotics lab: AUVs for inspection and intervention"**

given by Prof. Marc Carreras, *Computer Vision and Robotics Research Institute, University of Girona* (Spain) on Wednesday, 20th January 2016, starting at 15:00 in Grey Hall at the Faculty of Electrical Engineering and Computing.

[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. The talk will summarise the research activities of the lab in AUV capabilities for inspection and intervention. Real-time sensor processing is used for mapping, target identification and motion planning, allowing a close inspection of the underwater structures. Hovering AUVs equipped with a manipulator are able to recover a target, turn a valve or plug a connector from different configurations and using different techniques. A review of the work done will be given pointing out future steps for making these new AUVs capabilities, available for scientific or industrial applications.

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.





### Invited talk "Towards heterogeneous cooperative field robotics: the CNR-ISSIA experience"



The H2020 project "EXCELLABUST - Excelling LABUST in marine robotics" and IEEE Croatia Section, Robotics and Automation Chapter organized the lecture

### **"Towards heterogeneous cooperative field robotics: the CNR-ISSIA experience"**

given by Massimo Caccia and Marco Bibuli, Consiglio Nazionale delle Ricerche, Istituto di Studi sui Sistemi Intelligenti per l'Automazione (Genova, Italy) on Friday, 22nd January 2016, starting at 09:00 in Grey Hall at the Faculty of Electrical Engineering and Computing.

The talk will discuss challenge and opportunities given by the development of heterogeneous underwater, surface and aerial marine robots. In particular, cooperation can improve their capability in task execution at the price of increasing complexity in logistics, communication, perception, guidance and mission control. Examples in the field of marine and maritime robotics derived by CNR-ISSIA experience will be presented as well as some algorithmic details.

Marco Bibuli (MSc 2005, PhD 2010) is researcher at the CNR-ISSIA, focusing his research activity on the design and development of navigation, guidance and control algorithms for unmanned marine vehicles and software architectures for supervision and mission control. He is Work Package leader and CNR scientific responsible in the EC-funded project CADDY. He was task leader in the EC-funded projects MINOAS (2009-2012) and CART (2011-2013). He is currently Scientific Responsible for CNR and work-package leader within the scope of the EC FP7 CADDY project, Responsible of the action S5-WP6-A2 in the Italian Flagship Project RITMARE. He is collaborating with several national and international universities and research institutions. He is the author of about 60 papers in journals and international conferences, as well as active organizer of conferences, workshops and similar dissemination events.

Massimo Caccia (MSc 1991) is the director of CNR-ISSIA since October 2013. He is author of 2 book chapters, and more than 100 international journal and conference papers. Principal investigator of the projects: "SEa Surface Autonomous MODular unit" funded by the National Program of Research in Antarctica (2002-2004), "Harbour and coastal underwater anti-intrusion system" funded by IARP-FESR (2005-07), "Unmanned Multipurpose Vessel" funded by the Scientific and Technological Park of Liguria (2007-08), MINOAS, CART and MORPH projects (regarding CNR contribution), funded by EC. From 2010 he is member of the IFAC Technical Committee 7.2 Marine Systems, the Board of Directors of the Ligurian District of Marine Technologies.



**Invited talk "Overview of research activities in Mobile & Marine Robotics Research Centre, University of Limerick"**



The H2020 project "[EXCELLABUST](#) - Excelling [LABUST](#) in marine robotics" and IEEE Croatia Section, Robotics and Automation Chapter organized the lecture

**"Overview of research activities in Mobile & Marine Robotics Research Centre, University of Limerick"**

given by **Prof. Daniel Toal** and **Dr. Edin Omerdić**, *Mobile & Marine Robotics Research Centre, University of Limerick*, (Ireland) on **Friday, 22nd January 2016**, starting at **10:00** in Grey Hall at the Faculty of Electrical Engineering and Computing.

Established in 2000 by Director Dr. Daniel Toal, the Mobile & Marine Robotics Research Centre (MMRRC) in the University of Limerick is the only research centre focused on the application and development of marine robotics within the island of Ireland. This research centre is a highly capable engineering group focused on developing practical and smart marine technologies. From marine robotics to navigation, sensor development, emergency response planning, remote operated vehicle (ROV) and unmanned aerial (UAV) technologies, they are actively involved in developing a diverse range of emerging technologies in national funded, European funded and industry collaborative projects.

Over the last ten years the MMRRC research centre has developed OceanRINGS - a suite of smart technologies for subsea operations, designed to be integrated with any ROV – support vessel combination. It includes advanced control solutions for full range of ROVs – from mini ROVs used for remote monitoring & inspection to full-size work-class ROVs. Remotely Operated Vehicle (ROV) LATIS is a 1000m depth-rated underwater robot developed at MMRRC to test and validate OceanRINGS. System validation and technology demonstration has been performed over the last six years through a series of test trials with different support vessels off the north, south and west coast of Ireland, in Donegal, Bantry Bay, Cork Harbour, Galway Bay, Shannon Estuary and La Spezia, Italy.

This presentation provides background information about the MMRRC and University of Limerick, gives an overview of recent research activities, explains the main idea behind OceanRINGS concept, displays selected results from test trials and discusses possible applications.

**Daniel Toal** (BSc 1984, MSc 1986, PhD 2004) is an Associate Professor at the Electronic & Computer Engineering Department, Faculty of Science and Engineering, University of Limerick, Ireland, where he teaches courses related to automation, robotics, instrumentation, avionics, sensors and electrical machines. His research interests include field robotics for challenging environments (land-based, marine, airborne / ROVs, AUVs, UAVs). Successes in research are the result of hard work driven by the vision that the Marine Technology, Ocean

Environment; Renewable Energy Sectors will grow in crucial importance. Daniel is the founder and director of the Mobile & Marine Robotics Research Centre at the University of Limerick and is Co PI of the SFI Centre MaREI - Marine and Renewable Energy Ireland ([www.marei.ie](http://www.marei.ie)). With the MMRRRC research team, Dan has led the design/build of ROV Latis – a 1,000m depth rated ‘smart’ vehicle along with many other platforms. On-going research addresses unique challenges of operating in ‘high energy’ wind, wave and tidal regimes of marine renewable and airborne wind energy. Research also addresses robotic platform development for response in offshore marine incidents, search and rescue (SAR) and marine salvage. Dan is collaborating with research and industrial partners in Ireland, across Europe and North America. He has been chief scientist for numerous off shore research surveys on Celtic Explorer, Celtic Voyager, INS LÉ Eithne, and other vessels. He has numerous journals, book/book chapters, conference proceedings, invention disclosures, granted and pending patents in sonar technology and renewable energy. He has been awarded the Denny Medal - best journal paper award 2007/2008 - Journal of Marine Engineering. Technology. He has given numerous Plenary talks in Brazil, Korea, and elsewhere.

**Edin Omerdić** (BSc 1997, MSc 2001, PhD 2004) is currently employed by the University of Limerick as a Senior Research Fellow at the Department of Electronic and Computer Engineering. He has been engaged in numerous national-funded, European-funded and industry-sponsored research projects in the area of submersible robotics. He is also the main developer & designer of OceanRINGS concept & software suite, including design of state-of-the-art control architecture for ROV LATIS. Edin's research interests include modelling & simulation of dynamic systems (marine platforms, ocean dynamics & disturbances), renewable energy, real-time simulators, virtual reality, development and design of guidance, navigation and control system for marine vessels, nonlinear control systems, and implementation of soft-computing techniques in intelligent systems, underwater robotics, fault-tolerant systems. Dr. Omerdic received five awards for his work, including First Prize Winner in National Competition in Mathematics (Bosnia, 1985), Society of Underwater Technology (SUT) Prize for Best Multimedia Presentation (GCUV 2003) 'Thruster Fault Accommodation for Underwater Vehicles', IFAC prize for best on-line demonstration (MCMC 2003) 'Fault Detection and Accommodation for ROVs', IMarEST SMI Donald Maxwell Award Prize for Best Journal Paper (2004) 'A Fuzzy Track-Keeping Autopilot for Ship Steering' and Curriculum Paper Contest National Instruments International Competition LabVIEW in the Curriculum 2006 (First Prize Winner) 'Virtual Underwater Lab: Efficient Tool for System Integration & UUV Control Development'.



### Invited talk "Towards Reproducible Robotics Research"



The H2020 project "[EXCELLABUST](#) - Excelling [LABUST](#) in marine robotics" and IEEE Croatia Section, Robotics and Automation Chapter organized the lecture

### **"Towards Reproducible Robotics Research"**

given by **Prof. Fabio Bonsignorio**, *The BioRobotics Institute, Scuola Superiore Sant'Anna*, (Italy) on **Friday, 22nd January 2016**, starting at **14:00** in Grey Hall at the Faculty of Electrical Engineering and Computing.

The problem of replicability of research results affects many disciplines and is particularly felt in young fields such as robotics and AI. It is a basic prerequisite to performance comparison of intelligent robotic systems and a basic cornerstone of the scientific method.

What it does mean to perform an experiment in Robotics/AI? What should be considered a result? To what extent is robotics a science?

Reproducibility of published results is now a strategic objective for IEEE at large and RAS in particular.

Where are we heading?

**Fabio Bonsignorio** is currently a professor at the Biorobotics Institute of the Scuola Superiore S'Anna in Pisa. He has been professor in the Department of System Engineering and Automation of the University Carlos III of Madrid until 2014. In 2009 he was awarded the Santander Chair of Excellence in Robotics at the same university.

He is founder and CEO of Heron Robots (advanced robotic solutions), see [www.heronrobots.com](http://www.heronrobots.com). He has been working in the R&D departments of several major Italian and American companies, mainly in the applications of intelligent systems and technology transfer with coordination/management responsibilities for more than 20 years.

He is a Founding Director of euRobotics aisbl, the private part of SPARC, the Eu Robotics PPP. He is currently a member of the Research Board of Directors of SPARC.

He coordinated and has been the main teacher of the ShanghaiAI Lectures 2013, 2014 ([www.shanghailectures.org](http://www.shanghailectures.org)), edition an advanced network MOOC teaching initiated several years ago by Rolf Pfeifer. He is currently coordinating the 2015 edition.

His preferred research topics are in advanced robotics: cognition, control, modelling, software architectures, robot swarms, intelligent agents, epistemological issues in robotics, performance evaluation and foundational issues like 'morphological computation'.

He has pioneered the topic of Reproducible Research and Benchmarking in Robotics and AI. In this area he is one of the leading experts, with a long series of workshop, more than 20, at IROS, ICRA and RSS, involving more than 200 people from the research, industry and government area (in particular from the EU commission).



He is author or co-author of almost 140 publications in the areas of robotics, cognition and manufacturing systems in the last few years, since he became an almost full time researcher. His first paper on robot control dates back to 1985. He is a member of IEEE/RAS, AAAI, CLAWAR, and euCognition. He coordinated the EURON Special Interest Group on Good Experimental Methodology and Benchmarking in Robotics, is cochair of the IEEE RAS TC-Pebras and has been a board member of EURON III. He is a member of the Euron Training Board (the GeorgeGiralt PhD Award jury). He has been reviewer for several conferences and journals inside and outside IEEE. He is project reviewer for Ecsel and has been for FP7. He was a member of the joint Europ-Euron-other experts restricted team preparing the Robotics Public Private Partnership in Horizon 2020, the successor program at EU level of FP7.

He is the coordinator of the euRobotics Topic Group on Experiment Replication, Benchmarking, Challenges and Competitions and is co-chair of the IEEE TC-Pebras. He has participated to design and launch the new euCognition society, he is now a member of the euCognition society steering committee.

He has been general co-chair of the IEEE RAS 2015 Summer School on Replicable and Measurable Robotics Research. He has been the corresponding and more active editor of the Special Issue on Replicable and Measurable Robotics Research on IEEE Robotics and Automation Magazine, appeared in September 2015. This special issue is the very first example of a higher impact archival robotics journal issue with replicable and measurable results pioneering Reproducible Research in RAS and to a certain extent IEEE at large.

## Tutorial 1: "High-level architectures and path planning" by UdG



As part of the expert visit within the H2020 project "[EXCELLABUST](#) - Excelling [LABUST](#) in marine robotics", **Prof. Marc Carreras** and **Dr. Narcís Palomeras** from the Computer Vision and Robotics Research Institute, University of Girona (Spain) gave a tutorial "High-level architectures and path planning" on **19th - 20th January 2016** at the University of Zagreb Faculty of Electrical Engineering and Computing.

The agenda, lecture descriptions and materials used during the tutorial, are available in the [repository](#). A short report is available in the detailed news content and [here](#), while photos from the event are available in the [gallery](#).

The tutorial followed the planned contents about COLA2 control architecture and path planning, given by Marc Carreras and Narcís Palomeras from the University of Girona. The first day focused on the COLA2 control architecture, giving special emphasis on the ROS middleware, which was introduced with simple examples. The COLA2 architecture was detailed, including its localization and control modules. Examples and results were given to illustrate the possibilities of the architecture. During the afternoon, a first theoretical overview about general control architectures for autonomous robots was given, pointing out the advantages and disadvantages of deliberative and behaviour-based approaches. The latter ones were introduced as a simple and effective way of implementing an autonomous robot. The first day concluded with a long practical session in which COLA2 architecture was used to simulate the Sparus II AUV in a path planning and execution exercise, in which the OMPL library and UWSIM simulator were used. Exercises were proposed to attendees to check the correct understanding and use of the path planning module and control architecture. Students showed a very deep understanding of the practical exercises, which were completed successfully. The planned sessions finished within the planned time. During the second day, the tutorial was focused on theoretical algorithms used for general path planning. Bug algorithms, potential algorithms, topological maps, cell decomposition and sampling algorithms were presented with some details. Three research projects about path planning applied to different AUV applications were also described, showing the work done by the University of Girona in this research line. The second day finished within the planned time, concluding and achieving the goals of the tutorial.

The outcomes of the tutorial were:

- Participants were introduced with the COLA2 architecture, for AUV programming, with practical experiences in a ROS environment.

- Participants were introduced with the basics of high-level control architectures and an overview on path-planning algorithms, with real examples on AUVs.
- Participants performed simulated experiments about AUV path planning, with the COLA2 architecture, which can be used for future developments and collaborations.

The tutorial allowed meeting many students and researchers from University of Zagreb, with which Marc Carreras and Narcís Palomeras started conversations about their common research interests and potential future collaborations.

### Invited talk "Heterogeneous Adaptive Maritime Mobile Expeditionary Robots"



The H2020 project "[EXCELLABUST](#) - Excelling [LABUST](#) in marine robotics" and IEEE Croatia Section, Robotics and Automation Chapter organized the lecture

### **"Heterogeneous Adaptive Maritime Mobile Expeditionary Robots"**

given by **Dr. Vladimir Djapic**, *SPAWAR Systems Center - Pacific, Unmanned Maritime Vehicles Lab (USA)*.

The lecture took place on **Monday, 23rd May 2016**, starting at **14:00** in Grey Hall at the Faculty of Electrical Engineering and Computing.

For the ONR-funded Heterogeneous Adaptive Maritime Mobile Expeditionary Robots (HAMMER) project, we work on cooperative autonomy for a fleet of unmanned vehicles working together in the aerial, water surface, and underwater domains. Each of these systems work well independently, but our goal is to integrate their performance into one system of vehicles that can safely perform cooperative tasks. The challenges we are working on include creating reliable communications links between vehicles in the harsh low bandwidth maritime environment, integrating novel onboard sensors and inter-vehicle communication to create filters to estimate the state of the network, and creating autonomous takeoff-and-landing algorithms between the aerial/underwater vehicles and the surface "mothership" vehicle. The surface vehicle is envisioned to be capable of transporting the aerial and underwater vehicles as well as providing mission-lengthening power. Possible applications of this system include automated deployment and recovery of data-collecting unmanned underwater vehicles and an ad hoc wireless network where the aerial vehicle relays time-sensitive data collected from the surface or underwater vehicle to a human on a ship many miles away. In a separate but related project, we are also determining human-autonomy teaming required for future Naval programs, assessing the state-of-the-art algorithms, and creating open challenge problems to academia to fill gaps based on the Navy's need.

Despite longstanding effort, COTS UAVs, UUVs and USVs are still limited in their capabilities by battery life, challenging communication, and their ability to know their location in space in GNSS -denied situations. Also, even though microprocessor, sensor, and battery technology will continue to improve drastically in the future, the energy cost per bit and maximal bitrates on an RF communication channel are beginning to hit their physical limits. Furthermore, as the size of the networked system of unmanned vehicles grows, each vehicle gets a smaller bandwidth on which to transmit. Conversely, onboard computations are becoming increasingly more energy efficient; a BeagleBone Black computer consumes 210-460 mA at 5V. Therefore, one can utilize inexpensive onboard computation resources in novel ways: to determine the optimal allocation of expensive/limited resources (RF communication channel); to extract more information more reliably from data sources; and, to enable new sensing paradigms. Specifically, we argue that in GNSS-denied environments, sophisticated navigation algorithms can be inexpensively run onboard a team of unmanned vehicles that result in high-quality, reliable navigation solutions at a lower communication cost. We aim to develop a framework that utilizes the currently available





sensors (IMU, DVL, RADAR, Stereo camera, LIDAR, Virtual Reality RF tags), along with sensors that will soon be available (low power electric field and magnetic field sensors for electrolocation and geophysical navigation), within more solution paradigms that fully utilize today's computational platforms to go beyond the extended Kalman filter.

**Vladimir Djapic** received the B.S. and M.S. degrees from the University of California at San Diego, in 2000 and 2001, and the Ph.D. degree from the University of California at Riverside, Riverside, in 2009, all in electrical engineering. He returned to the Unmanned Maritime Laboratory in Space and Naval Warfare Systems Center Pacific in San Diego in 2014 where he is a Chief Scientist and a lead Principal Investigator (PI) for projects that utilize Maritime Autonomous Systems (air, surface, and subsurface). Dr. Djapic is also leading numerous international collaborative efforts, for example, Next Generation Autonomous Systems (NGAS) with multiple international partners and Coalition Warfare Program (CWP) with Croatia. From 2008 to 2013 he worked at Center for Maritime Research and Experimentation (CMRE), former NATO Undersea Research Centre (NURC), La Spezia, Italy, and served as a Scientist-in-charge for 5 major NATO sea trial that involved two CMRE ships, as well as shore-lab experiments set-ups with heterogeneous autonomous robots: Autonomous Surface and Underwater vehicles (ASVs and AUVs). The objective of his research effort at CMRE was to design an inexpensive, but robust and effective autonomous mine neutralization system and perform multiple at-sea experiments. From 2002 to 2007, he worked at Space and Naval Warfare Systems Center Pacific in San Diego. His ONR funded work focused on utilizing advances in navigation, control, and sonar processing to exploit AUVs for complex missions, for example, ship hull inspection.

Dr. Djapic has served as Technical Director of Student Autonomous Underwater Competition-Europe (SAUC-E, [sauc-europe.org](http://sauc-europe.org)) since 2010 and since 2013 as a PI for European Robotics Athlon ([euRathlon](http://euRathlon.eu), [www.eurathlon.eu/site](http://www.eurathlon.eu/site)) and Robocademy ([www.robocademy.eu](http://www.robocademy.eu)). He has over 50 publications at prestigious international journals and conferences and has served as an editor and reviewer during his scientific career.

## Tutorial 2: "Modelling, identification and motion estimation of unmanned marine vehicles" by CNR



As part of the expert visit within the H2020 project "[EXCELLABUST](#) - Excelling [LABUST](#) in marine robotics", **Massimo Caccia** from the National Research Council of Italy (CNR), the Institute of Intelligent Systems for Automation (ISSIA) gave a tutorial titled "Modelling, identification and motion estimation of unmanned marine vehicles" on **24th - 25th May 2016** at the University of Zagreb Faculty of Electrical Engineering and Computing. The agenda, lecture descriptions and materials used during the tutorial, are available in the [repository](#). A short report is available in the detailed news content and [here](#).

The tutorial followed the planned contents about modelling, identification and motion estimation of Unmanned Marine Vehicles, given by Massimo Caccia from CNR-ISSIA. The first day focused on modelling, identification, filtering and motion estimation techniques, placing special emphasis on practical issues and experience. Examples of modelling and identification of ROVs and catamaran-shaped USVs were given, focusing on the design of suitable experiments able to exploit the data of standard sensors mounted onboard the vehicles. During the afternoon, basic theoretical and practical aspects about smoothers and filters have been presented, focusing on outlier rejection, noise characterization and Kalman filtering.

During the second day, the tutorial was focused on open discussion about previous experience of the participants. Guidance and control aspects were discussed, too, as well as the behaviour of acoustic devices in reflective environments, such as, for instance, polar regions covered by ice.

The outcomes of the tutorial were:

- Participants were introduced to modelling and identification of UMVs, namely open frame ROVs and catamaran-like USVs
- Participants were introduced to sensor characterisation and motion estimation of UMVs.
- Participants discussed operational experiences with the tutor who provided hints about practical implementation of theoretical methods.

The tutorial also presented many opportunities for free discussion exchange of know-how and experiences and allowed meeting many students and researchers from University of Zagreb, with several conversations about past and future projects, the state of the art of several research fields of interest, and potential collaborations.

### Invited talk "Bio-Hybrid Systems: Challenges and Potentials"



The H2020 project "[EXCELLABUST](#) - Excelling [LABUST](#) in marine robotics", [Centre of Excellence ACROSS](#) and IEEE Croatia Section, Robotics and Automation Chapter organized the lecture

### **"Bio-Hybrid Systems: Challenges and Potentials"**

given by **Dr. Serge Kernbach**, *Cybertronica Research*, Stuttgart, Germany.

The lecture took place on **Thursday, 29th September 2016**, starting at **15:00** in Grey Hall at the Faculty of Electrical Engineering and Computing.

Bio-hybrid systems represent a new area of biological and technological developments. These systems vary from advanced bio-/phyto- sensors up to establishing an interface between natural and artificial ecosystems. In many cases, the biological part is presented by microbiology, plants, insects and animals; technological part uses mobile and stationary robots, sensor networks and smart artifacts. Current developments show the emergence of bio- and chemo-hybrid systems on micro- and macro-scales and in different organizational forms: individual and collective/network systems, techno-symbiosis, interconnected complex objects with feedback loops. Several research projects focus on integration of human/animal brain and technical devices in neuro-hybrids. Bio-hybrid systems demonstrate many specific features as a high sensitivity to ultraweak environmental and biophysical interactions, extended bio-techno homeostasis, embodied intelligence and other issues. In particular, some phenomena are expected to have the nature of quantum effects in macroscopic systems, which can be measured by precise physical and biochemical methods. The talk overviews the concepts bio-hybrid systems, some European projects on this topic and accurate measurement techniques.

Serge Kernbach, Dr.rer.nat., is a director of the Research Center of Advanced Robotics and Environmental Science "Cybertronica Research". He graduated in electronic engineering and computer science in 1994. In 1996 he was awarded Presidential Fellowship as a young researcher, in 1997 – the DAAD fellowship, he was a guest scientist in the center of Synergetics led by Prof. H. Haken, who also co-supervised his PhD work. In 2007 his doctoral thesis won the faculty-award as the best dissertation of the year at the University of Stuttgart, where he worked as a head of group until 2013. Since 2004 he has been a coordinator of several European research projects on the field of bio-hybrid systems and collective robotics. In 2016 he was elected as a Foreign Member of the Russian Academy of Natural Sciences. Serge's main research interest is focused on biological and technological collective systems, weak bio-physical interactions, he is an author and co-author of 4 books and over 150 articles in international journals and conferences with best paper awards. Since 2000 he acquired more than 6.0 M Euro in different research projects.

