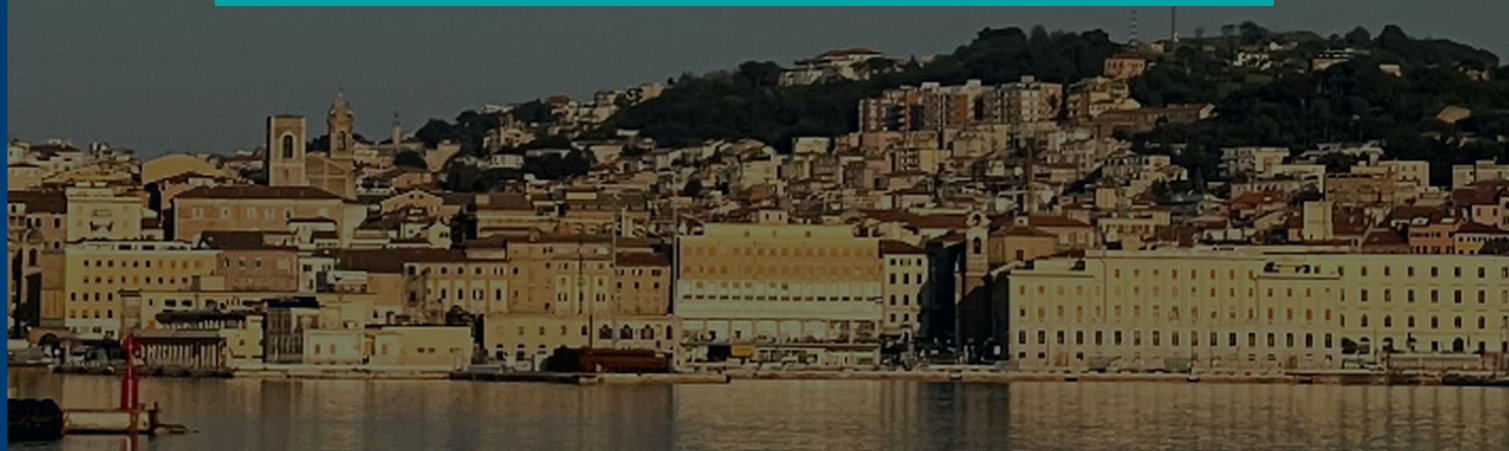
MCA

IEEE

UNIVERSITÀ POLITECNICA DELLE MARCHE

THE 34TH MEDITERRANEAN CONFERENCE ON CONTROL AND AUTOMATION

Technical Program and Book of Abstracts



MED'26

ANCONA, ITALY

23 - 26 JUNE 2026

Università Politecnica delle Marche

ANCONA, ITALY

www.med2026.org

ORGANISED BY

MCA

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UNIVERSITÀ POLITECNICA DELLE MARCHE

Società Italiana Docenti e Ricercatori di Automatica

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Loredana Zollo - *Università Campus Bio-Medico di Roma*

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WELCOME MESSAGE FROM THE MEDITERRANEAN CONTROL ASSOCIATION (MCA) PRESIDENT

Welcome MED'26 Attendees!

On behalf of MCA (www.med-control.org), the founding and parent organization of the MED conferences, I would like to welcome you to the 2026 MED, the 34th annual Mediterranean Conference on Control and Automation, taking place in Ancona, Italy. Thank you for your participation and contributions; they are absolutely essential in making MED a success. As a reminder, the MED Conference Proceedings are available online at http://ieeexplore.ieee.org.
The Proceedings of early MED Conferences may be downloaded from www.med-control.org, where you may also find the Book of Abstracts as well as conference reports of previous MED that have appeared in the IEEE Control Systems Magazine.
The very first MED took place in 1993 in Crete, Greece, and over the next 33 years the MED has been in Cyprus, Malta, Italy, France, Croatia, Turkey, Israel, Portugal, Morocco, Spain and several times in Greece (for a complete list of the MED conferences, see www.med-control.org). This year we are meeting in Ancona, Italy for the second time - Ancona was the venue for the 14th MED Conference, MED'06 as well.

All indications affirm that MED'26 will be a successful MED, and I would like to thank the General Chair of MED'26, David Scaradozzi, and his team for their time and effort to make this conference a success.
I would like now to take this opportunity to share some thoughts about our field and its future. We are doing well, but we could do better. Certainly, AI dominates the news. Businesses, educational institutions, and government are all working to discover how this powerful technology can benefit all aspects of work and entertainment. Large numbers of huge data centers are being constructed in the belief that this is the way of the future. In Controls, learning has been popular, reinforcement learning in particular. It is important to formulate our control problems carefully before we start applying popular AI algorithms, hoping for a good solution.

In Controls, we are in the decision-making business, and so far, we are not letting AI make important decisions by itself, e.g., on infrastructure and human health, without adequate supervision, when a wrong decision could be catastrophic. Do you have good ideas about improving the trustworthiness of the AI algorithms, especially when only limited data is available? This is a very important issue.
Enjoy the MED'26 conference in Ancona. Thank you for your participation!

Panos J Antsaklis
President, Mediterranean Control Association

WELCOME MESSAGE FROM THE MED'26 GENERAL CHAIR

Dear colleagues, authors, and participants,

It is my great pleasure and honor to welcome you to the 34th Mediterranean Conference on Control and Automation, MED'26, hosted by the Università Politecnica delle Marche in Ancona, Italy, from June 23 to 26, 2026.

This edition has a special meaning for us. MED returns to Ancona exactly twenty years after the 14th Mediterranean Conference on Control and Automation, which was held here in June 2006, on the same days of the year. Two decades later, we are proud to welcome back the Mediterranean control and automation community to our university and to the Italian side of the Adriatic coast.

Over the years, MED has become much more than a scientific conference. It is a place where researchers, practitioners, students, and institutions meet to exchange ideas, build collaborations, and discuss the future of control, automation, robotics, and intelligent systems. MED'26 continues this tradition by bringing together contributions from academia, research centers, industry, and young researchers working on the many challenges that define our field today.

The scientific scope of the conference reflects the growing role of control and automation in complex, interconnected, and intelligent systems. Topics such as cyber-physical systems, robotics, autonomous systems, artificial intelligence, systems theory, and control strategies for structured or hostile environments, industrial automation, and educational technologies are increasingly central to the way we address societal, environmental, and technological challenges. Hosting MED'26 in Ancona, a city deeply connected to the sea, also gives us the opportunity to highlight marine technologies and underwater robotics as strategic areas for research, innovation, and sustainability.

Education is another essential dimension of this conference. Control and automation are not only scientific disciplines but also powerful tools for training the next generation of engineers, researchers, and innovators. Through tutorials, workshops, technical sessions, and informal discussions, MED'26 aims to provide young participants with a stimulating environment in which they can learn, present their work, and become part of an international scientific community.

As General Chair, I would like to express my sincere gratitude to the Mediterranean Control Association, to all technical co-sponsors, to the Program Chairs and members of the Organizing Committee, to the invited speakers, session organizers, reviewers, authors, volunteers, and all those who have contributed to the preparation of this conference. Their dedication and commitment have been essential in making MED'26 possible.

I would also like to thank all participants for joining us in Ancona. I hope these days will offer you not only valuable scientific experience but also the opportunity to enjoy the city, its university, its connection to our sea and lands, and the welcoming spirit of the Marche region.

On behalf of the Organizing Committee, I warmly welcome you to MED'26 and wish you a productive, inspiring, and enjoyable conference!

With my warmest regards,

David Scaradozzi
Università Politecnica delle Marche

WELCOME MESSAGE FROM THE MED'26 PROGRAM CHAIRS

Dear authors and attendees:

On behalf of the MED'26 Organizing Committee, we are delighted to welcome you to the 34th Mediterranean Conference on Control and Automation. MED'26 proudly returns to Ancona, Italy, two decades after its last edition hosted here. The main three-day technical conference runs from June 24–26, 2026, preceded by an engaging day of Tutorials and Workshops on June 23.

Organized by the Mediterranean Control Association (MCA) and locally hosted by the Università Politecnica delle Marche (UNIVPM), the event takes place along the stunning Adriatic coast. Ancona is a dynamic hub for automation and cutting-edge research, embodying the renowned "Marche model" of collaborative innovation, in which academia, research bodies, and enterprises work closely together.

Our attendees represent a diverse mix of academia, industry, government agencies, and students. This year, the conference will primarily focus on emerging challenges and opportunities in automatic control and cyber-physical systems solutions, with a special emphasis on small and medium-sized enterprises (SMEs) and start-ups.

We extend our deepest gratitude to our local organizers (UNIVPM, SIDRA, ISME, IRIM) and technical co-sponsors—including the IEEE Control Systems, Robotics and Automation, Oceanic Engineering, and Education societies—for their vital support in making this event possible.

Finally, we thank you for your participation.

We hope you thoroughly enjoy the conference, connect with your peers, and take full advantage of Ancona's vibrant tech environment and beautiful surroundings!

With our warmest regards,

Gianluca Antonelli
Università degli Studi di Cassino e del Lazio Meridionale

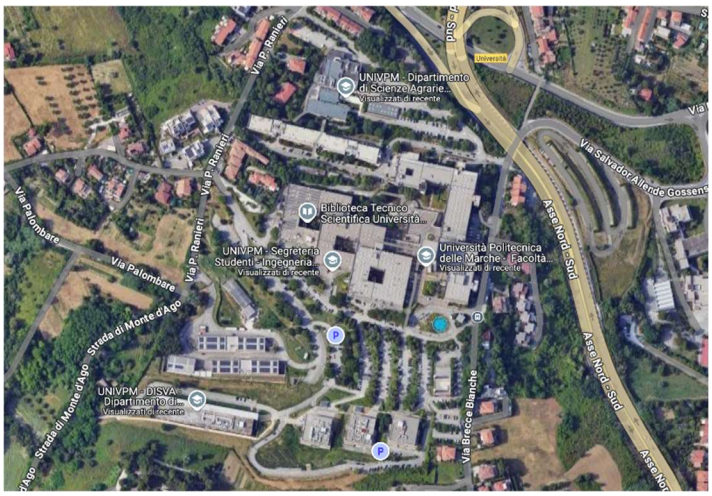
Kimon P. Valavanis
University of Denver

MED'26 GENERAL INFORMATION

The MED'26 conference will be held at the **Università Politecnica delle Marche**, specifically at the Faculty of Engineering. This modern academic facility provides an ideal environment for engaging in discussions and presentations on advanced control and automation.

Nestled on the scenic hills of Ancona, the venue combines state-of-the-art facilities with stunning views of the Adriatic Sea, offering an inspiring setting for conference participants. Attendees will have access to dedicated lecture halls, equipped with the latest audio-visual technology, fostering an optimal atmosphere for professional exchange and collaboration.





23/06/2026
D3A - Dipartimento di Scienze Agrarie, Alimentari ed Ambientali,
Università Politecnica delle Marche,
Via Brecce Bianche 10, 60131 Ancona, Italy

24-26/06/2026
Facoltà di Ingegneria
Università Politecnica delle Marche,
Via Brecce Bianche 12, 60131 Ancona, Italy

MED'26 GENERAL INFORMATION

TRAVELING TO ANCONA

Ancona, located on the Adriatic coast of Italy, is a lively port city with a rich history and a vibrant cultural scene. Situated along the Adriatic Sea, it combines Italian traditions with Mediterranean charm, providing an engaging experience for all MED'26 attendees.

ARRIVING BY AIR

The **Ancona-Falconara "Raffaello Sanzio" Airport** (IATA code: AOI) is located in Falconara Marittima, about 20 minutes from Ancona's city center.
Address: P.le Sordoni, 60015 Falconara Marittima

Airport contact details

Information Office: Ph: +39 071 28271 or Ancona Airport
Air Ticket Office: Email: biglietteria@ancona-airport.com
Parking facilities: Email: parking@ancona-airport.com

Public Transport Options

The **Raffaello Aerobus** offers a convenient shuttle service from the Airport to Ancona's city center (Piazza Cavour, Railway Station) running from 7:00 am to 10:30 pm. Tickets are available directly on the bus. All Aerobus information and timetables are available on this page.
Alternatively, passengers can travel by train **from Castelferretti–Falconara Aeroporto railway station**, located near the airport, **to Ancona Railway Station**. Tickets can be purchased on www.trenitalia.com.

Taxi Service

A taxi service is available directly from the Arrivals Terminal. To arrange a taxi to and from Ancona Airport, you can contact CTF Consorzio Taxi Falconara:

- Phone: +39 0719189531
- Website: www.ctftaxi.it

Renting a Car

Participants have the flexibility to rent a car either at the Ancona Airport or in the city center. Several rental companies offer a variety of vehicles, making it easy to explore Ancona and the surrounding Marche region independently.

ARRIVING BY TRAIN

Arriving from Rome

International attendees may opt to travel via **Rome's Fiumicino Airport** (IATA code: FCO) or **Ciampino Airport** (IATA code: CIA). Both airports connect easily to Ancona by high-speed trains or direct bus services:

- **By Train**: Trenitalia provides trains from Fiumicino and Ciampino airports to Ancona;
- **By Bus**: Flixbus operates direct routes from Rome to Ancona, with buses departing from both Fiumicino and Ciampino airports. Visit Flixbus for schedules and ticketing.

Arriving from Bologna

For those traveling through **Bologna Guglielmo Marconi Airport** (IATA code: BLQ), connections to Ancona are also straightforward:

- **By Train**: The "Marconi Express" shuttle service connects Bologna Airport to Bologna Centrale Station, where high-speed **Trenitalia** trains to Ancona are available.

ARRIVING BY SEA

Ancona is also accessible by **ferry**, with international routes from Croatia and Greece arriving at Ancona Port. Ferry services provide regular sailings to and from Split, Zadar, and other Adriatic locations.

LOCAL TRAVEL TO UNIVERSITÀ POLITECNICA DELLE MARCHE

By Car

The Università Politecnica delle Marche can be reached by car via the **A14 highway**. From the **Ancona Nord exit**, follow the SS16 road to Ancona's city center. For those traveling from the south, use the **Ancona Sud exit** and continue on the ring road, following signs to the university. Free parking is available on campus.

By Public Transport

- **From Ancona Centrale Station**: Take bus **1/4** directly from the station, transfer at the last stop to bus **46** to reach the university.
- **From the City Center**: Bus **46** departs from Piazza Cavour, providing a direct route to the university.



For more details on tickets and urban transport options, check https://www.conerobus.it/. You can also buy the ticket on the bus by cash.

Useful links and information for urban transport:

- https://www.conerobus.it/servizi-tpl/servizio-urbano-ancona/
  (Timetable for urban transport > "Orario Feriale Estivo 2026")
- https://www.conerobus.it/servizi-tpl/servizio-extraurbano/
  (Timetable for intercity transport > "Servizio Feriale Invernale – Scuole Chiuse")

LANGUAGE AND CURRENCY

The official language is Italian. English is widely used in academic and conference settings, and it is commonly spoken in hotels, restaurants, and tourist areas. The currency is the **Euro** (EUR). Major credit cards are accepted in hotels, restaurants, and most shops. ATMs are readily available throughout the city.

ELECTRICITY, PLUGS AND SOCKETS

Italy uses 230 V, 50 Hz AC electricity. The standard power plug types are C, F, and L. Travelers from the UK, US, or other countries using different plug types may need an adapter.

CONFERENCE LOGISTICS

MED'26 is a four-day event, starting with Workshops and Tutorials on Tuesday, June 23, followed by the three-day Technical Conference from Wednesday, June 24 to Friday, June 26, 2026. The Conference includes three Keynote Lectures and parallel technical sessions.

- **Workshops, Tutorials, and the Welcome Reception & Networking Event** will take place in the **D3A** building ("Dipartimento di Scienze Agrarie, Alimentari ed Ambientali").
- The **Opening Ceremony** and **Keynote Lectures** will be held in **Aula Magna "Guido Bossi"**, "Facoltà di Ingegneria".
- **Coffee breaks and lunches** will take place in the **Room Polifunzionale**, "Facoltà di Ingegneria".
- **Parallel technical sessions** will be held in dedicated rooms in **Q.155,** "Facoltà di Ingegneria".

CONFERENCE REGISTRATION

All attendees must register through the official conference website: www.med2026.org. Final paper submission and registration are required for paper presentation and publication in the conference proceedings before June 2, 2026.

Personal badges and registration packages will be available at the Registration Desk. Attendees are kindly requested to wear their badges at all MED'26 events, as access to conference areas will be permitted only to registered participants wearing a valid conference badge.

Registration Desk Hours and Locations

Tuesday, June 23

- Workshop and Tutorial Registration: 8:00, D3A Lobby.
- Registration for all participants: from 17:00, during the Welcome Reception & Networking Event, D3A Lobby, Dipartimento di Scienze Agrarie, Alimentari ed Ambientali

Wednesday, June 24 – Friday, June 26

- Registration Desk: 8:00–10:30, Aula Magna "Guido Bossi", Facoltà di Ingegneria.
- Registration Desk: 11:00–16:00, Q.155, Facoltà di Ingegneria, in front of the technical session rooms.

Registration Fees

Attendee Status	Advance/Early ~~(May 15 – May 20)~~ (May 15 - May 26, until 12 PM CEST)	Late/On-site (May 27 - June 23)	Max. # of papers per registration
Regular Registration	€600	€700	2
Student Registration	€300	€380	1
Retiree	€300	€300	1
Full-Day Workshop/Tutorial	€200	€240	-
Extra paper (above 2) upload fee per paper	€240	€240	-
Additional one-page charge (max. 2 pages)	€130	€130	-
Guest Registration (all social events)	€180	€180	-
Extra Welcome Reception Ticket	€50	€50	-
Social Event Ticket*	€45	€45	-
Extra Banquet Ticket	€85	€85	-

- **Full Registration** includes access to all technical sessions, proceedings, exhibits, coffee breaks, lunches, banquet, and receptions.
- **Student Registration and Retiree Registration** include access to all technical sessions, proceedings, exhibits, coffee breaks, lunches, and receptions.
- **Workshop/Tutorial Registration** includes access only to the selected Workshop/Tutorial activities on June 23, 2026

All registered participants will receive complimentary internet access.

Gala Dinner

The MED'26 **Gala Dinner** will take place on **Thursday, June 25, 2026**, starting at **19:30**. Participation is included for Regular registrations and is also open to participants and guests who have purchased an extra dinner ticket. The dinner venue will be announced at the Registration Desk.

Social Event

The MED'26 **Social Event** will take place on **Friday, June 26, 2026**, after the technical sessions. The event will consist of a **boat tour along the Conero coast**, including an on-board aperitif featuring local products.
Participants who have already purchased a Social Event ticket will receive all relevant information at the Registration Desk. Participants who have not yet purchased a ticket may ask at the Registration Desk whether any places are still available.

MED'26 TUTORIALS AND WORKSHOPS

MED'26 offers two pre-Conference Tutorials addressing current and emerging topics in control, automation, and dynamic systems. Interested participants may find further details on the official conference website at www.med2026.org and register through the online registration system.

The Tutorials will take place on **Tuesday, June 23, 2026**, in the **D3A building**, Dipartimento di Scienze Agrarie, Alimentari ed Ambientali.

T1: Harmonic Control Arrays: A Control Methodology for Systems Involving Periodic Signals



Organizer: Prof. Murat Dogruel

Affiliation: Istanbul 29 Mayis University, Türkiye

Type: Tutorial

Duration: Half-day tutorial

Date: Tuesday, June 23, 2026

Time: 09:00 - 13:00 Room N - D3A

Abstract

Eliminating periodic disturbances and tracking periodic reference signals pose significant challenges for many control systems across a wide range of application domains. This tutorial introduces Harmonic Control Arrays (HCA), a novel control methodology specifically designed for control systems involving periodic reference signals or disturbances. HCA provides a structured approach to achieving accurate periodic tracking and to mitigating the effects of periodic disturbance signals. The tutorial offers a comprehensive overview of HCA, covering its theoretical foundations, practical implementation using tools such as MATLAB/Simulink, and real-world applications in areas such as power electronics and electromechanical systems. Participants will gain hands-on experience with HCA through simulations and live demonstrations. The tutorial

also examines the relationship between HCA and traditional feedback control methodologies. Traditional control methods often struggle to handle such scenarios effectively, particularly in the presence of time delays, nonlinearities, and model uncertainties. The Harmonic Control Array (HCA) framework provides a robust and systematic way to address these challenges, enabling the design of high-performance control systems in the presence of periodic signals. The fundamental insight behind HCA is to decompose the error signal into complex-valued harmonic components using Fourier analysis, control each harmonic independently in the frequency domain, and then synthesize the real-time control input from these harmonically controlled components.

Speaker Biography

Dr. Murat Dogruel received his B.S. degree in Electronics and Communication Engineering from Istanbul Technical University, Türkiye, in 1988, and his M.S. and Ph.D. degrees in Electrical Engineering from The Ohio State University, Columbus, OH, USA, in 1992 and 1995, respectively. From 1995 to 2022, he served in the Faculty of Engineering at Marmara University, Istanbul, Türkiye, where he attained the rank of full professor and chaired the Department of Electrical and Electronics Engineering. He was a Visiting Associate Professor in the Department of Electrical and Computer Engineering at the University of Miami from 2001 to 2003. From 2006 to 2008, he served as Dean of the Faculty of Engineering and Natural Sciences at the International University of Sarajevo in Bosnia and Herzegovina, and as Dean of the Faculty of Engineering at Marmara University from 2014 to 2017. He is currently with the Department of Electrical and Electronics Engineering at Istanbul 29 Mayis University, Türkiye. His research interests include control, signal and image processing, and power electronics.
He has introduced the novel concept of Harmonic Control Arrays and is actively engaged in its theoretical and practical development.

T2: Object-Oriented Modelling with Modelica for Control and Cyber-Physical Systems

Organizer: Prof. Alberto Leva

Affiliation: DEIB, Politecnico di Milano, Italy

Type: Tutorial

Duration: Half-day tutorial

Date: Tuesday, June 23, 2026

Time: 14:00 - 17:00 Room N - D3A



Abstract

Modern control applications increasingly involve cyber-physical systems where physical processes, control algorithms, software components, and digital infrastructures interact across multiple engineering domains. In these contexts, modeling approaches based exclusively on causal block diagrams may become restrictive, especially when dealing with multi-domain physical systems, hybrid continuous/discrete dynamics, and tightly integrated control architectures. This tutorial introduces the principles of equation-based object-oriented modeling through the Modelica language and the OpenModelica environment. The tutorial combines a compact introduction to the modeling paradigm with hands-on examples and modeling activities. Participants will see how physical and control-oriented models can be developed within a unified equation-based framework using reusable components and acausal connections. Examples will include hybrid and controlled systems involving continuous-time dynamics, sampled-data control, logical supervision, and switching behaviors. The tutorial will also present selected examples drawn from ongoing research on cyber-physical and energy-aware systems, together with a brief overview of interoperability standards such as FMI and open modeling workflows.

Speaker Biography

Alberto Leva is Professor of Automatic Control at the Politecnico di Milano, Italy. His main research interests concern methods and tools for the automatic tuning of industrial controllers and control structures, process modeling, simulation and control, particularly within the object-oriented modeling paradigm, and modeling and control of energy systems with particular reference to large grids. He is also interested in advanced tools and methods for control education. In recent years, he has been concentrating on control and control-based design of computing systems, addressing in a system- and control-theoretical manner problems such as scheduling, resource allocation, time synchronization in wireless sensor networks, thermal and power/performance management, performance-driven software adaptation, and service composition.

MED'26 PLENARY LECTURES

MED'26 will feature three Plenary Lectures delivered by internationally recognized experts in their fields. We are pleased to welcome these distinguished speakers as part of the Technical Program.

All Plenary Lectures will take place in **Aula Magna "Guido Bossi"**, Facoltà di Ingegneria.

#1 PLENARY LECTURE – Prof. Silviu-Iulian Niculescu

Organizer: Prof. Silviu Iulian Niculescu

Affiliation: L2S, Laboratoire des signaux et systèmes, CNRS, CentraleSupélec and Université Paris-Saclay France

Date: Wednesday, June 24, 2026

Time: 09:30 - 10:30 Aula Magna "Guido Bossi"



When the Past Shapes the Future: On the Dual Nature of Delay in Dynamical Systems

Understanding the diversity and heterogeneity of temporal phenomena in dynamical systems often requires explicit consideration of their past evolution. Such memory effects arise in numerous natural and engineering processes, such as transport and propagation phenomena, population dynamics, traffic flow, and communication networks. In these contexts, delays provide a natural way to represent past influences and to capture interaction or coupling mechanisms. In control, the interconnection of dynamical systems may generate complex behaviors, while delays acting within or across interconnections can significantly

affect system performance, sometimes leading to unexpected or counterintuitive dynamics.

This talk focuses on delay-differential equation models; the key point is to interpret the delay as a parameter. User-friendly frequency-domain methods for the analysis and control of systems with constant delays are presented, with particular emphasis on exponential stability. The lecture also illustrates how delays can be exploited as control parameters. The presentation combines intuitive explanations, theoretical developments, illustrative examples, and selected applications.

Speaker Biography

Silviu-Iulian Niculescu received the B.S. degree from the Polytechnical Institute of Bucharest, Romania, and the M.Sc., Ph.D., and HDR degrees in Automatic Control from the Institut National Polytechnique de Grenoble and the Université de Technologie de Compiègne, France. He is Research Director at CNRS and a member of the Laboratory of Signals and Systems (L2S), a joint research unit of CNRS, CentraleSupélec, and Université Paris-Saclay. He is also a member of the Inria team DISCO and served as Director of L2S from 2010 to 2019. His research interests include delay systems, operator theory, and optimization methods in control. He has authored or coauthored 11 books and more than 675 scientific publications. He served as Chair of the IFAC Technical Committee on Linear Control Systems (TC 2.2) from 2017 to 2023 and is the Founding Editor and Editor-in-Chief of the Springer Nature book series Advances in Delays and Dynamics.

An IFAC Fellow (2026) and IEEE Fellow (2018), he received the CNRS Silver and Bronze Medals and several academic distinctions, including honorary doctorates from Romanian universities (Galati, 2023 and Craiova, 2016). For further information, please visit https://cv.archives-ouvertes.fr/silviu-iulian-niculescu.

#2 PLENARY LECTURE – Prof. Simone Del Favero

Organizer: Prof. Simone Del Favero

Affiliation: University of Padova, Italy

Date: Thursday, June 25, 2026

Time: 09:30 - 10:30 Aula Magna “Guido Bossi”



Automated Insulin Delivery: How Control Engineering is Changing Diabetes Care

Type 1 diabetes mellitus (T1D) is a chronic metabolic disease affecting more than 9 million people worldwide. Due to the autoimmune destruction of pancreatic β-cells, individuals with T1D are fully dependent on lifelong insulin replacement therapy and must solve a complex control problem daily: administering insulin to regulate blood glucose levels while compensating for disturbances caused by meals and physical activity.

Over the past decade, diabetes therapy has been transformed by automated insulin delivery (AID) systems, also known as artificial pancreas systems. These technologies have significantly improved glycemic outcomes while reducing the burden of disease management, representing one of the most successful examples of the translation of automatic control methodologies into medical devices with a tangible impact on patients' lives.

This presentation will review the evolution of AID systems and discuss key challenges for the next generation of these technologies, with a focus on personalization, prompt detection of anomalies and system malfunctions, and the coordinated management of automated insulin delivery and user-initiated therapeutic actions.

Speaker Biography

Simone Del Favero is Associate Professor in the Bioengineering Group at the Department of Information Engineering, University of Padova, Italy. He received both his M.Sc. degree and Ph.D. in Control Engineering from the University of Padova. Since joining the Bioengineering Group as a postdoctoral researcher, his work has focused on developing artificial pancreas (AP) technologies and, more broadly, on applying control engineering, machine learning, and mathematical modeling to biological and metabolic systems.

He has contributed to major international clinical studies that demonstrated the effectiveness of AP systems and supported their translation into clinical practice. He was Principal Investigator of the MIUR-funded project Learn4AP ("Learning Patient-Specific Models for an Adaptive, Fault-Tolerant Artificial Pancreas") and currently leads research activities within an industry-sponsored collaboration with Dexcom, a global leader in glucose sensor technologies. He has authored 85 peer-reviewed journal articles and is the inventor of 11 patents and patent applications in the field of diabetes technology.

#3 PLENARY LECTURE – Dr. Vladimir Djapic

Organizer: Dr. Vladimir Djapic

Affiliation: Institute for Artificial Intelligence Research and Development of Serbia, Serbia

Date: Friday, June 26, 2026

Time: 09:30 - 10:30 Aula Magna “Guido Bossi”



From Single Vehicles to Swarms: Embodied AI and Adaptive Ocean Sampling with Uncrewed Maritime Systems

This plenary lecture presents embodied artificial intelligence as a framework for understanding how intelligent systems operate when coupled with real bodies, sensors, energy constraints, infrastructures, and institutional environments. The lecture begins from the premise that intelligence in the real world cannot be reduced to disembodied computation alone. Instead, it emerges through the interaction of perception, state estimation, control, decision-making, and action under uncertainty. In this view, embodied AI is not only a topic within robotics, but a broader systems perspective that connects engineering, medicine, autonomy, and governance.

The first part of the lecture introduces the theoretical foundations of embodied AI through concepts from control theory, signal processing, and estimation. It emphasizes that every embodied intelligent system is a closed-loop system operating in an uncertain environment, where sensing is partial, decision-making is constrained, and action reshapes the world that is being observed. Particular attention is given to the distinction between reversible and irreversible dynamics, to the role of measurement in shaping controllability, and to the importance of designing systems that remain robust when models are incomplete and environments are nonstationary.

The second part focuses on robotics as the most visible and mature domain of embodied AI. The lecture discusses how autonomous aerial, surface, underwater, and ground systems combine perception, control, navigation, and energy management in real time. It then extends this perspective to heterogeneous autonomy and swarms, in which intelligence is distributed across multiple agents with varying sensing, communication, and mobility capabilities. In these systems, coordination emerges not from a single centralized controller but from local interactions, consensus, adaptive behaviors, and networked control, making them especially relevant for maritime operations, distributed sensing, and adaptive ocean observation.

The third part moves from robotics toward medical and mobile diagnostics, showing that embodied AI is equally relevant when intelligence is embedded in healthcare devices, workflows, and institutional structures. The lecture examines how AI in clinical environments must operate under strict constraints of safety, accountability, limited resources, and human trust. It argues that in such settings, the control loop extends far beyond the device itself, influencing hospital processes, decision pathways, and the generation of future data. This makes embodied AI a useful framework not only for smart machines, but also for understanding healthcare systems as dynamic, feedback-driven environments.

The final part broadens the discussion toward ethics, responsibility, and future directions. It considers how control architectures also exist in institutions, finance, and policy, and how these structures shape the conditions under which intelligent systems are developed and deployed. The lecture concludes by outlining future research directions in integrated embodied AI theory, robust autonomy, clinically grounded intelligent systems, and socio-technical system design. Its central message is that intelligence should be studied not as isolated computation, but as action embedded in physical, social, and institutional reality, and that the next generation of AI must therefore be designed with equal attention to technical performance, human context, and long-term systemic consequences.

Speaker Biography

Dr. Vladimir Djapic is a research associate at the Institute for Artificial Intelligence Research and Development of Serbia, where he leads the Belgrade office and works on embodied AI, autonomous systems, and real-world deployment of intelligent technologies.

He holds B.S., M.S., and Ph.D. degrees in Electrical Engineering from the University of California, with academic training in machine intelligence, robotics, control, and intelligent systems. Over more than two decades of professional work in the United States and Europe, he has built a career that connects rigorous autonomy research with operational deployment in demanding environments.

Dr. Djapic has held senior scientific and technical leadership roles in maritime autonomy, defense-oriented robotics, and intelligent transportation. His experience includes leading multidisciplinary teams in the development and field deployment of aerial, surface, and underwater autonomous systems for cooperative missions, maritime security, navigation, sensing, and complex real-world operations. He has also contributed to major sea trials, multi-robot coordination programs, and international research initiatives focused on autonomy in challenging environments.

His technical expertise spans localization and mapping, GNSS-denied navigation, multi-sensor fusion, simultaneous localization and mapping, behavior-based control, distributed autonomy, and coordinated control across heterogeneous robotic platforms. He has worked with a wide range of sensing modalities, including IMU, LiDAR, SONAR, stereo vision, UWB, and signals of opportunity, and has consistently focused on systems that can perceive uncertain environments, make robust decisions, and act safely outside the laboratory.

In industry, Dr. Djapic held a senior leadership role in autonomous driving, where he helped build high-definition mapping and multi-sensor localization technologies for self-driving vehicles and supported development of geofenced electric mobility platforms. His work bridges academic research, government

and defense programs, and applied engineering, giving him an unusual combination of theoretical depth and deployment experience.

Since returning to Serbia, he has remained active in research leadership and innovation, contributing to projects in trustworthy AI, privacy-preserving localization, embodied AI for healthcare and smart cities, intelligent sensing, and autonomous mobility. He has authored more than sixty scientific publications, contributed to international conferences and editorial activities, and is recognized for linking control theory, perception, navigation, and AI into capable embodied systems that operate in the real world.

With a career spanning underwater robotics, autonomous maritime systems, self-driving vehicles, and emerging AI applications, Dr. Djapic brings a broad international perspective and a strong record of interdisciplinary innovation at the intersection of engineering, autonomy, and intelligent systems.

MED'26 INVITED LECTURE

Session - Linear Systems



Organizer: Prof. Giuseppe Conte

Affiliation: Accademia Marchigiana di Scienze, Lettere ed Arti, Italy

Date: Wednesday, June 24, 2026

Time: 11:00 – 12:30 Aula Magna "Guido Bossi"

50+ years of the Geometric Approach to the Theory of Dynamical Systems

The invited lecture briefly reviews developments in the Geometric Approach across various classes of dynamical systems. Focusing on the main notion of controlled invariance and, in particular, on the disturbance decoupling problem, extensions from the classical case of linear systems to nonlinear systems, systems over rings, hybrid systems, and other classes of systems are examined and discussed, highlighting similarities and differences. The overall picture shows how the Geometric Approach is a versatile, powerful and efficient way to deal with complex control problems in many situations.

Speaker Biography

Giuseppe Conte got the Laurea in Matematica with Honors from the University of Genova, Italy, in 1974. He was a Researcher and Associate Professor at the University of Genova; a Fulbright Scholar; a Visiting Researcher and Visiting Professor at the Ohio State University, Columbus, OH, and at the École Centrale de Nantes, Nantes, France; and a Full Professor at the Università Politecnica delle Marche from 1990 to 2021. He has been Chairman of the IFAC Technical Committee on Linear Systems; Chairman of the IEEE Italian Chapter of the Control System Society. He has been General Chairman of several international conferences and he has published more than 400 papers on linear and nonlinear system theory, robotics and home automation.

MED'26 TECHNICAL PROGRAM

TUESDAY JUNE 23, 2026

08:00–09:00	**Workshop and Tutorial Registration**	Desk - Lobby D3A
09:00-13:00	**T1: Harmonic Control Arrays: A Control Methodology for Systems Involving Periodic Signals (Prof. Murat Dogruel)**	Room "N" – D3A
14:00 – 17:00	**T2: Object-Oriented Modelling with Modelica for Control and Cyber-Physical Systems (Prof. Alberto Leva)**	Room "N" – D3A
From 17:00	**General Registration** Registration will be open to all participants during the Welcome Event.	Desk - Lobby D3A
17:30 – 19:00	**Welcome Event** Open to all registered participants and Welcome/Guest extra-ticket holders.	Lobby D3A

MED'26 TECHNICAL PROGRAM

WEDNESDAY JUNE 24, 2026

From 08:00	**Registration**			Desk - Aula Magna "Guido Bossi"
09:00-09:30	**MED'26 Opening Ceremony**			Aula Magna "Guido Bossi"
09:30-10:30	**Plenary Session #1 – Prof. Silviu-Iulian Niculescu**			Aula Magna "Guido Bossi"
10:30-11:00	**Coffee Break**			Room Polifunzionale
11:00-12:30	**Linear Systems** 11:00-12:30 Aula Magna "Guido Bossi"	**Autonomous systems 1** 11:00-12:30 Room 155/d2	**Aerospace control** 11:00-12:30 Room 155/d3	**System identification** 11:00-12:30 Room 155/d4
12:30-14:00	**Lunch**			Room Polifunzionale
14:00-15:30	**Predictive control** 14:00-15:30 Room 155/d1	**Autonomous systems 2** 14:00-15:30 Room 155/d2	**Cyber-physical systems** 14:00-15:30 Room 155/d3	**Intelligent transportation systems 1** 14:00-15:30 Room 155/d4
15:30-16:00	**Coffee Break**			Room Polifunzionale
16:00-17:30	**Data-Driven Modelling** 16:00-17:30 Room 155/d1	**Cooperative Systems Control** 16:00-17:30 Room 155/d2	**Power systems** 16:00-17:30 Room 155/d3	**Intelligent transportation systems 2** 16:00-17:30 Room 155/d4

MED'26 TECHNICAL PROGRAM

THURSDAY JUNE 25, 2026

From 08:30	**Registration**				Desk - Aula Magna "Guido Bossi"
09:30-10:30	**Plenary Session #2 – Prof. Simone Del Favero**				Aula Magna "Guido Bossi"
10:30-11:00	**Coffee Break**				Room Polifunzionale
11:00-12:30	**Neural networks** 11:00-12:30 Room 155/d1	**Modelling and simulation 1** 11:00-12:30 Room 155/d2	**Robotics 1** 11:00-12:30 Room 155/d3	**Process and Adaptive control** 11:00-12:30 Room 155/d4	
12:30-14:00	**Lunch**				Room Polifunzionale
14:00-15:30	**Intelligent control** 14:00-15:30 Room 155/d1	**Modelling and simulation 2** 14:00-15:30 Room 155/d2	**Robotics 2** 14:00-15:30 Room 155/d3	**Adaptive control** 14:00-15:30 Room 155/d4	
15:30-16:00	**Coffee Break**				Room Polifunzionale
16:00-17:45	**Invited Session - Control Engineering and Robotics for Education** 16:00-17:45 Room 155/d1	**Invited Session - Estimation and Control for Automated Vehicles** 16:00-17:45 Room 155/d2	**Robotics 3** 16:00-17:45 Room 155/d3	**Linear systems 2** 16:00-17:45 Room 155/d4	
19:30- 23:30	**Gala Dinner** Open to regular registered participants and extra-ticket holders.				Venue TBA

MED'26 TECHNICAL PROGRAM

FRIDAY JUNE 26, 2026

From 08:30	**Registration**				Desk - Aula Magna "Guido Bossi"
09:30-10:30	**Plenary Session #3 – Dr. Vladimir Djapic**				Aula Magna "Guido Bossi"
10:30-11:00	**Coffee Break**				Room Polifunzionale
11:00-12:30	**Invited Session - Innovation in Marine Robotics: Systems, Sensing and Control 1** 11:00-12:30 Aula Magna "Guido Bossi"	**Advanced control systems 1** 11:00-12:30 Room 155/d2	**Robust control** 11:00-12:30 Room 155/d3	**Networked controlled systems** 11:00-12:30 Room 155/d4	
12:30-14:00	**Lunch**				Room Polifunzionale
14:00-15:30	**Invited Session - Innovation in Marine Robotics: Systems, Sensing and Control 2** 14:00-15:30 Room 155/d1	**Advanced control systems 2** 14:00-15:30 Room 155/d2	**Mechatronic systems** 14:00-15:30 Room 155/d3	**Distributed detection and control** 14:00-15:30 Room 155/d4	
15:30-16:30	**Awards and Closing Ceremony**				Venue TBA
17:30	**Social Event** Open to Social Event ticket holders.				Venue TBA

Technical Program for Tuesday June 23, 2026

TuT1T1	Room N - D3A
Harmonic Control Arrays: A Control Methodology for Systems Involving Periodic Signals (Workshop)	
Chair: Dogruel, Murat	Istanbul 29 Mayis University
09:00-13:00	TuT1T1.1

Harmonic Control Arrays: A Control Methodology for Systems Involving Periodic Signals

Dogruel, Murat Istanbul 29 Mayis University

Eliminating periodic disturbances and tracking periodic reference signals pose significant challenges for many control systems across a wide range of application domains. This tutorial introduces Harmonic Control Arrays (HCA), a novel control methodology specifically designed for control systems that involve periodic reference signals or periodic disturbances. HCA provides a structured approach to achieving accurate periodic tracking and to mitigating the effects of periodic disturbance signals. The tutorial offers a comprehensive overview of HCA, covering its theoretical foundations, practical implementation using tools such as MATLAB/Simulink, and real-world applications in areas such as power electronics and electromechanical systems. Participants will gain hands-on experience with HCA through simulations and live demonstrations. The tutorial also examines the relationship between HCA and traditional feedback control methodologies. Traditional control methods often encounter difficulties in effectively handling such scenarios, particularly in the presence of time delays, nonlinearities, and model uncertainties. The Harmonic Control Array (HCA) framework provides a robust and systematic way to address these challenges, enabling the design of high-performance control systems in the presence of periodic signals. The fundamental insight behind HCA is to decompose the error signal into its complex-valued harmonic components using Fourier analysis, to control each harmonic independently in the frequency domain, and then to synthesize the real-time control input from these harmonically controlled components.

TuT2T2	Room N - D3A
Object-Oriented Modelling with Modelica for Control and Cyber-Physical Systems (Workshop)	
Chair: Leva, Alberto	Politecnico Di Milano
14:00-17:00	TuT2T2.1

Object-Oriented Modelling with Modelica for Control and Cyber-Physical Systems

Leva, Alberto Politecnico Di Milano

Modern control applications increasingly involve cyber-physical systems where physical processes, control algorithms, software components, and digital infrastructures interact across multiple engineering domains. In these contexts, modelling approaches based exclusively on causal block diagrams may become restrictive, especially when dealing with multi-domain physical systems, hybrid continuous/discrete dynamics, and tightly integrated control architectures. This tutorial introduces the principles of equation-based object-oriented modelling through the Modelica language and the OpenModelica environment. The tutorial combines a compact introduction to the modelling paradigm with hands-on examples and modelling activities. Participants will see how physical and control-oriented models can be developed within a unified equation-based framework using reusable components and acausal connections. Examples will include hybrid and controlled systems involving continuous-time dynamics, sampled-data control, logical supervision, and switching behaviours. The tutorial will also present selected examples drawn from ongoing research on cyber-physical and energy-aware systems, together with a brief overview of interoperability standards such as FMI and open modelling workflows.

Technical Program for Wednesday June 24, 2026

WeAA	Aula Magna "Guido Bossi"
Linear Systems (Regular Session)	
Chair: Scaradozzi, David	Università Politecnica Delle Marche
Co-Chair: Loiseau, Jean Jacques	CNRS

11:00-11:30 WeAA.1

Invited Lecture: "*50+ years of the Geometric approach to the Theory of Dynamical Systems*"

Conte, Giuseppe	Accademia Marchigiana di Scienze, Lettere ed Arti
Perdon, Anna Maria	Accademia Marchigiana di Scienze, Lettere ed Arti
Zattoni, Elena	Alma Mater Studiorum Università di Bologna

The paper briefly reviews the developments of the Geometric Approach to various classes of dynamical systems. Focusing on the main notion of controlled invariance and referring in particular to the disturbance decoupling problem, extensions from the classical case of linear systems to nonlinear systems, systems over rings, hybrid systems and other classes of systems are examined and discussed, pointing out similarities and differences. The overall picture shows how the Geometric Approach is a versatile, powerful and efficient way to deal with complex control problems in many situations.

11:30-11:45 WeAA.2

The Computation of Congruential Closures Over the Max-Plus Semiring

Loiseau, Jean Jacques	CNRS
Martinez, Claude	LS2N (UMR CNRS 6004) and IUT De Nantes

Max-plus algebra R_{max} is the set of real numbers, endowed with the operations max and the usual addition, and completed by minus infinity as neutral element of the first oeration. A congruence over the max-plus semiring is a submodule of $R^{2n}{}_{max}$ that defines an equivalence relation over $R^{n}{}_{max}$. The kernel of a matrix is an example of congruence. For the sake of observation of a max-plus dynamical system, it is useful to compute conditioned invariant congruences. A crucial step in the computation algorithm consists in constructing the least congruence containing a given submodule of $R^{2n}{}_{max}$. We analyse this problem and describe how to complete a module to calculate its reflexive, symmetric, or transitive closures. We further analyse the case of a module defined as the image of a kernel, which corresponds to the computation of the least conditioned invariant congruence containing a given congruence.

11:45-12:00 WeAA.3

Residual Filter for Positive Systems Based on Coupled Differential-Difference Equations with Bounded Delays

Krokavec, Dusan	Technical University of Kosice
Filasova, Anna	Technical University of Kosice

This paper deals with an additive fault residual filter design for positive systems based on coupled differential-difference equations with bounded delays. New design conditions are defined using linear matrix inequalities with diagonal positive definite matrix variables to satisfy the diagonal stabilization rule and parametric system constraints. Finally, a

numerical example is given to confirm the validity of the synthesis result.

12:00-12:15 WeAA.4

Chatter Suppression in Turning Via the Maximal Multiplicity Approach: A Rightmost Characteristic Root Assignment

Castorena-Minor, Hugo D. Cinvestav
Saldivar, Martha Belem Cinvestav
Boussaada, Islam University Paris Saclay & IPSA

The present paper proposes a Proportional-Minus Delay control law that ensures chatter suppression in turning. The presented approach is based on a poles placement idea itself relying on a spectral property called Multiplicity-Induced-Dominancy. The main contribution of this paper is chatter suppression in turning processes through enforcing a triple real root in the closed-loop characteristic quasipolynomial as the rightmost spectral value. Hence, prescribing the desired root is equivalent to prescribe the desired decay-rate of the closed-loop time-domain response. Frequency domain and time-domain simulations are provided to illustrate the obtained result.

12:15-12:30 WeAA.5

A Lyapunov-Matrix Based Approach to the Stability Analysis of the Turning Process

Castorena-Minor, Hugo D. Cinvestav
Saldivar, Martha Belem Cinvestav
Mondie, Sabine CINVESTAV-IPN

This work aims to determine stability regions for turning processes based on a normalized amplitude of vibration formulation in the parameter plane: the normalized rotation frequency and the normalized limit depth of cut, using both time and frequency domain techniques. For the time domain, the delay Lyapunov-matrix based approach is employed, while for the frequency domain approach, the D-partitions method is applied. In particular, an interesting result of this work is that the delay Lyapunov-matrix approach provides a non-conservative description of the stability region, offering an alternative analysis tool whose application can be extended to more complex analyzes such as stability analysis of nonlinear turning models taking into account parameter uncertainties, and control-design guidelines for chatter suppression.

WeAB	Room 155/d2
Autonomous Systems 1 (Regular Session)	
Chair: Sklyar, Grigory	West Pomeranian University of Technology

11:00-11:15 WeAB.1

Collision Avoidance for Non-Cooperative Multi-Swarm Coverage Control with Bounded Disturbance Measurements

Schmidt, Karolina — Concordia University

Rodrigues, Luis — Concordia University

This paper proposes a methodology for collision-free motion in multi-agent scenarios. The method specifically accounts for disturbances and bounded uncertainty in their measurements. Formal guarantees for collision avoidance are derived. The proposed methodology is then used to develop an algorithm for collision-free coverage control with multiple non-cooperating swarms accounting for disturbances and bounded uncertainty in their measurements. The theoretical results are validated through simulations of multiple swarms that independently aim to cover a given region in an environment with bounded disturbances.

11:15-11:30 WeAB.2

Autonomous Water Surface Pollution Source Localization Using Deep Reinforcement Learning

Kulkarni, Raunak — University of Bremen

Clemens, Joachim — Bremen University

Schill, Kerstin — University of Bremen

The strategy to autonomously navigate and find the source of a pollution over the water surface fosters robust and continuous environmental monitoring without reliance on human operator in dynamic and hazardous environments over the surface of water. The objective of this research is to investigate, evaluate and deploy autonomous pollution source localization strategy using reinforcement learning on an Unmanned Surface Vessel (USV). The research vehicle possesses known capabilities for static environment mapping, localization, path planning and motion controller, as well as the ability to make intelligent decisions using behavior trees. The proposed pollution source localization strategy is developed and evaluated in simulation, where the research vehicle explores an unknown pollution environment and locates the source of pollution using a trained reinforcement learning agent. Test results are compared with primitive strategies to evaluate the proposed strategy. Finally, the results of simulation demonstrations showcased the designed strategy that guided the research vehicle toward a pollution source on the water's surface.

11:30-11:45 WeAB.3

Realizability and Homogeneous Approximation Problems for Nonlinear Control Systems: A Unified Algebraic Approach Based on a Left Ideal

Sklyar, Grigory — West Pomeranian University of Technology

Ignatovich, Svetlana — V.N. Karazin Kharkiv National University

In this paper, we study nonlinear control systems that are linear in the control by representing them as series in the free associative algebra of iterated integrals. We clarify the role of the left ideals generated by the system in two fundamental problems: the realizability problem and the homogeneous approximation problem. In particular, we show

that both the construction of a realizing system and that of a homogeneous approximating system are carried out using the annihilator of the corresponding left ideal, which is graded in the case of the homogeneous approximation problem.

11:45-12:00 WeAB.4

Intelligent Path Planning and Control for Autonomous Underwater Exploration

Veronese, Delia	University of Padua
Sumathy, Vidya	Luleå University of Technology
Haluska, Jakub	Luleå University of Technology
Nikolakopoulos, George	Luleå University of Technology, Sweden

This paper presents a comprehensive framework for the modeling, control, and autonomous operation of a BlueROV2 underwater vehicle. A 6-DOF nonlinear dynamical model is formulated, incorporating hydrodynamic effects and the specific thruster configuration of the heavy setup. The core of the work is the design of an augmented Model Predictive Controller (MPC) with integral action, developed to handle multi-variable dynamics and actuator constraints. The architecture is validated through a transition from MATLAB and ROS/Gazebo simulations to real-world pool experiments. A key contribution is the implementation of a low-level communication pipeline based on RC/PWM override via MAVROS, which enables autonomous remote control in GPS-denied environments without relying on high-level guided modes. Experimental results demonstrate the controller's robustness in stabilization and vertical motion, specifically its ability to compensate for unmodeled asymmetric disturbances. This work establishes a modular and reliable software infrastructure for future perception-driven autonomous underwater missions.

12:00-12:15 WeAB.5

Coalitional NMPC for Multi-Agent Systems with Static and Dynamic Obstacle Avoidance

Silva, Juliana S. F.	Federal University of Minas Gerais
Santos, Marcelo Alves	University of Bergamo
Raffo, Guilherme Vianna	Federal University of Minas Gerais

Distributed control schemes are essential for scalable multi-agent coordination, as they enhance communication efficiency and ensure safe interactions. Among these approaches, coalitional Model Predictive Control (MPC) stands out as a promising strategy capable of reducing information exchange through cooperation within dynamic clusters. Previous studies have successfully applied coalitional MPC to process and infrastructure systems, yet its use in autonomous navigation remains limited and typically does not address safety requirements such as obstacle avoidance. Motivated by this potential, this work proposes a coalitional Nonlinear MPC (NMPC) framework for multi-agent navigation based on a tracking formulation with artificial variables. This framework integrates Control Barrier Functions (CBFs) for static obstacles and reciprocal Acceleration-Velocity Obstacles (AVO) along with Optimal Reciprocal Collision Avoidance (ORCA) constraints for dynamic interactions. Results demonstrate safe navigation and dynamic coalition formation with a 21% relative reduction in the average normalized solver time per agent, compared to all-to-all communication, highlighting the framework's potential for efficient large-scale coordination.

12:15-12:30 WeAB.6

Particle Filter-Based Fusion of PDR and Geomagnetic Field for Indoor Localization

Medjahed, Ramdane	Ecole Militaire Polytechnique, Bordj El-Bahri, Algeria

Rabah, Louali	Ecole Militaire Polytechnique, Bordj El-Bahri, Algeria
Aimen Abdelhak, Messaoui	Ecole Superieure Ali Chabati, Reghaia, Algeria
Nabil, Hebbache	Ecole Militaire Polytechnique, Bordj El-Bahri, Algeria
Nemra, Abdelkrim	Ecole Militaire Polytechnique,
Baya, Melissa Azem	University of Boumerdes, Algeria
Lynda, Belounis	University of Boumerdes, Algeria
Atmane, Khellal	Ecole Militaire Polytechnique, Bordj El-Bahri, Algeria
Mehrez, Boulahmar	Ecole Militaire Polytechnique, Bordj El-Bahri, Algeria

Accurate indoor positioning remains a major challenge in GPS-denied environments. This work presents a high-precision indoor localization system based on the fusion of Pedestrian Dead Reckoning (PDR) and geomagnetic fingerprinting using a particle filter framework. A Gaussian Process (GP) model is employed to generate smooth and uncertainty-aware magnetic maps, while PDR provides motion-based localization. A key contribution is a motion-based proposal distribution that preserves high-weight particles and updates them with the PDR model, focusing the search on plausible trajectories and improving convergence over fully random particle propagation. The system is implemented in a real-time client--server architecture, offloading computationally intensive filtering to a server for efficient execution. Experimental validation demonstrates that the proposed fusion approach significantly outperforms standalone PDR and magnetic-only localization, achieving sub-meter accuracy with substantially reduced computational requirements, confirming that geomagnetic--inertial fusion provides high accuracy for infrastructure-free indoor navigation.

WeAC	Room 155/d3
Aerospace Control (Regular Session)	
Chair: Invernizzi, Davide	Politecnico Di Milano
Co-Chair: Bruschi, Pietro	Politecnico Di Milano

11:00-11:15 WeAC.1

Effects of Unknown Target Satellite on the Orbital Frame in Rendezvous Maneuvers

Pilone, Fabrizio — University of Pisa
Romagnoli, Giovanni — University of Pisa
Bucchioni, Giordana — University of Pisa

Autonomous rendezvous and proximity operations play a central role in a broad range of current and future space missions, including on-orbit servicing, inspection, debris removal, and cislunar exploration. Most guidance and control strategies for these maneuvers are formulated in a Local-Vertical Local-Horizontal (LVLH) reference frame centered on a target satellite, I mplicitly assuming an accurate knowledge of the target spacecraft's orbital state. While this assumption is generally valid in cooperative scenarios, it becomes questionable when the target is non-cooperative or poorly characterized. In such cases, errors in the estimated target state propagate directly into the definition of the LVLH frame, potentially degrading control performance and compromising safety. This paper investigates the impact of target state uncertainties on LVLH-based rendezvous maneuvers. Through analytical considerations and high-fidelity numerical simulations, the effects of reference frame misalignment are quantified in terms of tracking accuracy, fuel consumption, and constraint satisfaction. The results provide an overview of the weaknesses and limitations of LVLH-based guidance and control architectures when operating under realistic target uncertainties.

11:15-11:30 WeAC.2

Trajectory Control Design for Air-Launch Vehicle

Raharema, Najwa Rashika Az-Zahra — Bandung Institute of Technology
Sasongko, Rianto Adhy — Bandung Institute of Technology
Poetro, Ridanto Eko — Bandung Institute of Technology

Most small satellites reach orbit through ridesharing, which limits the launch schedule and target orbit selection. The Air-Launch to Orbit (ALTO) method offers an alternative to provide operational flexibility. However, air-launch vehicles flight profile exhibits rapidly changing dynamics driven by dynamic pressure changes, staging events, and control effector transitions. This work develops a longitudinal trajectory control architecture for Pegasus XL air-launch vehicle model from Stage 1 ignition to orbital insertion. The vehicle dynamics are approximated by a set of local Linear Time Invariant (LTI) models. For each stage, a guidance reference command is constructed and a set of Linear Quadratic Regulator (LQR) tracking controller is designed using the corresponding local LTI model. The vehicle model and control framework are evaluated through numerical simulation. The results show that the designed control architecture closely met the orbital insertion targets at t = 584.75 s with a near zero flight path angle and small radial velocity residual, resulting in a slightly elliptical orbit.

11:30-11:45 WeAC.3

Reinforcement Learning for Autonomous Satellite Inspection: An Integrated Framework for Orbit Planning and Resource Management

Gemignani, Gabriele — University of Pisa

Salzo, Francesco Paolo University of Pisa
Bucchioni, Giordana University of Pisa
Pollini, Lorenzo University of Pisa

The increasing density of near-Earth orbiting objects calls for higher autonomy in Space Situational Awareness (SSA) missions, particularly for long-duration inspection tasks. Beyond relative motion control, such missions require high-level decision-making to schedule inspection, communication, and recharging activities under limited onboard resources. This paper proposes a Markov Decision Process (MDP) formulation for autonomous satellite inspection around an Earth-orbiting target, where the agent selects among a discrete set of pre-defined orbital maneuvers and operational tasks. The environment combines simplified relative dynamics with models of energy and data resources, enabling the study of mission-level trade-offs rather than low-level trajectory design. A Reinforcement Learning (RL) agent is trained using a multi-objective reward that balances information gain, propellant usage, and resource feasibility. Simulation results across stochastic scenarios show that the learned policy achieves strong mission performance while significantly reducing online computational effort compared to optimization-based and heuristic baselines.

11:45-12:00 WeAC.4

Predecessor-Follower All-Electric Aircraft Platoons Performing String-Stable Coordinated Turns

Souza e Silva, Lucas Concordia University
Rodrigues, Luis Concordia University

This paper presents, for the first time, an optimal control framework to compute the airspeed of all-electric aircraft in predecessor-follower platoons performing coordinated turns. The optimal airspeed is obtained by minimizing a cost function that combines operating costs and airspace complexity. Moreover, an analytical suboptimal solution is derived, from which sufficient conditions are established for the string stability of all-electric aircraft platoons executing coordinated turns. Three simulated flight scenarios were considered to assess airspeed, bank angle, and aircraft separation. The results indicate that string stability is maintained throughout the procedure. The proposed methodology may be integrated into the traditional air traffic environment to aid the implementation of novel air transportation technologies, such as advanced air mobility.

12:00-12:15 WeAC.5

Task-Priority Control of Space Robots Using Control Lyapunov and Control Barrier Function

Dedomenici, Luca Politecnico Di Milano
Bruschi, Pietro Politecnico Di Milano
Rubinacci, Roberto Politecnico Di Milano
Invernizzi, Davide Politecnico Di Milano

This paper proposes a task-priority, optimization-based kinematic control framework for space robots based on Control Lyapunov Functions (CLFs) and Control Barrier Functions (CBFs). Building upon recent CLF–CBF formulations for redundant manipulators, the proposed method extends task-priority control to space robotics through a hierarchical Quadratic Programming (QP) structure, where safety constraints are enforced as hard inequalities via CBFs, while tracking objectives are encoded as soft CLF constraints. The framework enables systematic handling of multiple objectives, coordinated base–manipulator motion, and formal safety guarantees in proximity operations. The

approach is validated in simulation on a planar free-flying space robot performing the autonomous capture of a non-cooperative target.

12:15-12:30	WeAC.6

Motion Primitive–Based Kinodynamic Planning for Full-Flight Regime Lift+Cruise VTOL UAVs

Bona, Francesco	Politecnico Di Milano
Manzoni, Marta	Politecnico Di Milano
Invernizzi, Davide	Politecnico Di Milano

Hybrid Unmanned Aerial Vehicles (UAVs) combining Vertical Take-Off and Landing (VTOL) and fixed-wing flight are gaining interest in advanced air mobility due to their maneuverability, efficiency, and high cruise speed. Planning safe and dynamically feasible trajectories for these vehicles is challenging due to nonlinear dynamics, non-convex collision constraints, and time-varying control limits, especially during transitions between flight regimes. Kinematic approaches commonly adopted for VTOL planning neglect these effects and may yield infeasible paths. In this paper, we apply a general kinodynamic motion planning framework to generate a complete full-flight-regime mission for a Lift+Cruise VTOL UAV. A motion primitive library is computed offline via direct optimal control, covering multirotor, transition, and fixed-wing phases. Online, a search-based planner concatenates primitives to produce an initial trajectory with bounded junction discontinuities that are subsequently removed through a smoothing step. Numerical results on a simplified 2D VTOL model show that the method produces smooth, dynamically feasible trajectories across all flight regimes, successfully managing the transition phase.

WeAD	Room 155/d4
System Identification (Regular Session)	
Chair: Rodrigues, Luis	Concordia University
Co-Chair: Mukherjee, Joyjit	Birla Institute of Technology and Science Pilani, Hyderabad Campus

11:00-11:15 WeAD.1

Evaluating Hybrid Automata Learning Tools Based on Their Success in Formal Verification

Kochdumper, Niklas	Technical University of Munich
Hsieh, Chiao	Kyoto University
Dayekh, Hadi	VERIMAG, Université Grenoble Alpes, Grenoble INP, CNRS
Gurung, Amit	UPES
Dang, Thao	VERIMAG
Waga, Masaki	Kyoto University
Segawa, Hidekazu	Mitsubishi Electric Corporation
Suenaga, Kohei	Kyoto University

Learning hybrid automata models from data is an active area of research, with numerous approaches and tools proposed in recent years. A major challenge in comparing the performance of different learning methods lies in selecting an appropriate metric for evaluating model accuracy, since different metrics can yield significantly different conclusions. Motivated by a typical toolchain for the formal verification of real-world systems, consisting of system identification, conformant synthesis, and formal verification, we propose using the size of the reachable set of the conformant model as a performance metric for hybrid automata learning approaches. The reasoning behind this choice is that the size of the reachable set largely determines whether successful verification is possible, with more accurate hybrid automata models tending to produce smaller reachable sets. To demonstrate the utility of this metric, we evaluate it on several hybrid system benchmarks, including an industrial case study involving a boost-converter circuit. Our evaluation compares three state-of-the-art automaton learning approaches that exhibit distinct methodological characteristics.

11:15-11:30 WeAD.2

Identification of Alumina Transport Dynamics in Hall-H´eroult Cells

Giorgetti, Folco	University of Perugia
Mattioni, Andrea	Rio Tinto
da Silva Moreira, Lucas Jose	Rio Tinto
Fiacchini, Mirko	GIPSA-Lab, CNRS
Besancon, Gildas	Grenoble INP UGA, Gipsa
Ferrante, Francesco	Università Degli Studi Di Perugia
Roustan, Hervé	Rio Tinto
Fravolini, Mario Luca	University of Perugia

This paper addresses the modeling and identification of alumina transport dynamics in aluminum reduction cells. A structured parameterization of the exchange matrix governing alumina transport between zones is proposed, capturing the combined effects of convection and diffusion. The identifiability of the resulting parameterization is analyzed

numerically, and a parameter estimation framework is formulated using measurements of individual anode currents and cell voltage. The approach is validated using industrial data, showing that the identified model reproduces the spatial distribution of anodic currents and provides insight into the internal flow structure of the cell.

11:30-11:45 WeAD.3

Enhancing the Performance of Kalman Filters Via Monte Carlo Approaches and Riemannian-Manifold Covariance Estimation

Manca, Giorgio	PhD Student at Italian National Program in Autonomous Systems
Sassano, Mario	University of Rome, Tor Vergata
Galeani, Sergio	University of Rome Tor Vergata
Carnevale, Daniele	University of Rome

The Kalman filter and its extended variant are widely used algorithms for state estimation of dynamic systems. Given the system dynamics and measurement model, estimation performance critically depends on selecting accurate noise covariance matrices to describe disturbances and uncertainties. This work proposes a systematic method for optimizing these matrices within the linear Kalman filter framework via numerical gradient descent, employing Monte Carlo approaches to improve the robustness against data noise and utilizing optimization methods on Riemannian manifolds to preserve positive definiteness. The proposed approach is validated through numerical examples, demonstrating not only improved performance for the linear Kalman filter but also its effectiveness when applied to the extended Kalman filter.

11:45-12:00 WeAD.4

PWARX-Based Virtual Sensing for Cavity-Center Temperature Estimation in Domestic Ovens under Embedded Implementation Constraints

Millo, Nicolò Ermanno	University of Trieste
Burattini, Giulio	Electrolux S.p.A
Pin, Gilberto	Electrolux Italy
Raimondo, Davide Martino	University of Trieste
Salvato, Erica	University of Trieste

The cavity-center temperature is a key indicator of cooking performance and energy efficiency in domestic electric ovens. Since this quantity cannot be measured directly during normal operation, it must be estimated from sensors available in the appliance. Industrial solutions typically rely on a calibrated static correction of a wall-mounted temperature measurement. While simple and effective in nominal conditions, this approach has limited ability to reproduce the nonlinear thermal behavior induced by different operating modes and load conditions. This paper presents a virtual sensor for cavity-center temperature estimation based on a Piecewise AutoRegressive model with eXogenous inputs (PWARX). The model is identified through a modified K-means clustering procedure and uses only signals available during normal operation. The resulting estimator is suitable for embedded implementation. Experimental tests on a domestic electric oven show a clear improvement over the industrial baseline, with RMSE reductions of about 40% in convection mode and 45% in static mode, while requiring less than $SI{1}{kilobyte}$ of memory.

12:00-12:15 WeAD.5

LeARN: Learnable and Adaptive Representations for Nonlinear Dynamics in System Identification

Singh, Arunabh — Indian Institute of Science, Bengaluru
Mukherjee, Joyjit — Birla Institute of Technology and Science Pilani, Hyderabad Campus

System identification, the process of deriving mathematical models of dynamical systems from observed input-output data, has undergone a paradigm shift with the advent of learning-based methods. Addressing the intricate challenges of data-driven discovery in nonlinear dynamical systems, these methods have garnered significant attention. Among them, Sparse Identification of Nonlinear Dynamics (SINDy) has emerged as a transformative approach, distilling complex dynamical behaviors into interpretable linear combinations of basis functions. However, SINDy's reliance on domain-specific expertise to construct its foundational 'library' of basis functions limits its adaptability and universality. In this work, we introduce a nonlinear system identification framework LeARN that transcends the need for prior domain knowledge by learning the library of basis functions directly from data. To enhance adaptability to evolving system dynamics under varying noise conditions, we employ a novel meta-learning-based system identification approach that utilizes a light-weight Deep Neural Network (DNN) to dynamically refine these basis functions. This not only captures intricate system behaviors but also adapts effectively to new dynamical regimes. We validate our framework on the Neural Fly dataset, showcasing its robust adaptation and generalization capabilities. Despite its simplicity, our LeARN achieves competitive dynamical error performance to SINDy. This work presents a step towards autonomous discovery of dynamical systems, paving the way for a future where machine learning uncovers the governing principles of complex systems without requiring extensive domain-specific interventions.

12:15-12:30 WeAD.6

Least Squares Training of Deep Quadratic Neural Networks

Amiri Fard, Mohammad Reza — Concordia University
Rodrigues, Luis — Concordia University

Deep neural networks effectively model nonlinear functions but are typically trained by non-convex, gradient-based optimization. The main contribution of this paper is to show that the training of deep quadratic neural networks (DQNNs) can be equivalently formulated as a least squares problem. We first show that the output of a DQNN is a polynomial function of the input and derive an upper bound on its polynomial degree in terms of the network's depth. Based on this property, it is shown that a DQNN can be represented exactly by a lifted two-layer quadratic neural network (QNN) when the input is augmented with monomials of a sufficiently high degree. A relation between the DQNN depth and the lifting degree required for exact representation is also derived. This representation leads to a training approach in which the lifted two-layer QNN parameters are obtained by solving a least squares problem when the regularization term is not included, yielding a closed-form solution that achieves the global optimum for the ell_2 loss. Moreover, the resulting model provides an explicit input--output expression that facilitates subsequent analysis. System identification of a flexible robot arm validates the proposed method.

WeBA	Room 155/d1
Predictive Control (Regular Session)	
Chair: Vyhlidal, Tomas	Czech Technical University in Prague, Faculty of Mechanical Engineering
Co-Chair: Fourlas, George K.	University of Thessaly

14:00-14:15 WeBA.1

Koopman-Based Multi-Step Prediction of Nonlinear Body-Velocity Dynamics for an Underwater Vehicle

Fourlas, George K. University of Thessaly

Karras, George University of Thessaly

Autonomous marine vehicles operate in environments where hydrodynamic nonlinearities strongly influence the resulting velocity response. For underwater platforms such as the BlueROV2, accurate short- and medium-horizon prediction of body velocities is important not only for control design but also for monitoring and diagnostic tasks. In this work, the BlueROV2 platform is used as a reference system in order to construct and evaluate a reduced-order velocity predictor derived from simulation data. The study compares two identification approaches, a discrete-time linear time-invariant (LTI) model derived directly from data and a Koopman-based lifted linear predictor, identified through Extended Dynamic Mode Decomposition with control (EDMDc). Model performance is evaluated using one-step prediction error, multi-step root-mean-square error (RMSE) across horizons up to fifty steps, and long-horizon free-run simulations. The results show that both models provide similar accuracy for one-step prediction, whereas differences become more pronounced as the prediction horizon increases. Particularly, the Koopman-based predictor presents improved robustness in multi-step predictions and better preservation of velocity dynamics in long free-run simulations. These results show that Koopman lifting offers an effective balance between physical interpretability and predictive accuracy for marine vehicle velocity dynamics.

14:15-14:30 WeBA.2

Human Attention-Aware Motion Planning for Social Robot Navigation

Jeddi, Mohammad Università Di Modena E Reggio Emilia

Gaetan, Elisa PoliBa

Falcone, Paolo Chalmers University of Technology

Giarre', Laura Universita' Di Modena E Reggio Emilia

his paper presents a human attention-aware motion planning framework for social robots navigating human-populated environments. Collision avoidance is formulated as a Control Barrier Function (CBF) embedded in a receding-horizon Model Predictive Control (MPC) problem, with slack variables that relax the CBF constraints while maintaining a non-zero safety margin. Relaxation is optimally regulated via a cost term weighted by an attentiveness coefficient, allowing the controller to adjust its conservativeness based on perceived awareness of nearby humans. Simulation studies with one and two humans show that low attention leads to conservative, collision-averse behavior, while close attention permits less conservative yet safe maneuvers, demonstrating the framework's context-adaptive navigation capabilities.

14:30-14:45 WeBA.3

Hierarchical Nonlinear MPC for Interception and Autonomous Landing of a Quadrotor UAV on a Moving Platform

Abulkassov, Bakhtiyar	Astana IT University
Makhmudova, Valeriya	Astana IT University
Amangeldi, Arystan	Astana IT University
Kusdavletov, Sanzhar	Coventry University Kazakhstan

This paper presents a hierarchical nonlinear model predictive control (NMPC) system for autonomous landing of a quadrotor on a moving platform. The proposed framework splits the control problem into two predictive layers operating at different time scales: a high-level interception MPC planner that predicts the future motion of the platform and generates a dynamically feasible reference trajectory, and a low-level NMPC controller that tracks the reference using the full nonlinear quadrotor dynamics. To improve closed-loop performance, a data-driven calibration is introduced that automatically tunes both high-level planner and low-level controller parameters using the GLIS global optimization algorithm. The results from numerical simulations shows that the proposed hierarchical NMPC scheme achieves reliable interception and landing on maneuvering platforms while satisfying system constraints and maintaining stable tracking performance.

14:45-15:00 WeBA.4

Model Predictive Control for Epidemic Containment

Ajami, Mohamad	GIPSA-Lab
Sonveaux, Candy	University of Namur
Dumont, Morgane	HEC-Liege - Management School of ULiege
Fiacchini, Mirko	GIPSA-Lab, CNRS

This work proposes a Model Predictive Control (MPC) approach for epidemic containment, using COVID-19 in Wallonia, Belgium, as a case study. The proposed framework presents an optimal age-structured vaccination strategy that aims to minimize fatalities, promote early disease eradication, and adhere to operational constraints. By incorporating an age-structured Susceptible–Infected–Recovered–Deceased model with an explicit vaccination term, the MPC strategy adapts dynamically to the evolving epidemic states. Formal proofs of asymptotic stability and recursive feasibility of the proposed MPC algorithm are provided.

15:00-15:15 WeBA.5

ILQR Regularization Using Minimal Hessian Modification

Lieskovský, Juraj	Czech Technical University in Prague
Busek, Jaroslav	Czech Technical University in Prague
Vyhlidal, Tomas	Czech Technical University in Prague

Trajectory optimization solvers widely utilize modified variants of the iterative linear-quadratic regulator. When applied to problems with non-convex cost functions, these methods require regularization to ensure numerical stability and convergence. In this paper, we propose a regularization approach inspired by Hessian modification techniques from nonlinear programming. Unlike existing methods, the proposed approach guarantees a successful backward pass in every iteration and produces a locally stabilizing feedback policy as a byproduct. We also demonstrate that when applied to a benchmark trajectory optimization problem, it outperforms existing regularization approaches.

15:15-15:30 WeBA.6

Efficient Collision-Avoidance Constraints for Ellipsoidal Obstacles in Optimal Control:

Application to Path-Following MPC and UAVs

Leprich, David	University of Stuttgart
Rosenfelder, Mario	University of Stuttgart
Herrmann-Wicklmayr, Markus	Saarland University
Flaßkamp, Kathrin	Saarland University
Ebel, Henrik	University of Stuttgart
Eberhard, Peter	University of Stuttgart

This article proposes a modular optimal control framework for local three-dimensional ellipsoidal obstacle avoidance, exemplarily applied to model predictive path-following control, where static as well as moving obstacles are considered. Central to the approach is a computationally efficient and continuously differentiable condition for detecting collisions with ellipsoidal obstacles. A novel two-stage optimization approach mitigates numerical issues arising from the structure of the resulting optimal control problem. The effectiveness of the approach is demonstrated through simulations and real-world experiments with the Crazyflie 2.1 quadrotor. This represents the first hardware demonstration of an MPC controller of this kind for UAVs in a three-dimensional task.

WeBB	Room 155/ d2
Autonomous Systems 2 (Regular Session)	
Chair: Loizou, Savvas	Cyprus University of Technology
Co-Chair: Hayajneh, Mohammad	The Hashemite University

14:00-14:15 WeBB.1

An Integrated Autonomous Catamaran for Marine Environmental Monitoring and Debris Collection

Hayajneh, Mohammad	Hashemite University
Mahmoud, Hosam	Hashemite University
Al Abed, Giana	Hashemite University
Khalaf, Tanya	Hashemite University
Junaidy, Fayez	Hashemite University

This paper presents the design, modeling, and implementation of AutoBoat, an integrated autonomous catamaran system developed for intelligent aquaculture management and marine environmental preservation. The system addresses the challenges of labor-intensive fish farm maintenance by combining real-time water quality monitoring, automated feeding, and AI-driven surface debris collection within a single mobile platform. A three-degree-of-freedom (3-DOF) dynamic model of the vessel is derived, and a hierarchical control architecture is implemented featuring an NVIDIA Jetson Xavier NX for high-level perception and a Pixhawk autopilot for low-level navigation. A core contribution is the development of an autonomous switching logic that transitions propulsion between underwater thrusters and air propellers to ensure operational continuity in extreme weed-infested or shallow-water environments. Experimental results demonstrate 92% precision in debris detection using an optimized YOLOv11 model and robust trajectory following with a cross-track error within ±0.4 meters through refined PID tuning. The proposed system offers a scalable and sustainable solution for enhancing environmental stability in modern aquaculture.

14:15-14:30 WeBB.2

Sequential Multi-Agent Deep Reinforcement Learning for Platooning across Diverse Road and Leader Behaviors

Berdini, Emanuele	Sapienza University of Rome
Wrona, Andrea	Sapienza University of Rome
Menegatti, Danilo	University of Rome "La Sapienza"
Delli Priscoli, Francesco	Università Di Roma

Safety and efficiency are key challenges in autonomous vehicle platooning, particularly in scenarios where vehicles operate without inter-vehicle communication and must rely solely on local sensing. This work proposes a decentralized multi-agent platooning strategy based on Deep Reinforcement Learning, adopting a Predecessor-Based Sequential Training scheme in which follower vehicles are trained sequentially along the platoon. Under this approach, each agent learns a control policy using only local measurements of the preceding vehicle, enabling fully decentralized execution. The framework is evaluated in two representative scenarios: a highway environment with non-zero road grade and an urban setting characterized by stop-and-go leader behavior. Simulation results show that the proposed approach maintains safe inter-vehicle spacing and accurate speed tracking across both scenarios, demonstrating robustness to environmental disturbances and varying traffic conditions.

14:30-14:45 WeBB.3

Seabed-To-Sky Mapping of Maritime Environments with a Dual Orthogonal SONAR and LiDAR Sensor Suite

Westerdahl, Christian	Technical University of Denmark
Poulsen, Jonas	Technical University of Denmark - DTU
Holmelund, Daniel	Technical University of Denmark (DTU)
Hansen, Peter Nicholas	Technical University of Denmark
Thompson, Fletcher	Terma
Galeazzi, Roberto	Technical University of Denmark

This paper presents a GNSS-independent mapping framework that generates unified seabed-to-sky maps using LiDAR–IMU odometry and a dual orthogonal Forward-Looking Sonar (FLS) configuration. Localization is provided by the LiDAR–IMU subsystem, while acoustic measurements enrich the map with underwater structure. We extend orthogonal wide-aperture sonar fusion to support arbitrary inter-sonar translations, enabling the use of heterogeneous, non-co-located sensors. In addition, leading-edge extraction is applied to each FLS image to generate line-scan measurements that complement stereo-derived 3D sonar points. To integrate acoustic and LiDAR data, LIO-SAM is modified to incorporate both sonar point clouds and line scans at and between keyframes through motion-interpolated poses, allowing asynchronous sonar observations to contribute continuously to the map. The framework is validated on real-world data collected in Copenhagen harbour, demonstrating real-time operation with map and odometry update rates of approximately 2.65 Hz and 2.85 Hz, respectively. Experimental results show that the proposed system produces consistent, unified 3D representations spanning both underwater and above-surface environments, enabling robust maritime mapping in GNSS-denied conditions.

14:45-15:00 WeBB.4

Real-Time Motion Planning for Fully Actuated Autonomous Surface Vehicles

Damerius, Robert	University of Rostock
Eisenblätter, Nick	University of Rostock
Marx, Johannes Richard	University of Rostock
Mohd Fadil, Muhammad Khalis bin	University of Rostock
Jeinsch, Torsten	University of Rostock

This paper presents a motion planning algorithm for fully actuated autonomous surface vehicles, focusing on maneuvering in the vicinity of nonmoving obstacles. The proposed method calculates a collision-free trajectory from an initial motion state to a given goal pose. All nonmoving obstacles and the geometric shape of the vehicle are represented by convex polygons. The motion planner is based on an RRT* algorithm that samples a 3-dimensional configuration space. To generate optimal paths in the tree a cost function is defined that includes the path length, the distance to obstacles and the longitudinal movement of the vehicle along a path. For each branch, trajectories are generated by a numerical integration of a closed-loop control system that contains the nonlinear vehicle dynamics. These trajectories are used for collision testing with obstacles. The rewire procedure of the RRT* algorithm is modified to ensure that all branches affected by the reconnection remain dynamically feasible and collision-free. The proposed method is validated on realistic scenarios.

15:00-15:15 WeBB.5

Unified Stochastic Nonlinear MPC-Control Barrier Function Framework for Safe and

Optimal Autonomous Vehicle Collision Avoidance

Heyi, Muluneh Hailu	Université Bourgogne Europe
Hima, Salim	ESME Research LAB, France
Chaibet, Ahmed	Université Bourgogne Europe

Safe navigation of autonomous vehicles in uncertain and dynamic traffic environments remains a major challenge. This paper proposes a unified control framework, SNMPC-CBF, combining Stochastic Nonlinear Model Predictive Control (SNMPC) and Control Barrier Functions (CBF) to ensure collision-free trajectory planning under uncertainty. Safety constraints are formulated as Mahalanobis-distance-based chance constraints, enabling adaptive risk adjustment through a tunable confidence level β while preserving feasibility and closed-loop stability. The framework jointly optimizes longitudinal and lateral control and adapts safety margins in real time under disturbances due to surrounding traffic. Experiments on real highway scenarios from the highD dataset demonstrate faster obstacle clearance and smoother lane changes compared with deterministic NMPC. For $\beta \in [0.4, 0.95]$, the ego vehicle successfully performs lane change, overtaking, and lane return maneuvers without collision.

15:15-15:30 WeBB.6

Reference Surface-Following Guidance for Fuel-Efficient Terrain-Aware Precision Soft Landing

Barad, Abhishek	Indian Institute of Technology, Madras
Ghosh, Satadal	Indian Institute of Technology Madras
Swaminathan, Shriram	Vikram Sarabhai Space Center

During autonomous powered descent for planetary landing, it is essential to simultaneously ensure terrain avoidance, respect thrust limits, and achieve a soft, precise touchdown with low fuel usage. This paper presents a lightweight analytical guidance framework that augments a nominal fuel-efficient landing guidance law with a reference surface-guided terrain-avoidance mechanism. A virtual barrier surface is first constructed to cover the hazardous terrain. A prescribed clearance margin is then imposed over this barrier to obtain a safety-offset barrier surface, which defines the safe region used for guiding the lander during descent. Subsequently, a time-varying reference surface is considered that serves the dual purpose of ensuring motion safety of the lander and facilitating precision touchdown at the desired landing site. The commanded acceleration is computed as a minimal correction to the baseline optimal landing guidance law in a fixed-final-time set-up such that the reference surface is tracked following a second-order error dynamics, while thrust magnitude bounds are also respected. Following the developed guidance strategy, ad-hoc divert maneuvers for terrain-collision avoidance are avoided. Implementation of the same also does not require solving large-scale trajectory optimization problems online. To improve fuel-efficiency across varying initial conditions, the inner-loop terrain-aware guidance is coupled with an outer-loop selection of time-of-flight for optimal fuel usage. Extensive Monte-Carlo simulations with highly diverse initial conditions are performed to demonstrate the effectiveness of the developed guidance algorithm in terrain avoidance and soft precision landing with higher fuel-efficiency than the repulsion based methods.

WeBC	Room 155/d3
Cyber-Physical Systems (Regular Session)	
Chair: Dang, Thao	VERIMAG
Co-Chair: Gasmi, Noussaiba	ECAM Louis De Broglie

14:00-14:15 WeBC.1

Deterministic Privacy in Robust Federated Learning through Gradient Scaling

Öksüz, Halil Yigit	Technical University Berlin
Paternain, Santiago	Rensselaer Polytechnic Institute
Raisch, Joerg	Technical University Berlin

Federated learning enables multiple agents to collaboratively train a model by communicating through a central unit. However, the presence of abnormal (possibly malicious) agents or external eavesdroppers introduces tremendous challenges to resilience and privacy. In this paper, we propose a federated learning algorithm that allows normal agents to operate in adversarial environments while preserving their privacy without degrading the learning performance. The proposed algorithm is robust to abnormal agents and provides a degree of confidentiality regarding information shared by normal agents. We have presented the convergence analysis of the proposed algorithm under the standard assumptions in the literature. Unlike existing work, our convergence analysis provides a deterministic error bound that is independent of the privacy measure. Numerical experiments validate our theoretical findings, demonstrating the effectiveness of the introduced method.

14:15-14:30 WeBC.2

A Resilient Observer-Controller Framework for Discrete-Time Cyber-Physical Systems under Markovian Cyber-Attacks

Hassine, Eya	University of Gabes
Thabet, Assem	University of Gabes
Gasmi, Noussaiba	ECAM Louis De Broglie
Bel Haj Frej, Ghazi	BORDEAUX INP

This paper presents a comprehensive security approach for discrete-time Cyber-Physical Systems (CPS) that combines a Luenberger observer-based detection mechanism with a state-feedback control synthesis. The proposed approach simultaneously addresses attack detection and system stabilization by developing an integrated observer-controller architecture capable of identifying multiple cyberattack strategies, including Denial-of-Service (DoS) and False Data Injection (FDI) attacks - while maintaining closed-loop performance. The observer design incorporates residual generation with Markovian-distributed attack modeling to accurately detect compromised sensors and actuators under realistic attack scenarios, formulated through relaxed Linear Matrix Inequality (LMI) conditions derived using new relaxations variables, a diagonal form of the Lyapunov function, the S-procedure and the congruence principle. The complementary state-feedback control law leverages the observer's estimates to ensure system stability and preserve operational requirements even during attack intervals. The approach effectiveness is demonstrated through extensive numerical simulations on a three-tank interconnected system, showing significant improvements in both attack detection and control performance.

14:30-14:45 WeBC.3

Smart WindPark Laboratory: Holistic High Performance Hardware-In-The-Loop Wind

Farm Research Facility

Spichartz, Benedikt	Ruhr University Bochum
Kipke, Vile	Ruhr University Bochum
Breuer, Daniel	Ruhr University Bochum
Sourkounis, Constantinos	Ruhr-University Bochum

To ensure maximum energy production, reliable operation and extended service life of wind farms, it is crucial to consider the electrical and aerodynamic interactions between wind turbines as well as mechanical loads, during both planning and operation. The SWiPLab at Ruhr University Bochum offers a research facility for comprehensive wind farm studies and experimental validation ranging from turbine design and control through wind farm layout optimization to wake interactions, wind farm flow control and grid integration. Its hybrid approach combines distributed real-time simulation with physical test benches to represent a whole wind farm, covering dynamics on time scales from sub-microseconds (power electronics) to hours and days (wind and wake dynamics). Fifteen wind turbines with different drivetrain topologies are emulated on a laboratory scale through mechanical drivetrains and power converters, which are interconnected to a wind farm grid and finally to the utility grid via physical power transmission line models with adjustable impedance. Alternatively, the investigation of various AC grid events and fault scenarios as well as High-Voltage Direct Current (HVDC) interconnection can be emulated with a 1 MVA grid emulator. A dynamic three-dimensional wind flow model provides site-specific turbulent wind conditions and computes wake effects as well as aerodynamic forces acting on the wind turbine rotors on a set of high-performance real-time simulators. In this paper, the overall design of the Hardware-In-the-Loop system, the implemented control and model structures as well as measurement results of wind farm operation scenarios are presented, which highlight the complex dynamics within a wind farm and emphasize holistic WF optimization and control.

14:45-15:00 WeBC.4

A Polynomial-Based Quadratic Constrained Quadratic Program with Multiple Constraint Sets

Venturino, Antonello	Università Della Calabria
Franze', Giuseppe	Università Della Calabria
Tedesco, Francesco	Università Della Calabria

Cloud-based control and estimation schemes can substantially reduce on-board computational requirements in autonomous systems, but they also introduce confidentiality and privacy concerns when optimization is delegated to potentially untrusted remote platforms. Within this context, this work investigates the solution of Quadratically Constrained Quadratic Programs (QCQPs) in the presence of multiple ellipsoidal constraint sets. We propose a polynomial-penalty QCQP solver whose iterative procedure relies exclusively on addition and multiplication operations, thereby aligning with the capabilities and limitations of contemporary homomorphic encryption schemes. The effectiveness of the proposed method is demonstrated on a representative numerical example involving a two-dimensional quadratic cost function subject to three quadratic constraints.

15:00-15:15 WeBC.5

A Multi-Stage RLHF Pipeline for LLM-Based Smart Building Optimization

Papaioannou, Ioannis	Center for Research and Technology Hellas
Vamvakas, Dimitrios	Democritus University of Thrace
Tsaknakis, Christos	Democritus University of Thrace

Korkas, Christos University of Western Macedonia

Smart-building optimization requires transforming heterogeneous sensor measurements into reliable, human-interpretable operational guidance while preserving energy efficiency and thermal comfort. Although large language models (LLMs) provide strong reasoning capabilities, existing approaches remain weakly aligned with domain-specific control objectives and rarely exploit reinforcement learning from structured feedback. This paper proposes a multi-stage Reinforcement Learning from Human Feedback (RLHF) framework that aligns LLM-generated smart-building recommendations with explicit comfort, humidity, occupancy, and energy-efficiency constraints. The proposed pipeline integrates real world data from an operational building in Thessaloniki, Greece, simulation-driven scenario synthesis, hybrid human-rule preference annotation, neural reward modeling, and Proximal Policy Optimization (PPO)-based policy alignment. A supervised fine-tuned (SFT) baseline is systematically compared with PPO-aligned policies on previously unseen scenarios using the learned reward function and hybrid qualitative evaluation. Experimental results demonstrate stable alignment, improved semantic consistency, and robust behavior across diverse operating conditions, with PPO achieving approximately 18-20% higher mean reward than SFT. From a control-oriented perspective, the learned policy operates as a supervisory decision-support layer compatible with cyber-physical building energy management systems. These findings highlight RLHF as a scalable pathway toward stability-aware, energy-efficient, and human-centered intelligent building operation.

15:15-15:30 WeBC.6

A Control Perspective on Ion Cyclotron Range of Frequencies Systems in Tokamaks

Clarizia, Flavio DTT S.C.ar.l.,
Foglietta, Chiara San Raffaele Roma Open University
Panzieri, Stefano Università Degli Studi Roma Tre
Ceccuzzi, Silvio ENEA
Boncagni, Luca ENEA
Bonagura, Valeria Università Roma Tre

Ion Cyclotron Range of Frequencies (ICRF) heating is one of the primary auxiliary heating methods in magnetic confinement fusion devices. By injecting radio-frequency power in the range 20-120 MHz, ICRF systems deposit energy directly on the plasma ions at their cyclotron resonance layer, playing a key role in achieving and sustaining the temperatures required for fusion reactions.

Despite its importance, the control aspects of ICRF systems have received limited attention in the control engineering literature. This paper provides a survey of the main control problems encountered in ICRF heating systems, from a control engineering perspective.

Starting from a description of the plant, as a cascade of radiofrequency (RF) and electromechanical sub-systems driven by an uncertain and nonstationary plasma load, four interconnected control problems are identified and reviewed: real-time impedance matching, arc detection and protection, RF and coupled power regulation, and integration with the tokamak plasma control system. For each problem, the state of the art is discussed and open research directions are highlighted. The survey is intended to bridge the gap between the fusion engineering and control communities, and to stimulate new contributions at their intersection.

WeBD	Room 155/d4
Intelligent Transportation Systems 1 (Regular Session)	
Chair: Vassilakopoulou, Polyxeni	University of Agder
Kotsialos, Apostolos	University of Agder
Co-Chair: Terhorst-Kluge, Kevin	RWTH Aachen University

14:00-14:15 WeBD.1

Unifying Decision-Making and Trajectory-Planning in Unsignalized Intersections Using Time-Varying Potential Fields

Costa, David	Politecnico Di Torino
Cerrito, Francesco	Politecnico Di Torino
Canale, Massimo	Politecnico Di Torino
Novara, Carlo	Politecnico Di Torino

This paper presents a novel framework for integrated Decision-Making (DM) and Trajectory Planning (TP) for automated vehicles at unsignalized intersections. The approach leverages a Finite Horizon Optimal Control Problem (FHOCP) that employs Time-Varying Artificial Potential Fields (TV-APF). By utilizing short-horizon motion prediction and a dedicated conflict-zone occupancy coefficient, the framework suitably accounts for potential collisions within the FHOCP. The proposed method effectively unifies DM and TP, ensuring the generation of a feasible and safe reference trajectory. Simulation results in multi-vehicle traffic scenarios demonstrate the effectiveness of the approach.

14:15-14:30 WeBD.2

Li-Ion Battery State of Charge Estimation for Electric Vehicles: An Electrochemical Model-Based EKF Validated Using Real Data

Nawaz, Umar	Univ. Grenoble Alpes, CNRS, Grenoble INP, GIPSA-Lab, France
Bratcu, Antoneta Iuliana	Grenoble Institute of Technology
Besancon, Gildas	Grenoble INP UGA, Gipsa

This paper presents an Extended Kalman Filter (EKF)–based approach for state of charge (SoC) estimation in lithium-ion batteries using the electrochemical Single Particle Model (SPM). Accurate SoC estimation is critical for battery management systems, directly impacting safety, lifetime, and operational reliability. The SPM captures lithium diffusion dynamics through an electrochemical model, while the EKF exploits measured current and terminal voltage to compensate for modeling simplifications and measurement noise, assuming parameters obtained from prior identification. To avoid errors induced by transient surface concentrations, SoC is inferred from the equilibrium lithium concentration. The proposed estimator is validated using real current and voltage data from an electric vehicle driving cycle. MATLAB®/Simulink® simulation results demonstrate robust voltage prediction and consistent SoC estimation under noisy operating conditions. A sensitivity analysis highlights the trade-off between convergence speed and estimation smoothness induced by EKF covariance tuning. While reliable performance is achieved without online model recalibration, tuning complexity remains a practical limitation for real-time implementation.

14:30-14:45 WeBD.3

Route, Delay and Access Control for Truck Saturated Flow Utilizing Rest Areas

Kotsialos, Apostolos — PPC Hellas
Vassilakopoulou, Polyxeni — University of Agder

This paper explores the use of motorway Rest Areas as Storage Area Facilities (SAF) for managing truck traffic on saturated road networks. It discusses Delay Assignment (DA), utilizing time delay as a direct control variable to regulate truck flow. The study evaluates the concurrent application of three decentralized control strategies selectively applied to trucks: Route Guidance (RG) to regulate motorway mean speed; DA to manage the duration trucks are stored in SAFs; Ramp Metering (RM) at the SAF outlink to ensure smooth merging. The proposed framework is modeled using a multi-class METANET traffic flow model and the COPERT emissions family of models. A case study conducted on a road saturated with heavy truck traffic demonstrates that the integrated triplet of control measures can improve overall traffic conditions. Nevertheless, the effectiveness of SAF-enabled traffic management depends not only on control efficiency, but also on alignment between traffic control centers, fleet operators, and driver compliance practices. The results highlight the importance of queue override for controllers' efficiency. The paper concludes that SAFs can serve as dynamic buffers for efficient traffic management.

14:45-15:00 WeBD.4

Design of a Suboptimal Second-Order Sliding Mode Controller to Improve Robustness in Hybrid Trains

Camarda, Manuel — Polytechnic of Milan
Incremona, Gian Paolo — Politecnico Di Milano
La Bella, Alessio — Politecnico Di Milano
Colaneri, Patrizio — Politecnico Di Milano
Ferrara, Antonella — University of Pavia

Hybrid trains powered by energy storage devices represent a promising solution for sustainable and flexible railway transportation. However, they operate under highly variable conditions and are continuously subjected to load fluctuations, parameter variations, and modeling errors, which can compromise voltage regulation performance. So, ensuring robustness against such disturbances is fundamental to guarantee reliable and safe railway operations. This paper proposes a suboptimal second-order sliding mode (SSOSM) controller, designed to achieve accurate, fast, and robust voltage tracking of traction motors and auxiliary services in hybrid trains. The effectiveness of the proposal is evaluated through three increasingly complex simulation scenarios and compared against a conventional proportional-integral-derivative (PID) controller. The results demonstrate superior robustness and regulation performance, supporting the implementation of efficient control architectures in next-generation railway systems.

15:00-15:15 WeBD.5

Modeling Economic Feasibility of Freight on Transit

Cavallaro, Federico — Università IUAV Di Venezia
Nocera, Silvio — IUAV University of Venice
Rossi, Francesco — Università Iuav Di Venezia

Freight on Transit is a new paradigm aiming to improve efficiency of transportation system: it is based on integration of passenger and freight operations within a single service, by using vehicles for passengers (e.g. buses) to deliver a part of the freight parcels. Both advantages and disadvantages are clear: while cost-sharing, resource optimization, traffic and pollution reduction advocate for such integration, one needs to

take into account costs of operations, disadvantages for customers, reconciliation of needs of different markets.

We present here a model to evaluate the cost of switching from a separated to an integrated system, focusing on urban areas. Two main ratios (after over before the switch) arise: the ratio $gamma_{v_{TO}}$ of the commercial speed of passenger operator (given by taking care of freight) and the ratio $gamma_{FO}$ of the distance of the freight operator (taking care of the remaining freight).

We finally present a detailed case study for the city of Alessandria, Italy.

15:15-15:30 WeBD.6

Comparative Analysis of Collision-Cone and Higher-Order Control Barrier Functions for Safe Autonomous Highway Driving

Heyi, Muluneh Hailu	Université Bourgogne Europe
Hima, Salim	ESME Research LAB, France
Chaibet, Ahmed	Université Bourgogne Europe

This paper presents a comparative study between Higher-Order Control Barrier Functions (HOCBF) and Collision-Cone Control Barrier Functions (C3BF) for safe autonomous highway driving using a kinematic bicycle model with steering-rate actuation. The ellipsoidal safety function exhibits a relative degree of two, preventing standard CBF from generating feasible avoidance commands. HOCBF addresses this through recursive differentiation, at the cost of conservatism and tuning sensitivity, while C3BF embeds relative velocity directly into the barrier function, reducing the relative degree to one and yielding constraints affine in the control input. Both approaches are validated on a highway scenario that involves lane change, overtaking, and lane return using the HighD dataset. The results show that C3BF consistently outperforms HOCBF in control smoothness, lateral trajectory regularity, and post-maneuver stabilization, thanks to its anticipatory velocity-space reasoning.

WeCA	Room 155/d1
Data-Driven Modelling (Regular Session)	
Chair: Besancon, Gildas	Grenoble INP UGA, Gipsa
Co-Chair: Stylios, Chrysostomos	Athena RC

16:00-16:15 WeCA.1

Resource Allocation Optimization in O-RAN Using Prospect Theory and Reference Point Adaptation

Spyrou, Evangelos	Centre for Research and Technology Hellas
Kappatos, Vassilios	Hellenic Institute of Transport, Centre for Research and Technology Hellas
Stylios, Chrysostomos	Athena RC

Efficient resource management in Open Radio Access Networks (O-RAN) is critical for supporting diverse services and applications across multiple network slices. This paper proposes an Software-Defined Networking (SDN)-enabled O-RAN resource allocation framework that dynamically distributes resources among slices while ensuring service quality. Each slice's satisfaction is modeled using a Prospect Theory-based utility function, capturing gains and losses relative to a dynamically evolving reference point that reflects slice expectations over time. The SDN controller iteratively maximizes overall network utility under constraints on total resources and minimum slice requirements. To address the non convex and non-smooth nature of the utility functions, a Successive Convex Approximation (SCA) method is employed, constructing surrogate convex problems at each iteration. Reference points are updated via an Exponential Moving Average (EMA), allowing slices to adapt their expectations based on historical allocations. The proposed iterative scheme guarantees convergence to a stable allocation while adapting to changing traffic demands and slice-specific requirements, providing a flexible and practical solution for intelligent resource management in future O-RAN deployments. The proposed Prospect Theory framework is compared against two baseline schemes, namely the Equal Resource Allocation (EA), representing a uniform non-adaptive approach, and Channel Proportional Allocation (CPA), which reflects a greedy strategy based on channel conditions.

16:15-16:30 WeCA.2

Hybrid MobileNetV2–Vision Transformer Framework for Automated Multi-Class Renal Lesion Classification in CT Imaging

Hasnain, Syed Ibad	Department of Biomedical Engineering, Hamdard University
Khowaja, Rabail	Department of Biomedical Engineering, Hamdard University
Faris, Muhammad	Hamdard University
Pepe, Crescenzo	Università Politecnica Delle Marche
Ali, Mir Farooq	Dipartimento Di Ingegneria dell'Informazione, Università Politecnica Delle Marche
Zanoli, Silvia Maria	University Politecnica Delle Marche

Early detection of renal pathologies (cysts, calculi, neoplasms) is critical to allow timely treatment of patients. For the renal evaluation, Computed Tomography (CT) is still the method of preference, because it provides better spatial resolution and a consistent

diagnostic accuracy. However, the interpretation of CT scans by clinicians is still tedious, time consuming, and vulnerable to inter-observer error. In order to overcome issues that arise from manual analyses of CT scan, the current research study presents a hybrid Deep Learning framework that combines MobileNetV2 and a Vision Transformer (ViT) to achieve automated multi-classification of renal lesions based on CT scans. MobileNetV2 is a lightweight convolutional backbone able to extract discriminative local spatial features in a depth-separable convolution and maintain computational efficiency in this architecture. The extracted features are subsequently processed by a ViT, which models long-range contextual relationships using multi-head self-attention. The model combines convolutional inductive bias with global relationship modeling to operate effectively on a publicly available Kidney lesions Kaggle dataset. The pre-processing and data augmentation were done on the four-categories of the datasets and training and testing were performed by a tailored hybrid model. The empirical results show high diagnostic accuracy of 96.78%, a macro-precision of 94.96%, a macro-recall of 96.74%, and an overall macro-F1 of 95.76%. The Area Under the ROC Curve (AUC) is 0.997. These findings demonstrate that the proposed hybrid framework can effectively classify renal CT images in clinical settings, offering both high accuracy and cost efficiency.

16:30-16:45	WeCA.3

Hybrid Data-Driven Modeling and Control of Ship Fuel Consumption Using Explainable Machine Learning

El-Amrani, Abderrahim	LIS Laboratory (UMR CNRS 7020), Aix-Marseille University, France
Barhhouj, Aya	Aix-Marseille University, CNRS, LIS (UMR 7020), France
Ananou, Bouchra	LIS Laboratory (UMR CNRS 7020), Aix-Marseille University, France
Ouladsine, Mustapha	LIS Laboratory (UMR CNRS 7020), Aix-Marseille University, France

This paper proposes a hybrid data-driven framework for modeling and controlling ship fuel consumption using explainable machine learning and reinforcement learning techniques. The proposed framework integrates predictive modeling, SHAP-based feature selection, and policy learning directly from historical operational data. First, an XGBoost regression model is trained to accurately predict fuel consumption based on onboard sensor measurements. Subsequently, SHAP analysis is employed to identify the most influential variables and construct a compact state representation for the reinforcement learning (RL) controller. Using these selected features, an offline RL policy is trained to regulate propulsion speed while ensuring safe engine operation. Validation on historical operational data demonstrates a significant reduction in fuel consumption while maintaining stable operating conditions. The obtained results highlight the effectiveness and potential of data-driven control strategies for improving maritime energy efficiency and reducing operational costs.

16:45-17:00	WeCA.4

Towards a Supply Chain Digital Twin

Georgiades, George	Cyprus University of Technology
Kariolis, Marinos	Cyprus University of Technology
Leontiou, Rafaellos	Cyprus University of Technology
Loizou, Savvas	Cyprus University of Technology

This work proposes a novel concept of digital twin, the Supply Chain Digital Twin (SCDT),

aimed at supply chain operations in the manufacturing sector. The paper describes the development, architecture and implementation of SCDT, with the capability of both monitoring near real time data from various factories and simulating various scenarios of operations, recycling schemes and logistics between manufacturing factories in a supply chain. The proposed approach to factory representation, allows a variable degree of detail in the operational models and their visualizations, providing flexibility and scalability. An appropriate visual representation of the supply chain(s) is provided that includes concurrent visualizations of both the inter- and intra- factory logistics. The material flows are produced by logistic tasks, transferring materials from one factory to another, and manufacturing processes, asynchronously converting quantities of a combination of materials into scrap, waste and products. The tasks can be arbitrary (continuous) and sequential and/or concurrent. The complexity of the system can vary from a single factory to a group of defined supply chains exchanging and sharing resources. In addition to the operational process models, the SCDT develops an interactive 3D visualization of the requested setup of factories and their supply chain. The paper showcases the various plugins/tools that were developed, as well as the capabilities of the SCDT tool. Example case studies are presented and analyzed.

17:00-17:15 WeCA.5

Fault Diagnosis of Motion-Controlled Mechanical Systems Via Wavelet Packets and AR Spectral Estimation

Lenzi, Alice — University of Bologna
Diversi, Roberto — University of Bologna
Speciale, Nicolò Attilio — University of Bologna

This paper presents a data-driven methodology for fault diagnosis of motion-controlled electromechanical systems operating under periodic conditions, such as electronic cam mechanisms. The rationale of the approach consists of decomposing diagnostic signals (e.g. motor currents, vibrations) into an ideal 'regular' component induced by the reference motion law and a residual component containing fault-related information. Wavelet Packet Transform is used for signal decomposition, with the decomposition level selected via an entropy-based criterion. Autoregressive models are then identified on signals reconstructed from selected subbands, and the corresponding power spectral densities are computed. A symmetric Itakura–Saito (COSH) spectral distance between healthy and monitored spectra serves as a health indicator. The method is validated on an experimental electric-cam setup to detect unbalanced faults, demonstrating its effectiveness using both motor current and vibration signals.

17:15-17:30 WeCA.6

Kalman-Based Approach towards Automatic Analysis of Monitoring Signals for a Concrete Dam in Industrial Use

Pavanelli, Ana Luisa — Univ. Grenoble Alpes, CNRS, Grenoble INP, GIPSA-Lab
Besancon, Gildas — Grenoble INP UGA, Gipsa
Robbe, Emmanuel — EDF Hydro DTG

This paper is about Structural Health Monitoring for the special case of concrete dams, as used in hydroelectric production. It focuses on the measurement of some given phenomenon, as it can be available in that context (horizontal displacement of the structure for instance). On this basis, it is first emphasized how a recent study adapting Kalman filtering to the standard Hydraulic-Seasonal-Time HST statistical model can be extended to Hydraulic-Seasonal-Thermal-Time model for phenomenon estimation, and at

the same time, used for full parameter calibration. The Kalman approach is then further used to provide a possible automatic analysis of this estimation, via the decomposition of the time-effect component into reversible and irreversible parts. The approach is illustrated with results obtained by its application to real monitoring data.

WeCB	Room 155/d2
Cooperative Systems Control (Regular Session)	
Chair: Rossi, Francesco	Università Iuav Di Venezia

16:00-16:15 WeCB.1

Angle-Aware Coverage Control on SE(3): A Unified Approach for Drones with Various Actuator Configurations

Monden, Yuki	Institute of Science Tokyo
Takizawa, Yuga	Institute of Science Tokyo
Hatanaka, Takeshi	Institute of Science Tokyo

This paper addresses generalization of angle-aware coverage control for efficiently sampling images tailored to 3D structure reconstruction. To this end, we begin by formulating the drone camera motion on the Lie group SE(3) without relying on any local parametrization of rotation. Building on this representation, we reformulate the angle-aware coverage control problem, and then present a constraint-based controller for fully actuated drones. The present framework is further shown to extend seamlessly to drones with arbitrary actuator configurations by just altering a Jacobian matrix in the constraint, enabling a systematic design of the constraint-based controller. Simulation studies are conducted under various conditions, including two different actuator configurations. The results highlight the advantages of the proposed unified approach and provide quantitative evaluations of sensing performance and energy consumption across different actuator configurations and design parameter settings.

16:15-16:30 WeCB.2

Distributed CAN–ZigBee Control Architecture for Cooperative Multi-Robot Platoons: A TrueTime-Based Simulation Study

Lazar, Razvan-Gabriel	Gheorghe Asachi Technical University of Iasi
Pauca, Ovidiu	“Gheorghe Asachi” Technical University of Iasi
Caruntu, Constantin-Florin	Gheorghe Asachi Technical University of Iasi

This paper presents a distributed control architecture for cooperative multi-robot platoons intended for logistics and goods transport applications. The proposed solution combines CAN-based intra-robot communication with ZigBee wireless networking for inter-robot coordination, enabling reliable and scalable operation under communication constraints. The leader robot uses a discrete-time PID controller, while follower robots implement an LQR-based state-feedback controller with acceleration feedforward. To assess the effects of communication delays and network dynamics on closed-loop performance, the system is implemented in the TrueTime simulation framework, allowing realistic modeling of task scheduling, bus arbitration, and wireless transmission. Simulation results show that the proposed approach maintains platoon control under varying communication delay conditions.

16:30-16:45 WeCB.3

When to Trust Novelty: Consensus Strategies in Active Perception under Sensor Accuracy

Erić, Dorian	University of Zagreb Faculty of Electrical Engineering and Computing

Peti, Marijana	University of Zagreb, Faculty of Electrical Engineering and Computing
Petric, Frano	University of Zagreb
Bogdan, Stjepan	Univ. of Zagreb

Decentralized active perception systems are often modeled using a variant of Partially Observable Markov Decision Processes. However existing approaches assume a correctly specified observation models and do not analyze the impact of sensor accuracy. This paper investigates how true sensor accuracy and observation model mismatch affect the performance of POMDP-based multi-agent systems using novelty-biased consensus, method presented in [1]. Through extensive simulations on multiple benchmark problems, we evaluate task success and number of steps needed to make a final decision under varying sensing conditions. We introduce quality index that explicitly captures the trade-off between speed and accuracy. Results show that using novelty bias consistently reduces number of steps, but can significantly amplify errors when the observation model is overly optimistic relative to true sensor performance. We identify regimes where using novelty-biased consensus is beneficial and where average consensus provides a better robustness.

16:45-17:00 WeCB.4

Generalization of the Moreau Condition for Convergence to Consensus

Bentaibi, Mohamed	D-Fine S.r.l
Caravenna, Laura	Università Di Padova
Gauthier, Jean-Paul	Université De Toulon
Rossi, Francesco	Università Iuav Di Venezia

We study cooperative multi-agent systems with possible communication failures. Our goal is to generalize the Moreau's condition, that ensures convergence to consensus if a suitable communication graph has a globally reachable node. We prove here a new condition ensuring consensus. We define the connection graph in a much weaker sense: directed arrows correspond to connection functions that weakly converge to some function with a positive integral on all intervals of the form $[t,+infty)$. We also provide examples showing that our result ensures convergence in cases for which other conditions, based on reciprocity (e.g. cut-balance), do not apply.

17:00-17:15 WeCB.5

Design of a Partitioned Mixed-Criticality System for UAV

Fontalba, Marc	Universitat Politècnica De València (UPV)
Ortiz Enguix, Luis	Universitat Politècnica De València (UPV)
Simó Ten, Jose E.	Universitat Politecnica De Valencia
Guasque Ortega, Ana	Universitat Politècnica De València (UPV)
Balbastre, Patricia	Universitat Politècnica De València
Crespo, Alfons	UPV

Unmanned Aerial Vehicles (UAVs), such as quad copters employed in reconnaissance missions over confined environments, require the integration of safety-critical flight control functions alongside mission-critical image processing payloads on a shared hardware platform. In this paper, we describe the design of a partitioned mixed-criticality software architecture for a UAV system based on the ARINC-653 model. We identify 29 basic functions organised into 10 functional partitions. The system supports eight operating modes and uses a centralised On-Board Data Handling (OBDH) hub complemented by low-latency direct links for the flight control critical path. We describe the scheduling

strategy and safety constraints, and report on an experimental validation using a hardware-in-the-loop (HIL) testbed with a Zybo Z7 board connected to a simulator that emulates the UAV behaviour and provides access to its sensors and actuators. The results show that mixed-criticality UAV functions can be consolidated on a single platform while preserving temporal and spatial isolation guarantees.

17:15-17:30 WeCB.6

Robust Fixed-Time Sliding Mode Control for Autonomous Search and Rescue Quadrotor with Real-Time Visual Human Detection

Aimen Abdelhak, Messaoui	Ecole Superieure Ali Chabati, Reghaia, Algeria
Demim, Fethi	Ecole Militaire Polytechnique, EMP
Messaoui, Ali Zakaria	Ecole Militaire Polytechnique

In search and rescue (SAR) missions, quadrotor unmanned aerial vehicles (UAVs) are essential tools for efficiently exploring hazardous or inaccessible environments. Successful deployment in such challenging scenarios necessitates robust control algorithms capable of ensuring high tracking accuracy and resilience to external disturbances. This paper introduces a Continuous Fixed-Time High-Order Sliding Mode Control (CFHSMC) approach that guarantees fast convergence and superior disturbance rejection for quadrotor systems. The proposed control strategy is first validated through outdoor trajectory tracking experiments, where the UAV follows a helical reference path in the presence of environmental perturbations such as wind gusts. Following successful control validation, CFHSMC is integrated into a full SAR mission, where a vision-equipped UAV autonomously detects a missing person using an onboard SSD-MobileNet-v2 deep learning detector. A parallel grid-based search pattern is implemented to optimize area coverage. Experimental results confirm the controller's effectiveness in maintaining stable and precise flight during both the trajectory tracking and person detection phases. This work presents a tightly integrated solution combining robust nonlinear control with real-time visual perception for autonomous SAR applications.

WeCC	Room 155/d3
Power Systems (Regular Session)	
Chair: Zivanovic, Rastko	FH Upper Austria
Co-Chair: Fadel, Maurice	LAPLACE

16:00-16:15 WeCC.1

Constant Power Load Stabilization with Passivity Based Controller for More Electrical Aircraft

Derrien, Luc	LAboratoire PLasma Et Conversion D'Energie
Fadel, Maurice	LAPLACE
Kergus, Pauline	CNRS
Kahalerras, Mohamed Khaled	Airbus Operations S.A.S

The concept of the More Electric Aircraft is now well established, with widely recognized benefits in terms of energy efficiency, reliability, and system diagnosability. Consequently, new electrical architectures with increasing power levels are emerging, with a growing emphasis on high-voltage direct current distribution. In this context, the stability criteria commonly used in industry, which are primarily based on small-signal theory, are insufficient for the nonlinear behavior typically observed in high-power systems. This article proposes a Passivity-Based Control law, using the concept of input-to-state stability, developed for a specific yet representative case of MEA power grid stabilization, which ensures transient stability. The proposed approach is based initially on an idealized constant-power load model. In a second step, the system model is enhanced to achieve greater realism by using a three-phase electric generator. Mathematical proofs are provided to demonstrate the validity of the approach and to guarantee the stability of the real system despite the use of a simplified model in the design.

16:15-16:30 WeCC.2

Global Stability Analysis of PI-Controlled Grid-Following Inverters Incorporating the Time-Varying Nature of the PLL Mechanism

Alexandridis, Theodosis	University of Patras
Papageorgiou, Panos	University of Patras
Konstantopoulos, George	University of Patras

In this paper, we study stability properties of grid-following inverters in the synchronously rotating dq-reference frame under time-varying angular frequency resulting from the dynamics of any phase-locked-loop (PLL) device. This problem is formulated when conventional PI controllers are applied to the inverter without the addition of decoupling terms, i.e. without requiring knowledge of system parameters, and it is shown that the resulting closed-loop system takes the form of a linear time-varying port-Hamiltonian system. Considering that the PLL achieves grid synchronization, we show global exponential stability and robustness results for the closed-loop system, by employing a linear state transformation to study the homogeneous part of the error dynamics. The validity of the theoretical analysis is demonstrated on a simulated grid-connected inverter under grid frequency and voltage variations.

16:30-16:45 WeCC.3

Capability of Grid-Forming Converter Control for Mitigating Power Quality Problems and Effects on the DC-Link

Tölle, Tim	Ruhr University Bochum

Siepelmeyer, Lars Michael — Ruhr University Bochum
Sourkounis, Constantinos — Ruhr-University Bochum

Grid-forming control algorithms for grid-connected converter systems are becoming increasingly popular, promising not only a stable operation in weak grid scenarios but even the ability to damp subsynchronous oscillations injected by e.g. conventional grid-following converter systems. Multiple control algorithms for enabling a grid-forming behavior and also for the active mitigation of harmonics are well discussed in various publications. However, the capability of such controls to naturally damp various power quality aspects, including harmonics and negative sequence components without additional specific control structures for active mitigation of the latter, has been barely investigated. Therefore, this paper presents the mentioned behavior with theoretical analysis and a simulation study based on one exemplary grid-forming control algorithm. The results of the grid-forming control are compared to those of a conventional grid-following control with regard to the damping of power quality aspects. Different sources for the cause of the power quality problems are considered and the resulting behavior of the controlled systems are analyzed. Additionally, effects and repercussions of described grid-forming controls on the DC-link and on the upstream energy conversion process are briefly investigated.

16:45-17:00 WeCC.4

A Numerical Analytic Continuation Method for Tracing Solution Branches in Power Flow Problems

Zivanovic, Rastko — FH Upper Austria

In this paper, we present a numerical analytic continuation method based on quadratic approximation that can trace solution branches in power flow problems. The proposed quadratic approximation is constructed using conventional power flow software, unlike the Padé or Hermite-Padé approximation which requires a special type of software where the power flow equations are embedded in the complex plane. Using a standard example, we explain the main steps of the algorithm and compare its performance, in terms of accuracy and computational efficiency, with that of the MATPOWER continuation power flow software.

17:00-17:15 WeCC.5

Stability Analysis of Load Frequency Control of a Single-Area Power System with Communication and Actuator Delays

Bayram, Furkan — Eskisehir Technical University
Ozer, Mert — Eskisehir Technical University
Iftar, Altug — Eskisehir Technical University

This paper investigates the stability characteristics of a single-area load frequency control (LFC) system with a steam turbine in the presence of both communication and actuator delays. While the communication delay has been extensively considered in the literature, actuator delay arising from the physical dynamics between the governor and the turbine has not been explicitly incorporated into stability analyses of LFC systems. To address this gap, a linearized single-area LFC model is formulated in which communication and actuator delays are simultaneously incorporated into the state-space representation, yielding a retarded time-delay system with incommensurate delays. Stability regions and exact delay margins are determined using the critical-eigenvalue tracing method, which provides non-conservative results by directly tracing characteristic root crossings on the imaginary axis. The influence of proportional-integral controller parameters and system parameters on the stability region is systematically examined for different single-area

configurations. Stability analyses demonstrate that the actuator delay imposes more restrictive stability limits compared to the communication delay. Time-domain responses under step load disturbances are also analyzed to illustrate the impact of increasing delays on the performance of LFC systems.

17:15-17:30	WeCC.6

Leonov Redesign: A Robustification Method for Multistable Systems with State-Periodic Dynamics

Mendoza-Avila, Jesus	Brandenburg University of Technology Cottbus-Senftenberg
Mercado Uribe, Jose Angel	Brandenburgische Technische Universität Cottbus-Senftenberg
Efimov, Denis	Inria
Schiffer, Johannes	Brandenburg University of Technology Cottbus-Senftenberg

In this paper, the Lyapunov redesign technique is revisited for a class of state-periodic systems. The proposed robustification method is based on the novel Leonov function approach that offers relaxed conditions for establishing global boundedness of solutions of state-periodic systems compared with using Lyapunov functions. Then, assuming that the system under study achieves a desired behavior described by a known Leonov function in the absence of perturbations, our main result provides a robustifying controller that preserves this desired behavior in the presence of matched bounded perturbations. The proposed approach is applied to enhance the robustness of a microgrid with a mixed rotational and inverter-interfaced generation pool. Numerical simulations show the effectiveness of this technique.

WeCD	Room 155/d4
Intelligent Transportation Systems 2 (Regular Session)	
Chair: Dimarogonas, Dimos V.	KTH Royal Institute of Technology
Co-Chair: Cavanini, Luca	Industrial Systems and Control Ltd

16:00-16:15 WeCD.1

A Modular Platooning and Vehicle Coordination Simulator for Research and Education

Jamsahar, Kevin	KTH Royal Institute of Technology
Wiltz, Adrian	KTH Royal Institute of Technology
Charitidou, Maria	University of Maryland
Dimarogonas, Dimos V.	KTH Royal Institute of Technology

This work presents a modular, Python-based simulator that simplifies the evaluation of novel vehicle control and coordination algorithms in complex traffic scenarios while keeping the implementation overhead low. It allows researchers to focus primarily on developing the control and coordination strategies themselves, while the simulator manages the setup of complex road networks, vehicle configuration, execution of the simulation and the generation of video visualizations of the results. It is thereby also well-suited to support control education by allowing instructors to create interactive exercises providing students with direct visual feedback. Thanks to its modular architecture, the simulator remains easily customizable and extensible, lowering the barrier for conducting advanced simulation studies in vehicle and traffic control research.

16:15-16:30 WeCD.2

A Data-Driven Hybrid Electric Vehicle Driver Classification and Coaching System

Cavanini, Luca	Industrial Systems and Control Ltd
Majecki, Pawel	University of Strathclyde
Grimble, Michael John	University of Strathclyde
Devine, Alan	NXP Semiconductors
Hillier, Curt	NXP Semiconductors

This paper presents the design and development of the proof of concept of a driver classification and coaching system for Hybrid Electric Vehicles. Modern electrified vehicles require a change of behavior of drivers to achieve expected economic performance. The design of the system aimed to detect and train a driver to adjust his driving style is approached by exploiting capabilities of modern data-driven Machine Learning paradigm and combining Supervised and Unsupervised Learning techniques. A simulation model of a hybrid vehicle is considered to generate the dataset needed for Artificial Intelligence training and to test the performance of the developed driver classification and coaching system. The performance of the developed system is validated over a wide set of simulation tests performed by using the considered hybrid vehicle simulation system.

16:30-16:45 WeCD.3

Load-Constrained Multi-Vehicle Construction and Demolition Waste Collection Problem

Velhal, Shridhar	Lulea Technical University
Saradagi, Akshit	Luleå University of Technology, Sweden
Sawlekar, Rucha	Luleå University of Technology
Nikolakopoulos, George	Luleå University of Technology, Sweden

Efficient transport of construction and demolition waste (CDW) is essential for sustainable urban operations, especially in container-based systems where empty containers are delivered to sites and later collected as a new task when filled. We introduce the Construction and Demolition Waste Collection Problem (CDWCP) as a capacitated multi-vehicle pickup and delivery routing problem and develop a mixed integer linear programming (MILP) formulation that explicitly encodes container lifecycle dynamics in a deterministic single horizon planning. The model represents both delivery (depot → site) and collection (site → depot) tasks, propagates load changes on each task that operates within capacity constraints, and maintains depot flow conservation. The formulation also supports flexible assignment rules, enabling temporally separated delivery and pickup events to be served by the same or different vehicles without altering the core model. A simulation study is conducted on a representative urban scenario show that the MILP produces implementable, cost-effective routes with no capacity violations, improves concurrent vehicle utilization, and yields practical deployable plan. The framework bridges strategic waste-management objectives and day-to-day operational routing for containerized CDW logistics. Video: https://youtu.be/YCcu6uLi4Q4

16:45-17:00	WeCD.4

Constraints and Tests for Optimized Train Rescheduling on a Railway Network Triangle

Duluta, Andrei-Stefan	National University of Science and Technology Politehnica Bucharest
Stamatescu, Iulia	University Politehnica of Bucharest
Mocanu, Stefan	Politehnica University of Bucharest
Ionita, Anca Daniela	Universitatea Națională De Știință și Tehnologie Politehnica București

Considering that train traffic can be affected by a variety of events, rescheduling is often needed so that overall train operations and passenger comfort are affected as little as possible. In this context, the paper studies the application of an existing optimization model to a real-life railway network triangle, proposing adaptations and several new constraints. The case study considers an important railway node daily crossed by forty-five long-distance trains, for which the optimization model implemented in Julia led to solutions to simulated disruptions, considering objectives regarding the number of passengers affected by delays, cancellations, or other unforeseen events.

17:00-17:15	WeCD.5

Experimental Validation of Hybrid Optimal Control for a Hydrogen Combustion Engine Vehicle

Terhorst-Kluge, Kevin	RWTH Aachen University
Himmelseher, Katrin	RWTH Aachen
Lorei, Dennis	FEV Europe GmbH
Müller, Volker	FEV Europe GmbH
Querel, Carole	FEV Europe GmbH
Heimowski, Peter	FEV Europe GmbH
Günther, Marco	RWTH Aachen University
Basler, Maximilian	RWTH Aachen University
Pischinger, Stefan	RWTH Aachen University
Vallery, Heike	TU Delft

By combining the efficiency of lean combustion with the high specific power output of

stoichiometric combustion, the spark-ignited hydrogen combustion engine can replace gasoline and diesel engines, decarbonizing conventional power trains. To exploit the full potential of the hydrogen engine and address its broad operating range with changing non-linear behavior, we propose a hybrid approach that combines the proven advantages of conventional control algorithms for stoichiometric operation with those of optimal control for lean operation. For this, a governor controls switching between the conventional and the optimal control based on the requested engine load and the state of the air path. Simulation studies promise a fuel reduction of up to 9 % compared to conventional engine control. An experimental validation on public German roads with a passenger car demonstrates the viability of such hybrid control for real-world driving.

Technical Program for Thursday June 25, 2026

ThAA	Room 155/d1
Neural Networks (Regular Session)	
Chair: Mancini, Adriano	Università Politecnica Delle Marche
Co-Chair: Gioiello, Flavia	Università Politecnica Delle Marche

11:00-11:15 ThAA.1

Physics-Guided Hybrid Neural Networks Based on Minimal Gated Recurrent Units for Model Predictive Control

Zarzycki, Krzysztof — Warsaw University of Technology
Lawrynczuk, Maciej — Warsaw University of Technology

This work presents a Physics-Guided Hybrid Neural Network (PGHNN) model architecture that combines a first-principles process description with Minimal Gated Unit (MGU) neural networks. The model structure and the development methodology are described in detail. The model performance is evaluated using a polymerization reactor. The analysis considers realistic conditions in which data for neural submodel identification are available only in the vicinity of the operating point, while the first-principles model is affected by modeling inaccuracies. The proposed MGU-based hybrid model is compared with a GRU-based alternative and achieves comparable prediction accuracy despite having significantly fewer parameters. Moreover, the hybrid model outperforms each of its constituent submodels individually. Finally, the MGU-based PGHNN model is applied within a Model Predictive Control (MPC) framework, demonstrating good closed-loop control performance.

11:15-11:30 ThAA.2

Deep Learning-Based Fish Detection in Challenging ROV Images: A YOLOv8 Approach for Offshore Environmental Monitoring

Fiorentino, Maria Chiara — Università Degli Studi ”Gabriele D'Annunzio”
Mancini, Adriano — Università Politecnica Delle Marche
Di Nardo, Francesco — Università Politecnica Delle Marche, Ancona
Dell'Anno, Antonio — Università Politecnica Delle Marche
Fanelli, Emanuela — Università Politecnica Delle Marche
Martino, Ilaria — Cnr - Irbim
Anzani, Mauro — ENI S.p.A
Russo, Giovanni — ENI S.p.A
Friederichs, Carlos Henrique — ENI S.p.A
Scaradozzi, David — Università Politecnica Delle Marche

This paper presents an automated fish detection pipeline for ROV-acquired underwater imagery collected in the Mediterranean Sea. The task poses significant challenges due to low image quality, high inter-scene variability in water turbidity and depth, and the presence of visually confounding elements such as algae and offshore platform structures. We adopt the YOLOv8 architecture in both its Small and Large variants and evaluate four training configurations under a 5-fold cross-validation scheme. To address the limitations of the default Ultralytics checkpoint selection strategy, we introduce a custom weighted scoring function that jointly optimizes precision, recall, mAP50, and validation losses, promoting more balanced and generalizable model selection. The best-performing configuration YOLOv8-Small with online data augmentation, trained for

250 epochs—achieves a precision of 0.639, recall of 0.599, F1 score of 0.616, and mAP50 of 0.574, while limiting training time to 41 hours and carbon footprint to 3.90 kg CO2eq. These results demonstrate the viability of the proposed pipeline for large-scale ecological monitoring, while highlighting the need for further dataset refinement to address persistent annotation noise and image quality constraints.

11:30-11:45 ThAA.3

Neural Network Augmented Model Reference Adaptive Control for Systems with Nonlinear High-Frequency Uncertainty

Yareshe, Feleke Tsegaye	Tomas Bata University
Pekar, Libor	Tomas Bata University in Zlin
Song, Mengjie	Beijing Institute of Technology,
Roba, Meron Tadele	Tomas Bata University
Wolde, Mihret Kochito	Tomas Bata University

This work proposes a single-hidden-layer neural-network-augmented model reference adaptive control (NN-MRAC) approach for systems subject to mixed state-dependent nonlinear high-frequency time-varying matched uncertainties. First, the traditional Model Reference Adaptive Controller (MRAC) is examined under high-frequency harmonic disturbances, where parameter drift is observed despite acceptable tracking performance. To reduce this drift, a $sigma$-modification term is incorporated into the adaptive laws to ensure bounded parameter adaptation. The controller is then augmented with an online single-hidden-layer NN disturbance estimator, where the hidden-layer output is used to approximate the nonlinear and harmonic uncertainty terms through adaptive output weights. A Lyapunov-based stability analysis is provided to guarantee the uniform ultimate boundedness of the tracking error and adaptive parameters. Simulation results show that the proposed NN-MRAC achieves a 23.39% reduction in RMS tracking error, 60.71% reduction in integral absolute error (IAE), 67.94% reduction in integral squared error (ISE), 5.58% reduction in RMS control effort, and 24.31% reduction in the RMS of the control effort derivative compared with the $sigma$-MRAC controller.

11:45-12:00 ThAA.4

Bidirectional Transfer Learning for Closed-Loop LSTM Control across Coupled Control Loops in the BSM1 Wastewater Benchmark

Adil, Muhammad	Universitat Autònoma De Barcelona
Vilanova, Ramon	Universitat Autonoma De Barcelona

Artificial neural network (ANN)-based controllers have demonstrated improved tracking performance compared to conventional Proportional-Integral (PI) strategies in wastewater treatment plants, under nonlinear and disturbance-driven operating conditions. However, training separate neural controllers for each loop limits scalable deployment in multi-loop systems. This raises a fundamental control question: do neural feedback controllers learn loop-specific control laws or shared process dynamics reusable across actuators. A bidirectional transfer-learning study is conducted using Long Short-Term Memory (LSTM) feedback controllers in the Benchmark Simulation Model No. 1 (BSM1). A fixed four-sample lookback window is adopted, and two base controllers (DO-Base and NO-Base) are trained and employed as source models for bidirectional transfer learning. Multiple adaptation strategies are evaluated under a unified training protocol, showing that reliable transfer requires end-to-end fine-tuning. Closed-loop simulations under Dry, Rain, and Storm influent scenarios show that transfer-learned controllers reproduce the temporal closed-loop behavior of fully trained controllers without independent retraining, while preserving closed-loop stability and plant-wide performance. Plant-level indicators,

including Effluent Quality Index (EQI) and Operational Cost Index (OCI), remain stable across all configurations. The results indicate that the LSTM controller learns a transferable representation of disturbance-driven process dynamics, while actuator-dependent mappings are adapted during fine-tuning. Therefore, transferable closed-loop representations exist between heterogeneous biological control loops, enabling scalable neural controller deployment without retraining each loop.

12:00-12:15 ThAA.5

From Pixels to Points to Attention: Deep Models for Online Robot Collision Detection

Golluccio, Giacomo	University of Cassino and Southern Lazio
Di Vito, Daniele	University of Cassino and Southern Lazio
Antonelli, Gianluca	University of Cassino and Southern Lazio
Marino, Alessandro	Università Degli Studi Di Cassino

This work addresses the collision detection between robot structure and objects in cluttered environments using deep learning models with reduced computation time compared to geometric methods. Such task is crucial for re-planning and object grasping in scenarios with many items. In fact, although geometric approaches exist, they may not meet the strict time constraints that deep learning can satisfy. Thus, a classification approach is adopted using neural models that perform online collision detection from camera data, which contain information about the robot and the environment. In particular, starting from a scenario involving a redundant robot, namely the KINOVA Jaco2 7-DoFs arm, four different architectures are proposed and validated, ranging from convolutional to transformer models for depth images and 3D point clouds. A performance analysis is reported showing the remarkable low processing time with respect to geometric approaches. Furthermore, the influence of injected noise and data corruption is also analyzed to demonstrate the robustness of the approach.

12:15-12:30 ThAA.6

A Heuristic Approach for Performance Tuning in RL-Based Quadrotor Control Via Reward Design and Termination Conditions

Lagos, Fausto	Luleå University of Technology
Saradagi, Akshit	Luleå University of Technology, Sweden
Sumathy, Vidya	Luleå University of Technology
Nikolakopoulos, George	Luleå University of Technology, Sweden

Reinforcement learning (RL)-based quadrotor control policies have achieved impressive performance in tasks such as fast navigation in cluttered environments and drone racing, where the focus is on speed and agility. However, in several applications, such as infrastructure inspection, it is critical to achieve precise, controlled maneuvers with tunable performance. In this article, we present a novel heuristic approach to achieve tunable performance in RL-based Quadrotor control through reward design and termination conditions. We present a novel reward structure containing dual bandwidth exponential functions that achieves a baseline critically damped response in setpoint tracking, with small steady-state error. When trained with a Proximal Policy Optimization (PPO) algorithm, in conjunction with episode truncation conditions, the desired performance is achieved in 6 million time steps of training in a sample-efficient manner. In order to tune the performance about the baseline behavior, we present intuitive heuristic rules to adjust the reward weights and exponential coefficients to achieve faster (acrobatic-like) and slower (inspection-like) settling time performance, while retaining the baseline critically damped response and approximately 2% steady-state error. We evaluate the three RL policies (baseline, acrobatic, and inspection) across 100 trials and

show accurate and tunable performance in position and yaw tracking from random initial conditions, thereby demonstrating the effectiveness of the proposed heuristic approach.

ThAB	Room 155/d2
Modelling and Simulation 1 (Regular Session)	
Chair: Ruderman, Michael	University of Agder
Co-Chair: Zuyev, Alexander	Max Planck Institute for Dynamics of Complex Technical Systems

11:00-11:15 ThAB.1

Data-Driven Modeling of a Controlled Orthotropic Plate Using Machine Learning

Kim, Yongho	Max Planck Institute for Dynamics of Complex Technical Systems
Zuyev, Alexander	Max Planck Institute for Dynamics of Complex Technical Systems
Pellicano, Francesco	University of Modena and Reggio Emilia
Zippo, Antonio	University of Modena and Reggio Emilia

We study the problem of learning the input-output map of a controlled vibrating plate with a composite structure from experimental measurements. Analytical modeling of this control system faces challenges due to the essential orthotropy and unknown damping characteristics of the material. Surrogate models based on linear regression, multilayer perceptrons, and gated recurrent units are constructed from the available sampled data. Through comparative analysis, we show that the multilayer perceptron model provides an acceptable approximation of this dynamical system, capturing the potentially nonlinear phenomena in its input-output behavior.

11:15-11:30 ThAB.2

Valve Control Logic Impact on Defrost Cycle Operations in Cold Start Conditions

Ali, Mir Farooq	Università Politecnica Delle Marche
Perticaroli, Francesco	Ariston Group SpA
Marra, Lorenzo	Ariston Group SpA
Pepe, Crescenzo	Università Politecnica Delle Marche
Zanoli, Silvia Maria	University Politecnica Delle Marche

This study investigated the behavior of a residential heat pump during defrost cycle operation under cold start operating conditions. One promising approach consists of implementing intelligent valve control strategies that dynamically modify the hydraulic configuration of the heating system during the defrost cycle. Instead of permanently increasing the water volume through the installation of a buffer tank, additional heating zones can be temporarily activated during the defrost period in order to increase the circulating water volume and provide additional thermal support. Several simulation scenarios were analyzed in order to understand when the available thermal energy in the hydraulic circuit can guarantee the success of the defrost process. The results highlight an important aspect of defrost cycle operation that was not fully evident in previous analyses.

11:30-11:45 ThAB.3

Analysis and Extensions of Control-Oriented Hydraulic Actuator Model

Ruderman, Michael	University of Agder

In this paper, some structure- and physics-based limitations of a standard control-oriented modeling of hydraulic cylinder-driven actuators are analyzed and discussed, and possible extensions to bypass them are provided. While using a lumped-parameter

signals-oriented modeling approach, we describe the transfer elements and subsystems, both in linear and nonlinear way, while a valve-controlled hydraulic servo system with the output displacement of the loaded cylinder rod can be seen in an input-output modeling paradigm. In particular, we provide the extensions for: sign-dependent pressure gradients in the orifice equations, smoothing dead-zone nonlinearity in the controlled servo valve, incorporating presliding into the force-velocity friction map, and capturing the mechanical motion boundaries at both end-caps of the cylinder stroke. Moreover, several important linearized transfer characteristic properties are complementary addressed, being essential for any feedback control design for such hydraulic actuators. Specifically measured and monitored experimental features from a hydraulic laboratory test bench are also demonstrated and highlighted along with the explanatory characteristic maps and graphs.

11:45-12:00	ThAB.4

An Observation-Oriented Optimal Finite Difference Discretization of the Single Particle Model

Autieri, Andrea	University of Naples Federico II
Lo Iudice, Francesco	Università Degli Studi Di Napoli Federico II
Onori, Simona	Stanford University
Glielmo, Luigi	University of Napoli Federico II

In this paper, we consider the problem of optimizing the Finite Difference Method (FDM) discretization scheme of the Single Particle Model (SPM) for lithium ion batteries so to minimize the norm of the State of Charge (SoC) estimation error between a reduced and a full-order model. Specifically, we first recall the FDM discretization over a non uniform grid of the SPM. Then, we propose an algorithm to optimize the grid coordinates so to minimize the norm of the SoC estimation error produced by an extended Kalman Filter whose number of discretization points is much smaller than that of a baseline fullorder model that is also affected by measurement and process noise. Our results indicate that optimizing the discretization scheme can lead to substantial reductions in the root mean square estimation error, attaining an optimal trade-off between accuracy and computational efficiency.

12:00-12:15	ThAB.5

Topological Robustness in Formation Flight: A Sensitivity Study

Benvenuti, Luca	Univ. Di Roma
De Santis, Alberto	Sapienza University of Rome

In long-haul aviation, formation flying is a promising strategy to reduce fuel consumption by leveraging aerodynamic upwash. Finding optimal flight plans is a complex hybrid optimization problem, involving both discrete decisions (the sequence of aircraft groupings and separations) and continuous variables (rendezvous and breakaway coordinates). While previous research has focused on coordinate sensitivity, this paper investigates the topological robustness of the optimal structure. By analyzing three-aircraft scenarios across diverse trans- Atlantic routes, we evaluate how variations in follower efficiency gains affect the stability of the optimal topology. Our analysis identifies ‘topological plateaus'—parameter regions where discrete flight-plan decisions remain invariant—providing a reliable basis for operational planning under performance uncertainties. Results demonstrate that the core formation segments of the flight plan exhibit significant resilience to variations in efficiency parameters, with robustness being highly dependent on route pairing. These findings offer critical insights for the reliable implementation of commercial formation flight operations.

12:15-12:30 ThAB.6

A Mixed Integer Linear Programming Approach to Bridge the Gap between Diet Plans and Realistic Menus

Benvenuti, Luca Univ. Di Roma
De Santis, Alberto Sapienza University of Rome

Dietary patterns are provided to help individuals achieve specific health goals, such as sustainable weight loss, chronic disease management, improved nutrition, and the establishment of long-term healthy eating habits. However, implementing these patterns in real-world settings remains a challenge. While Linear Programming is widely and successfully used to define theoretical sustainable Reference Dietary Patterns (RDP), translating these optimized targets into realistic, culturally acceptable menus remains a significant operational challenge. Manual menu planning often fails to adhere strictly to RDP specifications, thereby compromising the intended nutritional and environmental benefits. To bridge this implementation gap, this study develops a Mixed Integer Linear Programming framework that transforms theoretical RDPs into practical menus. The approach is validated through a case study on the Italian diet for a two-week menu.

ThAC	Room 155/d3
Robotics 1 (Regular Session)	
Chair: Freddi, Alessandro	Università Politecnica Delle Marche

11:00-11:15 ThAC.1

Simulation-Based Evaluation of Robustness and Energetic Efficiency of Snake Robot Locomotion in Pipes

Vagas, Marek	Technical University of Kosice
Rusinak, Darius	Technical University of Kosice
Virgala, Ivan	Technical University of Kosice

Snake robots are well suited for inspection and navigation in confined pipe environments, where continuous contact with the surroundings is essential for locomotion. This paper presents an actuation-aware simulation-based evaluation of planar snake robot locomotion inside a straight pipe using an established dynamic interaction model and a fixed traveling-wave gait. Performance is assessed in terms of forward progression, actuator power, cost of transport (COT), robustness to selected model and environment parameters, and joint torque saturation. The results show that energetic efficiency is strongly influenced by contact and geometric properties, with pipe diameter and tangential friction dominating the sensitivity of COT. In the studied nominal configuration, realistic torque limits alter the intermittent contact regime and reduce COT compared with idealized unconstrained actuation. These findings indicate that energetic efficiency, robustness, and actuation feasibility should be jointly considered when evaluating snake robot locomotion in pipe environments.

11:15-11:30 ThAC.2

Integration of Generative Artificial Intelligence in Social Robots: Technical and Social Assessment of Next-Gen Human-Robot Interaction

Freddi, Alessandro	Università Politecnica Delle Marche
Genova, Oleg	Università Politecnica Delle Marche
Iarlori, Sabrina	Università Politecnica Delle Marche
Monteriù, Andrea	Università Politecnica Delle Marche

The purpose of this work is the integration and assessment of modern generative Artificial Intelligence text chatbots in combination with social robots, which permits to establish a human-friendly and human-like interaction. In detail, a human-robot vocal interaction scheme is presented, using OpenAI text generation service application programming interface in combination with a robot. The scheme implementation consists of delegating the messages management to an external device linked to the robot, which then provides feedback which is returned to the user via the robot. The implemented scheme was technically evaluated in terms of real-time use and computational burdens. Finally, the robotic platform was tested with a group of 23 users, who were asked to interact with the robot and fill in a survey to assess the quality of human-robot vocal interaction.

11:30-11:45 ThAC.3

PathPlanLLM: A LLM Based Path-Planning Framework for Scalable Context Window and Privacy-Aware Execution

Kulkarni, Nilesh Vivek	Luleå University of Technology
Kotpalliwar, Shruti	Luleå Tekniska Universitet
Saradagi, Akshit	Luleå University of Technology, Sweden

Nikolakopoulos, George Luleå University of Technology, Sweden

As robots are increasingly deployed in real-world environments, users expect to issue high-level navigation instructions in natural language and have the robot handle the details. A key challenge is that directly applying Large Language Models (LLMs) to path planning over 3D scene graphs exposes three fundamental failure modes: context windows overflow as map size grows (prompt complexity scales as O(|V|), where |V| is the number of graph nodes), geometric hallucinations produce paths over nonexistent edges, and transmitting scene graphs to cloud APIs risks leaking sensitive spatial data about private environments. We present PathPlanLLM, a neuro-symbolic framework that resolves all three limitations by shifting the LLM's role from planner to data engineer. Rather than serializing the scene graph into the prompt, PathPlanLLM provides the LLM only with a lightweight structural schema, the set of object category labels (typically 85–120 for indoor scenes) and uses a threestage pipeline: a Parser that maps natural language queries to structured intents, a Semantic Linker that resolves categories to unique node identifiers, and a Generative Code Executor (GCE) that prompts the LLM to synthesize, execute, and iteratively debug Python code against a local, sandboxed scene graph. This architecture achieves O(|C|) prompt scaling (sublinear in graph size), privacy by design (no instance-level spatial data ever leaves the local system), and formal path validity (every returned path is execution-verified or rejected). We evaluate PathPlanLLM on a 404-node hierarchical scene graph across 30 test cases spanning eleven query categories, achieving a 97% success rate and outperforming both baselines by a significant margin using the same Qwen2.5-Coder 14B model

11:45-12:00 ThAC.4

Real-World Deployment of a 5G-Connected Edge-Controlled Aerial Robot in Industrial Subterranean Mines

Seisa, Achilleas Santi Lulea University of Technology
Emanuele, Pagliari Ericsson Research
Damigos, Gerasimos Ericsson Research, Lulea University of Technology
Small, Elias Luleå University of Technology
Nikolakopoulos, George Luleå University of Technology, Sweden

This article presents the first real-world autonomous flight of a 5G-connected aerial robot controlled by an edge-offloaded controller, and aims to bridge the gap between controlled and factual setups. The robot operates within an active industrial subterranean mine, while the high-level controller is deployed in a nearby Kubernetes-based edge cluster. Communication between the robot and the edge is enabled via a 5G New Radio (NR) Standalone (SA) network. The chosen controller is a Model Predictive Controller (MPC), which generates control actions to allow the robot to navigate seamlessly through the mining environment. A human operator selects waypoints for the aerial robot, and the MPC generates smooth, collision-free paths for autonomous executions. The proposed 5G edge-based closed-loop system is evaluated in a real industrial setting and demonstrates the potential of edge-controlled robotic systems toward time-critical, safe and efficient future deployments.

12:00-12:15 ThAC.5

Consensus-Oriented Robot Navigation in Shared Spaces Via Opinion Dynamics and Adaptive Limit Cycles

d'Addato, Giulia	University of Trento
Falqueto, Placido	University of Trento
Palopoli, Luigi	Università Di Trento
Fontanelli, Daniele	University of Trento

When humans move in a shared space, they choose navigation strategies that preserve mutual safety while minimising unnecessary path modifications. To achieve this, humans rely on unwritten social rules and reach a consensus on motion direction through non-verbal cues, which is then implemented in a mutually acceptable way. Socially-aware navigation aims to replicate this logic in robotic systems. Existing approaches typically focus either on how robots can participate in such negotiations or on how they can move in a socially acceptable way. We propose a unified framework that couples opinion dynamics for directional consensus with vortex-based vector fields for trajectory generation, through a closed-loop integration where the consensus state modulates the vector field geometry. The results show that the proposed architecture produces consistent and socially compliant behaviours, outperforming the application of the two techniques in isolation.

12:15-12:30 ThAC.6

Observed Immediate Flight Response of Farmed Atlantic Salmon (salmo Salar) Using Horizontally Deployed EK15 Sonars

Evjemo, Linn Danielsen	SINTEF Ocean AS
Jónsdóttir, Kristbjörg Edda	SINTEF
Kelasidi, Eleni	NTNU

With growing attention to fish welfare in Norwegian salmon farming, new methods are needed to detect sudden changes in swimming behaviour, which may indicate stress. This study explores the use of horizontally deployed echosounders to monitor immediate behavioural responses in farmed Atlantic salmon. Although echosounders are widely used to monitor vertical school positioning in sea-cages, cameras dominate for detailed reactions, but face visibility issues. To address this, four horizontally oriented echosounders were mounted on a rig inside a sea-cage, alongside a camera and three vertical echosounders for comparison. Data were analysed to measure fish distance from the structure and detect abrupt changes. Results show that horizontal echosounders can reveal immediate reactions and shifts in biomass distribution around an object, offering a novel approach to behaviour monitoring.

12:30-12:45 ThAC.7

Design of a Water Current Estimate Law for Trajectory Tracking Control of Marine Surface Vessels

Sarkar, Antara	Indian Institute of Technology Guwahati
Basireddy, Sandeep Reddy	Indian Institute of Technology Guwahati
Dwivedy, Santosha K.	Indian Institute of Technology Guwahati

Water current estimation is essential for accurate trajectory tracking in marine surface vessels (MSVs). Traditional measurement methods incur high costs and maintenance while risking failures, while observer-based approaches often fail to adequately mitigate signal noise. Recent research has presented alternatives in the form of adaptive estimate

laws in the MSV kinematic model. However, results have shown a poor transient response. This paper proposes a simple water current estimate law that, apart from providing estimation and compensation for water currents, improves the MSV error system's transient response. Comparative trajectory tracking simulations on a 3-DOF MSV are presented to illustrate the superiority of the proposed approach.

ThAD	Room 155/d4
Process and Adaptive Control (Regular Session)	
Chair: Leva, Alberto	Politecnico Di Milano
Co-Chair: Rampazzo, Mirco	Università Di Padova

11:00-11:15 ThAD.1

Fast Autotuning without Initial Steady-State Detection

Verga, Federico Politecnico Di Milano

Leva, Alberto Politecnico Di Milano

Autotuning is widely adopted in industrial control systems, yet its deployment is often constrained by the duration and intrusiveness of the required tuning experiment. In step-based autotuning, reliable establishment of steady initial conditions represents a structural bottleneck, particularly in noisy industrial environments. This paper analyses model parametrisation under initial non-equilibrium conditions and quantifies how residual initial dynamics propagate through a selected model parametrisation procedure–tuning rule (MPP–TR) pair to affect closed-loop behaviour. A conceptual experimental framework is introduced to compute conservative admissible bounds on the initial output slope across representative process classes and IMC-based tuning configurations. The results show that tolerance is primarily identification-driven and strongly dependent on the dynamic character of the process. Rather than proposing universal thresholds, the analysis provides a structured procedure by which domain knowledge can be translated into quantitative tolerance bounds for fast, application-aware autotuning.

11:15-11:30 ThAD.2

An Advanced Regulatory Control Architecture for Coordinated DVFS and Liquid Cooling in High-Power Computing Nodes

Dionigi, Federico Politecnico Di Milano

Zheng, Jianwen Politecnico Di Milano

Terraneo, Federico Politecnico Di Milano

Leva, Alberto Politecnico Di Milano

Control of modern high-power computing nodes involves a fundamental trade-off between hardware safety, computational performance, and cooling effort. This paper presents an advanced regulatory control (ARC) architecture for the coordinated management of dynamic voltage and frequency scaling (DVFS) and liquid cooling at node level. The proposed structure combines fast DVFS-based temperature protection with slower modulation of coolant flow rate, enforcing temperature constraints while recovering the operating-system requested frequency whenever thermal conditions allow it through demand-driven cooling. Simulation results under time-varying workloads show effective constraint enforcement, graceful degradation under cooling limitations, and coordinated operation achieved using simple PI controllers. The results highlight the practical value of structured regulatory design for data centre operation and suggest ARC as a complementary foundation for higher-level supervision and optimisation.

11:30-11:45 ThAD.3

Modeling and Estimation of Alumina Concentration and Bath Temperature for Hall-Héroult Process

Maouche, Taha Moncef Gipsa-Lab, CNRS

Besancon, Gildas Grenoble INP UGA, Gipsa

Fiacchini, Mirko	GIPSA-Lab, CNRS
Mattioni, Andrea	Rio Tinto
da Silva Moreira, Lucas Jose	Rio Tinto
Roustan, Hervé	Rio Tinto

Advanced alumina regulation strategies have been developed in recent the years for the Hall-Héroult process. Temperature is typically a key factor studied to improve alumina concentration regulation, optimize aluminum production, and detect irregular operating conditions. However, the extreme operating conditions of the process make the implementation of sensors difficult. Smart state-observer–based sensors are therefore suggested to reconstruct the physical characteristics of the process from the available measurements. In this article, a state observer is designed to estimate the bath temperature and alumina concentration using only a single cell voltage measurement and available input signals. A candidate model combining thermal and mass balance dynamics is proposed, jointly with the design of its associated EKF-observer. The state observer is validated using real industrial data.

11:45-12:00 ThAD.4

A Control-Aware Neural Predictive Framework for Constrained Aeration Management in Wastewater Treatment Plants

Voipan, Daniel	Dunărea De Jos University of Galați
Solea, Razvan	Dunarea De Jos University of Galati
Barbu, Marian	Dunarea De Jos University of Galati

The extensive calibration burden of mechanistic process models is a common impediment to the deployment of Model Predictive Control (MPC) in wastewater treatment plants. In this paper, the Control-Aware Temporal Transformer (CATT) is introduced as a neural architecture that explicitly conditions effluent ammonium (SNHe) forecasts on candidate aeration sequences. This integration is made seamless with derivative-free MPC optimization. CATT outperforms LSTM-based baselines in both prediction accuracy and parameter efficiency when trained on Benchmark Simulation Model 2 (BSM2) data. The control-aware design is instrumental in ensuring reliable multi-step forecasting. Using probabilistic candidate rejection, a Cross-Entropy Method (CEM) optimizer enforces hard regulatory and actuator limits to ensure constraint satisfaction. Throughout the closed-loop simulation, CATT-MPC achieves zero regulatory violations, delivers substantial aeration energy savings, and maintains effluent quality within the target operational band in comparison to constant open-loop operation, all without requiring any mechanistic model calibration.

12:00-12:15 ThAD.5

Real-Time Optimisation of a Data Center Free-Cooling System Via Dither-Free Least-Squares Extremum Seeking

Hajaltoom, Lubna Eltayeb Kamaleldeen	University of Padova
Bregolato, Simone	University of Padova
Sisti, Enrico	University of Padova
Lionello, Michele	Vertiv
Beghi, Alessandro	Università Di Padova
Rampazzo, Mirco	Università Di Padova

This paper addresses the supervisory real-time optimisation (RTO) of a data center free-cooling (FC) system, with the aim of minimising auxiliary power consumption while meeting thermal requirements. The problem is handled in a measurement-based way by

adapting the pump and fan speed references online through a dither-free Least-Squares Extremum Seeking Control (LS-ESC) strategy based on first-order least-squares gradient estimation. The approach is assessed in a Simscape-based simulation environment of a coupled thermo-fluid FC system under a selected representative operating condition. The results show that the proposed method can recover the desired inlet temperature at the data center side while reducing the auxiliary power demand and coordinating the control effort between pump and fan in a non-trivial way. Overall, the study suggests that dither-free LS-ESC can serve as a practical supervisory RTO tool for FC applications and, more generally, for coupled thermo-fluid energy systems.

12:15-12:30 ThAD.6

A Reproducible Uncertainty Ladder Benchmark of MILP-MPC and PPO for Residential HVAC-PV-Battery Control

Tsaknakis, Christos	Democritus University of Thrace
Korkas, Christos	University of Western Macedonia
Vamvakas, Dimitrios	Democritus University of Thrace
Papaioannou, Ioannis	Center for Research and Technology Hellas
Boutalis, Yiannis	Democritus University of Thrace
Kosmatopoulos, Elias	Democritus University of Thrace and CERTH, Greece

This paper presents a runtime information parity benchmark comparing optimization-based and learning-based control strategies for residential HVAC-PV-battery systems operating under time-varying electricity prices and on-site PV generation. Using the Energym SimpleHouseRad-v0 environment in a heating-only scenario, we consider a 15-minute control interval with two discrete control decisions at each step: a heat-pump power command (u_hvac) and a battery command (u_bat) that maps to charge or discharge energy subject to power and state-of-charge limits. We compare (i) a real-time mixed-integer linear MPC (MILP-MPC) that optimizes a combined cost-comfort objective over a 6-hour horizon using a data-driven linear thermal predictor, and (ii) a model-free PPO policy trained under identical discrete action sets, reward definition, and horizon information. Fairness is ensured by using the exact same energy accounting model (PV-first, no-export grid balance), tariff handling, occupancy-driven comfort constraints (occupied comfort band and unoccupied safety bound), and identical forecast slices whenever forecasts are used. The main contribution is an uncertainty ladder that stress-tests both controllers under progressively harder deployment conditions: (1) perfect information, (2) noisy forecasts of weather, PV, and occupancy, and (3) model mismatch, where the actual plant deviates from the MPC's nominal prediction model. This protocol enables a reproducible and controlled quantification of robustness in cost-comfort trade-offs, clearly revealing how forecast errors and modeling inconsistencies affect MILP-MPC versus PPO under fully consistent assumptions.

ThBA	Room 155/d1
Intelligent Control (Regular Session)	
Chair: Ito, Kazuhisa	Shibaura Institute of Technology
Co-Chair: Tsuruhara, Satoshi	Shibaura Institute of Technology

14:00-14:15 ThBA.1

Explainable Adaptive PID Tuning with Reinforcement Learning in Anesthesia Induction

Poli, Cecilia	Istituto Superiore Di Sanità, Department of Technologies and Health
Menegatti, Danilo	University of Rome "La Sapienza"
Giuseppi, Alessandro	La Sapienza
Pietrabissa, Antonio	Consorzio Per La Ricerca nell'Automatica E Nelle Telecomunicazioni (CRAT)

Total Intravenous Anesthesia (TIVA) automation requires rapid induction while avoiding excessive depth of anesthesia, a challenge exacerbated by strong interpatient pharmacodynamic variability. Fixed-gain PID controllers often fail to balance responsiveness and safety, whereas advanced methods such as MPC or neural networks introduce opacity that complicates regulatory certification and clinical acceptance. This work proposes a Real-Time Adaptive PID controller whose gains are scheduled through a deterministic policy derived via offline tabular Q-Learning. The learned gain-scheduling map links discretized tracking-error states to optimal PID parameters, enabling dynamic adaptation from induction to maintenance while preserving full interpretability and deterministic behavior, key requirements for European Medical Device Regulation approval. The approach was evaluated through Monte Carlo simulations on 100 virtual patients generated by randomizing Schnider and Hill model parameters. Compared to a conventional fixed-gain PID, the Adaptive RL-PID significantly reduced safety violations while maintaining deterministic, explainable behavior. The framework offers RL-driven performance improvements while remaining compatible with certification pathways for safety-critical medical controllers.

14:15-14:30 ThBA.2

Hybrid Game-Theoretic and Reinforcement Learning for Collision Avoidance and Optimal Multi-Agent Aerial Coverage

Jeddi, Mohammad	Università Di Modena E Reggio Emilia
Nikoofard, Amirhossein	K. N. Toosi University of Technology (KNTU)

Efficient cooperative control and communication among multirotor UAVs face notable challenges, particularly in complex mission environments. This paper addresses these challenges by incorporating strategies to manage both static and dynamic obstacles while optimizing the number of agents required for specific tasks. We propose an enhanced action selection strategy that allows multirotor UAVs to navigate obstacles effectively, ensuring collision avoidance and maintaining comprehensive area coverage. Additionally, we introduce an innovative integration of cooperative search algorithms with reinforcement learning to minimize the number of multirotor UAVs needed, thus optimizing energy consumption. Simulation results validate the proposed approach, demonstrating its effectiveness in improving obstacle avoidance, optimizing agent deployment, and reducing operational costs. These contributions advance the state-of-the-art in cooperative multirotor UAV systems and have implications for applications such as search and rescue missions.

14:30-14:45 ThBA.3

Koopman-SHRED Sparse Identification of Epileptic Neural Dynamics

Lancia, Mattia — University of Rome La Sapienza
Federiconi, Filippo — La Sapienza
Giuseppi, Alessandro — La Sapienza

Explicit resolution and analysis of highly complex nonlinear dynamical systems has been partially exploited in years of traversal research, introducing increasingly good linear approximate solutions, the Koopman operator among others; still, formal identification of such systems remains a challenge common to every relevant field of engineering, assuming extreme relevance within control theory applications. The way generalized epilepsy-related phenomena have been studied is a perfect example of how good results can be archived in spite of incomplete knowledge, but lead to the affirmation of different parallel models, with their respective pro and cons. In this paper, a recent (artificial) intelligent and fully data-driven framework, SINDy-SHRED, is tested in the identification of a sparse linear surrogate dynamic of a set of epileptic neuronal populations, both in its classical learning and real-time integration.

14:45-15:00 ThBA.4

Spiking Neural Network Control for Mobile Robot Path Following

Troconis, Luigi Gabriel — Università Politecnica Delle Marche
Vella, Francesco — Università Politecnica Delle Marche
Chen, Qinyu — Leiden University
Freddi, Alessandro — Università Politecnica Delle Marche
Genova, Oleg — Università Politecnica Delle Marche
Monteriù, Andrea — Università Politecnica Delle Marche

This paper presents a novel Spiking Neural Network (SNN) Controller for high-level kinematic control of a mobile robot. Such a controller is equipped with a Pure Pursuit (PP) path planning logic to ensure smooth movement across predetermined random waypoints and, in kinematic simulations across 100 random scenarios, it is benchmarked against three alternatives: the PI expert controller, a structurally similar Artificial Neural Network (ANN) controller (all embedded with such PP logic), and the classical Pure-pursuit controller. Simulation results show comparable performance in tracking (average error $approx 0.33$ m on a 40-by-40 meter map). Crucially, due to its sparse event-driven processing, the SNN achieves lower (approximately halved) estimated computational energy consumption than the dense ANN counterpart, while preserving equivalent tracking performance, highlighting its primary advantage for mobile, possibly resource-constrained, robot platforms. As a preliminary, empirical robustness analysis, our approach was further validated in an additional, high-fidelity simulation of a Stretch RE-2 robot in Simscape/Simulink environment with added measurement and control noise, maintaining proper tracking and achieving a Mean Absolute Error of 0.58 m on a new unforeseen trajectory. Finally, successful runs stemming from the deployment of SNN controller on the physical Stretch RE-2 robot further confirm the validity and viability of the proposed controller for real-world applications.

15:00-15:15 ThBA.5

Data-Driven Model-Matching Error Compensator with Optimal Prediction-Based Design for Constrained Systems

Tsuruhara, Satoshi — Shibaura Institute of Technology
Yamamoto, Shota — Shibaura Institute of Technology

Ito, Kazuhisa Shibaura Institute of Technology

Advancements in the fusion of data-driven and model-based control, including fictitious reference iterative tuning (FRIT)-based model predictive control, and their effectiveness have been demonstrated in numerous studies. However, their control performance is strongly dependent on the model-matching accuracy of the inner loop. Thus, efficient design is a critical issue. This study focuses on improving the model-matching accuracy of data-driven control. In general, this can be improved by employing a model error compensator (MEC) or disturbance observer; a combination of MEC and FRIT has been studied. However, these methods require nominal models or filters, which limit the advantages of data-driven control. In this study, we propose a novel conditional feedback-type data-driven model-matching error compensator (MMEC) that explicitly reflects the model-matching error without a nominal model. Despite its data-driven approach, the proposed method enhances the robustness of existing control systems while considering the input constraints during the design phase. Furthermore, this study proposes a design method using prediction that eliminates the need to select a compensator structure and enables a more fully data-driven approach. The experimental results showed the effectiveness of the proposed method using a displacement control for a water-hydraulic artificial muscle with strong asymmetric hysteresis characteristics.

15:15-15:30 ThBA.6

Safe Urban Route Planning Via Semantic Graphs and Neural Cost Shaping

Plaku, Evis University Metropolitan Tirana
Lici, Geraldo University Metropolitan Tirana
Niculescu, Silviu-Iulian University Paris-Saclay, CNRS, CentraleSupelec, Inria
Cela, Arben Université Gustave Eiffel, ESIEE Paris

Urban route planning requires geometrically feasible paths that strictly adhere to traffic regulations encoded in high-definition semantic maps. We present a semantic lane-segment road-graph planner that reweights a nominal edge cost (distance plus rule penalties) using an edge-aware Graph Neural Network (GNN) to predict bounded multiplicative cost-shaping factors. This approach guides A* search while preserving auditability and compatibility with admissible geometry-based heuristics. To reduce reliance on hand-tuned supervisors, the GNN is trained via multi-teacher distillation with a calibration regularizer that prevents unnecessary deviations from the nominal cost. In CARLA simulations (2,100 trials), our planner improves success to 96.8% A*: 78.0%) and reduces collisions/violations to 1.2/2.1 per trip (A*: 12.5/22.0), while maintaining near-baseline path lengths.

ThBB	Room 155/d2
Modelling and Simulation 2 (Regular Session)	
Chair: Monteriù, Andrea	Università Politecnica delle Marche
Co-Chair: Baldini, Alessandro	Università Politecnica delle Marche

14:00-14:15 ThBB.1

Stochastic Tube-Based MPC Framework for the Problem of Anesthesia Administration

Nappini, Alessandra	Sapienza Università Di Roma
Iacoviello, Daniela	Sapienza University of Rome
Di Giamberardino, Paolo	Sapienza, University of Rome

Drug dosage represents an interesting topic in view of providing guidance to determine efficient and less toxic as possible personalized dosing. In particular, anesthesia effects strongly depends on subject's characteristics, weight, height, age; the bispectral index (BIS), in the scale 0-100, is an index ranging from deep unconsciousness up to the normal brain activity, used to define the suitable anesthesia doses. In this paper, an optimal control strategy is proposed to regulate the drug concentration close to a reference value (corresponding to the BIS reference one), employing a new stochastic Model Predictive Control (SMPC) reformulation of the optimal administration problem, including uncertainty in the model as well.

14:15-14:30 ThBB.2

Structure-Preserving Object-Oriented Modelling of Reaction-Driven Plants

Esposito, Federico	Politecnico Di Milano
Punzo, Giorgio	Politecnico Di Milano
Leva, Alberto	Politecnico Di Milano

Object-oriented modelling (OOM) offers modularity and reuse, yet its application to large-scale chemical plant models may introduce a structural tension between species-based reaction dynamics and port-based interconnection abstractions. This paper analyses this tension and formulates a structure-preserving architectural principle for reaction-driven plants within equation-based OOM frameworks. The proposed organisation keeps reaction source terms local to unit operations while handling inter-unit coupling exclusively through transport interfaces, thereby preserving plant-level structural decomposition. The approach is demonstrated on the Tennessee Eastman benchmark and validated against a literature reference. Simulation results show identical dynamic trajectories and unchanged differential–algebraic properties with respect to a monolithic implementation, confirming that the architectural reformulation preserves the structural and numerical characteristics of the underlying large-scale nonlinear system.

14:30-14:45 ThBB.3

Comparative Kinematic Modeling and Control Validation of a 4-DOF Robotic Arm Using CAD-Based and Analytical Approaches

Roba, Meron Tadele	Tomas Bata University
Radek, Matušů	Tomas Bata University
Yareshe, Feleke Tsegaye	Tomas Bata University
Wolde, Mihret Kochito	Tomas Bata University
Wendimu, Abebe Alemu	Tomas Bata University

This paper present a comparative kinematic modeling and control validation study of a

4-DOF robotic arm using CAD-based and analytical approaches. The CAD model of the robotic arm was generated in SolidWorks and exported to MATLAB/Simscape Multibody to obtain a physics based simulation plant. In parallel, a geometric Denavit–Hartenberg (DH) model was formulated to provide compact forward- and inverse-kinematic equations.The two models were compared in task space by applying the same joint trajectory and comparing the position of the end effector position with the analytical FK output after fixed frame alignment. FK and IK consistency was also verified within the analytical model. The task space RMS and max position errors were 0.004593 m and 0.009696 m, respectively, confirming close kinematic agreement between the CAD-derived and analytical models. A baseline PD controller was implemented on the Simscape model for testing the joint tracking and actuator torque feasibility. As the maximum error was observed in Joint 3, the PSO based PD controller tuning was performed which resulted in minimizing the RMS tracking error while keeping the torque below the actuator threshold limit.

14:45-15:00 ThBB.4

Physics Validation of Simulation Engines for Plant–Robot Interaction in Agricultural Settings

Unlu, Muhammed Veli Istanbul Technical University
Yilmaz, Abdurrahman Istanbul Technical University

The development, training, and testing of agricultural robots requires simulation environments that combine photorealistic sensing with physically credible plant interaction. While modern game engines offer high visual fidelity, their suitability for plant-level dynamic interaction remains insufficiently validated for robotic applications. This study presents a hybrid UE5--ROS2 simulation framework and systematically evaluates the physical behavior of Unreal Engine~5 (Chaos) against Gazebo Classic (ODE) for articulated plant models. A unified cross-engine architecture enables deterministic model reconstruction and synchronized state comparison under identical boundary conditions. Verification and validation are conducted in two stages: canonical benchmark systems (mass–spring–damper, pendulum, and bouncing ball) are used to verify solver-level numerical behavior, followed by plant-level cross-engine validation experiments on articulated strawberry models. Results show that although the Chaos solver exhibits stronger cumulative numerical dissipation compared to ODE, both engines produce stable and bounded dynamic responses within short-horizon interaction regimes. These findings support the use of UE5 as a credible simulation platform for perception-driven agricultural robotics when long-term elasticity fidelity is not the primary objective.

15:00-15:15 ThBB.5

Predicting Dengue Outbreak Dynamics from Climate and Socio-Economical Data

Federiconi, Filippo La Sapienza
Giuseppi, Alessandro La Sapienza
Iacoviello, Daniela Sapienza University of Rome

Dengue fever represents a significant public health threat, particularly in tropical and subtropical regions. The incidence of this mosquito-borne viral infection has increased dramatically in recent decades, posing a considerable challenge to healthcare systems. Accurate and early prediction of dengue outbreaks is crucial for effective public health intervention, yet remains a challenge due to the complex spread factors. This paper addresses this challenge by developing and comparing two machine learning models for forecasting dengue incidence in several South American countries. We constructed a comprehensive dataset integrating heterogeneous data sources, including climatic,

socio-economic, and historical epidemiological records. We propose and evaluate two distinct approaches: a stacking ensemble model composed of CatBoost regressors and a feed-forward Neural Network. The models were evaluated on an unseen test set composed by up to 14 months into the future. Our results demonstrate that the Neural Network generally achieves superior performance in terms of error metrics, whereas the ensemble model, while effective in identifying key predictive features such as temporal and environmental variables, showed limitations in accurately capturing the peak magnitude of outbreaks. Our findings highlights the potential of integrating heterogeneous datasets with advanced machine learning techniques for early dengue epidemic detection.

15:15-15:30 ThBB.6

Simulation of a Realistic Mining Environment for Near Field Evaluation of LiDAR and IMU Based SLAM Algorithms

Frantzis, Theodore	University of Patras
Kousios, Achilleas	University of Patras
Kritikou, Georgia	University of Patras
Koustoumpardis, Panagiotis	University of Patras
Nikolakopoulos, George	Luleå University of Technology, Sweden

Underground mines are highly dangerous for both humans and the environment, thus the utilization of robotic systems in mines can provide an additional layer of safety for workers. However, testing and experimenting with robots in real-world conditions can be challenging, as mining operations may be disrupted, and robotic equipment may be damaged. Therefore, simulating accurate mining environments is crucial to support the development and integration of robotic systems before field testing them in realistic mining scenarios. This article presents the development of a novel mining simulated environment for the motion of a teleoperated vehicle in realistic mining conditions via physics-based simulations in Gazebo Fortress. The Light Detection and Ranging (LiDAR) and the Inertial Measurement Unit (IMU) sensors integrated into the vehicle were simulated and the resulted data were applied to the Direct LiDAR-Inertial Odometry (DLIO) and LiDAR-Inertial Odometry via Smoothing and Mapping (LIO-SAM) SLAM algorithms, which were chosen over others as the most suitable for this application based on specific criteria. The efficacy of the proposed scheme is presented through multiple realistic simulated environments, the operations of the vehicle and the corresponding results of the developed SLAM algorithms.

ThBC	Room 155/d3
Robotics 2 (Regular Session)	
Chair: Simetti, Enrico	University of Genova
Co-Chair: Lino, Paolo	Technical University of Bari

14:00-14:15 ThBC.1

A Near–Far Hybrid Architecture for Disturbed Unicycle Moving-Reference Tracking

Do, Thanh Binh	Le Havre University
Guerin, François	Université Le Havre

We study moving-reference tracking for a dis- turbed unicycle using a controller that switches once from a far polar chart to a near body-frame chart. The far chart is used only for approach, where target-relative geometry is natural but ill-conditioned near the reference. The near chart is used only for terminal regulation, where body-frame errors remain regular and admit a local robustness certificate. The paper develops a single-handoff tracking framework with three components: a conditional contraction estimate on a certified far shell, an exact Lyapunov-based handoff condition, and a local practical stability result for a geometric near controller that compensates for reference-speed variation. This near-layer correction closes the previous certification gap at the disturbance level used in the experiments. The numerical study is organized to match the theory. It verifies theorem-compatible post-handoff behavior in the certified near regime and compares far-only, near-only, and hybrid controllers on a common benchmark. On the tested grid, all three controllers capture, but far-only and near-only each require impractical control effort, whereas the hybrid achieves comparable terminal precision at two orders of magnitude less effort. Keywords— hybrid tracking, unicycle, practical ISS, coor- dinate patching, acquisition, terminal regulatio

14:15-14:30 ThBC.2

A Modular Safety Supervision Architecture for Functional Safety in Collaborative Robotic Systems

Montanaro, Delio	Polytechnic University of Bari
Timpone, Pierfrancesco	Polytechnic University of Bari
Lino, Paolo	Technical University of Bari
Gioscia, Amelia	Politecnico Di Bari
Saltarelli, Nicola	Polytechnic University of Bari
Tomaselli, Michele	Politecnico Di Bari
De Carlo, Pietro	CVIT S.p.A
Sciusco, Adriano	CVIT S.p.A

This paper presents a modular and reusable safety supervision architecture for collaborative robotic systems, addressing Functional Safety as an integrated control and supervision problem rather than as a set of hard constraints. The proposed framework introduces a clear separation between nominal control and safety supervision, a plugin-based state machine for safety mode management, and centralized fault handling with event traceability. Safety is implemented as a control-layer mechanism through command scaling, saturation, and controlled transitions between operational modes. The architecture is validated through a fault-injection campaign on a digital twin of a collaborative robot, including corrupted distance measurements, artificial logic latency, and temporary sensor dropout. Results show a temporally consistent supervisory response, with an end-to-end reaction time of approximately 0.060s and an internal

controller latency of a few milliseconds. These findings support the effectiveness of the proposed architecture as a safety-aware supervisory layer for collaborative robotic operation in industrial contexts.

14:30-14:45	ThBC.3

RePO: Reactive Policies with Observation Augmentation

Vaaler, Aksel	Norwegian University of Science and Technology
Høeg, Sigmund Hennum	Norwegian University of Science and Technology
Stige, Helle	Norwegian University of Science and Technology
Holden, Christian	Norwegian University of Science and Technology

Robotic imitation learning (IL) in dynamic environments, where object positions or external forces change unpredictably, poses a major challenge for current state-of-the-art methods. These methods often rely on multi-step, open-loop action execution for temporal consistency, but this approach hinders reactivity and adaptation under dynamic conditions. As a response, we propose RePO, a robust and responsive IL framework that predicts single-step actions based on a sequence of past image observations. To mitigate the susceptibility to covariate shift that arises from longer observation horizons, RePO injects adversarial noise into low-dimensional spatial image embeddings during training. This enhances robustness to out-of-distribution states while preserving semantic content. The framework can be used with any transformer-based action policy. We present two variants, RePO-BCT and RePO-DP, and show that using RePO consistently improves model performance on a diverse set of real and simulated robotic tasks featuring unpredictable perturbations. Our results demonstrate that the proposed method enables both temporally consistent and reactive policy learning for dynamic robotic tasks.

14:45-15:00	ThBC.4

Online Reinforcement Learning for Adaptive Gain Tuning in Image-Based Visual Servoing

Saltarelli, Nicola	Polytechnic University of Bari
Lino, Paolo	Technical University of Bari

This paper proposes a novel image-based visual servoing (IBVS) controller for robotic manipulators that combines an optimized Extreme Learning Machine (ELM) with an online Reinforcement Learning (RL) strategy. An ELM optimized by Particle Swarm Optimization (ELM-PSO) is employed to approximate the pseudo-inverse of the visual interaction matrix, improving robustness against calibration errors. To enhance adaptability, a Continuous Action Q-Learning (CAQL) algorithm adjusts the visual servo gain online within a continuous action space. This hybrid framework enables the controller to achieve faster convergence and increased stability without offline training. Simulation results on a 6-DOF manipulator confirm superior tracking performance and robustness compared with conventional Q-learning and classical IBVS methods.

15:00-15:15	ThBC.5

Online Deformation Estimation in Compliant Hyper-Redundant Robots Via Lumped Parameter Modeling and Extended Kalman Filtering

Piemontese, Marzia	Università Campus Bio-Medico Di Roma
Zollo, Loredana	Università Campus Bio-Medico Di Roma
Lauretti, Clemente	Università Campus Bio-Medico Di Roma

Hyper-redundant robots (HRRs) offer exceptional dexterity and intrinsic safety, making them ideal for constrained and unstructured environments. However, their long and slender bodies pose significant challenges for accurate kinematic modeling and control, as their shape is heavily influenced by gravity and external payloads. Accurate configuration estimation is therefore crucial and has been previously done via a Lumped Parameter Model (LPM), adding a compliant Virtual Passive Joint (VPJ) to the kinematic chain. This paper proposes a novel approach for estimating the VPJ angles and compliance and the overall shape of an HRR using an Extended Kalman Filter (EKF). The manipulator is modeled using an LPM that alternates active and virtual passive joints (VPJs) to capture the flexibility of the structure. By relying exclusively on a single position marker at the end-effector, the EKF dynamically estimates the VPJ angles and the elements of the diagonal compliance matrix. The observability of the system is mathematically analyzed, highlighting the necessary dynamic conditions for successful estimation. The proposed filter is validated in a simulated environment on HRRs with 8, 12, and 16 degrees of freedom (DOFs) during both free-space movement and payload manipulation. Results demonstrate rapid convergence and robust tracking capabilities, achieving an end-effector position error of less than 0.2 mm under dynamic payload variations, and less than 0.5 mm in the case of discrepancies between the model and the real compliance of the VPJs. Computational times are compatible with a 50 Hz control loop using compiled language.

15:15-15:30 ThBC.6

Automated Tactile Data Collection for Generalization in Robotic Slip Detection

Ayral, Théo Université Paris-Saclay
Aloui, Saifeddine Université Grenoble Alpes, CEA, Leti
Grossard, Mathieu CEA List

Reliable slip detection is essential for stable robotic grasping, enabling rapid corrective actions while limiting grasp forces. Although data-driven tactile slip detectors show strong performance in controlled settings, their deployment on real robotic hands is constrained by the lack of scalable, well-instrumented data and by limited understanding of generalization across objects and contact conditions. We present an automated tactile data-collection framework for a multi-fingered gripper, leveraging a robotic bench for generating parameterized slip events with precise ground-truth timing. The setup enables systematic variation of grasp configurations, contact forces, object geometries, surface materials, and slip kinematics. Using this framework, we evaluate a spectro–temporal slip detection model operating at 100 Hz and study data efficiency and generalization to unseen materials and shapes. The proposed approach achieves 98.1% balanced accuracy with an average detection latency of 20 ms. Experiments demonstrate that generalization in tactile slip detection benefits from structured data-collection methodologies providing data diversity. The results provide practical guidance for deploying low-latency slip detection on dexterous robotic grippers.

ThBD	Room 155/d4
Adaptive Control (Regular Session)	
Chair: Aksikas, Ilyasse	Qatar University
Co-Chair: Zarzycki, Krzysztof	Warsaw University of Technology

14:00-14:15 ThBD.1

Scalability, Stability, and Real-Time Feasibility of Hierarchical Reinforcement Learning for Large-Scale EV Charging Control

Vamvakas, Dimitrios	Democritus University of Thrace
Korkas, Christos	University of Western Macedonia
Tsaknakis, Christos	Democritus University of Thrace
Ioannis, Papaioannou	Center for Research and Technology Hellas
Kosmatopoulos, Elias	Democritus University of Thrace and CERTH, Greece

This paper evaluates the operational scalability of a hierarchical reinforcement learning framework for coordinated electric vehicle charging, where a Distribution System Operator (DSO) generates dynamic pricing signals to indirectly shape the charging behavior of multiple Load Aggregators (LAs) managing electric vehicle charging stations. To stress-test fleet-scale deployment, we consider three progressively larger configurations, comprising 10, 25 and 100 charging stations. Beyond control performance, a systems-level characterization of computational cost is provided, including wall-clock training times, inference latencies, and learning stability indicators. Results show near-linear growth of end-to-end training time and inference time with system size, while inference remains within real-time operational requirements for all three configurations. From a grid perspective, larger fleets exhibit higher load fluctuation, without sacrificing end-user satisfaction, while operator profit increases as expected with scale. We further evaluate robustness to deployment stressors by perturbing price actions via quantization, dropouts, and ramp-rate limits, and the observations via noisy and delayed telemetry. Results show performance is comparatively tolerant to telemetry corruption, while price-based constraints are the dominant source of degradation.

14:15-14:30 ThBD.2

An L1-Adaptive Control Lyapunov Function Quadratic Program for Torque Constrained Space Manipulators under Uncertainty

Skandalakis, Nikolaos	National Technical University of Athens
Nanos, Kostas	National Technical University of Athens
Poulakakis, Ioannis	University of Delaware

Accurate on-orbit operations of Space Manipulator Systems (SMS) require model-based controllers that rely on the precise knowledge of system parameters, which may vary in practice. Such uncertainties—e.g., joint motor friction—can degrade tracking accuracy, motivating the need for advanced control strategies. This work investigates an L1-adaptive Control Lyapunov Function-based Quadratic Programming approach selected for its ability to incorporate system constraints directly into the design, and evaluates its performance against established approaches such as Model-based PD control. The objective is to drive the manipulator to a desired joint-space configuration while simultaneously maintaining the desired spacecraft attitude, thereby reducing mission-critical risks. The proposed formulation accounts for the coupled rigid-body dynamics of the SMS and demonstrates robustness to realistic parameter variations, as

verified through simulation results.

14:30-14:45 ThBD.3

Adaptive Control Allocation for Incremental Nonlinear Dynamic Inversion under Actuator Degradation

Franceschini, Giulio Politecnico Di Milano
Raos, Giorgio Politecnico Di Milano
Gozzini, Giovanni Politecnico Di Milano
Invernizzi, Davide Politecnico Di Milano

Incremental Nonlinear Dynamic Inversion (INDI) control is known to possess robustness properties with respect to modeling uncertainties, primarily due to its limited model dependence, but it can struggle to maintain performance under severe actuator degradation and, more generally, when the input map used for control allocation is highly inaccurate. Since control allocation is the only explicitly model-dependent element in INDI, this paper proposes and analyzes adaptive strategies to improve the accuracy of the allocation step. A predictor-based model reference adaptive control (PMRAC) approach is first introduced, followed by two online parameter-estimation methods: concurrent learning with directional forgetting and a two-layered recursive least-squares scheme. Simulation results on a nonlinear overactuated aircraft model demonstrate improved tracking performance compared with baseline INDI and the PMRAC augmentation under substantial input-map uncertainty, including severe actuator degradation.

14:45-15:00 ThBD.4

IRL–Based Adaptive Control of a Plug-Flow Reactor Nonlinear PDEs Model Via the Method of Characteristics

Aksikas, Ilyasse Qatar University

This paper develops an integral reinforcement learning (IRL) approach for optimal adaptive temperature regulation in a nonisothermal plug-flow reactor modeled by nonlinear convection--reaction partial differential equations (PDEs). Exploiting the hyperbolic structure, the method of characteristics is used to derive an equivalent characteristic representation that avoids spatial discretization in the control design. An online IRL policy-iteration scheme is then formulated via an integral Bellman relation, enabling policy evaluation and improvement from measured trajectories without requiring explicit knowledge of the system dynamics. In the numerical simulations, a finite-dimensional approximation of the value function using basis functions is employed to implement the policy-iteration updates in real time. The simulation results demonstrate closed-loop stabilization and progressive performance improvement over policy iterations.

15:00-15:15 ThBD.5

Adaptive Differentiating Filter: Case Study of PID Feedback Control

Pavlov, Alexey Norwegian University of Science and Technology
Ruderman, Michael University of Agder

This paper introduces an adaptive causal discrete-time filter for derivative estimation, exemplified by its use in estimating the relative velocity in a mechatronic application. The filter is based on a constrained least-squares estimator with window adaptation. It demonstrates low sensitivity to low-amplitude measurement noise, while preserving a broad bandwidth for large-amplitude changes in the process signal. Favorable performance properties of the filter are discussed and demonstrated in a practical case

study of PID feedback controller and compared experimentally to a standard linear low-pass filter-based differentiator and a robust sliding-mode based homogeneous differentiator.

15:15-15:30	ThBD.6

Adaptive Reference Speed Selection for Mobile Robot Via a Data-Driven Multi-Objective Learning

Chellal, Arezki Abderrahim	IPB
Braun, João	Instituto Politécnico De Bragança
Gonçalves, José A.	IPB
Valente, Antonio	University of Tras-Os-Montes and Alto Douro
Lima, Jose	CeDRI - Research Center in Digitalization and Intelligent Robotics, Instituto Politécnico De Bragança

The robot's energy efficiency can often be optimized during the early stage of robot design. The robot's speed highly influences its energy consumption, in particular, a robot's reference speed strongly influences the trade-off between energy consumption and mission duration, yet it is commonly selected as a fixed parameter, independently on the path geometry. An extensive offline simulation has been conducted at different speeds (0.3 m/s - 1.1 m/s) to collect performance data for a Mecanum-wheeled robot. After a Pareto front analysis, an offline method based on a Random Forest Regressor has been developed to dynamically adjust the optimal reference speed for each path. The H∞ controller has been preferred for its robustness and disturbance rejection for a range of speeds. The proposed approach was first evaluated on a held-out test set and subsequently assessed on a multi-goal navigation task comprising 15 sequential objectives. Comparative results against several fixed speed baselines demonstrate that the proposed speed selector achieves a favorable energy-time compromise. In particular, it reduced total energy consumption by 7% at the cost of a minor increase in execution time of about 2% compared to a constant speed reference of 0.70 m/s, a speed that was identified as optimal for 45% of the studied paths.

ThCA	Room 155/d1
Control Engineering and Robotics for Education (Invited Session)	
Chair: Nulli, Giovanni	Istituto Nazionale Di Documentazione, Innovazione E Ricerca Educativa
Co-Chair: Morano, Martina	Università Politecnica Delle Marche
Co-Chair: Castagna, Benedetta	Università Politecnica Delle Marche
Organizer: Morano, Martina	Università Politecnica Delle Marche
Organizer: Nulli, Giovanni	Istituto Nazionale Di Documentazione, Innovazione E Ricerca Educativa
Organizer: Sović Kržić, Ana	University of Zagreb
Organizer: Scaradozzi, David	Università Politecnica Delle Marche

16:00-16:15 ThCA.1

Extending Hospital Edutainment in Pediatric Care through Virtual and Augmented Reality: A Feasibility Study (I)

Di Nardo, Francesco	Università Politecnica Delle Marche
Reinini, Andrea	Università Politecnica Delle Marche
Morano, Martina	Università Politecnica Delle Marche
Coccia, Paola	Presidio Ospedaliero Di Alta Specializzazione "G.Salesi", Azienda Ospedaliero Universitaria Delle Marche, Ancona, Italy
Castagna, Benedetta	Università Politecnica Delle Marche
Fiara, Giacomo	Università Politecnica Delle Marche
Mancini, Adriano	Università Politecnica Delle Marche
Scaradozzi, David	Università Politecnica Delle Marche

Prolonged pediatric hospitalization can affect children's cognitive, emotional, and social development by limiting access to education, play, and peer interaction. Hospital-based edutainment programs have been shown to mitigate these effects. Unfortunately, in-person activities are often constrained for patients with severe illness or immunosuppression. The present study was designed to assess the feasibility of a bedside educational curriculum in a pediatric onco-hematology context, based on virtual (VR) and augmented reality (AR). The curriculum consists of three progressive instructional modules: conceptual introduction to VR/AR; guided exploration of interactive virtual environments via Delightex EDU platform; and autonomous creation of personalized virtual worlds. A preliminary implementation was performed, involving a single hospitalized patient, supported by an educator and a parent, using standard mobile devices at the bedside. Observational data were acquired, focused on engagement, usability, and experiential outcomes. Results indicate that the VR/AR module is technically feasible, compatible with clinical routines, and capable of fostering attention, curiosity, and creative expression. The combination of VR and AR modalities allowed immersive interaction while maintaining environmental awareness. These findings suggest that bedside VR/AR interventions can complement traditional hospital edutainment, supporting learning, autonomy, and emotional well-being.

16:15-16:30 ThCA.2

From SAUC-E to RAMI: Robotics Competitions to Breed the Next Generation of Marine Roboticists (I)

Celi, Federico	NATO-STO CMRE, Centre for Maritime Research and Experimentation
Faggiani, Alessandro	CMRE
Ferri, Gabriele	NATO-STO CMRE, Centre for Maritime Research and Experimentation

Robotics' student competitions serve as structured environments for developing the practical, system-level competencies that the marine robotics sector requires but that university curricula alone cannot always provide. This paper presents an analysis of the Robotics for Asset Inspection and Maintenance (RAMI) competition, organized by the NATO STO Centre for Maritime Research and Experimentation (CMRE) in La Spezia, Italy, with particular focus on the 2025 edition. We trace the historical evolution of CMRE-organized competi- tions from the Student AUV Challenge – Europe (SAUC-E), launched in 2010, through the euRathlon Grand Challenge and the European Robotics League Emergency series, to the current RAMI format. The competition's design philosophy centers on realistic inspection and maintenance scenarios for Critical Undersea Infrastructure, with emphasis on autonomous perception, multi-domain interoperability, and adaptive mission planning. An analysis of RAMI25 outcomes supports the intuition that this competition model is both educationally productive and strategically relevant. We conclude by outlining the path towards future editions that aim to further broaden the competition's multi-domain interoperability ambitions together with the involvement of the industrial sector.

16:30-16:45 ThCA.3

PEARL – Platform for Expert Annotation of Robotics Learning (I)

Uroić, Leon Stjepan	University of Zagreb Faculty of Electrical Engineering and Computing
Livaja Musac, Petra	University of Zagreb Faculty of Electrical Engineering and Computing
Puškar, Liljana	University of Zagreb Faculty of Electrical Engineering and Computing
Sović Kržić, Ana	University of Zagreb

Educational robotics environments, such as LEGO Spike Prime, are used to support the development of programming skills in school workshops. These activities often involve multiple students solving programming tasks, which creates the need for an efficient and structured assessment of their solutions. Assessing programs developed for educational robots can be time-consuming and inconsistent without clearly defined evaluation criteria and dedicated tools that support systematic annotation during the grading process. To address this challenge, we defined a grading methodology for evaluating student programming solutions created for LEGO Spike Prime educational robots. Based on this methodology, we designed and implemented the PEARL (Platform for Expert Annotation of Robotics Learning) user interface that enables structured annotation and assessment of student submissions. This paper presents the design of the proposed interface and the set of annotations integrated in it to support the grading process in educational robotics workshops. The proposed interface supports a more structured and transparent assessment process for student programming solutions in educational robotics workshops.

16:45-17:00 ThCA.4

A Serious Game Approach for Teaching Control Concepts from Simulation-To-Real Robotic Framework (I)

Morano, Martina	Università Politecnica Delle Marche
Collevecchio, Davide	Università Politecnica Delle Marche
Ripani, Alessandro	Università Politecnica Delle Marche
Giachini, Francesco	Università Politecnica Delle Marche
Fiara, Giacomo	Università Politecnica Delle Marche
Gioiello, Flavia	Università Politecnica Delle Marche
Bartolucci, Veronica	Università Politecnica Delle Marche
Di Nardo, Francesco	Università Politecnica Delle Marche
Scaradozzi, David	Università Politecnica Delle Marche

Control engineering is traditionally introduced through formal mathematical modelling, which may limit pre-university students' ability to link learned notions with system behaviour. Recent discussions in the control education community advocate approaches emphasising feedback and basic control principles over excessive formalism. In this context, Serious Games (SGs) offer a promising way to combine structured control concepts with interactive experimentation. This paper presents the design and preliminary validation of a SG for introducing PID control to high-school students. The SG is embedded in a two-step educational framework combining virtual experimentation with a Segway-based robot, and subsequent hands-on activities on the same physical platform. Educational effectiveness was evaluated along two complementary dimensions, perception and knowledge. Perception captures students' self-reported confidence and attitudes toward robotics and control, while knowledge measures their objective understanding of PID concepts. A pilot study involving 33 students (31 with complete matched data) was conducted using a pre–post design. Perception scores increased significantly from 3.18 to 3.66 (Δ = +0.48, $p < 0.001$), while knowledge scores increased from 3.61 to 4.29 out of 5 (Δ = +0.68, $p = 0.0014$), corresponding to a gain of +13.5 percentage points. These results indicate that SGs can effectively support the initial understanding of PID control while facilitating the transition toward physical implementation.

17:00-17:15 ThCA.6

Design and Teacher Validation of a Marine Educational Robotics Toolkit for Fostering Control Education (I)

Morano, Martina	Università Politecnica Delle Marche
Di Nardo, Francesco	Università Politecnica Delle Marche
Castagna, Benedetta	Università Politecnica Delle Marche
Scaradozzi, David	Università Politecnica Delle Marche

Control education represents a foundational component of engineering literacy, as it introduces students to feedback regulation, system behaviour, and the interaction between sensing and actuation. However, in primary and lower secondary education, robotics activities are often limited to programming logic, while explicit treatment of control concepts and dynamic system understanding remains marginal. At the same time, many teachers lack formal preparation in core engineering domains. This paper presents the validation of a marine educational robotic toolkit (WetToolkit) developed within the Erasmus+ project RoboAquaria, together with a teacher-training workshop (LTTA). The proposed framework integrates elementary control concepts through structured hands-on activities. A pre/post intervention study involving 21 educators was conducted to evaluate changes in perception and technical knowledge. Results show a statistically significant increase in perception, especially in self-efficacy related to robotics, along with improvements in knowledge items addressing underwater robotics principles and system

integration. The findings indicate that structured teacher training can strengthen both conceptual understanding and operational confidence, thus supporting the integration of control education into K–12 STEM pathways through dedicated teacher preparation.

17:15-17:30 ThCA.7

Digital Transformation in Elderly Care: A Factor Analysis of Communication and Emotional Support in Smart Cities

Lučan, Jelena Alma Mater Europaea University

Mežnarec-Novosel, Suzanna Alma Mater Europaea University

Bogataj, David Alma Mater Europaea University

The aging population in smart cities challenges the maintenance of meaningful family relationships among care home residents, emphasizing the need for improved communication and emotional support. This study aims to identify key dimensions of family interaction and examine how digital transformation can enhance communication and emotional support in institutional elderly care. A cross-sectional survey was conducted among care home residents and their family members using a structured 5-point Likert scale questionnaire. Data were analyzed using principal component analysis to identify latent interaction patterns. Results revealed two key factors for residents: “Quality of Family Communication” (65.85% of explained variance) and “General Satisfaction and Emotional Support” (14.52%), and two for family members: “Family Relationship” (52.98%) and “Family Engagement and Communication” (15.06%). All factors demonstrated high internal consistency (Cronbach's $\alpha > 0.8$) and stable structural validity. Moderate inter-factor correlations ($r = 0.38–0.42$) indicate that these dimensions are distinct yet interconnected. Findings show that communication quality, clarity, emotional depth, and perceived meaningfulness has a greater impact than frequency of contact. A divergence between residents' and family members' perspectives highlights the need for bidirectional, user-centered digital solutions. The study provides a data-driven basis for developing digital interventions that strengthen family interaction, enhance emotional support, and improve quality of life. By linking empirical results with digitally supported social infrastructure, it contributes to more inclusive and human-centered age-friendly smart city care models.

ThCB	Room 155/d2
Estimation and Control for Automated Vehicles: From Human-In-The-Loop to Fully Autonomous Systems (Invited Session)	
Chair: Arezki, Hasni	UPHF
Co-Chair: Zemouche, Ali	University of Lorraine
Organizer: Arezki, Hasni	UPHF
Organizer: Sentouh, Chouki	LAMIH - University of Valenciennes
Organizer: Belkhatir, Zehor	University of Southampton

16:00-16:15 ThCB.1

Modeling and Experimental Analysis of a Haptic Force-Feedback Traction Manipulator for Shared Human-Train Remote Operation (I)

Haq, Zaid Cahya Dinul	Universite Polytechnique Hauts-De-France
Sentouh, Chouki	LAMIH - University of Valenciennes
Rijanto, Estiko	National Research and Innovation Agency
Popieul, Jean-Christophe	Uniuversité De Valenciennes
Ait Ghezala, Amel	LAMIH UPHF
Conreur, Gérald	Universite Polytechnique Hauts-De-France

This paper presents the experimental system identification and analysis of a haptic force-feedback traction manipulator designed for teleoperation scenarios. A physics-based dynamic model was formulated, and its unknown parameters were identified using nonlinear grey-box estimation. The model achieved high fitting accuracy within the 0.2–0.8 Nm torque range and exhibited approximately linear behavior in specific operating regions, supporting region-based control design. A momentum-based observer was implemented to estimate unmodeled dynamics and external disturbances, successfully distinguishing internal effects from human-induced forces. Experimental results indicate that a disturbance threshold of approximately 0.2 Nm can characterize external intervention in shared control scenarios. A further experiment validated a simple haptic control strategy, where the observer-triggered threshold activated torque amplification, demonstrating stable interaction and robust disturbance detection. These findings provide a foundation for advanced region-based torque control in shared teleoperation systems.

16:15-16:30 ThCB.2

Robust MHE-Based Trajectory Tracking for Autonomous Vehicles (I)

Arezki, Hasni	UPHF
Bougherara, Selsabil	Université Polytechnique De Haut De France
Sentouh, Chouki	LAMIH - University of Valenciennes
Popieul, Jean-Christophe	Uniuversité De Valenciennes

This paper addresses the trajectory tracking problem for autonomous vehicles navigating roundabouts under varying longitudinal velocity. The vehicle lateral error dynamics are modeled as a quasi-LPV system with the longitudinal velocity as a measurable scheduling parameter, yielding an exact two-vertex polytopic representation. A Moving Horizon Estimator with corrected prediction is proposed, where a parameter-dependent gain is introduced in the prior update to improve the prediction quality and relax the convergence conditions under the incremental exponential input-output-to-state stability (i-EIOSS)

framework. A unified block-diagonal LMI is derived for the joint synthesis of the state-feedback controller gain and the prediction correction gain, with an explicit account of the conditioning gap between the weighted contraction rate provided by the LMI and the spectral-norm contraction factor required by the MHE stability analysis. Sufficient conditions on the horizon length and the cost function parameters are provided to guarantee robust exponential stability of the estimation error under bounded process and measurement disturbances. The proposed architecture is validated in simulation on a realistic roundabout scenario, demonstrating accurate state reconstruction, bounded tracking errors, and smooth steering commands.

16:30-16:45 ThCB.3

Concurrent Learning Adaptive T-S Observer for Human Torque and Friction Estimation in Power-Assisted Wheelchairs (I)

Ait Ghezala, Amel	LAMIH UPHF
Arezki, Hasni	UPHF
Sentouh, Chouki	LAMIH - University of Valenciennes
Conreur, Gérald	Universite Polytechnique Hauts-De-France
Pudlo, Philippe	Uvhc - Lamih

This paper proposes a concurrent learning (CL) adaptive observer for Takagi-Sugeno systems with unmeasured premise variables and time-varying parameters. The adaptation law combines a real-time gradient term with a finite history stack of recorded input-output data, replacing the classical persistent excitation requirement by a verifiable rank condition on the stored regressors. Observer stability and $mathcal{L}_2$-gain boundedness are established via Lyapunov analysis, and the resulting synthesis is cast as a convex LMI problem with explicit $mathcal{H}_infty$ performance bounds. The framework is applied to simultaneous estimation of human propulsion torque and ground friction in power-assisted manual wheelchairs using wheel encoder measurements alone. Experimental validation on the PSCHITT-PMR simulator across four scenarios (straight line, turn, slope, and cross-slope) demonstrates that CL achieves torque estimation improvements of $+3.6%$ to $+34.0%$ over standard gradient-based adaptation, while maintaining equivalent speed tracking.

16:45-17:00 ThCB.4

Joint Design of Matrix-Weighted Communication Topologies and Distributed Controllers for Vehicular Platoons: An LMI-Based String Stability Approach (I)

Meng, Shengya	Universite De Lorraine
Alma, Marouane	CRAN, Université De Lorraine
Zemouche, Ali	University of Lorraine

This paper presents a novel Linear Matrix Inequality (LMI)-based co-design framework for distributed controllers and communication topologies in vehicular platoons. To address the coupling between controller gains and network structure, we employ a matrix-weighted graph approach, wherein each edge weight corresponds to a multi-dimensional feedback gain matrix. Sufficient conditions for achieving L_2 weak string stability are derived and formulated as LMIs. Furthermore, an L_1-norm penalty is incorporated into the optimization objective to induce topology sparsity, thereby balancing control performance with communication overhead. The effectiveness of the proposed joint design method is validated through high-fidelity simulations on the Quanser Interactive Labs (QLabs) platform.

17:00-17:15 ThCB.5

Adaptive Extremum-Seeking-Based Energy Optimization for Tilt-Quadrotors under Wind Disturbances (I)

Eliker, Karam	Technical University of Denmark
Sidi Brahim, Khelil	University of Picardie Jules Verne
Glida, Hossam Eddine	Université Caen Normandie
Yi, Bowen	Polytechnique Montreal
Sentouh, Chouki	LAMIH - University of Valenciennes

This paper investigates the energy-efficiency operation of two-dimensional (2D) tilt-quadrotor systems under wind disturbances and parameter uncertainties. To address the minimum-energy objective, an adaptive extremum-seeking (ES) optimizer is employed to determine the optimal pitch angle in real time, thereby minimizing the energy consumption during flight. Meanwhile, an adaptive super-twisting sliding mode controller (ASTSMC) is used to stabilize the system around the desired trajectory, ensuring robust tracking performance in the presence of disturbances. Numerical simulations and comparative studies with the conventional ES approach and a tilt-quadrotor with a fixed zero pitch angle demonstrate that the proposed method significantly reduces energy consumption, thereby improving flight endurance.

17:15-17:30 ThCB.6

Continuous-Discrete Adaptive Observer for Nonlinear Systems with Sampled Outputs: Application to Vehicle Dynamics (I)

Benoudiba, Amayas	Université D'Évry Paris-Saclay
Ait Oufroukh, Naima	Université d'Evry - Laboratoire IBISC
Ahmed Ali, Sofiane	University of Evry, IBISC Lab
Ichalal, Dalil	IBISC Lab, Univ Evry, Paris-Saclay University

This paper presents a continuous-discrete adaptive observer for jointly estimating the states and unknown parameters of nonlinear systems with sampled output measurements. The observer combines a state estimator, a parameter estimator, and a reset-based inter-sample output predictor. By analyzing the interconnected error dynamics through an Input-to-State Stability (ISS) framework and the small-gain theorem, we establish sufficient stability conditions and derive an explicit computable bound on the Maximum Allowable Sampling Period (MASP). The proposed methodology is applied to a vehicle longitudinal dynamics model with uncertain mass, showing accurate state and parameter estimation under sampled-data measurements and bounded disturbances.

17:30-17:45 ThCB.7

A Distributed Observer for Sensor Fault Estimation in T-S Fuzzy Multi-Agent Systems with Unmeasured Premise Variables: Application to Vehicle Lateral Dynamics (I)

Cherigui, Aioub	Université De Paris Saclay
Nachidi-Labourel, Meriem	Icam, Grand Paris-Sud
Chadli, M.	University Paris-Saclay Evry

This paper proposes a distributed Takagi-Sugeno (T-S) fuzzy observer framework for nonlinear multi-agent systems (MAS) with unmeasured premise variables, targeting joint state estimation and sensor fault reconstruction over a general directed communication graph, with application to cooperative automated vehicles. An augmented-state descriptor formulation embeds the sensor fault into the output equation, while each agent exploits only local measurements and neighborhood information. Sufficient conditions for stability and convergence are derived as linear matrix inequalities (LMIs), yielding observer gains

robust to membership-function mismatch due to unmeasurable premise variables (UPVs) and bounded external disturbances. Numerical validation on a vehicle lateral dynamics benchmark confirms the effectiveness of the proposed observer in terms of state estimation accuracy, sensor fault reconstruction, and robustness against membership-function mismatch induced by unmeasured premise variables.

ThCC	Room 155/d3
Robotics 3 (Regular Session)	
Chair: Skarpetis, Michael	National and Kapodistrian University of Athens
Co-Chair: Kastritsi, Theodora	C.R.E.A.T.E. Consortium

16:00-16:15 ThCC.1

A Reinforcement Learning Framework for the Control of Wheeled-Bipedal Robots

Leontiou, Rafaellos	Cyprus University of Technology
Loizou, Savvas	Cyprus University of Technology
Deliparaschos, Kyriakos	Cyprus Univerity of Technology

This work presents a reinforcement learning framework tested on a wheeled biped robot using a pipeline based on well known robotics software tools. The proposed system combines ROS 2, Gazebo Classic, Gymnasium, and Stable Baselines3 to provide a modular and reproducible environment for robot simulation, training, and evaluation. Using this framework, two algorithms, TD3 and PPO, were trained and compared for locomotion control. The results show that TD3 achieved faster initial learning, whereas PPO provided more stable behavior, better evaluation performance, and more accurate tracking of commanded angle and velocity profiles. The study demonstrates that reinforcement learning can be effectively applied to wheeled biped robot control while leveraging established robotics software to create an accessible and practical development pipeline.

16:15-16:30 ThCC.2

Model-Based Detection of Anomalous Events in Submarine Cables Using Distributed Deformation Sensing and Kalman Filtering

Fioravanti, Camilla	Università Campus Bio-Medico Di Roma
Mazzà, Bianca	Campus Bio-Medico University of Rome
Menci, Marta	University Campus Biomedico
Oliva, Gabriele	Università Campus Bio-Medico Di Roma
Setola, Roberto	University Campus BioMedico of Rome

Submarine power and telecommunication cables constitute critical global infrastructure, yet they remain vulnerable to mechanical damage caused by maritime activities and intentional tampering. Continuous monitoring of these assets is therefore essential for early detection of anomalous events. This paper proposes a model-based framework for real-time anomaly detection in submarine cables using spatially distributed deformation measurements along the cable. The cable is modeled as a tensioned structure governed by a damped wave equation with fixed boundary conditions. A finite-dimensional state-space representation is obtained through spatial discretization, enabling the use of a Kalman filter to estimate the cable's dynamic state under stochastic environmental disturbances. Anomaly detection is then formulated as a statistical hypothesis test applied to the innovation sequence of the filter. Numerical simulations indicate that the proposed framework can reliably identify localized disturbances while remaining robust to ambient environmental excitation.

16:30-16:45 ThCC.3

Gain-Adaptive Finite-Time SE(3) Control of Robotic Manipulators Interacting with Sensitive Environments

Kastritsi, Theodora	C.R.E.A.T.E. Consortium
Villani, Luigi	Università Di Napoli Federico II
Siciliano, Bruno	Univ. Degli Studi Di Napoli Federico II
Ficuciello, Fanny	Università Di Napoli Federico II

In tasks requiring high precision, such as robotic-assisted surgery, accurate motion is crucial. However, unexpected interactions can become hazardous if the robot lacks sufficient compliance. Classical control strategies, which guarantee only asymptotic stability, may be too slow for delicate operations, while traditional finite-time control approaches, which offer faster convergence, often lack compliance. To address this, the present work proposes a control framework based on fast terminal sliding surfaces, which guarantees finite-time convergence of the tracking error while employing adjustable gains to modulate the robot's compliance, allowing safe handling of interactions. An energy tank approach is incorporated to ensure system passivity during contact. Simulation results with a patient-side da Vinci manipulator demonstrate the framework's effectiveness in SE(3) tracking tasks, achieving accurate position and orientation tracking while preserving compliance during interactions.

16:45-17:00 ThCC.4

SVN-NDT: Extending Stein Variational Newton to Probabilistic LiDAR Registration for Surface Vehicle Localization

Mohd Fadil, Muhammad Khalis bin	University of Rostock
Karez, Ian	University of Rostock
Kolewe, Björn	University of Rostock
Jeinsch, Torsten	University of Rostock

Reliable state estimation is a fundamental prerequisite for the safe control of autonomous surface vessels, particularly during satellite positioning outages. While LiDAR-based navigation offers a viable fallback, the marine domain presents unique challenges: repetitive structures in inland waterways and complex vessel dynamics frequently compromise the stability of point-cloud registration. Furthermore, safety-critical automation requires consistent uncertainty quantification for downstream estimators. While recent methods have adapted Stein Variational Newton (SVN) theory to manifold-based pose estimation using point-to-point metrics, the high computational cost of finding correspondences inhibits real-time operation on embedded marine platforms. This paper presents a probabilistic registration framework that extends this manifold-based SVN to the Normal Distributions Transform (NDT). Experimental validation in real-world inland waterways demonstrates that SVN-NDT reduces per-frame inference time by approximately 63% compared to a hardware-matched implementation of the point-based baseline. We show that the proposed method yields statistically consistent trajectories and reliable covariance bounds, ensuring efficient real-time localization for marine automation even in satellite-denied scenarios.

17:00-17:15 ThCC.5

An Adaptive-Horizon Model Predictive Control Approach for Robot Navigation in Dynamic Environments

Lici, Geraldo	University Metropolitan Tirana
Plaku, Evis	University Metropolitan Tirana
Niculescu, Silviu-Iulian	University Paris-Saclay, CNRS, CentraleSupelec, Inria
Cela, Arben	Université Gustave Eiffel, ESIEE Paris

In robot navigation, no fixed prediction horizon for Model Predictive Control can equally satisfy the conflicting demands of efficient planning and immediate reactivity. To resolve this we propose a continuous multi-factor adaptation law that adjusts the horizon in real time based on obstacle proximity, local density, and path curvature. A critical flaw of horizon adaptation is that contraction also reduces accumulated obstacle costs. We address this through an inverse coupling law that scales the obstacle cost weight with the horizon, thus preserving risk sensitivity across the full adaptation range. Where horizon adaptation alone is insufficient, a pre-solve time-to-collision supervisor handles dynamic crossing events. We evaluate the complete system, integrated into a hybrid architecture, across simulated environments of increasing complexity. Results confirm statistically significant improvements in navigation success rates across all scenarios, demonstrating that the coupling ensures safer autonomous navigation.

17:15-17:30	ThCC.6

Robust Control of Vehicles Lateral Motion in a 3D-Printed Experimental Prototype Model

Skarpetis, Michael	National and Kapodistrian University of Athens
Koumboulis, Fotis N.	National and Kapodistrian University of Athens
Sigalas, Ioannis	National and Kapodistrian University of Athens

The problem of designing a robust controller for the lateral motion of a vehicle traveling on a road with unknown curvature is studied. A robust Proportional-Integral-Derivative (PID) type controller is employed using robotic vision measurements of vehicle's lateral deviation from the desired path. The controller parameters are derived using recursive analytic algorithms based on Hurwitz invariability results, combined with appropriate metaheuristic optimization techniques. The proposed controller's effectiveness is demonstrated through real-time experiments on a low-cost, 3D-printed prototype. The experimental results validate the controller's performance in realistic scenarios, providing practical evidence of its robustness and applicability in real-world conditions.

17:30-17:45	ThCC.7

Topological Awareness for Reinforcement Learning in Multibody Systems

Agin, Berk	Istanbul Technical University
Yazar, Musa Nurullah	Istanbul Technical University
Yesiloglu, S. Murat	Istanbul Technical University

Designing locomotion controllers that generalize across varying robot morphologies remains a fundamental challenge, as standard Reinforcement Learning (RL) policies frequently overfit to specific kinematic structures. To address this, we propose a topology-aware RL framework for multibody systems utilizing the Path Defined Directed Graph Vector (pGraph). By systematically extracting the parent-child relations and contact information of a given multibody system, we encode its kinematic hierarchy and degrees of freedom into compact pGraph features. Appending these explicit structural descriptors to the RL observation space enables the conditioning of a topology-aware policy on the agent's underlying morphology. We evaluate our approach on Monoped and Biped embodiments under rigorous stress tests involving mass, inertia, and kinematic perturbations. Simulation results demonstrate that the pGraph-enhanced topology-aware policy achieves improved robustness and adaptation across diverse perturbation scenarios compared to baseline RL, proving that explicit topological awareness substantially enhances morphological generalization and control stability.

ThCD	Room 155/d4
Linear Systems 2 (Regular Session)	
Chair: Koumboulis, Fotis N.	National and Kapodistrian University of Athens
Co-Chair: Di Biase, Alessandro	Università Politecnica delle Marche

16:00-16:15 ThCD.1

A Neural Network-Based Disturbance Predictor for Periodic Output Regulation of Input Delay Systems

Yuksel, Can Kutlu	Czech Technical University in Prague
Kuchar, Michal	Czech Technical University in Prague
Vyhlidal, Tomas	Czech Technical University in Prague, Faculty of Mechanical Engineering
Niculescu, Silviu-Iulian	University Paris-Saclay, CNRS, CentraleSupelec, Inria

The paper presents a predictor-based control approach to make systems suffering from input time-delay adaptively follow or reject periodic signals. The prediction is formed for the estimated output disturbance and is provided by a time-varying neural network. The overall control scheme is inspired by the Smith Predictor and constructed using the Internal Model Control(IMC) framework. This decision of framework allowed us to design the controller as if the closed-loop is finite-dimensional and to straightforwardly ensure the closed-loop stability in the presence of the time-delays and added predictor. The ideas are demonstrated through a simulation of a vibration suppression for a fourth-order system with a significant input delay.

16:15-16:30 ThCD.2

Greatest Common Right Divisors for Quaternion Polynomial Matrices: Computation, Extraction, and Certification

Sebek, Michael	Czech Technical Univesity in Prague

Quaternion-valued models arise in several control-relevant applications, including attitude dynamics, quantum control, and multi-channel signal processing. We study greatest common right divisors (GCRDs) of quaternion polynomial matrices in a central indeterminate. Two complementary computation fronts are considered: a staircase-based method working directly in the quaternion setting, and a Sylvester-based method realized through the real-adjoint embedding. Quotient matrices are then reconstructed by embedded least squares and validated by solver-independent residual certificates. We also point out quaternion-specific phenomena showing that, for quaternion polynomial matrices, a GCRD is primarily a divisibility object rather than an object determined by common right-evaluation zeros. A planted example and small-scale experiments illustrate the workflow and indicate that both approaches can be made reliable, while the present staircase-based implementation is faster and numerically sharper on the reported tests.

16:30-16:45 ThCD.3

Common Proportional Controller Design for the Multi-Model Linear Approximants of Alcoholic Fermentation Processes

Koumboulis, Fotis N.	National and Kapodistrian University of Athens
Kouvakas, Nikolaos	National and Kapodistrian University of Athens

Gourgouvelas, George — National and Kapodistrian University of Athens

The design goal is to control the concentration of the product by adjusting the dilution rate for an alcoholic fermentation process that takes place in a continuous stirred bioreactor, via a set of common proportional linear controllers. This controller type is chosen due to its simplicity and immediate practical application. The controller design is based on the linear approximants of the nonlinear process model at various operating points. The design requirements of common asymptotic command following and common disturbance attenuation are investigated and solved. The general solution of the parameters for the common controller is explicitly derived in the form of a set of admissible inequality constraints on the controller parameters. Simulations of the linear approximant closed-loop system and the nonlinear closed-loop system illustrate the satisfactory performance of the controller. The present results serve as the basis for future development of more complex control processes, with the aim of optimizing the performance of multi-input nonlinear processes.

16:45-17:00 ThCD.4

Interval Observer for Linear Discrete-Time System: An L1-Gain Characterization Approach

Nguyen, Dang Khai — Independant Researcher

This paper introduces a robust interval observer for linear discrete-time systems subject to unknown but bounded uncertainties. First, a discrete-time T–N–L approach, which is named after the structure of the parameter matrices, is proposed. Next, a novel stability analysis of the resulting error system is developed based on L1-gain performance. The design conditions are formulated as a linear programming (LP) problem. The proposed method provides a more direct framework for observer design using the T–N–L approach and improves the accuracy of interval estimation. A numerical example is presented to demonstrate the effectiveness and superiority of the proposed method.

17:00-17:15 ThCD.5

Guaranteed Inter-Sample Safety for Linear Tube MPC: An Explicit Error Bound Approach

Sun, Jiaxun — Swiss Federal Institute of Technology Zurich
Xue, Hengyu — Beihang University
Zhao, Yuyang — Beihang University

Robust Tube Model Predictive Control (MPC) has become a dominant framework for controlling constrained linear systems subject to bounded disturbances. However, standard discrete-time formulations typically guarantee constraint satisfaction only at sampling instances, potentially leading to critical safety violations during the inter-sample intervals in continuous-time physical systems. This paper addresses the problem of inter-sample safety for linear systems controlled by discrete-time Tube MPC. By leveraging Gronwall-Bellman inequalities and the properties of the matrix exponential, we derive a rigorously proven, explicit, and closed-form upper bound on the deviation between the continuous-time trajectory and the discrete-time state at sampling instances. We show that this bound relies solely on the system dynamics, constraints, sampling time, and disturbance magnitude, allowing for offline computation. Furthermore, we propose a constraint-tightening strategy that integrates this bound into the standard Tube MPC framework, ensuring continuous-time constraint satisfaction without increasing the online computational complexity. The effectiveness of the proposed approach is demonstrated through numerical simulations, highlighting its ability to prevent inter-sample constraint violations where standard methods fail.

17:15-17:30 ThCD.6

Sequential Data-Driven Design of a Complete Controller-Allocator Scheme for Strongly Input Redundant LPV Systems

Faleschini, Michelangelo University La Sapienza, Rome
Cristofaro, Andrea Sapienza University of Rome

This paper proposes a sequential three-step data-driven framework to design a complete controller-allocator scheme directly from noisy input-state data, bypassing parametric system identification. First, a gain-scheduled state-feedback controller is designed to stabilize the Linear Parameter-Varying (LPV) plant. Second, a constant basis for the input matrix kernel is extracted directly from the dataset, allowing the allocator structure for output invisibility, meaning that control effort is redistributed among actuators without altering the system output. Third, a parameter-independent dynamic allocator gain is designed to regulate the allocation convergence speed, providing a robust design across the entire scheduling space. The three design steps are entirely formulated through data-based Linear Matrix Inequalities (LMIs). This combined approach guarantees closed-loop quadratic stability and minimizes an upper bound on the total actuator energy consumption over time. The effectiveness of the framework is validated through a numerical example on a randomly generated strongly input redundant LPV system, demonstrating a clear reduction in control energy while preserving closed-loop stability.

17:30-17:45 ThCD.7

On the Possibility of Achieving an Exact State Estimate under Non Vanishing Measurement Noise

Orsini, Valentina Università Politecnica Delle Marche
Bonci, Andrea Università Politecnica Delle Marche
Di Biase, Alessandro Politecnico Di Bari

It is commonly accepted that an exact state observer cannot be constructed in the presence of imperfect measurements, unless the measurement noise asymptotically converges to zero. In this note, however, we show that this claim does not apply to a class of stable scalar systems where the measurement noise can be represented as an unknown signal bounded within a predefined uncertainty range.

Technical Program for Friday June 26, 2026

FrAA	Room 155/d1
Innovation in Marine Robotics: Systems, Sensing and Control 1 (Invited Session)	
Chair: Indiveri, Giovanni	University of Genova
Co-Chair: Antonelli, Gianluca	University of Cassino and Southern Lazio
Co-Chair: Bartolucci, Veronica	Università Politecnica Delle Marche
Organizer: Indiveri, Giovanni	University of Genova
Organizer: Antonelli, Gianluca	University of Cassino and Southern Lazio
Organizer: Omerdic, Edin	University of Limerick
Organizer: Bartolucci, Veronica	Università Politecnica Delle Marche
11:00-11:15	FrAA.1
Invited Lecture: "*Polo Nazionale della Dimensione Subacquea: Research and Innovation in the Underwater Domain"*	
Ranieri, Giampiero	Polo Nazionale della Dimensione Subacquea
11:15-11:30	FrAA.2
Force Control of Underwater Vehicle Manipulator Systems Based on a Reduced Dynamic Model: Simulation Results (I)	
Xinhui, Zheng	Shenyang Institute of Automation Chinese Academy of Sciences
Di Lillo, Paolo	University of Cassino and Southern Lazio
Cieslak, Patryk	University of Girona
Pi Roig, Roger	Universitat De Girona
Ridao, Pere	University of Girona
Di Vito, Daniele	University of Cassino and Southern Lazio
Tian, Qiyan	Zhejiang University
Zhang, Yunxiu	Shenyang Institute of Automation Chinese Academy of Sciences
Zhang, Qifeng	Shenyang Institute of Automation Chinese Academy of Sciences
Xiaohui, Wang	Shenyang Institute of Automation Chinese Academy of Sciences
Antonelli, Gianluca	University of Cassino and Southern Lazio

Underwater vehicle manipulator systems (UVMS) face interaction challenges in contact force control due to, among the others, the limited sensing technology. To address the issue, we implement an admittance interaction control which benefits from the contact force estimate output by a properly designed observer. The latter is implemented by pragmatically exploiting a reduced dynamic model which takes into account the sole dynamic terms effectively present during the interaction. As a first step toward the experimental campaign, this paper presents a numerical validation obtained by resorting to the software Stonefish and the vehicle Girona 500, which consists of a 5 degrees of freedom (DOFs) vehicle and a 4 DOFs manipulator. Even if the simulation engine integrates over the full dynamic model, the proposed controller efficiently implements interaction control without the need for a force-moment sensor at the end effector.

11:30-11:45 FrAA.3

Enabling Trustworthiness for Underwater Robotic Agents: A Case Study on Multi-Modal Classification (I)

Casini, Simona	University of Pisa
Cavaliere, Chiara	University of Pisa
Amariei Cojocaru, Alexandru Mina	University of Pisa
Gentili, Alessandro	University of Pisa
Marinelli, Paolo	University of Pisa
Regoli, Alberto	University of Pisa
Ryals, Andrea Dan	University of Pisa
Pollini, Lorenzo	University of Pisa
Costanzi, Riccardo	University of Pisa

Data-driven perception for autonomous underwater robotic agents is constrained by the cost and limited availability of real-world data. Although simulation and synthetic data support the development of learning-based perception systems, discrepancies between simulated and real environments often lead to performance degradation during deployment, exacerbated by typical low-visibility conditions in real marine scenarios.

This paper proposes a multi-modal perception framework designed to improve trustworthiness through redundancy and multi-level validation, enabling informed human intervention in failure-prone scenarios. The framework is developed in simulation by modelling and integrating multiple underwater acoustic sensors within the robotic platform and by incorporating an AI subsystem for objects classification. Both synthetic and real data are used to validate, and test the data-driven module, providing a controlled setting for initial deployment. The framework is evaluated through a real-data case study focused on a YOLO-based neural network failure detection. This approach enables custom algorithms suitable for different scenarios and existing hardware and software capabilities. The results offer actionable insights for model analysis and demonstrate how multi-modal, simulation-informed perception can improve the robustness, transparency, and trustworthiness of underwater robotic systems.

11:45-12:00 FrAA.4

Feasibility Analysis of an Embedded AI Vision System for Automated Underwater Bivalve Visual Census (I)

Gioiello, Flavia	Università Politecnica Delle Marche
Bartolucci, Veronica	Università Politecnica Delle Marche
Beni, Federico	Università Politecnica Delle Marche
Dimitri, Roberto	Università Politecnica Delle Marche
Pizzuto, Andrea	Università Politecnica Delle Marche
Scaradozzi, David	Università Politecnica Delle Marche

Benthic bivalves, such as clams and mussels, are commonly used as ecological indicators to assess the condition of marine ecosystems. Underwater Visual Census (UVC) of these organisms often relies on diver surveys, fixed cameras, or manual inspection of underwater images, which limits spatial coverage and requires substantial human effort. This paper studies the feasibility of a low-cost intelligent robotic system based on a compact AI camera to support ecological monitoring through automated UVC of benthic organisms. The proposed module integrates synchronized image acquisition and onboard neural inference within a pressure-rated device designed for deployment on

underwater robotic platforms. A lightweight YOLOv8 Nano detector is exported to TensorFlow Lite for deployment on the embedded cameras and used to identify bivalves in the acquired images. In addition to annotated images with bounding boxes, the system generates structured reports that record the number of detected clams and mussels and their image coordinates. Experimental evaluation is conducted on a representative underwater dataset comprising scenes with natural substrates, suspended particles, and non-uniform illumination. The results show that the system achieves a mAP@0.5 of 86.9% and an F1-score of 85.2%, confirming reliable detection and localization of bivalves in challenging underwater conditions.

12:00-12:15 FrAA.5

Clustering-Based Semantic SLAM for Autonomous Underwater Vehicles (I)

Pela, Riccardo	Università Degli Studi Di Firenze
Topini, Alberto	University of Florence
Parati, Filippo	University of Florence
Bucci, Alessandro	University of Florence
Battistelli, Giorgio	University of Florence
Ridolfi, Alessandro	University of Florence

Reliable data association remains one of the main challenges in landmark-based Simultaneous Localization and Mapping (SLAM), especially in perceptually ambiguous environments. Many approaches rely on explicit correspondences and modality-specific assumptions, which can limit robustness and generality across different sensing configurations. This paper proposes a clustering-based semantic SLAM framework in which data associations are inferred through an iterative clustering–optimization process rather than prescribed by explicit observation-to-landmark matching. Observations are grouped into landmark hypotheses through density-based clustering in an augmented metric–semantic space, allowing landmark identities to emerge implicitly from data consistency rather than enforced correspondences. The resulting associations are used to build and optimize a factor graph, jointly refining vehicle poses and landmark positions. The proposed framework is modality-agnostic and does not rely on appearance-based matching, making it applicable to both visual and non-visual sensing scenarios. Robustness to noise and spurious detections is further enhanced through a life-points policy that stabilizes clustering across iterations. The approach is validated in simulation using a model of the FeelHippo Autonomous Underwater Vehicle equipped only with sonar-based perception, demonstrating the effectiveness of the proposed method for non-visual SLAM scenarios.

12:15-12:30 FrAA.6

Kinematic 3D Path Following Controller for an Underactuated Underwater Robot Subject to a Constant Unknown Current (I)

Sabouri, Mohammad	University of Genova
Indiveri, Giovanni	University of Genova

This paper proposes a kinematic controller for three-dimensional path following of underactuated autonomous underwater vehicles (AUVs) subject to constant and unknown ocean currents. The solution is designed for a kinematic model with actuated surge, yaw and pitch following a reference target (possibly virtual) moving on an arbitrary path with known linear and angular velocities. The control law builds on addressing two tasks: at larger distances from the target, the task is to align the vehicle velocity with the relative target position vector while progressing with an overall speed that is larger than the target's one. At closer distances, the control task switches to aligning the linear velocity of

the vehicle with the target's one while moving at the same speed. The overall solution exploits a current estimator based on the knowledge of the relative position between the target and the vehicle. The control synthesis is designed using Lyapunov methods. The performance of the proposed solution is validated through numerical simulations.

FrAB	Room 155/d2
Advanced Control Systems 1 (Regular Session)	
Chair: Perev, Kamen	Technical University of Sofia
Co-Chair: Fiacchini, Mirko	GIPSA-Lab, CNRS

11:00-11:15 FrAB.1

Probabilistically Certified PID Control of Anesthesia Induction with Data-Driven Gain Scheduling Using Deep Reinforcement Learning

Ajami, Mohamad GIPSA-Lab
Dang, Thao VERIMAG
Fiacchini, Mirko GIPSA-Lab, CNRS

This work proposes a probabilistically certified data-driven gain-scheduling strategy based on reinforcement learning (RL) for anesthesia induction under propofol--remifentanil co-administration. Using the bispectral index (BIS) as measured output, the goal is to achieve rapid sleep onset while limiting the probability of BIS undershoot. Two PID controllers designed to satisfy different safety requirements define a probabilistically certified safety envelope within which an RL agent adapts the controller gains online. Simulation results across different models from the literature demonstrate the effectiveness and generalizability of the proposed approach.

11:15-11:30 FrAB.2

Guaranteed Stabilizing Control During Automated Propofol Anesthesia Based on the Theory of Robust and Contractive Invariant Sets

Ajami, Mohamad GIPSA-Lab
Dang, Thao VERIMAG
Fiacchini, Mirko GIPSA-Lab, CNRS

This work presents a set-theoretic control framework to regulate the depth of hypnosis during general anesthesia. Parametric uncertainties are considered by modeling them as additive disturbances acting on the nominal system. A robust contractive set is constructed, and a tube model predictive controller is designed to drive the system into it, ensuring closed-loop stability by construction. The stability, safety, and limitations of the proposed approach are thoroughly detailed.

11:30-11:45 FrAB.3

Observer-Based Model Predictive Control for COD Regulation in a Biological Reactor

Ciuccoli, Nicolò Università Politecnica Delle Marche
Baldini, Alessandro Università Politecnica Delle Marche
Eusebi, Anna Laura Università Politecnica Delle Marche
Fatone, Francesco Università Politecnica Delle Marche
Monteriù, Andrea Università Politecnica Delle Marche

In this paper, we propose an observer-based constrained control scheme for the regulation of the effluent substrate concentration in an Upflow Anaerobic Sludge Blanket (UASB) reactor affected by unknown influent biomass and substrate concentrations. More precisely, an extended state observer is designed as the interaction of nonlinear and decoupled disturbance observers and output transformations, thus providing ultimately bounded estimates of the unmeasured variables. Hence, a baseline MPC strategy is designed to effectively solve the resulting constrained control problem. Simulation results

are finally reported to verify the proposed approach.

11:45-12:00 FrAB.4

Control Structure for Nonlinear Plant Linearization

Perev, Kamen Technical University of Sofia

The paper considers the problem of nonlinear plant linearization and to answer the question of how to use linear techniques for nonlinear plant control. A particular control structure having integrator in the forward path and inverse derivative of the nonlinear function in the feedback path for plant linearization is presented. The advantages and disadvantages of this control structure are discussed. It is shown that the derivative restriction of the initial structure is avoided by using analytic approximations of the static nondifferentiable nonlinear characteristics. Using such approximations further improve system behavior by reducing the gain in the feedback loop and thus, avoiding the second main restriction in the initial structure practical implementation. The approximation approach is further extended to nonlinear characteristics exhibiting jump behavior and having the memory effect in their description. It is shown that the ideal relay characteristic can be used to model any discontinuous nonlinear function. An error analysis for the ideal relay approximation is also provided. It is shown that the presented approximate relay characteristic can be successfully applied for characteristics with hysteresis. Finally, the presented in the paper approach for nonlinear plant linearization is justified by using numerical simulations.

12:00-12:15 FrAB.5

Distributed Model Predictive Control for Heterogeneous UAV–UGV Cooperative Navigation

Nicolaides, Savvas University of Cyprus
Constantinou, Christos South East Technological University
Christoforou, Eftychios University of Cyprus

This paper presents a Distributed Model Predictive Control (DMPC) framework for cooperative navigation of a Heterogeneous Multi-Robot System (HMRS) consisting of Unmanned Aerial Vehicle (UAV) and Unmanned Ground Vehicle (UGV). A constraint-coupling architecture is proposed, in which both agents enforce formation proximity through separating hyperplane constraints included in their respective Optimal Control Problems (OCPs). The UAV solves a linear double-integrator OCP with general linear constraints for both inter-agent collision avoidance and formation coupling, while the UGV solves a kinematic unicycle OCP with formation constraints that prevent it from advancing beyond the UAV's reach. The proposed approach is implemented in ROS 2 Jazzy with the acados solver and validated in PX4 Software-in-the-Loop (SITL) with Gazebo Harmonic, using Zenoh middleware.

12:15-12:30 FrAB.6

Approximate Model Predictive Control for Load Shifting in Supermarket Refrigeration

Henkel, Patrick RWTH Aachen University / E.ON ERC
Steuler, David RWTH Aachen University / E.ON ERC
Roß, Simon RWTH Aachen University / E.ON ERC
Rätz, Martin RWTH Aachen University / E.ON ERC
Müller, Dirk RWTH Aachen University

Supermarkets possess significant thermal flexibility that can be leveraged for load shifting to align demand with renewable energy availability. However, deploying advanced control

strategies such as model predictive control on existing local infrastructure is often computationally demanding and requires substantial implementation effort. To address this, this paper presents a supervisory approximate model predictive control approach for supermarket refrigeration systems and cooling cabinets with low implementation and hardware requirements. By utilising decision trees to learn explainable control rules from a teacher model predictive control, the proposed method enables efficient deployment. Simulation results indicate that the approximation reliably replicates the teacher's decisions and achieves operational cost reductions of up to 8 % compared to standard operation, slightly outperforming the teacher control by filtering out suboptimal short-term fluctuations. The approach is shown to be robust against variations in the thermal capacity of the cabinets. Furthermore, the control strategy is validated through a field test in a pilot supermarket in Germany, demonstrating the practical feasibility of deploying decision trees on limited hardware. This represents the first deployment of approximate model predictive control in a real supermarket refrigeration setting.

FrAC	Room 155/d3
Robust Control (Regular Session)	
Chair: Colaneri, Patrizio	Politecnico Di Milano
Co-Chair: Kali, Yassine	Université Du Québec En Abitibi-Témiscamingue

11:00-11:15 FrAC.1

Sensorless Vector Control of Permanent Magnet Synchronous Motors for Household Appliances Using a Discrete-Time Variable Structure Observer

Brasili, Eleonora	Università Politecnica Delle Marche
Fagnano, Luigi	Whirlpool Management EMEA Srl
Ippoliti, Gianluca	Università Politecnica Delle Marche
Javier, Kevin	Università Politecnica Delle Marche
Orlando, Giuseppe	Università Politecnica Delle Marche

A discrete-time sliding mode observer is proposed for the sensorless control of Permanent Magnet Synchronous Machines (PMSMs). By deriving specific sliding conditions,the study ensures robust motion around the sliding surface, supported by a comprehensive observer design methodology. The efficacy of the proposed sensorless vector control is substantiated through simulation tests on a PMSM drain pump integrated within a dishwasher.

11:15-11:30 FrAC.2

Guaranteed Safe and Accurate Quadrotor Flight Using Robust Fixed-Time Control

Sanchez Sanchez, Kevin Ashely	Université Du Québec En Abitibi-Témiscamingue
Kali, Yassine	Université Du Québec En Abitibi-Témiscamingue

This paper addresses the problem of safe and accurate flight control for quadrotor systems in constraint environments. A robust fixed-time controller is developed to guarantee both safety constraint satisfaction and high-precision attitude tracking. The approach incorporates safety constraints via a logarithmic barrier transformation of the attitude error and employs prescribed performance functions to shape the sliding manifold, improving accuracy and reducing chattering. A fixed-time reaching law ensures convergence independent of initial conditions, while Lyapunov analysis guarantees fixed-time stability and provides an explicit bound on the convergence time. The effectiveness of the proposed method is validated through numerical simulation using the Parrot Rolling Spider mini-drone. The results demonstrate accurate trajectory tracking and smooth control torques, confirming that the proposed strategy ensures safe and precise flight.

11:30-11:45 FrAC.3

Adaptive Stiffness Formation Control of Differentially Driven Mobile Robots for Trajectory Tracking

Joon, Arpit	Poznan University of Technology
Kowalczyk, Wojciech	Poznan University of Technology

This paper presents a trajectory-tracking controller for mobile robot formations that integrates an Artificial Potential Function (APF)-based collision avoidance module with a novel adaptive mechanism for formation preservation. Each agent tracks a prescribed

trajectory while locally generating repulsive potentials to ensure collision avoidance with neighboring agents. The proposed adaptive mechanism attenuates the impact of transient disturbances on the formation elements, thereby preventing undesired deviations when a new robot attempts to join the formation. As a result, the rigidity of the formation increases, which in turn reduces its susceptibility to deformation. A Lyapunov-based stability analysis is provided. Simulation studies conducted in ROS (Robot Operating System) using the Gazebo environment for planar multi-robot formations validate accurate trajectory tracking, robust collision avoidance, and the ability to accommodate joining agents without disrupting the ongoing formation.

11:45-12:00	FrAC.4

Two-Degree-Of-Freedom Feedback Loop Factorisation with Zeros in Compensator Strategies Comparison

Dlapa, Marek — Tomas Bata University in Zlin

Two modifications of two-degree-of-freedom (2DOF) feedback loop are compared applied to oscillating system with periodic changes of parameters and uncertain time delay. The uncertain time delay is treated using multiplicative uncertainty, the parametric uncertainty is modelled using general interconnection for the systems with parametric uncertainty in numerator and denominator. Structured singular value denoted μ is used as measure of robust performance and stability. For comparison reasons, both D-K iteration and algebraic μ-synthesis are used for simple feedback loop controller derivation. Due to multimodality of the cost function, minimisation of the μ-function in algebraic μ-synthesis is treated using evolutionary algorithm Differential Migration as a tool for global optimisation in algebraic μ-synthesis. The final controllers are verified using the μ-plots and simulations for worst case perturbation and periodic changes of parameters with maximum time delay.

12:00-12:15	FrAC.5

Model-Based Terminal Second Order Sliding Mode Control for Robotic Exoskeletons

Brahmi, Brahim — KFUPM
Lotfi, Mostefai — University of Saida Dr Moulay Tahar
Jawhar, Ghommam — Sultan Qaboos University
Saad, Maarouf — Ecole De Technologie Superieure

This paper presents a nonlinear terminal second-order sliding mode control (SOSM–NTSM) strategy for precise trajectory tracking of a 2-DoF upper-limb exoskeleton. By embedding the robot dynamic model into the switching manifold, the proposed approach simplifies the torque control structure and mitigates inter-joint chattering effects. The nonlinear terminal term ensures finite-time convergence of tracking errors while improving transient response and disturbance rejection. Compared to classical sliding mode control, the proposed scheme generates smoother control inputs, significantly reducing chattering and actuator stress under modeling uncertainties. Validation on the iTbot exoskeleton demonstrates improved tracking accuracy, reduced torque chattering, and enhanced robustness, making the method suitable for safe and reliable rehabilitation applications.

FrAD	Room 155/d4
Networked Controlled Systems (Regular Session)	
Chair: Leva, Alberto	Politecnico Di Milano
Co-Chair: Brasili, Eleonora	Università Politecnica Delle Marche

11:00-11:15 FrAD.1

Energy-Latency Trade-Off of Max-Consensus in Industrial IoT Networks under Unreliable Links

Stich, Katharina — FAU Erlangen-Nürnberg
Lübke, Maximilian — FAU Erlangen-Nürnberg
Franchi, Norman — FAU Erlangen-Nürnberg

Max- and Min-Consensus protocols are essential for decentralized coordination and control in Industrial Internet of Things (IIoT) systems. While energy–latency trade-offs have been studied for average consensus under deterministic communication models, this paper analyzes the energy–latency trade-off of Max- and Min-Consensus over transmit-power-dependent stochastic wireless channels modeled by Rayleigh-fading-based outage probabilities. Consensus latency and energy consumption are characterized as functions of transmit power, resulting in a Pareto frontier whose knee point provides a preference-free energy-latency compromise. Numerical evaluations and simulation results further show that a design-preference-optimal transmit power is obtained via the weighted scalar optimization and can be systematically selected by adjusting the weighting parameter or by enforcing explicit latency and energy constraints relevant to application-specific IIoT scenarios.

11:15-11:30 FrAD.2

Global Exponential Stability of Discrete-Event Networks under Supervisory Moore Automaton Control

Fiuzy, Mohammad — LIT Secure and Correct Systems Laboratory,
Stefa, Ras — LIT Secure and Correct System Lab

This study introduces a robust stability analysis framework for discrete-event networks subject to time-varying interaction topologies dictated by external supervisory logic. Diverging from traditional continuous or hybrid multi-agent models, the system dynamics are driven exclusively by event-based transitions and logicbased switching. We initially develop a nonnegative matrix representation to model the network as a nonnegative comparison system. Through this approach, we rigorously prove the uniform boundedness of the network state across arbitrary coupling variations. Furthermore, by employing Lyapunov bounds specifically tailored for Moore-supervised closed-loop discrete-event networks, we establish the system's exponential relative stability. To ensure practical applicability, the framework is extended to guarantee robust exponential stability under bounded mode perturbations. Numerical simulations confirm the effectiveness of the proposed theoretical results within event-driven multi-agent frameworks.

11:30-11:45 FrAD.3

Sampled Event-Triggered Distributed Secondary Frequency Control for Islanded Microgrids under Communication Delays

Mahesh, Sarnavi — Flemish Institute for Technological Research (VITO) NV

The increasing integration of inverter-based distributed energy resources in islanded microgrids requires communication-efficient distributed control strategies for frequency regulation. Conventional distributed secondary frequency control schemes typically rely on continuous or periodic communication among inverters, which may lead to unnecessary communication overhead. Event-triggered control offers a promising alternative by enabling communication only when needed. This paper proposes a sampled event-triggered distributed secondary frequency control framework for islanded microgrids operating under bounded communication delays. The triggering condition is evaluated at discrete sampling instants, consistent with digital controller implementation, and a maximum inter-event time mechanism is introduced to prevent communication starvation under delayed information exchange. A theoretical analysis establishes practical stability of the resulting closed-loop system under sampled triggering and bounded delays. Simulation results demonstrate significant communication reduction compared with periodic communication while maintaining satisfactory frequency regulation performance under varying delay conditions.

11:45-12:00 FrAD.4

Entropic Value-At-Risk for Inter-Vehicle Collision in Platoons: Network and Delay-Induced Bounds on Risk Due to Extreme Events

Pandey, Vivek Lehigh University
Motee, Nader Lehigh University

Safe operation of connected vehicle platoons under stochastic disturbances and time-delayed dynamics requires accurate quantification of rare but dangerous events, such as inter-vehicle collisions. We propose a rigorous framework for quantifying the risk of inter-vehicle collisions in connected vehicle platoons subject to time-delayed stochastic dynamics. We adopt the entropic value-at-risk (EVaR) as a conservative metric to capture risk due to extreme events, highlighting its advantages over conventional Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR). By expressing the inter-vehicle distance covariance in terms of the Laplacian eigenvalues of the communication network, we derive network-and time-delay-induced bounds on both the minimum inherent risk and the worst-case risk. Specifically, the algebraic connectivity dictates the maximum EVaR, while the largest Laplacian eigenvalue determines the minimum risk inherently induced by the network structure. Numerical simulations illustrate how network topology and time delay shape collision risk, offering actionable insights for the safe design of vehicle platoons operating under stochastic disturbances.

12:00-12:15 FrAD.5

Encrypted MPC Design Using Orthonormal Functions to Control Distributed Electrical Drive Systems

Baldi, Marco Università Politecnica Delle Marche
Brasili, Eleonora Università Politecnica Delle Marche
Chiaraluce, Franco Università Politecnica Delle Marche
El Mechri, Rahmi Università Politecnica Delle Marche
Ippoliti, Gianluca Università Politecnica Delle Marche
Orlando, Giuseppe Università Politecnica Delle Marche

This study presents an encrypted Model Predictive Control (MPC) framework for linear constrained systems, complemented by experimental validation across a networked communication architecture for electric drive systems. The functionality of the encrypted controller is twofold: it safeguards communication links and prevents the exposure of sensitive internal control parameters. The processing latencies of the encrypted scheme

we propose are shown to be negligible, ensuring compatibility with the strict real-time constraints of the electrical drive control system.

FrBA	Room 155/d1
Innovation in Marine Robotics: Systems, Sensing and Control 2 (Invited Session)	
Chair: Antonelli, Gianluca	University of Cassino and Southern Lazio
Co-Chair: Bartolucci, Veronica	Università Politecnica Delle Marche
Organizer: Indiveri, Giovanni	University of Genova
Organizer: Antonelli, Gianluca	University of Cassino and Southern Lazio
Organizer: Omerdic, Edin	University of Limerick
Organizer: Bartolucci, Veronica	Università Politecnica Delle Marche

14:00-14:15 FrBA.1

Nerites Framework: An Open-Source ROS2 Gym Environment for Intelligent Underwater Robotics

Stefanopoulou, Aliki	Democritus University of Thrace
Kapsacheilis, Dimitris	Certh
Karatzinis, Georgios	Democritus University of Thrace
Michailidis, Iakovos	Informatics & Telematics Institute, Center for Research and Technology Hellas
Youssef Mohsen Mahmoud, Attia	UniGe
Wanderlingh, Francesco	Università Di Genova
Simetti, Enrico	University of Genova
Kosmatopoulos, Elias	Democritus University of Thrace and CERTH, Greece
Boutalis, Yiannis	Democritus University of Thrace

Reinforcement Learning for Autonomous Underwater Vehicles is hindered by the lack of simulation frameworks that combine realistic underwater dynamics, modern robotic middleware, and standardized learning interfaces. Existing simulators often provide high-fidelity physics but rely on legacy software stacks and ad hoc RL setups. This paper presents an open-source, ROS2-native bridge for a widely used legacy underwater vehicle simulator, enabling RL-ready autonomy without re-implementing the underlying physics. The simulator is treated as a physics back-end, with sensing and actuation exposed through ROS2 and a Gym-compatible environment that supports episodic execution, standardized observation and action spaces, and integration with state-of-the-art RL algorithms. As a case study, we integrate the Graal Tech X300 Twin AUV, including its overactuated thruster configuration and sensor suite, and train a Soft Actor Critic policy for waypoint navigation under realistic hydrodynamic conditions. Results show stable learning and reliable convergence, indicating that the proposed framework offers a practical and reusable basis for RL research in underwater robotics and sim-to-real development. The full framework is open-source at https://github.com/alice-st/Nerites

14:15-14:30 FrBA.2

Multi Criteria Decision Analysis for Offshore Platform Decommissioning : Development of a Descriptor for Sediment Mobilization

Zitti, Gianluca	Università Politecnica Delle Marche
Di Nardo, Francesco	Università Politecnica Delle Marche
Scaradozzi, David	Università Politecnica Delle Marche
Brocchini, Maurizio	Università Politecnica Delle Marche

Multi-Criteria Decision Analysis (MCDA) is widely used as a decision-support tool for offshore oil and gas platform decommissioning. Within the MCDA framework, environmental, technical, economic, and social criteria are typically operationalized through specific parameters, known as descriptors. A major challenge of this procedure lies just in condensing the complexity and multidimensionality associated with each decommissioning aspect into single, meaningful quantitative descriptors. To address this issue, the present study developed a structured quantitative descriptor to represent the impact of a sediment plume resulting from cutting and extraction operations during offshore platform decommissioning, enabling its efficient incorporation into an MCDA framework. Starting from a depth-averaged analytical advection–diffusion equation, the maximum spatial impact distance corresponding to a prescribed suspended sediment concentration threshold was derived. The analytical solution was then reformulated into a simplified exponential expression, explicitly accounting for hydrodynamic forcing, suspended sediment mass, diffusion coefficient, settling velocity, water depth, and concentration threshold. The proposed formulation provides a physically grounded and clearly interpretable descriptor, facilitating transparent and consistent integration within MCDA procedures while preserving the model-based representation of the underlying transport processes. Future work will focus on testing and calibrating the proposed descriptor in real offshore decommissioning case studies to assess its practical effectiveness and robustness in supporting informed decision-making.

14:30-14:45 FrBA.3

A Model-Based Virtual DVL for Underwater Vehicle Navigation (I)

Vangi, Mirco — University of Florence
Bucci, Alessandro — University of Florence
Topini, Alberto — University of Florence
Ridolfi, Alessandro — University of Florence
Allotta, Benedetto — University of Florence

This paper presents a model-based Virtual Doppler Velocity Log (Virtual DVL) framework for estimating underwater-vehicle linear velocity when direct DVL measurements are unavailable, degraded, or unreliable. The proposed method is built on a physics-based dynamic model of the vehicle and is designed for onboard use with limited computational resources. Starting from the standard six-degree-of-freedom underwater dynamics, the formulation is reduced to the horizontal plane (surge and sway motion are considered), inverted to compute acceleration terms, and integrated in discrete time to reconstruct body-fixed velocity components. The approach is experimentally validated on the reconfigurable RUVIFIST vehicle in hovering configuration by comparing the estimated velocities with measurements acquired from the onboard DVL. Experimental results show that the proposed Virtual DVL is capable of accurately reconstructing the vehicle velocity while maintaining limited drift over medium-range navigation segments, with a mean error of 1.82m. The analysis also highlights reduced estimation accuracy during deceleration phases, suggesting the need for further refinement of hydrodynamic parameter modeling, particularly added-mass effects. Overall, the proposed framework demonstrates the feasibility of using a lightweight model-based Virtual DVL as a robust fallback solution during temporary DVL outages, improving navigation resilience in underwater operations.

14:45-15:00 FrBA.4

Seagrass-Aware Underwater Visual Odometry: A Semantic Masking Approach for Improved AUV Navigation (I)

Marinelli, Paolo — University of Pisa

Regoli, Alberto	University of Pisa
Ruscio, Francesco	University of Pisa
Scarpelli, Gabriele	University of Pisa
Tani, Simone	University of Pisa
Costanzi, Riccardo	University of Pisa

Seafloor monitoring with Autonomous Underwater Vehicles (AUVs) in seagrass-colonized environments poses a distinctive navigation challenge. Doppler Velocity Logs (DVLs), commonly used as the primary source of velocity estimation, can suffer from degraded performance in the in dense vegetation, where long seagrass leaves interfere with acoustic bottom-lock. Visual Odometry (VO) represents a promising complementary or alternative solution in such conditions, exploiting optical imagery already acquired for perception purposes. However, the non-rigid motion of seagrass induced by water currents violates the static scene assumption underlying feature-based VO, leading to degraded motion estimation accuracy. To address this limitation, this paper proposes a seagrass-aware monocular VO framework that integrates multi-class semantic segmentation to identify and mask regions associated with living seagrass during feature extraction. By restricting motion estimation to semantically stable areas of the seafloor, the proposed approach improves the consistency of feature correspondences and mitigates the impact of dynamic scene elements. The approach is validated on real underwater data collected during an autonomous monitoring mission in Niasca Bay (Portofino, Italy) using the Zeno AUV. Comparison against DVL measurements shows that the proposed masking strategy improves estimation accuracy in partially vegetated environments, while highlighting limitations when the available feature support becomes excessively constrained. These findings demonstrate that semantic filtering is an effective mechanism to enhance VO robustness under partial vegetated coverage, supporting its use as a complementary navigation modality in scenarios where acoustic sensing may be unreliable.

15:00-15:15 FrBA.5

Embedded Multi-Rate Sensor Fusion for Underwater Navigation: Experimental Assessment in Confined Environments (I)

Bartolucci, Veronica	Università Politecnica Delle Marche
Gioiello, Flavia	Università Politecnica Delle Marche
Libofsha, Angjelo	Università Politecnica Delle Marche
Brunella, Federico	Università Politecnica Delle Marche
Colletta, Matteo	Università Politecnica Delle Marche
Scaradozzi, David	Università Politecnica Delle Marche

Underwater navigation in the absence of Global Navigation Satellite System signals remains challenging due to limitations in underwater sensing and communication. This paper presents an embedded multi-rate sensor fusion architecture for underwater position estimation, designed as a modular payload for generic underwater platforms. The proposed system integrates an inertial measurement unit, a depth sensor, and range-only Ultra-Short Baseline (USBL) acoustic positioning within an Extended Kalman Filter framework handling asynchronous sensor updates. The architecture is implemented on an embedded computing platform and experimentally evaluated through two test campaigns under static and dynamic conditions, conducted in a confined pool environment, where multipath propagation and unfavorable acoustic geometry degrade the quality of USBL measurements. Experimental results show stable convergence of the proposed estimator when consistent acoustic updates are available, highlighting the

limitations of range-only USBL measurements in dynamic scenarios.

15:15-15:30	FrBA.6

Adaptive Synchronization-Based Locomotion Control of Underwater Snake Robots

Lysø, Mads Erlend Bøe	Norwegian University of Science and Technology (NTNU)
Orucevic, Amer	Norwegian University of Science and Technology (NTNU)
Pettersen, Kristin Y.	Norwegian University of Science and Technology (NTNU)
Gravdahl, Jan Tommy	Norwegian University of Science and Technology (NTNU)

In this paper, we propose an adaptive locomotion control scheme for underwater snake robots operating under fluid forces with parametric uncertainties. The controller builds on a recent synchronization framework that allows for generating and stabilizing a family of sinusoidal joint patterns without artificially imposing a global phase on the resulting pattern, thus avoiding undesired transient behavior that is associated with gait controllers based on trajectory tracking. The resulting controller is proven to globally stabilize the desired gait and provide parameter-error boundedness. Furthermore, a simulation study using a complex nonlinear model of an underwater snake robot illustrates the efficacy of the controller, and indicates that the desired gait likely exhibits nonlocal attractivity properties in the closed-loop system.

FrBB	Room 155/d2
Advanced Control Systems 2 (Regular Session)	
Chair: Aitouche, Abdel	CRISTAL/JUNIA
Co-Chair: Baldini, Alessandro	Università Politecnica Delle Marche

14:00-14:15 FrBB.1

Optimal Allocation Control in Microbial Growth under a Heat-Shock

Innerarity Imizcoz, Javier	Université Côte D'Azur
Yabo, Agustín Gabriel	INRAE Occitanie-Montpellier
Djema, Walid	Inria L2s Cnrs
Mairet, Francis	Ifremer
Gouze, Jean-Luc	INRIA

Resource allocation models are a highly useful tool to study microbial growth in a variety of contexts. We use here a model of this kind describing the metabolism of a micro-organism subjected to a heat-shock. Under extreme temperatures, proteins have a higher tendency to unfold and lose their ability to perform their function, which is counteracted by an increase in the production of folding-assisting chaperones. The model considers a two-dimensional control, representing precursors allocation to the production of chaperones and ribosomes, with the remainder going to the metabolic machinery. We are interested in determining the control that maximizes growth rate following a temperature change. We begin with a theoretical analysis of the resulting optimal control problem (OCP) by use of Pontryagin's Maximum Principle (PMP). We show that this control follows a bang-bang structure, and characterize and give analytical expressions for some of the singular arcs that can emerge. We use the numerical resolution package OptimalControl.jl to solve the OCP in fixed final time in the case of a heat-shock from 37textcelsiustext{ }to 42 textcelsius. The resulting control presents a simple structure consisting of an arc maximizing chaperone production followed by a constant arc corresponding to the optimal equilibrium in the different internal concentrations at the new temperature, in line with biological observations. Finally, we show how the optimal response to a heat-shock follows this structure independently of the temperature prior to the shock.

14:15-14:30 FrBB.2

Observer-Based Active Fault-Tolerant Sliding Mode Control for Delayed PEM Fuel Cell Systems in LPV Form

Aitouche, Abdel	CRISTAL/JUNIA
El Hajjaji, Ahmed	Univ. of Picardie Jules Verne

PEMFC air supply systems are affected by actuator faults, parameter uncertainties, and transport delays associated with oxygen flow dynamics. These factors may degrade the regulation of the oxygen excess ratio and compromise the safe and efficient operation of the fuel cell system. This paper proposes an observer-based active fault-tolerant control strategy for a delayed PEMFC air supply system modeled in a Linear Parameter Varying (LPV) framework. A delay-dependent Unknown Input Observer (UIO) is developed to estimate both the system states and actuator faults. Based on these estimates, an active fault-tolerant control law using sliding mode control is designed to ensure robust tracking of the desired oxygen excess ratio. The convergence of the observer and stability of the estimation error dynamics are analyzed using Lyapunov-Krasovskii theory and Linear Matrix Inequality (LMI) conditions. Simulation results demonstrate effective fault estimation and compensation under load variations and parameter uncertainties.

14:30-14:45 FrBB.3

The Construction of Asymptotic Bode Plots: A New Direct Method

Tebaldi, Davide — University of Modena and Reggio Emilia
Zanasi, Roberto — University of Modena and Reggio Emilia

Bode plots represent an essential tool in control and systems engineering. In order to perform an initial qualitative analysis of the considered systems, the construction of asymptotic Bode plots is often sufficient. The standard methods for constructing asymptotic Bode plots are characterized by the same drawbacks: they are not systematic, may be not precise and time-consuming. This is because they require the detailed analysis of the different factors composing the considered transfer function, meaning that more and more intermediate steps are required as the number of factors increases. In this paper, a new method for the construction of asymptotic Bode plots is proposed, which allows to directly draw the asymptotic Bode magnitude and phase plots of the complete transfer function without requiring the detailed analysis nor the plots construction of each factor. The comparison of the proposed direct method with the standard approaches is performed, in order to examine the benefits offered by the direct method.

14:45-15:00 FrBB.4

Infinite-Time Horizon Dirichlet Boundary Optimal Control for 1D Reaction-Advection-Diffusion PDEs

Samadzadeh, Ardalan — University of Ghent
Lefebvre, Tom — Ghent University
Crevecoeur, Guillaume — Ghent University

The optimal control of processes described by reaction-advection-diffusion PDEs remains a notoriously difficult problem appearing in various areas. Limited access to the spatial domain introduces significant underactuation, rendering the global stabilization of such systems a non-trivial task. This paper investigates infinite-time horizon optimal control for a general one-dimensional linear parametric reaction-advection-diffusion PDE system using a weak variation method. We consider a generic an parametric boundary condition for this study, i.e. using Robin boundary condition. By generalizing a previous finite-time horizon approach, we developed an infinite-time horizon stable controller for systems governed by such PDEs. Beyond the algorithmic extension, we provide a formal Lyapunov-based proof to verify the stability of the developed controller. Simulations for 2 different unstable cases and boundary conditions including one reaction-advection-diffusion PDE and one reaction-diffusion confirm the effectiveness of the proposed method.

15:00-15:15 FrBB.5

SARISA: A Cost-Effective Open-Source USV Platform for Port Security Applications

Lazarou, Andreas — Frederick University
Paparistodimou, Christos — University
Christofi, Marios — Frederick University
Demetriou, Giorgos — Frederick Research Center

This paper presents SARISA (Surveillance and Autonomous Response Integrated System Architecture), a cost-effective unmanned surface vehicle (USV) designed for port security and maritime surveillance applications. The platform features a 2-meter custom fiberglass planing hull, dual electric thrusters with differential steering, and an open-source control architecture based on the Raspberry Pi 4B with a Navigator flight controller HAT running a modified ArduRover autopilot. Key design choices prioritize

modularity, maintainability, and a hardware architecture that accommodates future GPS-denied navigation research. The system incorporates a high-precision Septentrio mosaic-H dual-antenna GNSS receiver capable of compass-free heading determination, addressing magnetic interference challenges common in port environments. With an estimated top speed of 25-40 km/h and 100 Ah battery capacity, SARISA provides a research-grade platform at a fraction of commercial USV costs. Reliability is ensured through a legacy control architecture derived from the field-proven SeaBot platform. System validation combines heritage data from a six-month field testing campaign with static benchmarking of the new propulsion subsystem. The paper details the mechanical design, power system, control architecture, and communication infrastructure, providing a reproducible blueprint for researchers developing similar platforms.

FrBC	Room 155/d3
Mechatronic Systems (Regular Session)	
Chair: Feldmann, Carlo	Fraunhofer Research Institution for Battery Cell Production FFB

14:00-14:15 FrBC.1

Modelling a Consistent and Open Information Model for Control Cabinets

Feldmann, Carlo	Fraunhofer Research Institution for Battery Cell Production FFB
Porrmann, Mario	Osnabrück University
Lampe, Siegmar	University of Applied Sciences

The new EU Directive 2024/2853 imposes greater liability for defective products, posing challenges for the control cabinet industry. Fragmented workflows, processes that rely on inconsistent media, and a lack of end-to-end traceability increase the risk of product liability. This article presents an open, extensible information model for control cabinets, developed by (I.) formulating a cross-disciplinary, object-oriented data model, (II.) adding semantic clarity through referenced standards, (III.) selecting AutomationML as an open and standardised data format that supports libraries, and (IV.) representing the information model in AutomationML. The model was developed using speed standardisation and validated by experts. A practical example of its implementation is provided, and its open-source publication invites collaborative further development. The model addresses the urgent need for consistent, machine-readable data to support digitisation, automation, and legally compliant documentation in control cabinet manufacturing.

14:15-14:30 FrBC.2

Reset Control with Adaptive Feedforward Applied to the Heating System of Snow Groomers' Cabins

Elia, Bontempelli	Prinoth
Salis, Francesco	Prinoth
Zaccarian, Luca	University of Trento

We address a low-level industrial controller regulating an internal loop associated with the cabin temperature control of a snow groomer. Conventional solutions comprise PI architectures but due to the large uncertainty affecting the dynamics and the external signals, the resulting control input was damaging for the valve-based actuator operating on the actuation system. We report here on the successful use of a reset control paradigm that combines a First-Order Reset Element with an adaptive feedforward action, ensuring high performance in reference tracking and a more parsimonious use of the actuator, so as to avoid its progressive degradation. The proposed solution has been operating on the Prinoth medium-size snow groomers operating in Europe and North America. In addition to illustrating the simplicity of implementation and tuning, we report here on the desirable features of the reset-based solution, as compared to the preceding PI-based architecture, based on an ample set of collected field responses during field operation, which are dumped in the control systems for diagnostic reasons.

14:30-14:45 FrBC.3

Modeling and Nonlinear-Dynamic-Inversion (NDI) Based Current Control of an Electromagnetic Suspension System

Kleikemper, Oliver	TUM Hyperloop, Technical University of

	Munich
Steinert, Agnes Christine	Technische Universität München
Holzapfel, Florian	Technische Universität München

Accurate modeling and control are essential for stable and reliable levitation of an electromagnetic suspension (EMS). The system is challenged by nonlinear force–current characteristics, nonlinear current dynamics and material saturation. Linear control methods are widely used for these kind of systems but are typically limited to narrow operating regions.

This paper therefore investigates the modeling and nonlinear dynamic inversion (NDI) based control of the current dynamics of an Electromagnetic suspension system. A control-oriented LR-circuit representation of the current dynamics is derived from an Equivalent magnetic circuit (EMC) model and used to formulate an NDI control law that compensates nonlinear inductance effects caused by both air gap variations and magnetic saturation. The resulting inner-loop current controller enforces a desired first-order reference behavior over a wide operating range. The performance and robustness of the proposed controller are analyzed via simulation studies including parameter variations and air gap disturbances. The results show that the inversion law linearizes the current dynamics effectively under nominal conditions but requires additional error feedback to maintain robustness in the presence of model uncertainties.

The findings demonstrate that the proposed NDI control approach on the current dynamics level extends the operating range while being robust and provides a suitable foundation for outer-loop air gap position control in EMS systems.

14:45-15:00 FrBC.4

Emulation and Control of DFIG Based Wind Turbine Test Bench with Grid Synchronization and Reactive Power Compensation

Kipke, Vile	Ruhr University Bochum
Tölle, Tim	Ruhr University Bochum
Siepelmeyer, Lars Michael	Ruhr University Bochum
Sourkounis, Constantinos	Ruhr-University Bochum

This publication presents the operational characteristics and reactive power compensation possibilities of a DFIG-based wind turbine, which are validated experimentally on a 22 kW test bench. It is part of a wind farm HIL-system and emulates wind turbine torque based on variable wind inflow and aerodynamic interactions within the wind farm. A physical three-mass model of the drive train replicates torsional oscillations of a real turbine. In detail, the grid synchronization process, the start-up and run-through of the synchronous speed, as well as a detailed description of the two possible types of reactive power compensation using the existing converter system are discussed. A comparison of compensation methods reveals a dependency on speed and winding ratios, which ultimately requires dynamic adjustment of the compensation type in order to get the most out of both the rotor-side converter and the grid-side converter. Active compensation makes it possible to save on the installation of hardware-intensive additional equipment such as FACTS or STATCOM.

15:00-15:15 FrBC.5

Robust Fixed-Time Sliding Mode Control for Autonomous Search and Rescue Quadrotor with Real-Time Visual Human Detection

Aimen Abdelhak, Messaoui	Ecole Superieure Ali Chabati, Reghaia, Algeria

Demim, Fethi — Ecole Militaire Polytechnique, EMP
Messaoui, Ali Zakaria — Ecole Militaire Polytechnique

In search and rescue (SAR) missions, quadrotor unmanned aerial vehicles (UAVs) are essential tools for efficiently exploring hazardous or inaccessible environments. Successful deployment in such challenging scenarios necessitates robust control algorithms capable of ensuring high tracking accuracy and resilience to external disturbances. This paper introduces a Continuous Fixed-Time High-Order Sliding Mode Control (CFHSMC) approach that guarantees fast convergence and superior disturbance rejection for quadrotor systems. The proposed control strategy is first validated through outdoor trajectory tracking experiments, where the UAV follows a helical reference path in the presence of environmental perturbations such as wind gusts. Following successful control validation, CFHSMC is integrated into a full SAR mission, where a vision-equipped UAV autonomously detects a missing person using an onboard SSD-MobileNet-v2 deep learning detector. A parallel grid-based search pattern is implemented to optimize area coverage. Experimental results confirm the controller's effectiveness in maintaining stable and precise flight during both the trajectory tracking and person detection phases. This work presents a tightly integrated solution combining robust nonlinear control with real-time visual perception for autonomous SAR applications.

15:15-15:30 FrBC.6

A Hierarchical NMPC Framework for Path Tracking of Skid-Steer Mobile Robot with Unmodelled Dynamics

Uppalapati, Venkata Prashanth — Schmalkalden University of Applied Science
Schrödel, Frank — University of Applied Science Schmalkalde

This paper presents a hierarchical control architecture for the path tracking of a four-wheeled skid-steer robot with unmodelled dynamics. In order to deal with the difficulties of wheel slippage and unmodelled friction, lowlevel PI controllers provide closed-loop wheel velocity control, while an Extended Kalman Filter (EKF) fuses data from a low-cost IMU and odometry for reliable state estimation. The need for high-fidelity mathematical modelling is avoided by characterising the combined response of the low-level controllers, the EKF and the actuators as a first-order system through data-driven system identification. A high-level Nonlinear Model Predictive Control (NMPC), formulated using Acados and CasADi, utilises this identified model along with skid-steer kinematics to achieve optimal path tracking. The framework has been integrated into ROS2 and experimentally validated on a custom-built platform, demonstrating tracking performance in indoor factory conditions.

FrBD	Room 155/d4
Distributed Detection and Control (Regular Session)	
Chair: Iftar, Altug	Eskisehir Technical Univ
Co-Chair: Oliva, Gabriele	Università Campus Bio-Medico Di Roma

14:00-14:15 FrBD.1

Multi-Layer Graph Partitioning Based Performance Analysis of Distributed Vehicle Platoons under Information Topologies without a Spanning Tree

Sermet, Nergiz — AVL Türkiye Research and Engineering
Akar, Mehmet — Bogazici University

This study investigates the dynamic behavior and performance of vehicle platoons that use Information Flow Topologies (IFTs) without a spanning tree. In general, vehicle platoon systems rely on a spanning tree assumption to ensure connectivity between the leader and its followers. It has been observed that when the leader's state information cannot be received by all followers, the vehicle platoon splits into independent subgroups. By employing a multi-layer graph partitioning algorithm named the Primary and Secondary Layer Subgraphs (PLS/SLS), these newly formed subgroups are identified, and their respective equilibrium points are evaluated. Eigenvalues of the Information Flow Matrix (IFM) are analyzed to determine necessary closed-loop stability conditions for a vehicle platoon system with a linear decentralized controller. In conclusion, simulation results confirm that, even if IFTs lacking a spanning tree lose global string stability, individual subplatoons can maintain local stability if controller parameters meet the derived conditions.

14:15-14:30 FrBD.2

Event-Triggered Decentralized Distillation Over Multiagent Networks

Matsukawa, Shunichiro — The University of Osaka
Hayashi, Naoki — The University of Osaka
Inuiguchi, Masahiro — The University of Osaka

Knowledge distillation enables collaborative learning by exchanging model outputs rather than full parameter vectors. We study a decentralized setting in which N devices keep their labeled data locally and interact only through a shared, unlabeled reference dataset. Each device minimizes a supervised empirical loss augmented with a distillation term that encourages its soft decisions to agree with a network-level teacher prediction. To reduce neighbor traffic, we develop an event-triggered decentralized distillation method: each device maintains a buffer of the most recently transmitted soft decisions and communicates only when this buffered information becomes sufficiently stale. Under standard smoothness assumptions and diminishing step sizes, we prove that the gradient norm converges to zero almost surely.

14:30-14:45 FrBD.3

Geometry-Informed Maritime Anomaly Detection Using Probabilistic Roadmaps

Oliva, Gabriele — University Campus Bio-Medico of Rome
Tomei, Andrea — University Campus Bio-Medico of Rome
Setola, Roberto — University Campus Bio-Medico of Rome

Maritime anomaly detection is essential for navigational safety and for the protection of critical underwater infrastructure. This paper proposes a geometry-informed supervised framework for detecting anomalous vessel trajectories in the Baltic Sea using Automatic

Identification System (AIS) data. A Probabilistic Roadmap (PRM) is constructed over the navigable maritime domain and used as a structural prior to project trajectories onto feasible corridors. This representation enables the extraction of interpretable voyage-level features capturing route efficiency, geometric deviation from nominal paths, kinematic variability, and proximity to submarine cables. To address the scarcity of labeled anomalous events, synthetic anomalies are generated through controlled trajectory perturbations and infrastructure-aware distortions, producing a balanced dataset for supervised training. A Random Forest classifier is trained on the resulting feature set and evaluated under cross-validation and a held-out test split. Experimental results show stable generalization performance, achieving a test ROC AUC of 0.837, indicating the effectiveness of embedding navigational feasibility constraints into the anomaly detection process. The proposed approach provides an interpretable and operationally relevant framework for infrastructure-aware maritime monitoring in geometrically complex environments.

14:45-15:00 FrBD.4

Cooperative Online Safe Reinforcement Learning Over Multiagent Networks

Ikeda, Kosuke The University of Osaka
Hayashi, Naoki The University of Osaka
Inuiguchi, Masahiro The University of Osaka

This paper considers a decentralized safe multiagent reinforcement learning problem in an online setting, where multiple agents repeatedly interact with a common environment while exchanging information over a connected communication network. By introducing a Lagrangian relaxation with non negative multipliers, we reformulate the constrained problem as a time-varying nonconvex-concave saddle-point problem. We propose a distributed online primal-dual algorithm that combines consensus mixing with primal descent and projected dual ascent updates. We show a theoretical performance bound for decentralized safe learning under networked information constraints and online environments.

15:00-15:15 FrBD.5

A Robust Local Control Design Approach for Interconnected Time-Delay Systems

Iftar, Altug Eskisehir Technical Univ

Robust local control of linear time-invariant interconnected time-delay systems is considered. An uncertainty measure, which quantifies the effect of known and uncertain interactions between the systems, as well as the uncertainties in the individual system models and in the time-delays, is first derived. Using this measure, a robust local controller design approach is then proposed. Excluding the derivation of the uncertainty measure, the controller design for each individual system is completely independent of each other, is based on an individual local nominal unconnected model, and does not require any knowledge of the interactions or the uncertainties. However, besides local stability and performance, by satisfying a simple scalar condition, the approach ensures robust stability of the overall actual system. An example is also presented to demonstrate the proposed approach.

15:15-15:30 FrBD.6

Learning-Based Online Cooperative Control Over Time-Varying Directed Networks

Ishikawa, Daichi The University of Osaka
Hayashi, Naoki The University of Osaka
Inuiguchi, Masahiro The University of Osaka

This paper studies learning-based online cooperative control of a multi-agent system communicating over a time-varying directed network. The agents act on discrete-time linear time-varying dynamics subject to disturbances. In each episode, they aim to minimize the sum of stage costs over a finite horizon. To cope with unknown disturbances and episode-wise varying losses, we parameterize each agent's control policy by a deep neural network and update a local estimate of a common trainable parameter online using locally available trajectory information and neighbor-to-neighbor messages. By casting the cooperative control task as a realized-trajectory surrogate distributed online optimization problem, we propose a push-sum based learning algorithm that is compatible with directed graphs and column-stochastic mixing. Numerical experiments show that the proposed method enables cooperative performance under time-varying communication.

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Event based systems	WeCD.5

F	
Fault tolerant control	FrBB.2, ThBC.2, ThBD.3, WeAA.2, WeBC.2
Feedback stabilization	ThCB.2, WeAA.3, WeAA.4, WeCC.1
Formation control	FrAB.5, FrAC.4, WeAC.4
Fuzzy logic and fuzzy control	ThCB.3, ThCB.7, WeCA.3

H	
Hybrid systems	FrBC.2, ThAA.1, ThBC.1, ThCB.6, WeAD.1, WeCA.3

I	
Image processing	FrAA.2, FrAA.3, FrBA.4, ThAA.2, ThAA.5, ThAC.6, WeBB.3, WeBD.5, WeCA.2
Industrial automation, manufacturing	FrBC.1, WeCA.4
Integrated control and diagnostics	ThBC.2
Intelligent control	ThBA.1, ThBA.2, ThBA.3, ThBA.4, ThBA.5, ThBA.6, ThBB.5, ThBC.3, ThBC.4, ThBD.2, WeAB.2, WeAC.3, WeBB.4, WeBC.5
Intelligent transportation systems	WeBB.5, WeBD.1, WeBD.2, WeBD.3, WeBD.4, WeBD.5, WeCD.1, WeCD.2, WeCD.3, WeCD.4, WeCD.5

L	
Linear systems	FrAB.4, FrBB.3, FrBD.1, ThCD.1, ThCD.2, ThCD.3, ThCD.4, ThCD.5, ThCD.6, ThCD.7, WeAA.1, WeAA.2, WeAA.3, WeAA.4, WeAC.2, WeAD.3, WeCC.2, WeCC.5

M	
Marine control	FrAA.1, FrAA.4, FrAA.5, FrBA.1, FrBA.2, FrBA.3, FrBA.5, FrBA.6, FrBB.6, FrBD.3, ThAC.4, ThCA.2, ThCC.4, ThCC.7, WeBB.6, WeCA.3
Max-Plus Systems	WeAA.1
Mechatronic systems	FrAA.3, FrAC.3, FrBC.1, FrBC.2, FrBC.3, FrBC.4, FrBC.5, ThAB.3, ThCB.3, WeAA.3, WeAA.4, WeBC.3
Modelling and simulation	FrAB.4, FrAC.1, FrBA.1, FrBB.1, FrBB.3, FrBC.3, FrBD.1, ThAB.1, ThAB.2, ThAB.3, ThAB.4, ThAB.5, ThAB.6, ThAD.3, ThBA.3, ThBB.1, ThBB.2, ThBB.3, ThBB.4, ThBB.5, ThBB.6, ThBC.5, ThCB.4, ThCC.1, TuT1T1.1, TuT2T2.1, WeAD.2, WeAD.4, WeAD.5, WeBC.6, WeBD.6, WeCA.4, WeCA.6, WeCB.4, WeCC.2, WeCC.3, WeCC.4, WeCD.1, WeCD.2

N	
Networked controlled systems	FrAD.1, FrAD.2, FrAD.3, FrAD.4, FrAD.5, FrBD.2, FrBD.4, FrBD.5, FrBD.6, WeBC.4, WeCB.3, WeCB.5
Neural networks	FrAD.6, FrBA.1, ThAA.1, ThAA.2, ThAA.3, ThAA.4, ThAA.5, ThAA.6, ThAD.4, ThBA.2, ThBA.3, ThBA.4, ThBA.6, ThBB.5, ThBC.3, ThBC.6, ThCC.1, ThCC.2, WeAC.3, WeAD.5, WeAD.6, WeBB.2, WeCD.3
Nonlinear systems	FrAC.1, FrAC.6, FrBB.4, FrBC.2, FrBC.3, FrBC.6, ThAA.4, ThAB.3, ThAB.4, ThBB.3, ThBC.1, ThBC.5, ThBD.4, ThCB.6, ThCB.7,

	ThCC.3, ThCD.3, WeAB.3, WeAB.4, WeCC.1, WeCC.4

O	
Optimisation	FrAB.1, FrBB.1, FrBB.5, ThAB.4, ThAB.5, ThAB.6, ThBA.5, ThBB.1, ThBD.1, ThBD.6, ThCC.4, ThCD.6, WeAC.4, WeAC.6, WeAD.2, WeAD.3, WeAD.6, WeBA.4, WeBA.5, WeBA.6, WeBB.4, WeBC.4, WeCA.1, WeCD.2, WeCD.4, WeCD.5

P	
Power systems	FrAB.6, FrBC.4, TuT1T1.1, WeCC.1, WeCC.2, WeCC.3, WeCC.4, WeCC.5, WeCC.6
Predictive control	FrAB.2, FrAB.3, FrAB.5, FrAD.5, FrBC.6, ThAA.1, ThAD.4, ThAD.6, ThBA.5, ThBB.1, ThCC.5, ThCD.5, WeAB.4, WeAB.5, WeBA.1, WeBA.2, WeBA.3, WeBA.4, WeBA.5, WeBA.6, WeBB.5, WeBD.2, WeCD.3
Process control	ThAA.4, ThAD.1, ThAD.2, ThAD.3, ThAD.4, ThBA.1, ThBB.2, ThBD.4, ThCD.3
Prognostics and diagnostics	WeCA.5, WeCA.6

R	
Real-time control	FrAD.5, FrAD.6, FrBC.4, FrBC.5, ThAD.5, ThBD.5, ThCB.3, WeAB.6, WeBC.3, WeCB.6
Robotics	FrAA.1, FrAA.2, FrAA.3, FrAA.4, FrAA.5, FrAB.5, FrAC.4, FrAC.6, FrBA.3, FrBA.4, FrBA.5, FrBB.6, FrBC.6, ThAA.2, ThAA.5, ThAA.6, ThAC.1, ThAC.2, ThAC.3, ThAC.5, ThAC.6, ThAC.7, ThBA.4, ThBA.6, ThBB.3, ThBB.4, ThBB.6, ThBC.1, ThBC.2, ThBC.3, ThBC.4, ThBC.5, ThBC.6, ThBD.6, ThCA.2, ThCA.5, ThCA.6, ThCC.1, ThCC.2, ThCC.3, ThCC.4, ThCC.5, ThCC.6, WeAB.2, WeAC.1, WeAC.5, WeAC.6, WeBA.2, WeBA.6, WeBB.3, WeCB.1, WeCB.2
Robust control	FrAC.1, FrAC.2, FrAC.3, FrAC.4, FrAC.5, FrAC.6, FrBC.5, FrBD.5, ThCB.2, ThCC.2, ThCC.6, ThCD.4, ThCD.5, WeCC.5, WeCC.6

S	
SmartGrid	FrAB.6, FrAD.3, FrAD.6, WeAB.6, WeCC.3
Soft computing	ThBC.4
System identification	FrAA.1, WeAD.1, WeAD.2, WeAD.3, WeAD.4, WeAD.5, WeAD.6

U	
Uncertain Systems	FrAB.1, FrAB.2, FrAC.2, FrAC.5, FrAD.4, ThAC.4, ThAD.6, ThCB.7, ThCC.6, ThCD.6, ThCD.7, WeBC.6, WeCC.6
Unmanned systems	FrAA.5, FrAC.2, FrBA.3, FrBB.6, ThAA.6, ThBB.6, ThCB.5, WeAB.1, WeBA.3, WeBB.1, WeBB.6

V	
Verification and Validation	FrBB.4, ThBB.4, ThCA.7, ThCB.1, WeAD.1, WeCD.6
Virtual and augmented reality	ThCA.1