EXCELLABUST

EXCELLING LABUST IN MARINE ROBOTICS

TRAINING 2

“Intervention AUVs”

17-18/05/2017

Universitat de Girona

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FER UNIVERSITY OF ZAGREB FACULTY OF ELECTRICAL ENGINEERING AND COMPUTING

LABUST LABORATORY FOR UNDERWATER SYSTEMS AND TECHNOLOGIES

Consiglio Nazionale delle Ricerche

UNIVERSITY of LIMERICK OLLSCOIL LUIMNIGH

Universitat de Girona Institut de Recerca en Visió per Computador i Robòtica

GIRONA UNDERWATER VISION AND ROBOTICS

1. VENUE

Parc Cientific I Tecnològic de la Universitat de Girona
Edifici Jaume Casademont - Sala VIP
GIRONA

2. 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 14.04
  http://releases.ubuntu.com/16.04/
- To install ROS
  http://wiki.ros.org/ROS/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_s2.git

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

3. SCHEDULE

Day 1: 17 May 2017 (Wed)

09:00 – 10:00	Course Presentation & Software Installation
10:00 – 11:00	Introduction: State of the Art
11:00 – 11:30	**Coffee Break**
11:30 – 12:30	Hands on: ROS –Control 1/2
12:30 – 13:30	Hands on: ROS –Control 2/3
13:30 – 15:00	**Lunch**
15:00 – 16:00	Kinematics
16:00 – 17:00	Hands on: Kinematics-ROS Implementation 1/2
17:00 – 18:00	Hands on: Kinematics-ROS Implementation 2/2

Day 2: 18 May 2017 (Thu)

09:00 – 10:00	Task Priority
10:00 – 11:00	Hands on: Task Priority 1/2
11:00 – 11:30	**Coffee Break**
11:30 – 12:30	Hands on: Task Priority 2/2
12:30 – 13:30	Example: Valve Turning using Task Priority
13:30 – 15:00	**Lunch**
15:00 – 16:00	Hands on: Moveit! 1/2
16:00 – 17:00	Hands on: Moveit! 2/2
17:00 – 18:00	Example: Moveit! Based I-AUV.

4. LECTURE DESCRIPTION:

1. **Course Presentation by Pere Ridao.**
2. **Software Installation by Albert Palomer.** This session will be devoted to the installation of software components that will be required for the hands on training.
3. **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.
4. **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).
5. **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.
6. **Experimental Results in Autonomous Valve Turning by Patryck Cieslack.** 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.
7. **Moveit! By Dina Youakim.** As self-defined in its web page, "*MoveIt! is state of the art software for mobile manipulation, incorporating the latest advances in motion planning, manipulation, 3D perception, kinematics, control and navigation. It provides an easy-to-use platform for developing advanced robotics applications, evaluating new robot designs and building integrated robotics products for industrial, commercial, R&D and other domains. MoveIt! is the most widely used open-source software for manipulation and has been used on over 65 robots.*" In this lecture, the students will be introduced to Moveit!. Its purpose will be presented and its block diagram

including the main components will be reported. Next, a tutorial will be followed to introduce the students to the Moveit! setup assistant, the move group interface, the motion planners provided by the OMPL library and the planning scene and the collision avoidance system. Next it will be explored how to write a controller interface and how to to link Moveit! with ROS-control already introduced in a previous lecture.

8. **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.

9. DESCRIPTION OF THE PARTNER INSTITUTION:

Universitat de Girona
Institut de Recerca en Visió per Computador i Robòtica

Computer Vision and Robotics Research Institute,
University of Girona

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The University of Girona is a public institution devoted to excellence in teaching and research and to participating in the progress and development of society through the creation, transmission, diffusion and criticism of knowledge related to sciences, technology, humanities, social sciences and arts. The Computer Vision and Robotics Research Institute (VICOROB) at the University of Girona is devoted to the research related to the areas of computer vision, image processing and robotics. VICOROB is composed of 75 members (22 PhDs) and in the period 2007--2012 has participated in 21 European and Spanish Research Projects (4,5M€) and 23 Industry Contracts (1M€), has supervised 55 PhD/MSc theses and published 97 articles in journals, 47 book chapters and 180 conference attendances.

GIRONA **UNDERWATER VISION AND ROBOTICS**

Girona Underwater Vision and Robotics Lab

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17003 Girona
Spain
Website: http://cirs.udg.edu
Contact: Assoc. Prof. Dr. Pere Ridao
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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.

10. BIOGRAPHIES OF LECTURERS

	**Pere Ridao** received the Ph.D. degree in computer engineering in 2001 from the University of Girona, Spain. Since 1997, he has participated in 19 research projects (10 European and 9 National), he is author of more than 100 publications, and he has directed 5 PhDs thesis (3 more under direction) and 13 MS Thesis. His research activity focuses on designing and developing Autonomous Underwater Vehicles for 3D Mapping and Intervention. He is the director of the Computer Vision and Robotics Research Institute (VICOROB) and the head of the Underwater Robotics Research Center (CIRS) and an Associate professor with the Department of Computer Engineering of the University of Girona. Dr. Ridao is the chair of the IFAC's Technical Committee on Marine Systems and a co-founder of Iqua Robotics SL UdG Spinoff Company devoted to the commercialization of AUVs.
	**Patryck Cieslak** acquired his Doctoral degree at the Department of Robotics and Mechatronics, 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, especially 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 stage at UdG 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. Included mathematical modelling, control design based on kinematic control with some original ideas and implementation on the real robot, in a ROS-based architecture. 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 Grant to work as a Postdoc at CIRS-UdG developing control strategies for I-AUVs.
	**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** 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.