ACROSS

Centre of Research Excellence
for Advanced Cooperative Systems

ACROSS Workshop on Cooperative Systems

Organizer

Centre of Research Excellence for Advanced Cooperative Systems,
Faculty of Electrical Engineering and Computing,
University of Zagreb

September 10-12, 2014
Dubrovnik, Croatia

ACROSS Workshop on Cooperative Systems

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Organized by:

Centre of Research Excellence for Advanced Cooperative Systems,
Faculty of Electrical Engineering and Computing,
University of Zagreb

Organizers

Centre of Research Excellence for Advanced Cooperative Systems
University of Zagreb Faculty of Electrical Engineering and Computing

Sponsors

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University of Zagreb Faculty of Electrical Engineering and Computing

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Dear Colleagues,

I am honoured to welcome you to the 1st ACROSS Workshop on Cooperative Systems – WoCS 2014, which is held on September 10–12, 2014 in the Grand Hotel Park, Dubrovnik, Croatia. The workshop is organized by the Centre of Research Excellence for Advanced Cooperative systems (ACROSS Centre for short) of the University of Zagreb, Faculty of Electrical Engineering and Computing, which is funded by the European Commission under FP7-REGPOT-2011-1 ACROSS project (grant No. 285939).

The key idea of the ACROSS project is to utilize inter-disciplinary approach for cooperative systems in four strategic research domains: cognitive systems and robotics, networked embedded systems, renewable energy systems, and control methods. The objective of the workshop is to foster exchange of ideas between internationally leading experts from various fields and to highlight challenges in the area of cooperative systems and their applications in ACROSS strategic research domains.

The workshop program includes invited lectures by twenty three distinguished researchers from thirteen countries presenting state-of-the-art research and development in: cooperative renewable energy systems, cooperative robotic systems, autonomous robotic systems, human-robot cooperative systems, advanced sensing and signal processing for cooperative systems, cooperative and optimal control, and cooperative networked embedded systems. Furthermore, the program is enriched with eleventh brief talks by the ACROSS Centre leading experts as well as with forty nine posters organised in three poster sessions presenting research activities of research groups from ACROSS Centre and several collaborating research centres.

I wish you all a pleasant and successful participation in the 1st ACROSS Workshop on Cooperative Systems.

With my best wishes,

Ivan Petrović
General Chair

ACROSS Workshop on Cooperative Systems – Technical Program

Time	Wednesday, 10th September	Thursday, 11th September	Friday, 12th September
8:00	Registration	Registration	Registration
9:00	Opening Session	Session Th01: Autonomous Robotic Systems	Session Fr01: Cooperative and Optimal Control
10:00	Session We01: Cooperative Renewable Energy Systems		
	Coffee Break and Poster Session 1	Coffee Break and Poster Session 2	Coffee Break and Poster Session 3
11:00	Session We01: Cooperative Renewable Energy Systems	Session Th01: Autonomous Robotic Systems	Session Fr01
			Session Fr02
12:00	Lunch and Poster Session 1	Lunch and Poster Session 2	Lunch and Poster Session 3
13:00	Session We02: Cooperative Robotic Systems	Session Th02: Human-Robot Cooperative Systems	Session Fr02: Cooperative Networked Embedded Systems
14:00			
	Coffee Break and Poster Session 1	Coffee Break and Poster Session 2	Closing Session and Poster Session 3
15:00	Session We02: Cooperative Robotic Systems	Session Th03: Advanced Sensing and Signal Processing for Cooperative Systems	
16:00			
17:00			

08:15 – 16:00	Registration	
	Opening Session	
09:15 – 09:30	Welcome Note *Ivan Petrović, ACROSS Coordinator, University of Zagreb, Croatia*	
	Session We01: Cooperative Renewable Energy Systems *Chairs: Igor Kuzle and Mario Vašak*	Page
09:30 –10:00	Power Management in Renewable Energy Microgrids with Hybrid Storage: Optimal Schedule and Operation *Carlos Bordons Alba, University of Seville, Spain*	10
10:00 – 10:30	Control and Interconnection Issues of AC and DC Microgrids *Rosa Anna Mastromauro, Polytechnic University of Bari, Italy*	10
10:30 – 11:00	Coffee Break and Poster Session 1	
11:00 – 11:30	Optimal Distributed Generation Placement in Power Distribution Networks *Pavlos S. Georgilakis, National Technical University of Athens, Greece*	11
11:30 – 11:45	Integration of Wind Power Plant in the Transmission Network *Igor Kuzle, University of Zagreb, Croatia*	11
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	Session We02: Cooperative Robotic Systems *Chairs: Stjepan Bogdan and Nikola Mišković*	Page
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13:30 – 14:00	Bio-Inspired Design: A Perspective for Aerial Robotics *Mirko Kovač, Imperial College London, United Kingdom*	13
14:00 – 14:30	Collective Control, State Estimation and Human Interaction for Teams of Mobile Robots *Paolo Robuffo Giordano, INRIA, Rennes, France*	14
14:30 – 15:00	Coffee Break and continued Poster Session 1	
15:00 – 15:15	Research in cooperative robotic systems at UNIZG-FER *Zdenko Kovačić and Stjepan Bogdan, University of Zagreb, Croatia*	14
15:15 – 15:45	Cooperative Systems in Marine Robotics *Massimo Caccia, CNR-ISSIA, Genoa, Italy*	15
15:45 – 16:00	Research in Marine Robotics at UNIG-FER *Nikola Mišković and Zoran Vukić, University of Zagreb, Croatia*	15

08:15 – 15:00	Registration	
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09:30 – 10:00	Fair Control under Resource Constraints *Sandra Hirche, Technische Universität München, Germany*	24
10:00 – 10:30	Coordination of Large-Scale Populations of Systems via Mean Field Control Theory *Sergio Grammatico, ETH Zürich, Switzerland*	24
10:30 – 11:00	Coffee Break and Poster Session 3	
11:00 – 11:30	Function Approximation Techniques in Modeling and Control *Michal Kvasnica, Slovak University of Technology in Bratislava, Slovakia*	25
	Session Fr02: Cooperative Networked Embededed Systems *Chairs: Maja Matijašević and Vedran Bilas*	Page
11:30 – 12:00	A Distributed Perception Infrastructure for Robot Assisted Living (Integration of Robots and Sensor Networks) *Emanuele Menegatti, University of Padova, Italy*	25
12:00 – 13:00	Lunch and continued Poster Session 3	
13:00 – 13:30	Nano Power Wake Up Radio Receivers to Eliminate Idle-Listening Consumption in Wireless Sensor Network *Michele Magno, ETH Zürich, Switzerland, and University of Bologna, Italy*	26
13:30 – 13:45	Research Activities in the Networked Media Research Group *Maja Matijašević and Ivana Podnar Žarko, University of Zagreb, Croatia*	27
13:45 – 14:15	Estimating Location and Magnetic Polarizability Tensor of Metallic Targets for Security and Landmine Clearance Applications *Anthony Peyton, University of Manchester, United Kingdom*	27
14:15 – 14:30	Cooperative Sensing for Enhanced Information Capture System Performance *Vedran Bilas and Darko Vasić, University of Zagreb, Croatia*	28
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WoCS 2014 List of Posters

Poster Session 1, Wednesday, 10th September, 2014

1. *Z. Kovačić, D. Miklić, G. Vasiljević, F. Petric, T. Petrović.* EC-SAFEMOBIL: Estimation and Control for Safe Wireless High Mobility Cooperative Industrial Systems.
2. *S. Bogdan, D. Miklić, K. Griparić, T. Haus.* Animal and Robot Societies Self-Organise and Integrate by Social Interaction – ASSISIbf.
3. *S. Piperidis.* Biomimetic Behaviour Based Robotic Control.
4. *M. Horvat, K. Jambrošić, H. Domitrović.* Environmental Noise Control Group.
5. *F. Fele, J. M. Maestre, E. F. Camacho.* Coalitional MPC Control Applied to an Irrigation Canal.
6. *J. Babić, S. Marijan, I. Petrović.* Model-Based Real-Time Embedded Software Component Testing.
7. *M. Zidar, T. Capuder, D. Škrlec.* A Step Toward Sustainable Future – Active Prosumers and Distribution Systems.
8. *S. Bogdan, I. Palunko, D. Tolić, M. Orsag, T. Haus.* Human-in-the-loop Control of Multi-agent Aerial Systems Under Intermittent Communication.
9. *T. Pavlović, Ž. Ban.* Maximum Power Point Tracking Algorithm For All-Weather Conditions Based on the Nelder-Mead Optimization.
10. *N. Hure, M. Vašak, E. Camacho, N. Perić.* Constrained Model Predictive Control of a Wind Turbine.
11. *A. Nüchter, I. Petrović, J. Velagić.* ThermalMapper – Thermal 3D Modeling of Indoor Environments for Saving Energy.
12. *V. Lešić, M. Vašak.* Fault-tolerant Control of Wind Turbines Subject to Generator Electromechanical Faults.
13. *D. Miklić, F. Petric, D. Tolić, Z. Kovačić.* ADORE: Autism Diagnostic Observation with a Robot Evaluator.
14. *N. Mišković.* Cognitive Autonomous Diving Buddy (CADDY).
15. *M. Vašak, G. Banjac.* UrbanWater – Intelligent Urban Water Management System.
16. *R. Turnar, M. Vašak.* CEESH – Centre of Excellence for Structural Health.
17. *M. Đalto, M. Vašak, M. Baotić, J. Matuško, K. Horvath.* Neural Network Based Ultra-Short-Term Wind Forecasting.
18. *A. Martinčević, A. Starčić, M. Vašak.* Enhancement of Research, Development and Technology Transfer Capacities in Energy Management Systems for Buildings.

Poster Session 2, Thursday, 11th September, 2014

1. *M. Đakulović, M. Baotić, I. Petrović.* Receding Horizon Control for Convergent Navigation of Mobile Robots.
2. *K. Lenac, A. Kitanov, I. Maurović, M. Đakulović, I. Petrović.* Fast Active SLAM for Accurate and Complete Coverage Mapping.
3. *I. Marković, M. Bukal, J. Ćesić, I. Petrović.* Directional Distributions Flavored Moving Object Tracking.
4. *M. Bukal, I. Petrović.* Consensus in Information Geometry.
5. *I. Cvišić, A. Kitanov, V. Sazdovski, I. Petrović.* Vision Based Approaches Toward Embedded Autonomous Navigation Systems for UAVs.
6. *D. Herceg, B. Novoselnik, I. Petrović, D. Kulić.* Trajectory Planning and Learning Control for Robotic Arms.
7. *M. Georgiev.* A Real-Time Scene-Adaptive 3D Scene Sensing System.
8. *S. Lončarić, D. Seršić, T. Pribanić, M. Subašić, T. Petković, H. Kalinić, V. Baličević, P. Prentašić, D. Jurić, I. Harbaš, N. Banić.* IPG – Image Processing Group
9. *T. Petković, S. Lončarić.* Gradient Orientation in Visual Quality Control.
10. *S. Šegvić, Z. Kalafatić, K. Brkić, J. Krapac.* ACVIG – Advanced Cognition and Vision Group.
11. *J. Krapac, S. Šegvić.* Weakly Supervised Object Localization with Large Fisher Vectors.
12. *K. Brkić, A. Aldoma, M. Vincze, S. Šegvić, Z. Kalafatić.* Temporal Ensemble of Shape Functions.

Poster Session 2, Thursday, 11th September, 2014 (continued)

13. *N. Markuš, M. Frljak, I. S. Pandžić, J. Ahlberg, R. Forchheimer.* High-Performance Face Tracking.
14. *A. Sović, D. Seršić.* Robust Image Enhancement.
15. *M. Butorac, M. Vučić.* Efficient FPGA Structures for Digital Signal Processing.
16. *G. Molnar, M. Vučić.* Design of Multirate Digital Filters Based on Sharpening Technique.

Poster Session 3, Friday, 12th September, 2014

1. *S. Erhart, S. Hirche.* Multi-Robot Cooperative Manipulation under Kinematic Uncertainty.
2. *M. Baotić.* Dynamic Management of Physically Coupled Systems of Systems (DYMASOS).
3. *M. Baotić, M. Gulin.* Optimization of Renewable Electricity Generation Systems Connected in a Microgrid.
4. *V. Petrović, C. L. Bottasso.* Wind Turbine Loads Envelope Protection during Storms.
5. *I. Palunko, S. Hirche.* Cooperative Manipulation of Suspended Objects.
6. *M. Mamduhi, A. Molin, S. Hirche.* An Event-based Scheduling Design for Multi-loop Stochastic Networked Control Systems.
7. *D. Tolić, S. Hirche.* Stabilizing Transmission Intervals and Delays: The Large Delay Case.
8. *J. Holaza, B. Takács, M. Kvasnica.* Simple Explicit MPC Controllers Based on Approximation of the Feedback Law.
9. *S. Ileš, J. Matuško, F. Kolonić.* Control of 3D Tower Crane Based on Polytopic LPV model.
10. *J. R. Medina Hernandez, S. Hirche.* Synthesizing Anticipatory Haptic Assistance Considering Human Behavior Uncertainty.
11. *M. Matijašević, L. Skorin-Kapov, O. Dobrijević, T. Grgić, M. Sužnjević, K. Ivešić.* Networked Media (NWMED) Research Group.
12. *K. Ivešic, L. Skorin-Kapov, M. Matijašević.* Resource Management for Multimedia Services Based on User- and Service-Related Knowledge.
13. *O. Dobrijević, A. Kassler, L. Skorin-Kapov, M. Matijašević.* Toward QoE-driven Path Optimization for Multimedia Services in Future Networks.
14. *M. Sužnjević, M. Matijašević.* Implications of User Behaviour in Online Games for Network Traffic Characteristics and Quality of Experience.
15. *A. Antonić, V. Bilas, M. Marjanović, M. Matijašević, D. Oletić, M. Pavelić, I. Podnar Žarko, K. Pripužić, L. Skorin-Kapov.* Urban Crowd Sensing for Environmental Monitoring: The OpenIoT Approach
16. *V. Jeličić, D. Tolić, V. Bilas.* Decentralized Resource Management Between Consensus-Seeking Networks.
17. *M. O'Toole, L. Marsh, J. Davidson, Y. M. Tan, D. Armitage, A. Peyton.* Magnetic Induction Spectroscopy System for Non-Contact Conductivity Measurements of Biological Samples.
18. *V. Jeličić, V. Bilas.* Holistic Approach to Energy Saving in Wireless Networks of Energy-Hungry Sensors for Smart Surveillance.
19. *D. Ambruš, D. Vasić, V. Bilas.* Advanced Electromagnetic Induction Methods in Humanitarian Demining.

Invited Talks

Session We01: Cooperative Renewable Energy Systems

Power Management in Renewable Energy Microgrids with Hybrid Storage: Optimal Schedule and Operation

C. Bordons Alba

University of Seville, Spain

Efficient energy generation and consumption is a key factor to achieve ambitious goals related to air pollution and climate change. Modern electricity networks can include different kind of sources, such as Renewable Energy Sources (RES). The unpredictability of renewable energy makes it necessary the integration of Energy Storage Systems (EES) in order to fulfill the demand. Then, hybrid systems are obtained in the concept called microgrid (MG). In order to draw the best performance from these hybrid systems, proper design and optimal operation are essential. The talk focuses on power management in MGs with RES (mainly wind and solar) and hybrid storage (hydrogen and electricity). Power management is carried out using Model Predictive Control (MPC), where several control objectives are considered. The use of MPC technique allows maximizing the economical benefit of the MG and minimizing the degradation causes of each storage system by fulfilling the different system constraints. Experimental results of a laboratory-scale MG are presented and assessed by the definition and use of Key Performance Indicators (KPI).

Control and Interconnection Issues of AC and DC Microgrids

R. A. Mastromauro

Polytechnic University of Bari, Italy

In the last years a growing interest toward Microgrids has been registered due to high penetration of Distributed Power Generation Systems (DPGS) with embedded storage. The microgrids can be divided in: AC Microgrids and DC Microgrids. AC Microgrids have experienced a wider spread than DC Microgrids since the actual power system is in AC. Focusing on AC Microgrids, the

DPGS converters are traditionally controlled differently in grid-connected mode and stand-alone mode and they are classified as grid-feeding and grid-forming converters. On the contrary a hierarchical control, based on multi-level cascade loops, can allow "universal operation" of the converter and optimal integration into the distribution network. However, trying to foresee the possible future scenarios of the power systems, it can be noticed that DC Microgrids can be even preferable to AC Microgrids in terms of flexibility and redundancy since they are compatible with the achievement of a DC Multibus working at different voltage levels. The Single-Star Bridge Cells Modular Multilevel Cascade Converter topology can be successfully used as bidirectional interface between the DC sources and the main AC grid contributing to the advancement of DC Microgrids.

Optimal Distributed Generation Placement in Power Distribution Networks

P. S. Georgilakis, N. D. Hatziargyriou

National Technical University of Athens, Greece

The integration of distributed generation (DG) units in power distribution networks has become increasingly important in recent years. The aim of the optimal DG placement (ODGP) is to provide the best locations and sizes of DGs to optimize electrical distribution network operation and planning taking into account electrical network operating constraints, DG operation constraints, and investment constraints. The ODGP is a complex mixed integer nonlinear optimization problem. DG placement impacts critically the operation of the distribution network. Inappropriate DG placement may increase system losses and network capital and operating costs. On the contrary, optimal DG placement (ODGP) can improve network performance in terms of voltage profile, reduce flows and system losses and improve power quality and reliability of supply. Several models and methods have been suggested for the solution of the ODGP problem. We present an overview of the state of the art models and methods applied to the ODGP problem, analyzing and classifying current and future research trends in this field.

Integration of Wind Power Plant in the Smart Transmission Network

I. Kuzle

University of Zagreb, Croatia

The penetration level of wind power into the power system over the world has been increasing very fast in the last few years and is still keeping the fast growth

rate. It is just a matter of time that the wind power will be comparable to the conventional power generation. The predictability of power sources (location and levels of power injections) decreases when a significant amount of variable power generation is connected to the system. Transmission system operators must then be more able to handle sudden drops or rises in electricity network injection, which were not foreseen in their usual way of managing electricity systems. Moreover, large wind power plants production sites may be very often located far away from electricity consumption sites.
This presentation discusses the grid codes technical requirements (regarding connection and operation) for the integration of a wind power plants into an electric power transmission network. Also, smart grids – concept for large scale wind power integration are described. These technologies, based on information-communication solutions, increase capacity, efficiency and reliability of existing and new transmission elements and dramatically helps the large scale penetration of renewable energy sources with variable generation.

From Smart Buildings to Smart Grids – Integration Concepts for Smart Cities

M. Vašak, M. Baotić

University of Zagreb, Croatia

Buildings are basic elements of a city which are integrated together through energy and water distribution systems. One of the smart city pillars is energy and water efficiency in buildings, but also buildings interoperability via city-wide distribution systems. The talk will present a bottom-up approach in achieving such an interoperability that resides on information technology and optimization supported control engineering. This will be a condensed cut-through of researches performed in several ongoing research projects: starting from control for efficient energy consumption in buildings (project ENHEMS-Buildings – European Regional Development Fund), through energy storages management with significant penetration of local renewable energy production, interaction with energy consumption on one side and the distribution grid on the other (projects Microgrid and 3CON – Croatian Science Foundation) up to the electrical energy and water distribution systems management based on interaction with such prosumers (projects DYMASOS and UrbanWater – EU 7^{th} Framework Programme for Research and Technological Development). Besides the basic research approach, some emerging opportunities that underpin these developments will be emphasized.

Session We02: Cooperative Robotic Systems

Simple Heuristics for Robotic Cooperation: Keep on Learning from Nature

N. C. Tsourveloudis

Technical University of Crete, Greece

Several cooperative behaviour schemes, initially observed in the wild, have been mimicked to compose bio-inspired solutions to almost all robotic related problems. Mimicking animal has proved to be an innovative tool for designing and controlling robotic systems. Emergent biomimetic control methodologies may be developed by focusing at the interaction among the layered animal behaviours themselves and between the behaviours and the dynamic environment. The talk will focus on the bio-inspired paradigm of group hunting mammals in land (wolves) and the sea (dolphins), intending to make this knowledge applicable to the coordination problem of heterogeneous robotic teams. The objective is to present, define and discuss the required level of inference capabilities and role specialization needed for robotic navigation and coordination purposes. Emphasis will be given on the fact that humans and animals decide and conclude about unknown features of their world under constraints of limited time, knowledge, and computational capacity. And despite their cognitive limitations built and use domain specific heuristics that allow for fast problem solving (and task specific successful behaviors). As robots and agents may be benefited from these observations, potential application areas will be included in the discussion.

Bio-Inspired Design: A Perspective for Aerial Robotics

M. Kovač

Imperial College London, United Kingdom

Biologically inspired design is an engineering synthesis approach for artificial systems that uses conceptual inspiration from biology. Its premise is the creation of unconventional mechanical solutions that have the potential to outperform classical engineering designs. In the field of aerial robotics, bioinspired design principles such as flapping wing flight or optical flow based navigation are often employed but it is not always clear where exactly and how the biological systems act as a source of inspiration. In this talk, I will formalise successful bio-inspired design strategies in the perspective of flying robot development. For illustration, I will present a number of bio-inspired robotic case studies that focus on hybrid locomotion in air, on ground and in water providing micro robots with greatly improved mobility in natural terrain. I will also give a general overview on

the aerial robotics research program at Imperial College London that aims at developing a robotic ecosystem consisting of swarms of mobile robots.

Collective Control, State Estimation and Human Interaction for Teams of Mobile Robots

P. Robuffo Giordano

INRIA, Rennes, France

This talk will give an overview of some recent theoretical and experimental results in the field of shared control of multiple remote mobile robots, with a special attention to the case of flying robots such as Unmanned Aerial Vehicles (UAVs). In these applications, a human operator partially controls the behavior of a semi-autonomous group of mobile-robots by means of one or more force-feedback interfaces, and receives back a force cue informative of the swarm tracking performance and of additional properties of the surrounding environment (e.g., presence of obstacles or loss of connectivity). These kinds of systems are designed in order to enhance the telepresence of the operator and the quality of the human robot interaction, especially when applied to practical scenarios like search and rescue, surveillance, exploration and mapping of remote/unaccessible sites. The talk will illustrate the nature and kind of problems addressed within this research line, by focusing on both theoretical analyses and experimental implementations, and then discuss some future research directions.

Research in Cooperative Robotic Systems at UNIZG-FER

Z. Kovačić, S. Bogdan

University of Zagreb, Croatia

In this talk we present current research activities on cooperative robotic systems at Laboratory for Robotics and Intelligent Control Systems (LARICS), Faculty of electrical engineering and computing, University of Zagreb. During presentation we will give an overview of the existing equipment that has been acquired through ACROSS funding, together with an outline of active research projects. Main emphasis will be on i) humanoid robotics and its usage in diagnostics of autism, ii) cooperative aerial robotics and aerial manipulations, iii) decentralized control of autonomous vehicles in large warehouse facilities, iv) collective bio-hybrid adaptive systems, and v) consensus control in multi-robot systems.

Cooperative Systems in Marine Robotics

M. Caccia

CNR-ISSIA, Genoa, Italy

Cooperation of heterogeneous unmanned robotic vehicles is a key issue toward the integrated multi-resolution observation of the marine environment from the air-sea interface to the sea floor. In this talk, the author will present experimental results on cooperative guidance of Unmanned Marine Vehicles achieved as CNR-ISSIA, summarise state-of-the-art and discuss new ideas about the development of cooperative systems integrating the four segments: space, i.e. satellite observations, air, i.e. Unmanned Air Vehicles, surface, Unmanned Ground Vehicles and/or Unmanned Surface Vehicles, and underwater, i.e. Unmanned Underwater Vehicles.

Research in Marine Robotics at UNIG-FER

N. Mišković, Z. Vukić

University of Zagreb, Croatia

Marine robotics is a growing research due to the fact that only 5% of Earth covered with water is fully explored. Laboratory for Underwater Systems and Technologies (LABUST) at the University of Zagreb focuses their research in both surface and underwater marine robotics. This talk will give a short description of a number of LABUST's research projects related application of marine robotics in marine biology, archeology, security etc. Special attention will be devoted to currently active projects: FP7-ICT project "CADDY – Cognitive Autonomous Diving Buddy", FP7 project "EUROFLEETS2", DG-ECHO project "Autonomous underwater vehicles ready for oil spill".

Session Th01: Autonomous Robotic Systems

A Navigation System for Robots Operating in Crowded Urban Environments

W. Burgard

Albert Ludwig University of Freiburg, Germany

Over the past years, there has been a tremendous progress in the area of robot navigation. Most of the systems developed thus far, however, are restricted to indoor scenarios, non-urban outdoor environments, or road usage with cars. Urban areas introduce numerous challenges to autonomous mobile robots as they are highly complex and in addition to that dynamic. In this paper, we present a navigation system for pedestrian-like autonomous navigation with mobile robots in city environments. We describe different components including a SLAM system for dealing which huge maps of city centers, a planning approach for inferring feasible paths taking also into account the traversability and type of terrain, and an approach for accurate localization in dynamic environments. The navigation system has been implemented and tested in several large-scale field tests in which the robot Obelix managed to autonomously navigate from the Campus of the Faculty of Engineering of the University of Freiburg over a 3.3 km long route to the city center of Freiburg.

Autonomous and Semi-Autonomous Navigation of a Wheelchair by Visual Servoing

F. Chaumette

INRIA, Rennes, France

The talk will present recent developments in image processing, visual servoing and hybrid control for the navigation of a wheelchair in indoor environment. The robotic tasks considered are corridors following and doorway passing, with or without a human in the loop.

Terrain Classification in Structured and Unstructured Environments

D. Paulus

University of Koblenz and Landau, Germany

When a robot has to navigate in an unstructured, unknown environment, the terrain has to be analyzed and maps have to be enriched by drivability information. This problem can also be important for structured environments, e.g. to navigate without prior knowledge or maps. Drivability can be nicely integrated into the maps that a robot acquires using SLAM techniques. We present a fast method to register 3D scans in order to generate 3D maps. We describe how such terrain maps are derived from various sensor data using probabilistic methods. As in the mapping stage, we fuse vision data with range data and additional sensors, if available. We present result from urban environments as well as maps acquired on acres and in the forest. We show how different sensor configurations result in different recognition rates for the terrain. All methods described operate in realtime.

Autonomous Navigation in Unknown and Dynamic Environments

I. Petrović

University of Zagreb, Croatia

This talk will present recent developments in autonomous navigation of mobile robots by Autonomous Mobile Robotics (AMOR) group at the Faculty of Electrical Engineering and Computing, University of Zagreb. The main emphasis will be given on the algorithms for real-time motion planning, complete coverage planning, and exploration of unknown environments with active SLAM for complete model building as well as moving objects detection and tracking. Recent developments on autonomous navigation of aerial vehicles will be also presented.

Global Localization in a Hybrid Metric-Topological Map Based on Planar Surfaces, Line Segments and Color/Texture Features

R. Cupec, E. K. Nyarko, D. Filko, I. Petrović, A. Kitanov

University of Osijek and University of Zagreb, Croatia

A 3D vision system for global localization of mobile robots in indoor environments based on planar surfaces and line segments is presented. A hybrid metric-topological map is built from a sequence of RGB-D images. The map consists of local models representing particular locations in the considered environment. Each local model represents a set of planar surfaces and line segments. Given

the aforementioned map, a robot can determine its current pose in this map by matching the features extracted from a RGB-D image acquired from that particular pose to the local models of the map. A computationally efficient pose hypothesis generation approach is presented which ranks the features according to their potential contribution to the pose information, thereby reducing the time needed for obtaining accurate pose estimation. From the set of generated hypotheses, the most probable one is selected. Two hypothesis evaluation approaches are considered: (i) size-of-consensus-measure and (ii) probabilistic independent surface model with dynamic object detection. The performance of the proposed hypothesis generation approach is compared to PROSAC and the performance of the complete system is compared to appearance-based methods FAB-MAP and DLoopDetector. Application of color and texture descriptors for formulating additional constraints in the initial correspondence phase is investigated as well as their application in the hypothesis evaluation phase for improving the hypothesis probability estimation.

Constrained Manipulation under Uncertainties

Y. Karayiannidis

Royal Institute of Technology, Stockholm, Sweden

Robots for human centered environments has been identified as an important robotics sector whose advancement would pave the road to a successful robot market. Constrained manipulation is one of the core problems involved when robots execute tasks such as grasping and manipulation of objects and interact with a dynamic and uncertain environment as well as dynamic actors of the environment such as humans that impose uncertain constraints. A key challenge in this direction is to address concurrently both action and estimation of the constraints imposed to the robot. This talk uses a variety of examples of constrained manipulation such as interaction with different types of domestic mechanisms e.g. doors, drawers and cupboards, robot tool use in contact with the environment as well as pHRI for object co-manipulation. We approach this problem by simultaneously addressing estimation and force/motion control, having developed theoretically justified adaptive controllers utilizing real-time kinematic parameter identification based on proprioception and force/torque sensing. In this talk, we also discuss how the constraints imposed by the robot to the object through the robot grasp affect the estimation of the kinematic parameters. The talk will be illustrated by videos of the experiments conducted in CVAP/CAS/KTH.

Session Th02: Human-Robot Cooperative Systems

Robotic Help for Supporting Older People to Stay Longer Independent at Home

M. Vincze

Vienna University of Technology, Austria

A fall of older people is the main reason to make the move into professional care necessary. Hence, a robot that could help to reduce risks of falling will enable older adults to stay longer independent at home. We developed a robot that provides fall prevention and fall detection. Measure of fall prevention are to pick up anything from the floor, report narrow passages, and help carry objects in the home. Fall detection is executed regularly to make sure that people are detected as soon as possible. First studies indicate that such help is welcome by target users. The development of the robot for user trials at home is presented.

Recognizing and Generating Expressive Movements during Human-Robot Interaction

D. Kulić

University of Waterloo, Canada

Human body movements are a significant source of non-verbal communication that are used to convey affective state. The ability to recognize affective expressions and generate appropriate responses with recognizable affective content is a key component for creating an engaging, entertaining, and empathic human-machine interaction. This talk will present our recent work on developing approaches to systematically identify movement features most salient to affective expressions and to exploit these features to design computational models for the automatic recognition and generation of affective movements. We describe a comprehensive framework to for understanding which features of movement convey affective expressions, the automatic recognition of affective expressions encoded in movements, and adapting pre-defined motion paths to overlay affective content. The proposed framework is validated through cross-validation and perceptual user studies.

Robot Audition – Progress and Perspectives

P. Danès

LAAS-CNRS & Paul Sabatier University, Toulouse, France

While Robotics has used the visual modality for decades, its interest for hearing is relatively recent. So, the first dedicated sessions at IEEE/RSJ IROS appeared only in 2004. Besides its omnidirectional nature and its insensitivity to illumination conditions, hearing is of obvious importance in the timely topic of Human-Robot Interaction. This modality is increasingly considered for rescue Robotics in hostile environments where vision is put out of action (darkness, smoke, etc.). Because of their mixed results, the initial binaural solutions, exploiting two transducers mounted on a head, were quickly supplanted by microphone arrays. However, there is a renewed interest in "active" binaural approaches, which combine the auditory perception with the motion of the sensor. Incidentally, this new paradigm gives rise to meaningful dialogs with theories of Psychology of Perception. After a brief overview of robot audition (constraints, basic functions, approaches), this talk will focus on the developments conducted in the Robotics Action Perception team at LAAS-CNRS since 2005, based on microphone arrays and binaural heads. Work in progress and perspectives will be presented (including the FP7 FET-Open TWO!EARS project, started on 2013/12/01), which aim to design and develop active and multimodal perception systems.

Session Th03: Advanced Sensing and Signal Processing for Cooperative Systems

Image Processing and Analysis Methods for Advanced Driver Assistance Systems

S. Lončarić, M. Subašić

University of Zagreb, Croatia

Advanced driver assistance systems (ADAS) play an important role in modern vehicles. ADAS reduce number of accidents to decrease environmental pollution, loss of human lives, and material damage to road infrastructure. Technologies on which ADAS are based are also important building elements for autonomous vehicles. In this presentation we give an overview of research in the area of image processing and analysis methods required for ADAS such as image processing methods for color constancy, vehicle surround view visualization, roadside vegetation detection, and vehicle headlights and taillights detection. The human visual system can recognize colors of objects regardless of the illumination under which they are observed and this ability is called color constancy. Such property is also

desired in computer vision-based systems, where it is required for invariance to changes of scene illumination. Several methods for color constancy have been developed. Another image processing application is for vehicle surround view systems where multiple video cameras are used to observe the area around the vehicle. Here, it is necessary to perform geometric correction of fish-eye distortion, panoramic stitching of multiple video streams, and correction of perspective to obtain a bird's eye view. Roadside vegetation detection has many uses in autonomous vehicles and mobile robots, where it can be used for vehicle navigation and obstacle detection and for service vehicles for road maintenance. The developed methods are based on analysis of images in visual spectrum. Methods for detection of vehicle headlights in night scenes have been developed, which are important for control of vehicle headlights to avoid blinding other drivers and collision avoidance.

Computer Vision and Cognition for Intelligent Transportation and Robotic Systems

Z. Kalafatić, S. Šegvić

University of Zagreb, Croatia

In this presentation we summarize recent research activities of the Advanced Cognition and Vision Group related to advanced sensing for cooperative transportation and robotic systems. We first briefly review our previous research on computer vision approaches for road safety inspection and describe in more detail our ongoing work in the field. In particular, we present research on weakly supervised sparse localization, recognition by convolutional neural networks, and multiplicative kernels for multi-class localization. Then we present work in progress on spatio-temporal descriptors for 3D object recognition. We also introduce recent work in image classification for fleet management, ongoing work in stereoscopic reconstruction of camera motion and scene structure, as well as some results in vehicle detection at urban intersections over extended periods of time. Finally, we present two new national research projects starting in October 2014.

Content Creation for 3D Light Field Displays

A. Gotchev

Tampere University of Technology, Finland

Emerging light field (LF) displays aim at supporting continuous parallax with high spatial and angular resolution thereby enabling a more realistic representation of 3D scenes. The price is a substantially higher data throughput, complex

data acquisition (sensing) and a high demand of computational power. Thus, the optimization of the content representation is of crucial importance for the performance of the whole display system. In this presentation, we discuss the requirements for LF based processing of 3D visual content for its visualization on the new generation of ultra-realistic LF displays. We analyze the overall processing chain from sensing (acquisition) through LF modelling and representation to visualization on the considered displays. By analyzing the visualization capabilities of a given LF display using spatial and frequency domain analysis, we draw guidelines on how to properly pre-process the sensed data and repurpose it based on the targeted display. We show that by taking into account the properties of the display during scene sensing and during LF processing, a good visual representation of 3D content on a given display can be achieved with a minimalistic capture setup.

Compression of Video with Geometric Information

R. Forchheimer

Linköping University, Sweden

Separating texture and geometric information in video sequences can be used to decrease their bitrates, while maintaining or even improving the visual quality. On the other hand, it enables also the introduction of novel applications like free-viewpoint and stereoscopic video. Furthermore, the same compression techniques can be applied in other areas where the geometric information can be utilized, like the fields of computer-vision or remotely controlled robots. The talk will give a short introduction to different techniques for the compression of geometric data, concentrating on the application to video compression.

Facial Features Tracking

I. S. Pandžić

University of Zagreb, Croatia

Tracking the face and facial features in video sequences has a number of applications including marketing, entertainment, market research, biometrics, assistive technology, safety and others. We present a hybrid method for real time facial features tracking. The method combines machine learning and feature based tracking for robust and fully automatic operation. The machine learning component utilizes simple pixel comparisons as basic features which makes it very fast, allowing real time implementation on a wide range of platforms including mobile and web.

Efficient Structures and Algorithms for Digital Signal Processing

M. Vučić, D. Petrinović

University of Zagreb, Croatia

Efficient algorithms are needed in systems performing real time processing at high date-rates as well as in systems for complex processing of high amount of data. In both cases, the optimum implementation is obtained by taking into account the technology requirements in the early stage of the algorithm design. In this context we present here our research in the field of software defined radio, as well as in the field of speech and audio processing. In particular, we describe the design of multiplierless digital colored noise generator used in mitigation of nonlinearities in analog to digital converters and the design of dedicated digital signal processor, both suitable for implementation on field programmable gate arrays. Furthermore, we considered efficient sample rate converters which are obtained by sharpened of the CIC filters. Finally, we present our research in audio synthesis, as well as the research in emotion estimation from speech signal.

Session Fr01: Cooperative and Optimal Control

Wind Farm Cooperative Control: Methods and Experimental Verification

C. L. Bottasso, F. Campagnolo, V. Petrović

Technische Universität München, Germany

In the past, most of the research in wind energy technology focused on the optimization of wind turbines. In recent years, interest has expanded from the level of the individual machines to the one of wind farms. Optimal site selection, layout and control of wind farms are extremely challenging tasks that require an understanding of the aerodynamic interactions among the various machines and with the environment. These problems that are not yet fully understood and are still challenging to model in an accurate way. In this paper we describe our ongoing work on wind farm control. Ad hoc observers are used for detecting wake interaction conditions, in turn enabling cooperative control strategies for power maximization and load mitigation by power curtailment and active wake deflection. Our research program includes a scaled experimental facility for the simulation of wind farms in a boundary layer wind tunnel, which is used for the validation of simulation tools and the verification of control strategies.

Fair Control under Resource Constraints

S. Hirche

Technische Universität München, Germany

Teleoperation over the Internet, robot control using distributed sensors and distributed computational resources in smart environments, and cooperative mobile robot manipulation are examples of cyberphysical systems in robotics where communication and/or computational resources are constrained. The scientific challenge is to design control schemes taking into account such resource constraints in first place, and preferably even include fair resource sharing mechanisms among different applications. Recent results indicate major benefits of event-based control compared to conventional designs, when resources are scarce. In this talk we present a novel approach for the fair event-based control of multiple control loops, which share the communication resource. We provide a distributed solution for the resource sharing, which exploits the adaptation ability of event-triggered control in terms of communication traffic elasticity. This property is used to implement a distributed price exchange mechanism, where event-triggers adapt their thresholds according to the resource constraints.

Coordination of Large-Scale Populations of Systems via Mean Field Control Theory

S. Grammatico

ETH Zürich, Switzerland

We consider decentralized control and optimization methodologies to coordinate large-scale populations of systems, consisting in agents with different individual behaviors, constraints and interests, and affected by the aggregate behavior of the overall population. We apply mean field control theory, recently extended to cope with heterogeneous convex constraints, for instance arising from agents with linear dynamics subject to convex state and control constraints. We propose several coordination methods and illustrate their benefits on a practical case study.

Function Approximation Techniques in Modelling and Control

M. Kvasnica

Slovak University of Technology in Bratislava, Slovakia

In this talk we review two techniques for approximating a given nonlinear function by a different function of desired properties. The properties we are interested in are the fixed complexity of the approximate function and optimality of the approximation, expressed as the minimization of the integrated squared error. The first method allows to approximate arbitrary smooth nonlinear functions by piecewise affine (PWA) functions with a given number of regions. Parameters of the optimal approximation are searched for by solving a nonlinear optimization problem. We will also illustrate how this technique can be extended to derive optimal PWA approximations of dynamical systems whose vector fields are nonlinear, hence obtaining a well-performing, yet simple model that can be used to accelerate simulations and to simplify control synthesis. The second method allows to search for simple PWA functions which approximates a different, more complex PWA function optimally. We illustrate how this approach can be used to derive simple feedback laws that provide guarantees of recursive feasibility and closed-loop stability, yet have lower complexity compared to traditionally used explicit MPC approaches. We show that the search for the optimal approximation in this case boils down to solving a series of convex optimization problems.

Session Fr02: Cooperative Networked Embedded Systems

A Distributed Perception Infrastructure for Robot Assisted Living (Integration of Robots and Sensor Networks)

E. Menegatti

University of Padova, Italy

This talk will present the expertise developed by the IAS-Lab (Intelligent Autonomous System Laboratory) of the University of Padova in the frame of "Distributed Perception Infrastructures for Mobile Robots". We will start presenting the results obtained in the RAMSES2 project integrating robotic systems with wireless sensor networks. We explored the problem of discovering, localizing and recognizing previously unknown smart objects placed in unknown environments. The robot is equipped with an onboard camera and both objects and robot are capable of exchanging data using low-cost, low-rate wireless sensor nodes. The appearance of the object is encoded by means of a set of Scale Invariant Feature

(SIFT) descriptors and stored in the object. The robot does not have any prior knowledge about the form and multiplicity of the objects, but when a subset of the SIFT descriptors extracted by the current image of the robot's camera matches the SIFT descriptors transmitted by a smart objects, the robot can locate the object in its current view and autonomously navigate toward the object, interacting with it. A second project called "SAFE Home" resulted in the integration of the robot in a network of audio and video sensors implementing an ambient intelligence system designed for assisted living. The system processes audio and video data acquired from multiple sensors spread in the environment to automatically detect dangerous events and generate automatic warning messages. Different processing nodes have been implemented which can cooperate to extract high level information about the environment running algorithms for people detection, face recognition, people fall detection, and sound classification. Example nodes will be presented together with successful experiments in two test bed scenarios. In the last part of the talk, the contribution of IAS-Lab to the project OpenPTrack will be presented. OpenPTrack is an open source project for large, scalable, multi-imager 3D person tracking for education, arts, and culture applications. The alpha version of the code supports multi-imager tracking using the Microsoft Kinect 360 and Mesa Imaging Swissranger cameras. IAS-Lab algorithms for people tracking, people reidentification and intrinsic and extrinsic calibration of 2D and 3D vision sensors in camera networks will be presented.

Nano Power Wake Up Radio Receivers to Eliminate Idle-Listening Consumption in Wireless Sensor Network

M. Magno

ETH Zürich, Switzerland, and University of Bologna, Italy

Wireless sensor networks (WSNs) have been recognized as a fundamental enabling technology for a wide range of applications in environmental monitoring, healthcare, security, and industrial domains, among others, due to the flexible distribution of WSN devices. Nodes in a WSN traditionally have limited power supply, while networks are often expected to be functional for extended periods. Therefore, the minimization of energy consumption and the maximization of network lifetime are key objectives in WSN. One major research effort focuses on reducing power consumption, especially communication power, as the radio transceiver is one of the highest power consumers in WSNs. Moreover, with the advent of energy-neutral systems, the emphasis has shifted toward research in micro-Watt (or even nano-Watt) communication protocols or systems. In this talk I will present both the design and architecture of nano-power wake up radio and power management at node level can exploit the that technology to extend the life time of the wireless devices.

Research Activities in the Networked Media Research Group

M. Matijašević, I. Podnar Žarko

University of Zagreb, Croatia

This talk presents research activities in the Networked Media (NWMED) research group within the Department of Telecommunications, Faculty of Electrical Engineering and Computing (FER), University of Zagreb. The research goal of the NWMED group is to gain deeper understanding of the quality of service (QoS) and quality of experience (QoE) requirements for advanced and interactive multimedia services in converged network settings, and to explore ways in which this insight may improve service and network management. The specific areas of interest currently include: a) QoE modeling for networked games, cloud and web-based multimedia services, b) network traffic models and resource management for such services, c) QoE-driven optimization in networks, using software defined networking approach, and d) context-based charging. Through its involvement in the FP7 project "Open Source cloud solution for the Internet of Things" (OpenIoT), the NWMED group also examines the QoS aspects of utility-based Internet of Things services, using an urban crowd-sensing environmental monitoring application as a case study.

Estimating Location and Magnetic Polarizability Tensor of Metallic Targets for Security and Landmine Clearance Applications

A. Peyton, V. Bilas

University of Manchester, United Kingdom, and University of Zagreb, Croatia

This presentation will address the problem of identifying concealed metallic objects in for example buried landmines and security portals and discriminating the objects from metallic clutter using low frequency electromagnetic induction (EMI) techniques. From dipolar fields, the magnetic polarizibility tensor extracted from the target response can be used as a basis for identification and hence discrimination. In the presentation a deterministic optimization methods will be presented to estimate object location and polarizability matrix by fitting EMI data collected from target to a dipole model in a least squares sense. The presentation will contain results from recent systems and discuss areas for future research.

Cooperative Sensing for Enhanced Information Capture System Performance

V. Bilas, D. Vasić

University of Zagreb, Croatia

Combining signals from various sensors enables higher quality of information and could lead to reduction in power consumption, size and costs of the sensing electronic system. Multi sensor nature of the systems introduces new challenges in hardware and algorithms for signal acquisition, processing, integration or cooperation. In this presentation we will address some challenges and solutions – from the design of electromagnetic inductive sensors and their combination in metallic object characterisation, to energy saving in wireless networks of energy-hungry sensors for smart surveillance and m-health, to resource sharing in coexisting wireless sensor networks. These aspects will be illustrated in the context of real applications.

Posters

Poster Session 1

EC-SAFEMOBIL: Estimation and Control for Safe Wireless High Mobility Cooperative Industrial Systems

Z. Kovačić, D. Miklić, G. Vasiljević, F. Petric, T. Petrović

University of Zagreb, Croatia

Autonomous systems and unmanned aerial vehicles (UAVs), can play an important role in many applications including disaster management, and the monitoring and measurement of events. Currently, many missions cannot be accomplished or imply a high level of risk for the people involved (pilots and drivers), as unmanned vehicles are not available or not permitted. These missions could be performed or facilitated by using autonomous helicopters with accurate positioning and the ability to land on mobile platforms, such as ship decks. These applications strongly depend on the UAV reliability to react in a predictable and controllable manner in spite of perturbations, such as wind gusts. On the other hand, the cooperation, coordination and traffic control of many mobile entities are relevant issues for applications such as automation of industrial warehousing, surveillance by using aerial and ground vehicles, and transportation systems. EC-SAFEMOBIL is devoted to the development of sufficiently accurate common 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.

Animal and Robot Societies Self-Organise and Integrate by Social Interaction – ASSISIbf

S. Bogdan, D. Miklić, K. Griparić, T. Haus

University of Zagreb, Croatia

The objectives of ASSISIbf are: i) to develop a fundamental new class of distributed ICT systems, which are bio-hybrid collective adaptive systems (CASs) that consist of two sub-systems: One is a self-organising society of animals; the other one is a society of technical devices, ii) to develop a fundamental new

method to design CASs by exploiting evolutionary computation on mathematical models that are used to drive the engineered part of the CAS. This way the collective of animals and robots will adapt to environmental changes and will maximise its efficiency and stability, iii) to develop several novel benchmarks, using the level of acceptance of robots by the animal society as a hard-to-reach criterion, iv) to derive a general model for heterogeneous CASs, which will be used to develop new algorithms for other heterogeneous robotic CASs.

Biomimetic Behaviour Based Robotic Control

S. Piperidis

Technical University of Crete, Greece

A novel cooperative controller scheme for Autonomous Underwater Vehicles (AUV) is presented. It was designed following the basic principles of behaviour-based systems. Two different bio-mimetic roles are implemented, encapsulating the group-hunting characteristics of bottle-nose dolphins', extremely rare, cooperative underwater predator behaviour (with division of labour and role specialisation): the Driver and the non-Driver. This behaviour-based cooperation exploits the Drivers individual capability, in fact a physical gift, of initialising, coordinating a hunting bout, detecting and herding the school of fish, along with the contribution of non-Driver dolphins ability to comprehend and follow the Driver's master plan. Controller testing, under several simulated scenarios, proved the reliability and modular functionality of the cooperative behaviour-based model and its potential for supporting the autonomy of underwater robotic vehicles serving tasks that can easily be seen as an extent of dolphins' group hunting. Apart from the simulation, the same behaviour-based controller was tested in real world, with the Ale III prototype AUV. In this case, due to certain limitations of the experimental apparatus, the behaviour-based controller implemented an individual bio-mimetic role inspired by the real life routine of wandering, hunting, feeding, hiding and nesting exercised by a typical underwater creature.

Environmental Noise Control Group

M. Horvat, K. Jambrošić, H. Domitrović

University of Zagreb, Croatia

The Environmental Noise Control Group has focused its research efforts on three main areas, the first one being the noise issues, the influence of noise on people, and ways it is dealt with, either by viewing it as waste to be reduced or removed from the environment or by considering it as a resource to be further exploited.

The second area of interest is the acoustic comfort of outdoor and indoor spaces which includes, but far exceeds typical noise problems. Finally, auralization as an invaluable research tool enables the laboratory recreation of any acoustical environment, real or virtual. Classic methods of dealing with noise coming from traffic, industry, entertainment installations and other sources are focused on its reduction at the source by reducing its sound power, along the propagation path by implementation of noise barriers and/or at the receiving point by implementing proper sound insulation measures. Innovative approaches investigate the quality of sound generated by a device or, on a larger scale, evaluate and design the soundscape of an entire environment. An aspect that is to gain importance in the future is the addition of sound or noise to noiseless objects such as electric vehicles traveling at low speeds. Acoustic comfort surpasses mere noise issues by attempting to create acoustically appropriate, acceptable and comfortable environments to improve the quality of life in general. The aforementioned soundscape approach attempts to fulfill this task on a large scale, especially in outdoor public spaces. For indoor spaces, sound insulation and room acoustics become the principal criteria to be met and evaluated. Special criteria are to be established to design acoustically appropriate spaces for visually impaired people as well. Auralization represents a precious tool that enables the conduction of experiments in laboratory conditions, rather than in-situ, thereby providing the repeatability and reproducibility of the experiments. To utilize these benefits, the Auralization Laboratory has been established by the researchers of the Environmental Noise Control Group at the home institution.

Coalitional MPC Control Applied to an Irrigation Canal

F. Fele, J. M. Maestre, E. F. Camacho

University of Seville, Spain

Consider a large-scale system whose components can exchange information through a data network. As case study, we analyze the application of a coalitional control scheme on an irrigation canal. The implementation is hierarchical. In order to achieve the best compromise between the overall control performance and the costs required for establishing the cooperation, a suitable global model partition is chosen through the manipulation of the network topology at the supervisory level. The chosen network topology dictates the set of control agents allowed for mutual exchange of information, and so the agents' knowledge of the complete system. At the bottom layer of the implementation scheme, each group of linked subsystems (a coalition) is independently controlled by means of a decentralized model predictive controller. Here constraints on states and inputs are considered. The performance of the proposed control scheme is validated on

the accurate simulator for water systems SOBEK, employing a model of the irrigation canal of Dez (Iran). Finally, the difference in performance and incurred costs w.r.t. a centralized MPC control scheme is discussed.

Model-Based Real-Time Embedded Software Component Testing

J. Babić, S. Marijan, I. Petrović

KONČAR – Electrical Engineering Institute, Zagreb, Croatia

Embedded control systems software is continually gaining importance, it is becoming more complex and it often must comply with very rigid requirements. Model-based development has established itself as an approach which can tackle the complexities of embedded control systems. However, it operates on a higher level of abstraction far away from low-level real-time properties, which can hinder introduction of model-based development practices in conservative industries that deal with safety-critical applications. This work presents a novel method for real-time properties validation that supplement existing functional model-based testing approaches. Software component real-time testing method is based on configuration space partitioning and on real-time testing pattern. The method itself has been thoroughly validated to establish confidence in testing results which have shown to be consistent and reliable. All steps in the process can be (i) fully automated, (ii) partially automated with fine tuning of particular aspects, or (iii) performed completely manually. This enables full control of the tests on the one side and effortless regression testing of large number of components on the other side. The method has been applied to testing software components in two real-life embedded control system development projects.

A Step Toward Sustainable Future – Active Prosumers and Distribution Systems

M. Zidar, T. Capuder, D. Škrlec

University of Zagreb, Croatia

Energy consumers traditionally did not have to care about how energy comes to their homes. As the regulatory imposed goals of decarbonisation highly relay on integration of renewable energy sources, the final consumer cannot stay passive. Changes in the perception of power system operation need to be supported by changes in the electricity business environment, creating market incentives and well defined benefits that can arise from including active consumers into the energy system operation. The stochastic nature of low carbon (LC) technologies will, when reaching a significant share in the grid, result in undesirable events

such as high spikes, overloading and under voltage sags demanding changes in operation and planning from the distribution system operators. The traditional approach to reinforcing the grid when the problems occur might result in over sizing and overinvesting into the infrastructure not utilized properly. An alternative approach to planning the operation and future network layout is taking into account prosumers flexibility potential. This flexibility can be exploited by coordinated control of flexible demand (such as heating, electric vehicles etc) or integration of storage units, creating benefits for all participants.

Human-in-the-loop Control of Multi-agent Aerial Systems Under Intermittent Communication

S. Bogdan, I. Palunko, D. Tolić, M. Orsag, T. Haus

University of Zagreb, Croatia

This project is related to research on decentralized control of heterogeneous multi-agent systems in degraded communication environments. We propose 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.

Maximum Power Point Tracking Algorithm For All-Weather Conditions Based on the Nelder-Mead Optimization

T. Pavlović, Ž. Ban

University of Zagreb, Croatia

Conventional MPPT algorithms like Perturb and Observe, or Incremental Conductance, which are commonly used in industrial MPPT converters, are not able to track global maximum power point (GMPP) of the PV system under partial shading or PV module (cell) mismatch conditions. This research was focused on utilization of the Nelder-Mead optimization algorithm for MPPT under uniform and non-uniform insolation conditions. The proposed MPPT algorithm works in local and global search mode, does not depend on any external algorithm, has only six parameters available for tuning, with unambiguous meaning, and provides fast and accurate convergence toward GMPP. The algorithm has been experimentally validated on real PV module in real-weather conditions.

Constrained Model Predictive Control of a Wind Turbine

N. Hure, M. Vašak, E. F. Camacho, N. Perić

University of Zagreb, Croatia, and University of Seville, Spain

In recent years, we have witnessed to a rapid growth of renewables in the world electricity generation. The energy that is extracted from the wind already has a significant share with a constant rise in the overall production and demands that producers have to comply with are stricter. Similarly, a wind turbine controller should assure high performance in a wide operating region of the wind turbine, while respecting the imposed constraints of the control system. In this research we present a parametrized approach to the wind turbine modelling and control in order to overcome the difficulties of the model nonlinearities, utilizing the predictions of the effective wind speed. Additionally, we propose effective algorithm for the hard real-time evaluation of the controlled-invariant set based constraints preserving algorithm.

ThermalMapper – Thermal 3D Modelling of Indoor Environments for Saving Energy

A. Nüchter, I. Petrović, J. Velagić

Jacobs University of Bremen, Germany, and University of Zagreb, Croatia, and University of Sarajevo, Bosnia and Herzegovina

Heat and air conditioning losses in buildings lead to a large waste of the limited energy resources and pollute the environment unnecessarily. To detect these flaws as quickly as possible and to prevent the negative consequences constant monitoring of power lines and heat sources is necessary. To this end, we propose a fully automatic system that creates 3D thermal models of indoor environments. The proposed system consists of a mobile platform that is equipped with a 3D laser scanner, an RGB camera and a thermal camera. A novel 3D exploration algorithm ensures efficient data collection that covers the entire scene. The data from all sensors collected at different positions is joined into one common reference frame using calibration and scan matching. In the post-processing step a model is built and points of interest are automatically detected.

Fault-tolerant Control of Wind Turbines Subject to Generator Electromechanical Faults

V. Lešić, M. Vašak

University of Zagreb, Croatia

Wind turbines are usually installed at low-turbulent-wind remote locations and high availability of such large systems is an imperative for increasing their market competence. With high motivation for avoiding costly unscheduled repairs, a fault-tolerant control line of research found its significance in the topic of wind energy. Detaching from the research trends in components redundancy, we propose a fault-tolerant control that adapts the generator operation to reallocate the stress from damaged rotor or stator parts to healthy generator area while extracting the maximum available power in the faulty operation. To this aim, a fault-tolerant control is utilized to modulate the generator stator flux or torque building current based on the instantaneous rotor flux position in order to suppress the rapid development of some of the most common generator electromechanical faults. Proposed methods are suitable for all of the generator types used in wind turbines, and with wide range of operation and fault conditions: from early stage of fault development to broken rotor cage or inter-turn short circuit. The methods are conceived as a modular extension to conventional wind turbine control system and can be applied to new or already installed wind turbines.

ADORE: Autism Diagnostic Observation with a Robot Evaluator

D. Miklić, F. Petric, D. Tolić, Z. Kovačić

University of Zagreb, Croatia

Notwithstanding intensive research and many scientific advances, diagnosing autism spectrum disorders remains a slow and tedious process. Due to the absence of any physiological tests, the outcome depends solely on the expertise of the clinician, which takes years to acquire. Complicating the matter further, research has shown that inter-rater reliability can be very low, even among experienced clinicians. As an attempt to facilitate the diagnostic process and make it more objective, this paper proposes a robot-assisted diagnostic protocol. The expected benefit of using a robot is twofold: the robot always performs its actions in a predictable and consistent way, and it can use its sensors to catch aspects of a child's behavior that a human examiner can miss.

Cognitive Autonomous Diving Buddy (CADDY)

N. Mišković

University of Zagreb, Croatia

Divers operate in harsh and poorly monitored environments in which the slightest unexpected disturbance, technical malfunction, or lack of attention can have catastrophic consequences. They manoeuvre in complex 3D environments, carry cumbersome equipment, while performing their mission. To overcome these problems, CADDY aims to establish an innovative set-up between a diver and companion autonomous robots (underwater and surface) that exhibit cognitive behaviour through learning, interpreting, and adapting to the diver's behaviour, physical state, and actions. The CADDY project replaces a human buddy diver with an autonomous underwater vehicle and adds 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. This poster focuses on the CADDY project objectives and some recent results.

UrbanWater – Intelligent Urban Water Management System

M. Vašak, G. Banjac

University of Zagreb, Croatia

Improving the efficiency of water management in Europe was recognised by the EC as essential for overcoming the growing exposure of European countries to Water Scarcity and Droughts. UrbanWater proposes a platform that will enable a better end-to-end water management in urban areas, accounting for 17% of freshwater consumption in the EU. The project will undertake the development, demonstration, and economic up-scaling of an innovative ICT-based platform for the efficient integrated management of water resources. The system will benefit end-users, utilities, public authorities, the environment and the general public, in terms of: (i) providing consumers with comprehensive tools enabling them to use water more efficiently thereby reducing overall consumption; (ii) helping water utilities to meet demand at reduced costs; and (iii) fostering new partnerships between water authorities, utility, equipment and software companies so as to ensure the successful commercialisation of the system and the evolution of the European water sector as a global leader. The system will incorporate

advanced metering solutions, real-time communication of consumption data and new data management technologies with real-time predictive capability, demand forecasting, consumption pattern interpretation, decision support systems, adaptive pricing and user empowerment solutions.

CEESH – Centre of Excellence for Structural Health

R. Turnar, M. Vašak

University of Zagreb, Croatia

In order to increase the competence of the Croatian HEIs and industry in the area of structural monitoring in engineering structures the overall objective of the project is to establish a virtual Centre of Excellence for Structural Health Analysis (CEEStructHealth) and to establish cooperation between the involved HEIs and industry for mutual benefit, with significant students involvement. During the project, extensive research on the KONČAR 2.5 MW wind turbine will be conducted in order to develop an advanced wind turbine control system. A wind turbine represents an extremely complex structure and its design, manufacture and exploitation is an interdisciplinary problem requiring the knowledge and skills from the mechanical, civil and electrical engineering. Therefore, there is an obvious need to include the listed partners from HEIs into the project. In addition to the collaboration on Research and Development (R+D) involving the wind turbines, the existing knowledge and competencies of these partners will promote project to a higher level and will enable the Structural Health Assessment of other complex engineering structures.

Neural Network Based Ultra-Short-Term Wind Forecasting

M. Đalto, M. Vašak, M. Baotić, J. Matuško, K. Horvath

University of Zagreb and Meteorological and Hydrological Service, Croatia

Several ultra-short-term wind speed and direction forecasting methods have been reported in the literature over the past years. Most of them are based on extraction of causal relations on large historical measurement datasets. Frequently used time-series models with well-developed theoretical background lack structural capabilities for modelling complex dynamics such as that of the wind. Often neural networks used do not include appropriate complexity reduction methods which results in lower performance. Input variable selection based on partial mutual information is found appropriate for use with nonlinear models such as neural networks. Developed neural network methodology can be used efficiently at a low computational cost for any location with varying number of input variables and

historical data samples. Performance improvements of the proposed prediction system relative to simple persistence and to commonly used neural prediction methods are evaluated for locations near the city of Split, Croatia.

Enhancement of Research, Development and Technology Transfer Capacities in Energy Management Systems for Buildings

A. Martinčević, A. Starčić, M. Vašak

University of Zagreb, Croatia

Energy audits result in static models of energy demands needed in order to maintain acceptable comfort conditions in buildings. In reality building energy consumption usually shows significant deviations—the reason for this is the building comfort control in dynamically changing inner and outer operative conditions of the building. Predictive control techniques will in the optimal way gather the whole building dynamic model with available information on meteorological conditions and forecast into an algorithm of energy-efficient building control. Global trend of energy prices rise puts buildings into focus, as technical systems responsible for 40% of energy consumed by mankind. Major research endeavours are performed globally in different technical areas which can contribute to buildings' energy-efficiency. Information-communication technologies (ICT) have a prominent role in this as they enable incorporation of different technological solutions into a unique system adaptable to the buildings itself and different modes of its use. The action Enhancement of Research, Development and Technology Transfer Capacities in Energy Management Systems for Buildings (ENHEMS-Buildings) aims to fill the gap in Croatian ICT base within the area of all-inclusive energy-efficient control of comfort in buildings, and unlocks the development possibilities for own competitive solutions. In order to accomplish that, ENHEMS-Buildings joins contributions in optimal and predictive control, meteorology, open building automation systems and telecommunication systems. That is accomplished through cooperation of the action partners and associates: University of Zagreb Faculty of Electrical Engineering and Computing (FER, the applicant), Meteorological and Hydrological Service, Elma Kurtalj Ltd. and Hrvatski Telekom d.d.

Poster Session 2

Receding Horizon Control for Convergent Navigation of Mobile Robots

M. Đakulović, M. Baotić, I. Petrović

University of Zagreb, Croatia

We present a navigation algorithm for mobile robots based on the receding horizon control (RHC) principle. The developed RHC navigation algorithm includes a generation scheme of feasible control sequences, among which an optimal sequence is found for a proposed objective function. The optimal value of the objective function is employed as a Lyapunov function, to prove asymptotic stability of the discrete-time nonlinear closed loop system. The objective function is composed of the proposed navigation function, which measures the cost-to-goal over the robot states by interpolation of path costs over a discretized search space. We present a compact representation of the discretized free space to keep path computations low. In particular, we create a graph of valid orientation intervals on top of non-occupied locations in a grid map. This representation enables efficient navigation of holonomic mobile robots with any-shape footprints. Opposed to holonomic mobile robots, which can move freely in any direction, differential drive mobile robots cannot move laterally, and to avoid local minima caused by that constraint, we have introduced an additional cost term in the navigation function, which takes into account the robot orientation. In comparison to the sample-based motion planning algorithm based on lattice graphs, our algorithm produces similar goal reaching times but with much lower computational costs and without any tuning of the navigation parameters.

Fast Active SLAM for Accurate and Complete Coverage Mapping

K. Lenac, A. Kitanov, I. Maurović, M. Đakulović, I. Petrović

University of Zagreb, Croatia

We present an active SLAM solution with an active loop closing component which is independent on exploration component and at the same time allows high accuracy robot's pose estimation and complete environment mapping. Inputs to our SLAM algorithm are RGBD image from the Kinect sensor and odometry estimates. SLAM is based on the Exactly Sparse Delayed State Filter for real-time estimation of robot's trajectory, vision based pose registration and loop closing. The active component ensures that localization remains accurate over a long period of time by sending the robot to close loops if a criterion function satisfies the predefined value. Once a state in which a loop closure should occur is

reached and an update is performed, the robot returns to its previous exploration goals. Our active SLAM integration with the 2D laser range finder based exploration algorithm ensures the complete coverage of a polygonal environment and therefore a detailed mapping. The developed Active SLAM solution was verified through experiments which demonstrated its capability to work in real-time and to consistently map polygonal environments.

Directional Distributions Flavored Moving Object Tracking

I. Marković, M. Bukal, J. Ćesić, I. Petrović

University of Zagreb, Croatia

The poster presents a part of the research within the Autonomous Mobile Robotics Group (AMOR) at FER-UNIZG. This research was focused on the development of tracking algorithms using Bayesian filtering approaches involving circular and spherical distributions. The motivation stemmed from the utilization of direction-only sensors like the microphone array and the omnidirectional camera in the context of mobile robotics. The poster presents two dimension dependent methods: (i) a solution for tracking an object with angle-only measurements (on unit circle) using a mixture filter based on the von Mises distribution and (ii) a solution for tracking multiple moving objects with direction-only measurements (on unit sphere) using a probabilistic data association approach with the von Mises-Fisher distribution.

Consensus in Information Geometry

M. Bukal, I. Petrović

University of Zagreb, Croatia

Consensus type models appear in various areas of science and technology describing collective behavior of a system of interacting agents. Well known examples include birds flocking, fish schools, opinion and price formation. In technical systems, they can be utilized in machine synchronization, cooperative control of robotic systems, distributed estimation etc. Our focus is on consensus models in information geometry, in particular, on exponential family manifolds, where we define these models as gradient systems of a disagreement potential (information loss) with respect to the Fisher metric on the exponential family manifold. Typical application of such models arises in distributed consensus estimation and filtering.

Vision Based Approaches Toward Embedded Autonomous Navigation Systems for UAVs

I. Cvišić, A. Kitanov, V. Sazdovski, I. Petrović

University of Zagreb, Croatia

Future smaller and maneuverable aerial vehicles have a need of high levels of autonomy and independence. This gives rise to the necessity for integrated navigation systems that supply reliable and accurate navigation parameters (position, velocity and attitude) in small and cost effective manner. Vision provides rich representation of the vehicle's environment, but this comes at the cost of more complex processing. Small UAVs also present challenging constraints such as limited payload and computational resources and fast vehicle's dynamics. In this work, several approaches are presented toward embedded autonomous navigation systems for UAVs.

Trajectory Planning and Learning Control for Robotic Arms

D. Herceg, B. Novoselnik, I. Petrović, D. Kulić

University of Zagreb, Croatia, and University of Waterloo, Canada

We consider a problem of planning and control of robotic arms. Firstly, a method for motion planning is devised with emphasis on algorithm performance. An extension to asymptotically optimal rapidly exploring random tree algorithm (RRT*) is presented with fast convergence in mind. Namely, the new algorithm uses two search trees and a simple cost-to-go heuristic to limit the number of nodes in trees, which speeds up the algorithm considerably. Furthermore, a variation of Gaussian process regression is used to learn the dynamics of the closed architecture robotic arm. Controlling the arm by nonlinear feedforward control strategy allows for superior control performance on closed architecture robotic arms. Feasibility and performance of both methods are tested on a realistic simulation scenario.

A Real-Time Scene-Adaptive 3D Scene Sensing System

M. Georgiev

Tampere University of Technology, Finland

Active depth sensors employing the so-called Time-of-Flight (ToF) principle have become popular for 3D scene sensing. They measure distances by illuminating the scene with near-infrared light and calculating the phase delay between emitted and reflected waves. Such sensors augment conventional 2D RGB cameras with

information about scene geometry. 2D/ToF data fusion is a challenging task since the two types of sensors are with different spatial resolution and different fields of view. ToF data can be also quite noisy especially if requirements for low power consumption are imposed. ToF sensors targeting power efficiency are said to be working in "low-power sensing mode" where depth measurements come degraded yet they are restorable by post-processing. In this work, we consider a 3D camera setup composed by a non-confocal RGB sensor of high resolution and a ToF range sensor with lower resolution working in low-power sensing mode. We specifically address the noise reduction problem as a post-capture process aimed at improving the subsequent 2D/3D fusion process. We present several approaches aimed at reducing different types of noises, and an effective depth upsampling and alignment with the color data.

IPG – Image Processing Group

S. Lončarić, M. Subašić, D. Jurić, I. Harbaš, N. Banić, P. Prentašić, T. Petković

University of Zagreb, Croatia

We present an overview of selected recent activities of the Image Processing Group (IPG): night-time vechicle light detection, automatic image quality adjustment, detection of roadside vegetation, advenced tiled panoramic visualizations, retinal image analysis, and visual quality inspection.

Gradient Orientation in Visual Quality Control

T. Petković, S. Lončarić

University of Zagreb, Croatia

In industrial practice visual quality control is usually implemented in software packages as a set of end-user inspection tools. In this poster we revisit the concept of image gradient orientation and we demonstrate how it may be used to improve the reliability of two basic methods used in visual quality control: straight line fitting and the Hough transform. The proposed least squares straight line fitting method uses both the point coordinates and the local gradient orientation to fit an optimal line by minimizing an algebraic distance, thus offering increased precision of the fit and better outlier rejection. The proposed extension to the Hough transform extends the accumulator space and uses local gradient orientation to reduce clutter and to yield more prominent peaks, thus enabling better line identification. We also demonstrate benefits in visual quality control.

ACVIG – Advanced Cognition and Vision Group

S. Šegvić, Z. Kalafatić, K. Brkić, J. Krapac

University of Zagreb, Croatia

We present an overview of activities of ACVIG group: visual odometry, traffic scene categorization, traffic sign localization, augmented reality, action recognition and object and scene categorization.

Weakly Supervised Object Localization with Large Fisher Vectors

J. Krapac, S. Šegvić

University of Zagreb, Croatia

We present a method for learning object localization models in a weakly supervised manner, by employing images annotated with object class labels but not with object location. Given an image, the learned model predicts both the presence of the object class in the image and the bounding box that determines the object location. The main ingredients of our method are a large Fisher vector representation and a sparse classification model enabling efficient evaluation of patch scores. The method is able to reliably detect very small objects with some intra-class variation in reasonable time. Experimental validation has been performed on a public dataset and we report localization performance comparable to strongly supervised approaches.

Temporal Ensemble of Shape Functions

K. Brkić, A. Aldoma, M. Vincze, S. Šegvić, Z. Kalafatić

University of Zagreb, Croatia, and Vienna University of Technology, Austria

We present novel descriptors that integrate information from multiple views of a 3D object, called Temporal Ensemble of Shape Functions (TESF) descriptors. The TESF descriptors are built by combining per-view Ensemble of Shape Functions (ESF) descriptors with Spatio-Temporal Appearance (STA) descriptors. ESF descriptors provide a compact representation of ten different shape functions per object view (obtained by virtually rendering the object from different viewpoints), and STA descriptors efficiently combine ESF descriptors of multiple object views. The proposed descriptors are evaluated on two publicly available datasets, the 3D-Net database and the Princeton Shape Benchmark. They provide a good performance on both datasets, similar to that of the Spherical Harmonic Descriptor (SHD), with the advantage that because of their view-based

nature the TESF descriptors might prove useful for the problem of object classification from limited viewpoints. Such property is of special interest in robotics where the agent is able to move around the object to improve single-view results.

High-Performance Face Tracking

N. Markuš, M. Frljak, I. S. Pandžić, J. Ahlberg, R. Forchheimer

University of Zagreb, Croatia, and Linköping University, Sweden

We describe a system for high-performance face tracking in monocular video sequences. The developed face tracker is resistant to rapid changes in pose and facial expressions, does not suffer from drift-related problems, is modestly computationally expensive, does not require previous training for successful tracking and recovers quickly from any losses. These characteristics make it suitable for a wide range of applications on desktop, mobile, web and embedded systems.

Robust Image Enhancement

A. Sović, D. Seršić

University of Zagreb, Croatia

Many images can be represented using piecewise constant or cosine models. Here, we present an adaptive wavelet filter bank based on least absolute deviation criterion. The method is unbiased, robust to noise and is used for denoising and compression of piecewise cosine signals. Furthermore, an improved separable denoising method based on the relative intersection of confidence intervals rule is presented. The method uses median averaging that accurately restores smooth parts and preserves edges and discontinuities. Moreover, we present no-reference image sharpness assessment method that results in the sharpness index.

Efficient FPGA Structures for Digital Signal Processing

M. Butorac, M. Vučić

University of Zagreb, Croatia

This work considers high data-rate algorithms for digital signal processing. Such algorithms take place in communications, measurement, as well as in 2- and 3-D signal processing. In this research, we consider algorithms and structures which are suitable for implementation on field programmable gate arrays (FPGAs). In this context, an implementation of high-dynamic range software defined receiver is presented. Such a receiver requires high-performance analog to digital converter. Its nonlinearities are often mitigated using a technique called dithering.

For this purpose, multiplierless digital colored noise generator is developed. Furthermore, for efficient processing of complex valued vectors, a dedicated digital signal processor is described. Finally, the application of FPGA devices in 3D scene sensing is considered.

Design of Multirate Digital Filters Based on Sharpening Technique

G. Molnar, M. Vučić

University of Zagreb, Croatia

Well-known sample rate converters employ the cascaded-integrator-comb (CIC) filter. However, its magnitude response often does not meet the requirement for selectivity. A popular technique for improving the response is sharpening. In this work, we describe methods for the design of sharpened CIC filters based on weighted least squares, weighted minimax, and almost equiripple error criterion. The features of the presented methods are illustrated with the design of narrowband and wideband filters. The filters presented are suitable for application in narrowband and wideband software radio receivers.

Poster Session 3

Multi-Robot Cooperative Manipulation under Kinematic Uncertainty

S. Erhart, S. Hirche

Technische Universität München, Germany

Cooperative manipulation of a common object requires precise kinematic coordination of the attached end effectors in order to avoid excessive forces on the object and the manipulators. A manipulation task is considered successful if the desired object motion and forces are tracked accurately. In this paper we present a systematic analysis on the effect of uncertain kinematic parameters on the tracking behaviour in a planar manipulation task. An adaptive control scheme is proposed, which achieves the desired control goal asymptotically. The presented scheme employs the current force/motion data of the attached end effectors without relying on a common reference frame. The algorithm is applicable to common manipulator types with wrist-mounted force/torque sensor and implementable in real-time. The performance of the proposed control scheme is evaluated experimentally with two 7DoF manipulators who cooperatively manipulate an object of uncertain length.

Dynamic Management of Physically Coupled Systems of Systems (DYMASOS)

M. Baotić

University of Zagreb, Croatia

The well-being of the citizens in Europe depends on the reliable and efficient functioning of large interconnected systems, such as electric power systems, large industrial production plants, etc. Such large systems consist of many interacting components, e.g. generation plants, distribution systems, and large and small consumers. The subsystems are usually managed locally and independently. The dynamic interaction of the locally managed components gives rise to complex behavior and can lead to large-scale disruptions as e.g. blackouts in the electric grid. Large interconnected systems with autonomously acting subunits are called systems of systems. DYMASOS addresses systems of systems where the elements of the overall system are coupled by flows of physical quantities, e.g. electric power, steam or hot water, materials in a chemical plant, etc. Within the project, new methods for the distributed management of large physically connected systems with local management and global coordination will be developed. The developed coordination methods will lead to improved system stability and lower resource consumption in industrial production, and in electric power generation and distribution. This will result in a reduction of the CO_2 emissions, higher competitiveness of the European industry and lower prices for the customers.

Optimization of Renewable Electricity Generation Systems Connected in a Microgrid

M. Baotić, M. Gulin

University of Zagreb, Croatia

The ever increasing electrical energy demands, limited fossil and nuclear fuel reserves, climate change, the national desire for energy independence and diversification of energy sources, thrust in the first plan distributed production of electric power from renewable sources as a key element in achieving sustainable development. Over 90% of the electricity generated in developed countries is consumed in homes, buildings, and industry. Greater attention must therefore be paid to end-use sectors if the promised benefits of smart grids are to be achieved. The main problem in the usage of renewable electrical energy sources (REES) is their intermittency, which leads to problems in regulation of the power system. This problem exists both on a local production-storage-consumption level and on

the power system level and becomes more pronounced with the increasing contribution of REES in the total energy production. A natural solution is to derive a coordinated and dynamic planning strategy for production-storage-consumption of electric power. With a local information- and power-connection of REES, energy storage facilities, and consumers in a system—a microgrid—one can control resulting energy flows while considering techno-economical criteria and the local energy yield forecast.

Wind Turbine Loads Envelope Protection during Storms

V. Petrović, C. L. Bottasso

Technische Universität München, Germany

The idea of envelope protection is used to enable wind turbine operation in very strong winds, typically present during storms. To this aim, an online optimization procedure is formulated that, based on the wind turbine state, calculates wind speed variations needed to produce maximal allowable wind turbine loads. Optimization results are compared to the actual wind speed and, if there is a danger of excessive loading, power reference is adjusted to ensure that loads stay in allowed limits.

Cooperative Manipulation of Suspended Objects

I. Palunko, S. Hirche

University of Zagreb, Croatia, and Technische Universität München, Germany

In this poster we present two approaches for cooperative manipulation of suspended objects. First, we use decentralized consensus based approach for suspended object transportation and damping of residual oscillations. Second, we combine reinforcement learning with energy based swing-up control to inject energy into various suspended objects of unknown parameters. The both proposed controllers are successfully verified experimentally and in simulation.

An Event-based Scheduling Design for Multi-loop Stochastic Networked Control Systems

M. Mamduhi, A. Molin, S. Hirche

Technische Universität München, Germany

A novel dynamic scheduling policy for stochastic multi-loop NCSs communicating over a shared constrained channel is presented. The scheduling policy allocates the channel access according to an error-dependent probabilistic measure. We model the overall network-induced error as a homogeneous Markov chain and show the stochastic stability of the overall NCS in terms of ergodicity, as well as deriving uniform performance bounds for the error variance.

Stabilizing Transmission Intervals and Delays: The Large Delay Case

D. Tolić, S. Hirche

University of Zagreb, Croatia, and Technische Universität München, Germany

We propose a methodology for computing Maximally Allowable Transfer Intervals (MATIs) that provably stabilize nonlinear Networked Control Systems (NCSs) in the presence of disturbances and signal delays. Accordingly, given a desired level of system performance (in terms of Lp-gains), quantitative MATI vs. Delay trade-offs are obtained. By combining impulsive delayed system modelling with Lyapunov-Razumikhin type of arguments, we are able to consider even the so-called large delays. Namely, the computed MATIs can be smaller than delays existent in NCSs. Out stability results are provided for the class of Uniformly Globally Exponentially Stable (UGES) scheduling protocols.

Simple Explicit MPC Controllers Based on Approximation of the Feedback Law

J. Holaza, B. Takács, M. Kvasnica

Slovak University of Technology in Bratislava, Slovakia

Explicit Model Predictive Control (MPC) is an attractive control strategy, especially when one aims at a fast and computationally less demanding implementation of MPC. Even thought that explicit MPC optimizer leads to a fast optimization based control, the complexity of which, in terms of memory occupancy is often prohibitive for application on simple control platforms which offer only limited amount of memory storage. Therefore, in order to circumvent this limitation, we propose to synthesize much simple, albeit suboptimal, explicit MPC

controller that will occupy less memory while providing guarantees of typical control requirements such as recursive satisfaction of input and state constraints as well as closed-loop stability. This task is tackled via two steps. Firstly, we synthesize much simpler representation of the explicit MPC optimizer, foundation of which will be used in the approximation. In the second step the approximation is performed such that the error between the optimal, but complex controller and its fitted replacement is minimized. We show that the aforementioned procedure can be formulated as a quadratic optimization problem which always yields an admissible solution.

Control of 3D Tower Crane Based on Polytopic LPV model

S. Ileš, J. Matuško, F. Kolonić

University of Zagreb, Croatia

In this poster we present two approaches for control of 3D tower crane based on its Linear Parameter Varying (LPV) polytopic model. Three motions of tower crane are considered as separate subsystems with couplings among them treated as a change in system parameters. Such linear parameter varying systems can be sampled and transformed into the corresponding polytopic model, by using Tensor Product (TP) Model Transformation. In the first approach Tensor product based controller is designed by solving Linear Matrix Inequalities (LMI). In the second approach real-time Model Predictive Control (MPC) is presented, while polytopic model is used to calculate a terminal set and ellipsoidal approximation of worst case initial feasible set in order to guarantee both stability and recursive feasibility.

Synthesizing Anticipatory Haptic Assistance Considering Human Behavior Uncertainty

J. R. Medina Hernandez, S. Hirche

Technische Universität München, Germany

Intuitive physical interaction is an essential requirement for robotic systems sharing their workspace with humans. While compliance is indispensable for human safety intelligent robots are also expected to exhibit goal-oriented behavior. However, when robot's goals conflict with human's intentions, negotiation is required to resolve the motion conflict. We present a novel scheme for anticipatory haptic assistance which adapts the robot behavior depending on human behavior uncertainty following a stochastic a risk-sensitive optimal control approach. Results indicate reduced disagreement and human effort as well as increased perceived helpfulness.

Networked Media (NWMED) Research Group

M. Matijašević, L. Skorin-Kapov, O. Dobrijević, T. Grgić, M. Sužnjević, K. Ivešić

University of Zagreb, Croatia

Networked Media (NWMED) is a research group within the Department of Telecommunications, Faculty of Electrical Engineering and Computing (FER), University of Zagreb. This poster outlines the group's research goal, research areas, current projects and selected publications.

Resource Management for Multimedia Services Based on User- and Service-Related Knowledge

K. Ivešić, L. Skorin-Kapov, M. Matijašević

University of Zagreb, Croatia

Since the existing resource management mechanisms in wireless networks are not suitable for complex multimedia services, we propose new ones that improve resource utilization, while keeping the users' perceived quality high. By applying the structure of Media Degradation Path (MDP), user- and service-related knowledge can be utilized to improve admission control and resource allocation mechanisms. We examine the proposed approach in the context of the 3GPP Evolved Packet System. We develop a simulator tool named ADAPTISE to evaluate the approach and verify the simulations in an LTE network simulator with consideration of low level transmission aspects. Simulation results have shown that the approach leads to increased session admission ratio while maintaining acceptable user-perceived quality levels and that network congestion can be dealt with by degrading sessions in a controlled manner.

Toward QoE-driven Path Optimization for Multimedia Services in Future Networks

O. Dobrijević, A. Kassler, L. Skorin-Kapov, M. Matijašević

University of Zagreb, Croatia, and Karlstad University, Sweden

This poster outlines motivation, research goal and problem formulation for a quality of experience (QoE)-driven optimization model of path assignment for multimedia services in future communication networks. The model, which is mathematically formulated as a mixed integer linear program, fairly maximizes aggregated end-user QoE by calculating the best path for each media flow.

Implications of User Behaviour in Online Games for Network Traffic Characteristics and Quality of Experience

M. Sužnjević, M. Matijašević

University of Zagreb, Croatia

Behaviour of users in complex multimedia services such as online games has a major impact on both network traffic characteristics as well on the perceived Quality of Experience of the users. Incorporating awareness of users' behaviour into network traffic models results in much more accurate generated network traffic patterns which is very important for classes of network traffic which have strict requirements on the network. With the rise of cloud gaming games do not only require low latency in the network, but also very high bandwidth. In our studies Quality of Experience (QoE) studies we have confirmed an impact of the context of the virtual world on the perceived QoE of the users. Therefore, we have proved that any future QoE models for online games need to take into account not only system and user factors, but also context based factors.

Urban Crowd Sensing for Environmental Monitoring: The OpenIoT Approach

A. Antonić , V. Bilas, M. Marjanović, M. Matijašević, D. Oletić, M. Pavelić, I. Podnar Žarko, K. Pripužić, L. Skorin-Kapov

University of Zagreb, Croatia

Urban crowd sensing labels a group of smart city applications for mobile community sensing involving individuals who collect and share sensor data on the move in urban environments. Such applications can produce dense sensor readings, both in space and time, and provide the means to discover new phenomena in urban environments. We present an urban crowd sensing application for monitoring air quality by use of specially-designed wearable sensors and mobile phones. The application is built upon the OpenIoT platform with the goal to support context-aware and energy-efficient acquisition and filtering of sensor data in mobile environments while ensuring adequate sensing coverage. We demonstrate how sensors and mobile devices jointly collect and share data of interest to measure air quality. In particular, we outline the main features of our wearable air quality sensors, present the data acquisition process as well as the user view of the system, which, in contrast to similar applications, provides a personalized real-time notification mechanism to mobile application users. The solution was used in an air quality measurement campaign "Sense the Zagreb Air" performed in the City of Zagreb, Croatia, in early July 2014 with 20 participants.

Decentralized Resource Management Between Consensus-Seeking Networks

V. Jeličić, D. Tolić, V. Bilas

University of Zagreb, Croatia

We propose a decentralized method for inter-network collaboration, where each node is able to initiate a consensus-reaching procedure among the nodes from its network and terminate it after the consensus is reached. After that, it exchanges the information with a node from a neighboring network. In order not to interfere with the main task of the Wireless Sensor Networks (WSNs), i.e., detecting and reporting interesting events, our consensus algorithm needs to be energy-efficient and fast. The performance of the consensus algorithm during intra-network communication (prior to inter-network communication) is experimentally investigated, using off-the-shelf wireless sensor platforms. In our experiments, the best performance is achieved for period of communication 0.1 s (i.e., 2% duty cycle). This research has been a collaborative work of AIG group and LARICS group.

Magnetic Induction Spectroscopy System for Non-Contact Conductivity Measurements of Biological Samples

M. O'Toole, L. Marsh, J. Davidson, Y. M. Tan, D. Armitage, A. Peyton

University of Manchester, United Kingdom

The conductivity spectra of a biological material is characterised by a set of dispersions caused by different mechanisms of current-flow operating at the cellular level. At different points in the frequency spectrum, different mechanisms dominate, giving the conductivity spectra its characteristic shape. Of particular interest is the beta dispersion. This dispersion is the result of two parallel current paths: (1) through the resistive extracellular fluid, and (2) through the capacitive effects of the cell membranes and resistive intracellular fluid. In principle, the state of the cell-structure of the sample—such as the degradation and porosity of the cell membrane, and the volume of extracellular fluid—should influence the shape of the spectral response of the dispersion. This is of particular interest to the food industry where rapid and non-invasive methods to assess the state of their product are much in demand. We present a new multi-frequency magnetic induction spectroscopy (MIS) system for obtaining conductivity spectra of biological samples over a frequency range of 160 kHz–2.5 MHz. The system is non-contact, can take rapid spectral measurements and its design is suitable for industrial-scale use. The system is described and preliminary results presented on the conductivity spectra of some common agricultural products.

Holistic Approach to Energy Saving in Wireless Networks of Energy-Hungry Sensors for Smart Surveillance

V. Jeličić, V. Bilas

University of Zagreb, Croatia

We investigate energy-saving techniques in battery-powered wireless networks of energy-hungry sensors, such as video cameras and gas sensors for smart surveillance applications. Our context-aware, multimodal and heterogeneous architecture of the wireless sensor network limits the energy-hungry sensor's active time and area. At the same time, the activity of the radio is limited to interesting events by a wake-up radio device, ensuring time- and energy-efficient network communication between nodes. By combining energy-savings in sensing and communication, we attain runtime prolongation of a wireless sensor node and network, without downgrading quality of service for the user (i.e., maintaining good recognition of interesting events). This research has been performed in AIG group, in collaboration with University of Bologna, Italy; University of Trento, Italy; and ETH Zürich, Switzerland.

Advanced Electromagnetic Induction Methods in Humanitarian Demining

D. Ambruš, D. Vasić, V. Bilas

University of Zagreb, Croatia

The poster summarizes recent research activities and results of the Advanced Instrumentation Group (AIG) in the field of novel electromagnetic induction (EMI) methods and devices applied to humanitarian demining. The research focuses on advanced concepts in metallic target detection and characterisation based on mathematical modelling and related inversion procedures for the estimation of parameters that are intrinsic to the buried target in order to reduce the huge amount of false alarm rates often encountered in humanitarian demining. Besides the research activities in the metal detection area, we also present our recent work in the EMI-based modelling of soil, with possible applications to landmine detection and precision agriculture. Finally, we introduce the cooperation of AIG with a partner research group from the University of Manchester, as well as cooperation with the industrial partner from Croatia (CROMAC – Croatian Mine Action Centre).

Author Index

Notes

http://across.fer.unizg.hr/

ACROSS Workshop on Cooperative Systems
September 10-12, 2014, Dubrovnik, Croatia