

ROBOTICS@FER.HR



UNIVERSITY OF ZAGREB
FACULTY OF ELECTRICAL ENGINEERING AND COMPUTING

2016, ZAGREB • CROATIA

ABOUT

UNIVERSITY OF ZAGREB - UNIZG



Website:

www.unizg.hr

The **University of Zagreb - UNIZG** (1669) is the oldest and biggest university in South-Eastern Europe. As a comprehensive public Central European university, University of Zagreb offers education and research and in all scientific fields (arts, biomedicine, biotechnology, engineering, humanities, natural sciences, and social sciences) and a broad spectrum of courses at all study levels, from undergraduate to postgraduate. With 29 Faculties, 3 Art Academies and the University Centre for Croatian Studies it is the flagship educational institution in the country, a place where more than 7900 teachers and 72480 students develop knowledge and acquire skills.

The University excels not only in teaching, but also in research, contributing with over 50 percent to the annual research output in Croatia and 80 percent of scientific productivity of all Croatian universities. The central strategic issue of the future development of the University of Zagreb is for it to be a research oriented institution with teaching of high quality. Accordingly, the focus will be on master and doctoral programs, encompassing all fields of science and art, boosting transdisciplinarity and interdisciplinarity as well as translational research, nurturing the culture of innovation and transfer of knowledge.

FACULTY OF ELECTRICAL ENGINEERING AND COMPUTING - FER



Website:

www.fer.unizg.hr

The **Faculty of Electrical Engineering and Computing - FER** is part of the University of Zagreb - UNIZG. With 130 professors, 220 graduate teaching and research assistants, 4900 students enrolled in various programs, and operating in facilities of more than 35000 m², FER is the largest technical high education institution and the leading educational and R&D institution in the fields of electrical and computer engineering and computer science in Croatia. It is the highest-quality member of the University of Zagreb, with a large and modern infrastructure devoted to research-based education. FER is organised in 12 Departments which represent the focal points of education and R&D. Currently FER participates in more than 20 projects financed by the EU through various grant schemes (FP7, H2020, IPA, COST, ...).

DEPARTMENT OF CONTROL AND COMPUTER ENGINEERING

The **Department of Control and Computer Engineering** was founded in 1954 at the University of Zagreb, College of Engineering. The first head of the department was distinguished and renowned prof. Vladimir Muljević (1913-2007) who is also regarded as the Department founder. Since then, the Department has been the place of study and research for numerous undergraduate and doctoral students, researchers, industrial partners, and academics, growing to be one of the largest department at today's Faculty of Electrical Engineering and Computing. It has also been recognized worldwide as the partner to renowned and most prestigious education and research institutions worldwide.

At present, the Department consists of 14 professors and 40 researchers.

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Robotics research at UNIZG-FER is conducted within three laboratories: **Laboratory for Robotics and Intelligent Control Systems - LARICS** (larics.rasip.fer.hr), **Laboratory for Autonomous Systems and Mobile Robots - LAMOR** (lamor.fer.hr) and **Laboratory for Underwater Systems and Technologies - LABUST** (labust.fer.hr). These laboratories are founders of **Centre of Research Excellence for Advanced Cooperative Systems - ACROSS** (across.fer.hr).

These groups are currently active in more than 20 scientific international and national projects with the topic of robotics in different area. They are also tightly collaborating with companies from all around the world.

Special attention is devoted to knowledge transfer to students at the undergraduate, graduate and PhD level. Starting with elementary robotics, all the way to advanced control, navigation, and estimation, robotics students at UNIZG-FER have the opportunity to adopt state of the art robotics knowledge and apply it on a large number of robotic platforms that are available in the laboratories.

RESEARCH ROBOTICS LABORATORIES AND CENTRE

LABORATORY FOR ROBOTICS AND INTELLIGENT CONTROL SYSTEMS - LARICS



Website:
larics.rasip.fer.hr

Contact:
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Head of LARICS
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Prof. Stjepan Bogdan
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In the last 15 years, the **Laboratory for Robotics and Intelligent Control Systems - LARICS** research group has been involved in research on integrated robotics and process control. LARICS researchers (2 professors, 3 post-docs, 8 PhD, over 15 MS and over 20 BS students) have mainly participated in research devoted to the unmanned aerial systems, intelligent control systems, service robotics, control of multi-agent systems, robot formations, planning, scheduling and decision making in autonomous systems, and application of new technologies in industrial control systems.

Particular emphasis has been given to collaboration with industry, which resulted in many successful implementations of novel control algorithms and human-machine-interfaces in industrial plants. LARICS members successfully completed the following selected industrial projects in collaboration with national and international companies: *Interactive simulator of the Ziegler fire-fighting vehicle control system; Control of a robot for hydrodynamic processing of concrete and metal surfaces; Control of the RCP manipulator for ultrasonic inspection of main pump welds in the VVER-1200 nuclear power plant; Advanced Control of Industrial Plants - Cold Rolling Mill Control (TLM Sibenik)*. Currently, the laboratory is involved in research on advanced evolutionary learning based methods for optimal characterisation of non-linear after treatment technologies funded by Ford Motor Company through the Ford Global University Research Program (URP).

Recently, together with partners, the Laboratory successfully brought to a close one EU FP7 project (*Estimation and Control for Safe Wireless High Mobility Cooperative Industrial Systems - EC-SAFEMOBIL*) and a project financed through the Air Force Office of Scientific Research (*Human-in-the-loop Control of Multi-agent Aerial Systems Under Intermittent Communication*). Currently LARICS researchers are involved in two EU FP7 projects: *European Robotics Challenge (EOLo: Wind generator remote inspection system) - EuRoC* and *Animal and robot Societies Self-organise and Integrate by Social Interaction (bees and fish) - ASSISL_bf*. The Laboratory is a partner on one Horizon 2020 project (*Submarine Cultures Perform Long-Term Robotic Exploration of Unconventional Environmental Niches - subCULTron*) and is currently coordinating a NATO Science for Peace project (*Unmanned system for maritime security and environmental monitoring - MORUS*). LARICS participates in several national projects financed by the government and industrial partners like for instance *Autism Diagnostic Observation with Robot Evaluator - ADORE*, and two projects with scientists from the USA and PR China.

LABORATORY FOR AUTONOMOUS SYSTEMS AND MOBILE ROBOTICS - LAMOR

Website:
lamor.fer.hr

Contact:
Prof. Ivan Petrović,
Head of LAMOR
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The **Laboratory for Autonomous Systems and Mobile Robotics - LAMOR** has a long tradition in research of advanced control strategies and estimation techniques for a variety of applications with a strong emphasis on autonomous navigation of ground and aerial robots in unknown and dynamic environments. Our methodology relies on a strong coupling between theoretical research, algorithm development, experimental evaluations, and a healthy dose of serendipity. It is directed by Prof. Ivan Petrović of the UNIZG-FER and currently consists of 3 postdoctoral fellows and 5 doctoral students. LAMOR's research activity is organized around three major axes: Motion Planning and Control (MPAC), Simultaneous Localization and Mapping (SLAM), and Detection and Tracking of Moving Objects (DATMO). The Laboratory is equipped with state-of-the-art ground and aerial robotic platforms, advanced perception sensors, and a motion capture covered arena.

LAMOR coordinated the major national robotic research program *Intelligent robotic systems and autonomous vehicles* (2007-2014), which involved 5 major robotic research groups in Croatia. LAMOR also has a long tradition of collaboration with research centres in the EU and worldwide. Prof. Petrović coordinated the EU project *ACROSS - Centre of Research Excellence for Cooperative Robotic Systems* (across.fer.unizg.hr), which involved 14 research groups from the University of Zagreb and 16 research institutions from 10 European countries. Furthermore, Prof. Petrović also coordinated the European Regional Development Fund project *Advanced technologies in power systems and rail vehicles* in partnership with the Končar Electrical Engineering Institute Inc. Currently, the group is involved in three projects: EOLO - *Wind generator remote inspection system* (Challenge competition 3 within FP7 project EuRoC), SafeLog - *Safe human-robot interaction in logistic applications for highly flexible warehouses* (H2020 RIA project) and cloudSLAM - *Cooperative cloud based simultaneous localization and mapping in dynamic environments* (Unity Through Knowledge Fund project).

LAMOR successfully organized two robotic conferences: the *4th European Conference on Mobile Robots - ECMR'09* (www.ecmr09.fer.hr) and the *10th IFAC Symposium on Robot Control - SYOROCO 2012* (www.syroco2012.org). Prof. Petrović is the Editor-In-Chief of the journal *Automatika - Journal for Control, Measurement, Electronics, Computing and Communications*.

LABORATORY FOR UNDERWATER SYSTEMS AND TECHNOLOGIES - LABUST



LABUST

Website:

labust.fer.hr

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Asst. Prof. Nikola
Mišković

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The **Laboratory for Underwater Systems and Technologies - LABUST** is a 10 member research group that serves as the focal point for applied research and development activities in unmanned marine systems and technology for end-users. We aim to create new knowledge, educate students, provide advice for end-users, innovate and implement solutions for our customers. We contribute to innovation in sustainable exploitation of ocean resources. LABUST sets itself apart from others in its values and mission to inspire and seek challenging tasks.

Our vision is to advance in a multidisciplinary engineering research that innovates, applies and teaches world class attainments in autonomous marine systems, sensor processing, and underwater acoustics for marine science, maritime archaeology, maritime security, the offshore energy sector, and other applications.

We are currently coordinating the FP7 project CADDY - *Cognitive Autonomous Diving Buddy* and Horizon 2020 project EXCELLABUST - *Excelling LABUST in marine robotics*; and are partner in FP7 EUROFLEETS2 - *New operational steps towards an alliance of European research fleets*, ECHO-DG URready4OS - *Autonomous underwater vehicles ready for Oil Spill*, Horizon 2020 subCULTron - *Submarine Cultures Perform Long-Term Robotic Exploration of Unconventional Environmental Niches*, NATO Science for Peace project MORUS - *Unmanned system for maritime security and environmental monitoring*, three ONRG projects: DINARO - *Diver navigation using range-only measurements from an autonomous surface vehicle*; SeaJumper - *Bio-inspired Synchronous Jumping Marine Sensor Networks*; SPATEL - *Spatial Auditory Human-Machine Interface for UxV Teleoperation*. In the last 5 years the group has also participated in 3 national projects related to marine robotics. We have experience in developing guidance and control software for industry (VideoRay, USA; LD TravOcean, France). LABUST is a light member of the HYCON2 network of excellence. We have organized 7 annual field trainings *Breaking the Surface - BtS* with the purpose of conducting multidisciplinary research within marine biology, archaeology and security.

CENTRE OF RESEARCH EXCELLENCE FOR DATA SCIENCE AND COOPERATIVE SYSTEMS

Website:
across-datascience.hr

Contact:
Prof. Ivan Petrović,
Centre Co-director
ivan.petrovic@fer.hr

The **Centre of Research Excellence for Data Science and Cooperative Systems** is the first national centre of research excellence in the area of technical sciences. It is a successor of the Centre of Research Excellence for Advanced Cooperative Systems - ACROSS which was an interdepartmental project at UNIZG-FER (across.fer.hr, see ACROSS description on page 17). Its establishment and operation was funded by the European FP-7 Capacities Research Potential program [285939, FP7-REGPOT-2011-1]. The Centre gathers 13 renowned partners including 11 higher education institutions from Zagreb, Split, Rijeka, Osijek and Dubrovnik, Ruđer Bošković Institute and the company Ericsson Nikola Tesla. The Centre's mission is to become a leading party in new technology research and development in the fields of data science and cooperative systems. The Centre will advance Croatian science and reinforce its inclusion in the European Research Area, i.e. foster participation in the EU and world research programmes and, additionally, act as a focal point of collaboration between the academia and the business and public sector. This will lead to a strong enhancement of the quality of life and economic growth of Croatia. The Centre consists of the Data Science (DS) and the Advanced Cooperative Systems (ACROSS) research units.

The DS research unit, headed by Prof. Sven Lončarić, studies the problem of extracting knowledge from data, including so called "big data". It is further divided into four Strategic Research Domains: i) multimodal data processing and information control, ii) machine learning and deep data analysis, iii) heterogeneous computing and advanced cloud services, and iv) multidisciplinary data intensive applications. Applications of data science are manifold and include particle and astroparticle physics, biological sciences and healthcare, business analytics and finance, complex networks and society, and analysis of data traffic.

The ACROSS research unit, headed by Prof. Ivan Petrović focuses on the following four Strategic Research Domains: i) autonomous and cooperative robotics systems, ii) cognitive computer vision systems, iii) ubiquitous sensors and networked human-oriented services and iv) advanced control and estimation strategies for cyber-physical systems. Fundamental methodological research within each Strategic Research Domain will be transferred to applications areas while establishing the compatibility of research between the domains. Applications of cooperative systems are truly numerous, and in the Centre we will focus on healthcare systems, security and protection, environment, advanced cities and factories of the future.

WORKSHOPS

ACROSS WORKSHOP



Contact:

Prof. Ivan Petrović

across@fer.hr

The **1st ACROSS Workshop on Cooperative Systems - WoCS 2014**, was held on September 10-12, 2014 in the Grand Hotel Park, Dubrovnik, Croatia. The workshop was organized by the Centre of Research Excellence for Advanced Cooperative systems - ACROSS of the UNIZG-FER, which was funded by the European Commission under FP7-REGPOT-2011-1 ACROSS project (grant No. 285939). The general Chair of the workshop was **Prof. Ivan Petrović**. The workshop will continue to be held annually under the auspices of the Centre of Research Excellence for Data Science and Cooperative Systems.

BREAKING THE SURFACE - INTERNATIONAL INTERDISCIPLINARY FIELD WORKSHOP OF MARINE ROBOTICS AND APPLICATIONS



Website:

bts.fer.hr

Facebook:

www.facebook.com/BtSCroatia

Contact:

Asst. Prof. Nikola

Mišković,

Programme Chair

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Breaking the Surface - BtS workshop is organized by LABUST laboratory for the 8th year in a row. BtS serves as a meeting place of experts and students of marine control engineering and signal processing and the marine robotics application areas in various types of ocean science. This is the world's first successful, multi-year field training program that combines academic topics in marine robotics and robotics application areas and hands-on working experience in the sea, doing remote sensing and sampling for various ocean sciences. It is also unique in that strong emphasis is put on the participation of principal investigators and established research group leaders from across the globe, catering not only to the EU or USA research communities.

BtS 2016 will be held from **2nd** until **9th October** in **Biograd na Moru (Croatia)**. In 2016 it will be organized in the scope of Horizon 2020 project EXCELLABUST - *Excelling LABUST in marine robotics* (GA No 691980) and in partnership with the Norwegian University of Science and Technology - NTNU. The programme novelities are a tutorial on startups organized by NTNU and innovation management training by experts from this field.

The general chair of the workshop is **Prof. Zoran Vukić** and the Programme Chair is **Asst. Prof. Nikola Mišković**.

SCIENTIFIC AND RESEARCH PROJECTS

Currently there are 22 ongoing research projects at the Department of Control and Computer Engineering, which makes more than 20% of all research projects at UNIZG-FER. The list of ongoing projects contains four Horizon 2020 projects, seven FP7 projects, one NATO project, one ERDF project, one Unity Through Knowledge Fund project, two projects by the Croatian Science Foundation, one COST project, one bilateral project, and four projects from other international funding programmes. There are also numerous R&D projects carried out with industry partners from Croatia and abroad.

Robotics projects leaders at FER are Prof. Stjepan Bogdan, Prof. Zdenko Kovačić, Asst. Prof. Nikola Mišković, Prof. Ivan Petrović and Prof. Zoran Vukić.

SELECTED ONGOING RESEARCH PROJECTS

ADORE - AUTISM DIAGNOSTIC OBSERVATION WITH ROBOT EVALUATOR



Contact:

Prof. Zdenko Kovačić

ADORE is a project funded by Croatian Science Foundation whose main goal is to help clinicians from the Faculty of Education and Rehabilitation Sciences to diagnose autism spectrum disorders more quickly and efficiently by using NAO humanoid robots from Aldebaran Robotics. Through this project LARICS laboratory is working on developing a new set of motoric and cognitive skills for NAO humanoid robots. Autism spectrum disorder (ASD) is a developmental disorder characterized by impairment in social interaction, verbal and nonverbal communication, and by repetitive behaviors and interests. The diagnosis, which is usually given during the preschool period, depends on the education and experience of human evaluators, which can be susceptible to personal bias. The goal of the project is the development of a robot-based diagnostic protocol and testing of its verification in clinical settings. The robots will be used as ASD co-evaluators to help a human evaluator to assess a child's behavior objectively. Technically, this means developing specific robot skills and behaviors to be deployed within the standard clinical diagnostic procedure of ASD. The robots will have two functions: observation and quantitative measurement of a child's social responses; and performance of standardized social presses designed to provoke child response. This involves actions such as analyses of the audio signal and differentiation of vocalizations and speech, detection of eye-gaze direction, performance of different actions and gestures and utilization of human-robot and robot-robot interaction to attract child attention. This involves work on cooperation, cognition and human-robot interaction, focusing on multimodal communication.

ASSISI_BF - ANIMAL AND ROBOT SOCIETIES SELF-ORGANISE AND INTEGRATE BY SOCIAL INTERACTION (BEES AND FISH)



Website:
assisi-project.eu

Contact:
Prof. Stjepan Bogdan

The main goal of ASSISI_bf project is to establish a robotic society that is able to develop communication channels to animal societies (honeybees & fish swarms) on its own.

These robots will adapt by evolutionary algorithms until they have learned to interact with animals in a desired way. This new technology is aimed to lay new foundations for the way in which humans can interfere with animal societies in order to manage the environment.

The researchers expect their work to have impact on agriculture, live stock management and environmental protection. In parallel, the mixed societies of animals and robots will represent a novel kind of bio-hybrid ICT system, as the animals will enrich the capabilities of the machines and vice versa. The research is conducted by six European institutions from Austria, Croatia, France, Germany, Portugal and Switzerland.

CADDY - COGNITIVE AUTONOMOUS DIVING BUDDY



Website:
caddy-fp7.eu

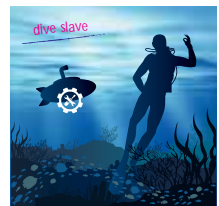
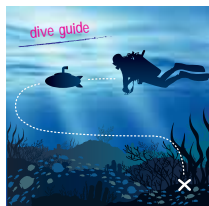
Facebook:
www.facebook.com/caddyfp7

Contact:
Asst. Prof.
Nikola Mišković,
Project Coordinator

CADDY is the first FP7-ICT Cognitive Robotics project coordinated by UNIZG-FER. It started in January 2014, and together with 7 EU partners CADDY aims to replace a human buddy diver with an autonomous underwater vehicle and a new autonomous surface vehicle to improve monitoring, assistance, and safety of the diver's mission.

The resulting system plays a threefold role similar to those that a human buddy diver should have:

- the **buddy "observer"** that continuously monitors the diver;
- the **buddy "slave"** that is the diver's "extended hand" during underwater operations performing tasks such as "do a mosaic of that area", "take a photo of that" or "illuminate that"; and
- the **buddy "guide"** that leads the diver through the underwater environment



The coordinator of this 3-year research project is **Asst. Prof. Nikola Mišković** and the project is executed by **LABUST** research staff.

cloudSLAM - COOPERATIVE CLOUD BASED SIMULTANEOUS LOCALIZATION AND MAPPING IN DYNAMIC ENVIRONMENTS



Website:
cloudslam.fer.hr

Contact:
Prof. Ivan Petrović

cloudSLAM is a Unity Through Knowledge Fund project coordinated by Prof. Ivan Petrović with partner principal investigator Prof. Dana Kulic from the University of Waterloo, Canada.

One of the main prerequisites for autonomous robot operation in unknown environments populated by humans or other robots is to perform simultaneous localization and mapping (SLAM) so that the robot can infer its position and relate it to other objects of interest. The main focus of the cloudSLAM project is to develop algorithms for solving the SLAM problem so that robots can operate reliably even in highly dynamic environments. This will be achieved through a mathematical framework accurately describing the non-Euclidean geometry of objects moving in space and through robot cooperation via a cloud based service.

The methodology of the proposed project will be grounded in a novel estimation approach based on the recently developed Kalman filter on Lie groups. We will estimate the state of the robot and the tracked objects in six degrees of freedom by representing the state with the special Euclidean group (SE3) and performing filtering directly on the introduced group. Finally, all information will be shared by multiple agents through a common cloud-based service, thus enabling robots which have just started operating to immediately exploit the experience of veteran team members.

COORDINATION CONTROL OF MULTI-AGENT SYSTEMS

Contact:
Prof. Stjepan Bogdan

Recent years have witnessed an increasing interest in decentralized control of multi-agent systems (MASs). Decentralized control is characterized by local interactions among agents where each agent exchanges information only with its neighbors. Based on these local interactions, a desired collective behavior of MASs is achieved. Examples are formation control, flocking, consensus control, etc. When compared with centralized control, decentralized control avoids a single point of failure which in turn increases the robustness of MASs, allows for inexpensive and simple agents, and lowers the implementation cost. In addition, decentralized control scales better as the number of agents increases and is sometimes an intrinsic property of MASs. For instance, in industrial applications, we are facing coordination and cooperation of a number of small, inexpensive autonomous systems which replace complex large-scale integration devices. In natural exploration, disaster prevention and handling (firefighting, earthquake, mine clearance etc.) as well as in the service sector (healthcare of senior citizens), autonomous robots, as parts of distributed networks, can help in many ways, and even replace a human in complicated, dangerous and repetitive tasks. Funding agency: Joint grant - PR China and Republic of Croatia.

DINARO - DIVER NAVIGATION USING RANGE-ONLY MEASUREMENTS FROM AN AUTONOMOUS SURFACE VEHICLE

Contact:
Asst. Prof.
Nikola Mišković,
Project Coordinator

Divers operate in an extremely unfriendly environment where human activities depend on technical systems. The goal of this project was to improve the current methodology of tracking and navigating divers during their underwater activities. We exploited range measurements from a single autonomous surface vehicle manoeuvring in such a way to increase the quality of diver position measurement and the observability of the measurement system.

EUROC - EUROPEAN ROBOTICS CHALLENGE (EOLO: WIND GENERATOR REMOTE INSPECTION SYSTEM)



Website:
euroc-project.eu

Contact:
Prof. Ivan Petrović
Prof. Stjepan Bogdan

The European manufacturing industry needs competitive solutions to keep global leadership in products and services. Exploiting synergies across application experts, technology suppliers, system integrators and service providers will speed up the process of bringing innovative technologies from research labs to industrial end-users. As an enabler in this context, the EuRoC initiative proposes to launch three industry-relevant challenges. It aims at sharpening the focus of European manufacturing through a number of application experiments, while adopting an innovative approach which ensures comparative performance evaluation. Each challenge is launched via an open call and is structured in 3 stages.

The FER team participates in Challenge 3 which aims at targeting the open problems in existing MAV solutions (especially in multicopters) to enable their deployment in real life scenarios. MAVs are naturally unstable platforms exhibiting great agility and they thus require a trained pilot to operate them, while being restricted to line-of-sight range. The scenario is the demonstration of high-level teleoperation of a single MAV for an inspection task. The goal is to enable an inspection expert untrained in piloting MAVs (e.g. trained boiler inspector) to tele-operate a MAV as an aid to his/her mission, while being able to focus on the inspection task at hand.

EUROFLEETS2 - NEW OPERATIONAL STEPS TOWARDS AN ALLIANCE OF EUROPEAN RESEARCH FLEETS



Website:
eurofleets2.eu

Contact:
Prof. Zoran Vukić

EUROFLEETS2 is about developing a new pan-European distributed infrastructure with common strategic vision and coordinated access to Research Vessels and marine equipment, leading to more interoperable and cost effective European research fleets.

Our work package aims to develop key technologies and innovative functions for underwater systems such as new Hybrid ROVs (Hybrid Remotely Operated Vehicle). FER is involved in research and development of optical 3D based mapping in strong relief and control strategies for AUVs, ROVs and HROVs: dynamic positioning, target tracking and terrain following. This 4-years FP7 project started in 2013 and is coordinated by Institut Francais de Recherrche pour L'exploitation de la Mer (IFREMER). At UNIZG-FER, project is led by **LABUST** and by **Prof. Zoran Vukić**.

MORUS - UNMANNED SYSTEM FOR MARITIME SECURITY AND ENVIRONMENTAL MONITORING



Website:
morus.fer.hr

Contact:
Prof. Stjepan Bogdan,
Project Coordinator

The main goal of NATO Science for Peace project MORUS is to design and develop a fully operational complex robotic system prototype comprised of an Unmanned Aerial Vehicle (UAV) and Unmanned Underwater Vehicle (UUV) capable of autonomous and cooperative mission execution related to environmental, border and port security. The proposed research thrives within internationally competitive field with the main objective to design and develop autonomous aerial and marine robotic system, capable of collective engagement in missions taking place in dynamic and nondeterministic environments. The design will focus mainly on payload enhancement and UAV autonomy which is mandatory for UUV transport.

Besides that, a docking system and cooperative control algorithms will be developed enabling autonomous deployment, re-deployment and data exchange at the open sea. The operating environment of the proposed prototype is unknown, uncertain and remote, i.e. far from a human operator. Therefore, a whole set of novel cooperative control algorithms, combined with an augmented human machine interface, will be designed and implemented in order to ensure safety and recoverability of the described system. The project is executed by two research groups, **LARCIS** and **LABUST**, coordinated by **Prof. Stjepan Bogdan**.

SAFELOG - SAFE HUMAN-ROBOT INTERACTION IN LOGISTIC APPLICATIONS FOR HIGHLY FLEXIBLE WAREHOUSES

Contact:
Prof. Ivan Petrović,
Principal Investigator

SafeLog is a Horizon 2020 ICT project coordinated by Prof. Björn Hein from the Karlsruhe Institute of Technology with UNIZG-FER being one of six partners (Principal Investigator: Prof. Ivan Petrović).

The European market for e-commerce is growing rapidly, with more than 16% just in the year 2014. With the internationalization of distribution chains, the key for success lies within efficient logistics. In such facilities, goods for the end-user or products in the B2B sector are stored, commissioned and shipped. To manage the supply chains, many new warehouses have been erected and more will follow. With the growing markets, the need for larger warehouses and their automation increases. To advance the position of the European trade sector, technical restrictions on the size of warehouses should be avoided and a new automation paradigm should be implemented to ensure their efficient operation. Therefore, European robotics and automation companies should be able to provide appropriate solutions, making scalable systems and scalable software mandatory. Current automation solutions based on strict separation of humans and robots cannot provide such efficient operation of large warehouses. SafeLog aims to overcome this issue by enabling much more efficient warehouse concepts joining human and robot workforce. Given that, the overall objective of SafeLog is the conception and implementation of a large-scale flexible warehouse system which enables safe and efficient collaboration of humans and robots in the same area and at the same time. On the way to reach this objective SafeLog will develop, integrate and test: (1) a holistic and certifiable safety concept based on the safety vest, which allows the collaboration of robots and humans in a flexible warehouse system, (2) planning and scheduling algorithms for a heterogeneous fleet manager, which allow the adhoc reactive planning and scheduling for human and robot workforce in a flexible warehouse system, and (3) augmented reality based interaction strategies to support workers in a robotized warehouse system with information about their current task and environment.

SEAJUMPER - BIO-INSPIRED SYNCHRONOUS JUMPING MARINE SENSOR NETWORKS

Contact:
Asst. Prof.
Nikola Mišković

SeaJumper is a joint effort with Imperial College London, with the main goal to develop novel distributed, low-energy, marine sensors inspired by jumping aquatic animals such as the flying squid. The system will be capable of transmitting obtained underwater data by executing the sinking, rising and jumping cycle. The envisioned system will exploit jumping properties to enable autonomous recovery on-board a small-scale autonomous surface marine platform. This project will kick-start the SeaJumper development and will focus on delivering the key scientific contributions in advanced mobility across the air-water interface and robust sensor communication. Future developments will combine these concepts and integrate the SeaJumpers with Autonomous Surface Vehicles (ASV) for fully automated sensing and recovery of sensor nodes in marine environments.

SPATEL - SPATIAL AUDITORY HUMAN-MACHINE INTERFACE FOR UXV TELEOPERATION

Contact:
Asst. Prof.
Nikola Mišković,
Project Coordinator

SPATEL investigates innovative uses of auditory interfaces in remote control of marine vehicles - both are coordinated by FER. For teleoperated unmanned vehicles, mishaps tend to occur during the periods of high workload, in situations where the operator must perform complex and stressful tasks. In order to address these unique human-factors problems associated with unmanned vehicles we use auditory display as a means to reduce visual workload, to enhance situation awareness, and mitigate the visual and cognitive demands of contemporary marine teleoperations.

LABUST demonstrated that the use of an auditory display that presents spatial auditory cues can be successfully used for guidance of unmanned vehicles. The system addresses two significant hearing downsides: the spatial acuity of the visual channel is much better than that of the auditory channel, and humans use vision on a permanent basis for navigation, we are very well trained for visual, but not for audio navigation.

The existing LABUST fleet of unmanned vehicles will be used to prove the exploitability of the basic research results related to the Spatial Auditory Interface and the quality of performance in real life conditions.

SUBCULTRON - SUBMARINE CULTURES PERFORM LONG-TERM ROBOTIC EXPLORATION OF UNCONVENTIONAL ENVIRONMENTAL NICHES



Website:
subcultron.eu

Contact:
Asst. Prof.
Nikola Mišković

subCULTron is a Horizon FET project that aims to achieve long-term autonomy in a learning, self-regulating, self-sustaining underwater society/culture of robots in a high-impact application area: Venice, Italy. It is the first Croatian Horizon 2020 FET project.

The envisioned heterogeneous system consists of 3 different agent types: 1) on the seabed, **artificial mussels** are the collective long-term memory of the system that monitors the natural habitat

2) on the water surface, **artificial lily pads** interface with the human society, delivering energy and information influx from ship traffic or satellite data

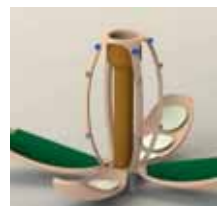
3) between those two layers, **artificial fish** move/monitor/explore the environment and exchange info with the mussels and lily pads.



aPad



aFish



aMussel

The four year project started in April 2015 and it is executed by two research groups, **LABUST** and **LARICS**, coordinated at UNIZG-FER by **Asst. Prof. Nikola Mišković**.

SELECTED FINISHED PROJECTS

ACROSS - CENTRE OF RESEARCH EXCELLENCE FOR ADVANCED COOPERATIVE SYSTEMS



Website:

across.fer.unizg.hr

Contact:

Prof. Ivan Petrović,
Project Coordinator

ACROSS Research Centre was a European FP-7 Capacities Research Potential program project [285939, FP7-REGPOT-2011-1]. The project research activities focused on four major Strategic Research Domains: Cooperative Cognitive and Robotic Systems, Cooperative Networked Embedded Systems, Cooperative Renewable Energy Systems, and Cooperative Control Methods. ACROSS gathered fourteen research groups from seven UNIZG-FER departments and tightly collaborated with sixteen leading EU research centres and three Croatian partner companies. Close to 100 months were spent by ACROSS researchers at the partnering renowned EU institutions, the project employed 26 experienced researchers during three years, including 4 researchers returning from abroad after obtaining their PhD degree, and 15 renowned EU experts held seminars at the UNIZG-FER. The members of the Steering Committee were distinguished scientists in the ACROSS strategic research domains, senior managers from industry as well as representatives of public authorities and funding agencies. The project was coordinated by **Prof. Ivan Petrović**.

EC-SAFEMOBIL - ESTIMATION AND CONTROL FOR SAFE WIRELESS HIGH MOBILITY COOPERATIVE INDUSTRIAL SYSTEMS



Website:

ec-safemobil-project.eu

Contact:

Prof. Zdenko Kovačić

The European Commission, under the 7th Frame Program, provided funds to perform the project EC-SAFEMOBIL, recognizing the growing importance of the UAV market and applications. In the case of EC-SAFEMOBIL project, these were related to the utilization of autonomous systems in general and UAVs in particular, in many applications that cannot be accomplished with manned systems, including disaster management, monitoring and measurement of events, rescue missions (particularly in stormy conditions) and in general all missions where there are risks for human beings. The awarded EC-SAFEMOBIL Consortium included the most important organizations and companies within the European sector and represented an appropriate mixture of research organizations and key players at an industry level. FADA-CATEC acted as the project leader and the consortium team included DLR, Astrium, Indra, SELEX GALILEO, Euroimpianti, University of Seville, University Duisburg-Essen and UNIZG. The EC-SAFEMOBIL project was devoted to the development of sufficiently accurate motion estimation and control methods and technologies in order to reach levels of reliability and safety to facilitate unmanned vehicle deployment in a broad range of applications. It also included the development of a secure architecture and the middleware to support the implementation. The EC-SAFEMOBIL project developed world first technology demonstrators in several applications dealing with the landing of UAVs on mobile platforms in challenging conditions, launching of an UAV from a manned vehicle, surveillance, and warehousing involving a large number of autonomous vehicles.

FER-KIET - ADVANCED TECHNOLOGIES IN POWER PLANTS AND RAIL VEHICLES



Website:
fer-kiet.fer.hr

Contact:
Prof. Ivan Petrović

The project goal is to develop four advanced technologies focusing on applications in power plants and rail vehicles. Research conducted within the Advanced Sensors Technologies aims to establish a knowledge base and develop new sensing technologies with expected commercial applications in rotational machines monitoring systems. In a broader sense, research in the area of advanced sensing technologies constitutes a specific segment in the ICT domain with applications in the electrical power and transport sectors, as well as other areas such as environmental protection, health, smart infrastructure, etc. Research conducted within the Advanced Estimation and Control Algorithms in Microgrids aims to develop an advanced battery management system with state-of-charge and state-of-health estimation, and development of the algorithm for prediction of renewable energy systems availability using free weather forecast. Research of the Multilevel Converters Electric Energy Storage Systems element of the project aims to investigate the possibilities of using multilevel converters for connecting renewable energy sources to the power grid and to explore the possibilities of efficient storage of electricity in rolling stock. Research of the Driver Assistance System aims to develop new technologies in the area of detection and tracking of vehicles and pedestrians. The project is coordinated by **Prof. Ivan Petrović**.

HUMAN-IN-THE-LOOP CONTROL OF MULTI-AGENT AERIAL SYSTEMS UNDER INTERMITTENT COMMUNICATION

Contact:
Prof. Stjepan Bogdan

The objective of this research is decentralized control of heterogeneous multi-agent systems in degraded communication environments. We proposed a novel design of an HMI that allows a human to become a supervisor, when necessary, instead of a single unit operator. By deploying dexterous aerial robots as components of multi-agent systems, we allow the supervisor to interact with its surroundings. We aim to utilize our aerial platforms in a multi-agent system that has the ability to perform both reconnaissance missions and missions that require interaction with its surroundings. Of course, building such a system raises the need for a completely new HMI, that we have introduced earlier. Given our heterogeneous testbed and strong history in modeling and control of autonomous agents, optimal control, robotic control systems, and nonlinear systems, as well as our published work on aerial robots and real communication artifacts, the PI was uniquely positioned to bring these areas together to develop new scientific results. The funding agency of the project was the Air Force Office of Scientific Research (AFOSR).

URREADY4OS - AUTONOMOUS UNDERWATER VEHICLES READY FOR OIL SPILL



Website:
upect.es/urready4os

Contact:
Prof. Zoran Vukić

The URready4OS project is co-financed by the Directorate-General Humanitarian Aid and Civil Protection of the the European Commission, and has the general aim to join forces to make available to the European Civil Protection a fleet of autonomous underwater vehicles (AUVs), unmanned aerial vehicles (UAVs), and unmanned surface vehicles (USVs) with operational capability to intervene against oil spills in European seas using new cooperative multi-vehicle robotic technologies. This two year project was executed by **LABUST**.

DEVELOPING CROATIAN UNDERWATER ROBOTICS RESEARCH POTENTIAL - CURE

Contact:
Prof. Zoran Vukić,
Project Coordinator

CURE significantly improved Croatian research potential in underwater systems and technologies and enabled intensification of dissemination of UNIZG-FER-LABUST research results and capabilities that can accommodate the needs of Croatia and the whole West Balkan region related to the exploration of underwater systems and technologies.

The CURE project enabled intensified proliferation of underwater robotics knowledge in Croatia. The transfer of knowledge undertaken during the duration of the project showed intense activity within the scope of the project providing both LABUST researchers and a diverse user community with an opportunity to have deep insight into the corresponding technology. Besides revealing a huge potential for underwater robotics, the CURE project also provided a big momentum for scientific and commercial applications in the region.

The project was coordinated by UNIZG-FER and **Prof. Zoran Vukić (LABUST)**.

CART - COOPERATIVE AUTONOMOUS ROBOTIC TOWING SYSTEM

website:
cart.posidonia.com

Contact:
Prof. Zoran Vukić

The project CART proposed a new concept for salvage operations of distressed ships at sea. The CART concept was based on the development of robotized unmanned marine platforms able to (semi-)automatically execute the high risk operation of linking the emergency towing system of distressed ships to towing vessels. This minimised the risk for human lives and increased the safeguard of the environment, helping, for instance, to prevent oil pollution at sea, during salvage operations.

The background of the page is a complex technical drawing in light grey lines. It features various mechanical components such as gears, shafts, bearings, and structural frames, all rendered in a clean, schematic style. The drawing is centered and occupies most of the page area.

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