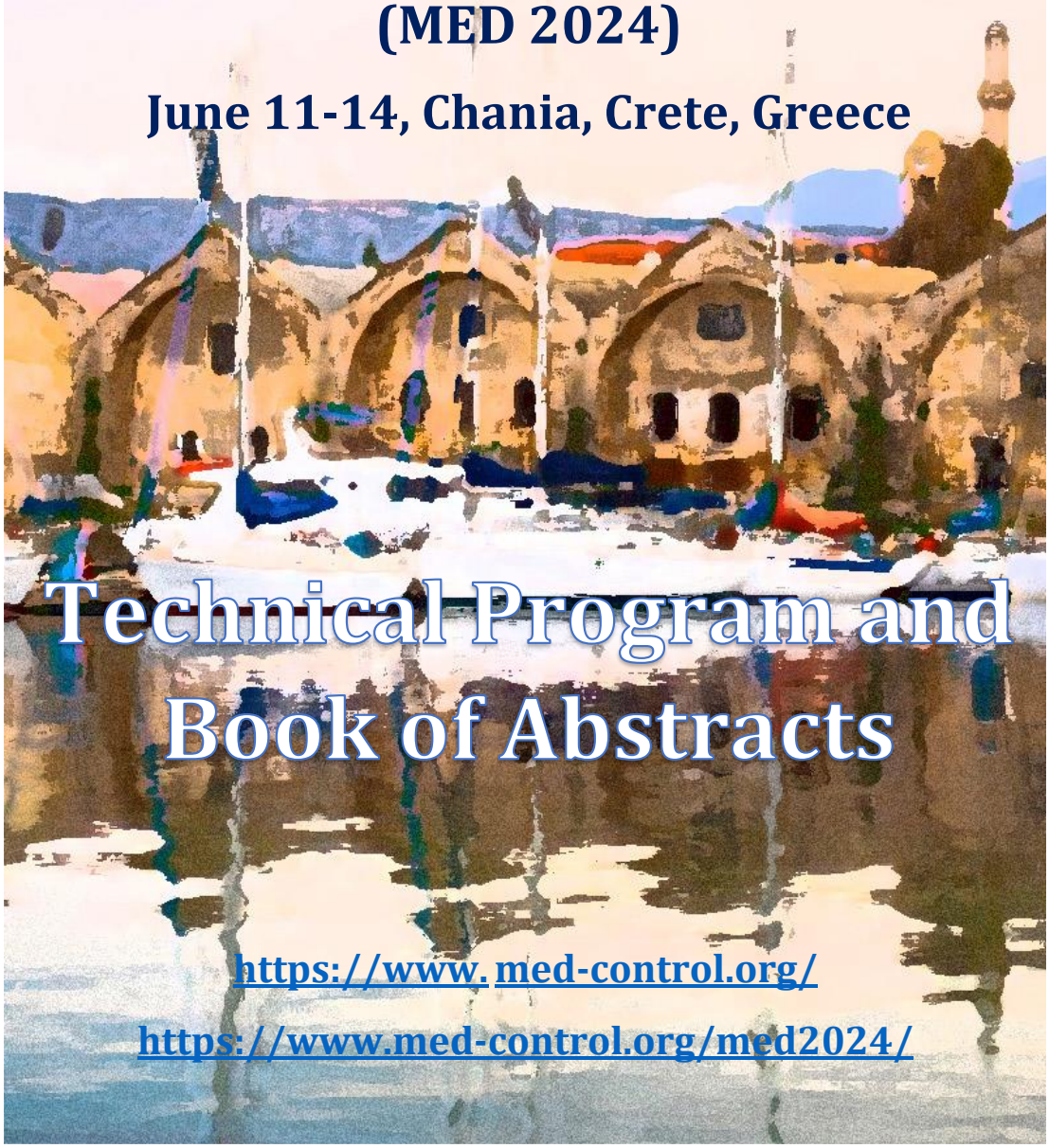
32nd Mediterranean Conference on Control and Automation (MED 2024)

June 11-14, Chania, Crete, Greece



Technical Program and Book of Abstracts

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Welcome Message from the MCA President

Dear authors, participants, and attendees:

Welcome to Chania! On behalf of MCA (www.med-control.org), the parent organization of all MED Conferences, I would like to welcome you to MED 2024, the *32nd Mediterranean Conference on Control and Automation*, which takes place in Chania, Crete, Greece.

Thank you for your participation and contributions; they are absolutely essential in making MED a success. Recall that all MED Conference Proceedings may be found online at http://ieeexplore.ieee.org. Moreover, Proceedings of early MED Conferences may be downloaded from www.med-control.org, where you may also find Book of Abstracts as well as Conference reports of previous MED Conferences that have appeared in the IEEE Control Systems Magazine (CSM).

I would also like to share some information with you regarding the origins of our field and the special place the island of Crete holds, being the home of ***Talos*** the most famous autonomous robot in Greek Mythology.

Autonomous systems have certainly captured the imagination of everyone in recent years. Significant progress in unmanned aerial vehicles (UAVs) and in autonomous underwater and surface ships is announced daily. These are exciting times, especially for researchers in Control Systems because every autonomous system is a control system, since it is designed to achieve specific goals under uncertainties – this is exactly the goal in control design. Autonomy in engineered systems is not a new concept. Automatic pilots for aircraft and ships have been operating very successfully for many years - the first autopilot for aircraft was introduced in 1912. These engineered systems are examples of accomplishments of the *Quest for Autonomy*, a pervasive theme in engineered systems through the centuries that started even earlier than *Ktesibios' water clock* with its feedback mechanism in the 3rd century BC, not far from here, in Alexandria, Egypt, and continuing strong today.

It seems that we always wanted to build machines that served us and accomplished more tasks by themselves, autonomously. In fact, as it was mentioned in the works of the ancient poets Hesiod and Homer around 700 BC, Hephaestus the Greek god of invention and blacksmithing had created several autonomous creatures that were accomplishing different tasks by themselves. The most famous of all was *Talos*, a giant bronze man commissioned by Zeus to protect the island of Crete and Europa. As the story goes, Talos marched around the island three times every day, autonomously, and hurled boulders at approaching pirate and enemy ships!

Looking ahead, MED 2025 goes to Tangiers, Morocco, and I am looking forward to seeing you all again there!

Enjoy the MED 2024 conference in Chania!

Panos J. Antsaklis
University of Notre Dame
President, Mediterranean Control Association

Welcome Message from the MED 2024 General Chairs

Dear authors and attendees:

On behalf of the MED 2024 Organizing Committee, we welcome you to this year's Conference. MED 2024 is coming back to Chania, Crete, where it started from 33 years ago. The three-day Conference, on June 12 - 14, is preceded by a one-day Tutorials / Workshop program, on June 11.

The Conference is organized under the auspices of, and it is sponsored by, the Technical University of Crete (TUC). MED 2024 takes place for the first time in the historical Center of Mediterranean Architecture (KAM), which is hosted in the *Great Shipyard* (*Megalo Arsenali*) of Chania - it is the last of the 17 shipyards located in the Venetian port of the Old Town of Chania. MED 2024 is a 'physical presence only' Conference.

Conference attendees represent academia, industry, government agencies and students, all having deep interest in the state-of-the-art and future directions in control and automation. In response to the Call for Papers, we received 221 contributed and invited session papers. Following a very thorough and in-depth peer review process we assembled a high-quality Technical Program that is composed of 154 contributed and invited session papers, which will be presented over the three-day Conference.

MED 2024 includes three Keynote Lectures suitably distributed over the three-day Conference. The keynote speakers are authorities in their perspective areas. Moreover, the Conference includes a panel discussion (organized and coordinated by Dr. Maria Prandini) on the topic of "*Opportunities and Challenges for Control in the Current AI Era*".

The Organizing Committee members have devoted an enormous amount of time and effort to making sure that the Conference is exciting, informative, and educational. We are privileged to know all the members. We are honored to have worked with them and we are truly indebted to everyone for their dedication and professionalism. We also extend a wholehearted "thank you" to all Associate Editors, reviewers, and members of the Technical Program Committees; their help was key to assembling a top-quality Technical Program.

The peer review process was coordinated by the Program Chairs and Vice-Chairs, and the Technical Committee members. We thank all of them. Dr. Pradeep Misra has been the essential "glue" that has kept everything together, since all papers were submitted online through https://controls.papercept.net, managed by Pradeep. He has been indispensable throughout, and we wouldn't have been able to complete the paper review process without his help.

Finally, we thank you for your participation and contributions. We hope you will enjoy the Conference and take advantage of what Chania and Crete has to offer.

With our warmest regards,

Nikos Tsourveloudis and Elisa Capello

Welcome Message from the MED 2024 Program Chairs

Dear authors and attendees:

It is with great pleasure that we welcome you to the 32nd Mediterranean Conference on Control and Automation, which returns to Chania, Crete.

This year, in response to the call for papers, we received 221 technical and invited session papers. The paper review process has been extremely thorough and rigorous. All papers were also checked for originality using the *iThenticate Document Viewer Guide*. The objective was for each submitted paper to also be reviewed by one of the Program Chairs or members of the Organizing Committee.

The review process resulted in the Technical Program composed of 154 contributed and invited session peer reviewed papers. The Technical Program spans three days, during which all accepted papers are presented, in addition to the Tutorials and Workshops and the three Plenary Sessions.

We would like to thank everyone who contributed to the program for their enthusiastic involvement and substantial efforts. We want to acknowledge the Associate Editors for their kind support during the review process. Special thanks go to the organizers of Tutorials / Workshops and Invited Sessions. Our gratitude goes to all reviewers for their valuable contributions and, finally, to all authors for submitting their work to MED 2024.

Thanks also to Dr. Pradeep Misra who helped us in working and effectively using the on-line paper submission and review system. He has been very responsive and helpful in technical issues related to the on-line system.

We really hope that MED 2024 will provide all attendees and participants with a unique chance to extend their knowledge and network of contacts, to generate new ideas, and to get a better understanding of what is going on in control and automation.

Enjoy not only the technical aspects of the conference but also your stay in Chania. Stay safe around the ‘equilibrium’, to the next MED!

With our warmest regards,

Costas Tzafestas and Lefteris Doitsidis

MED 2024 General Information

The Venues

The Conference venues are the "*Centre of Mediterranean Architecture* (KAM)" and the "*Mikis Theodorakis*" Theatre Hall, two historical and iconic buildings from the 15th century, which are in the Venetian harbor of the Old Town of Chania. The KAM building is also called the "*Great Shipyard*" (Megalo Arsenali).

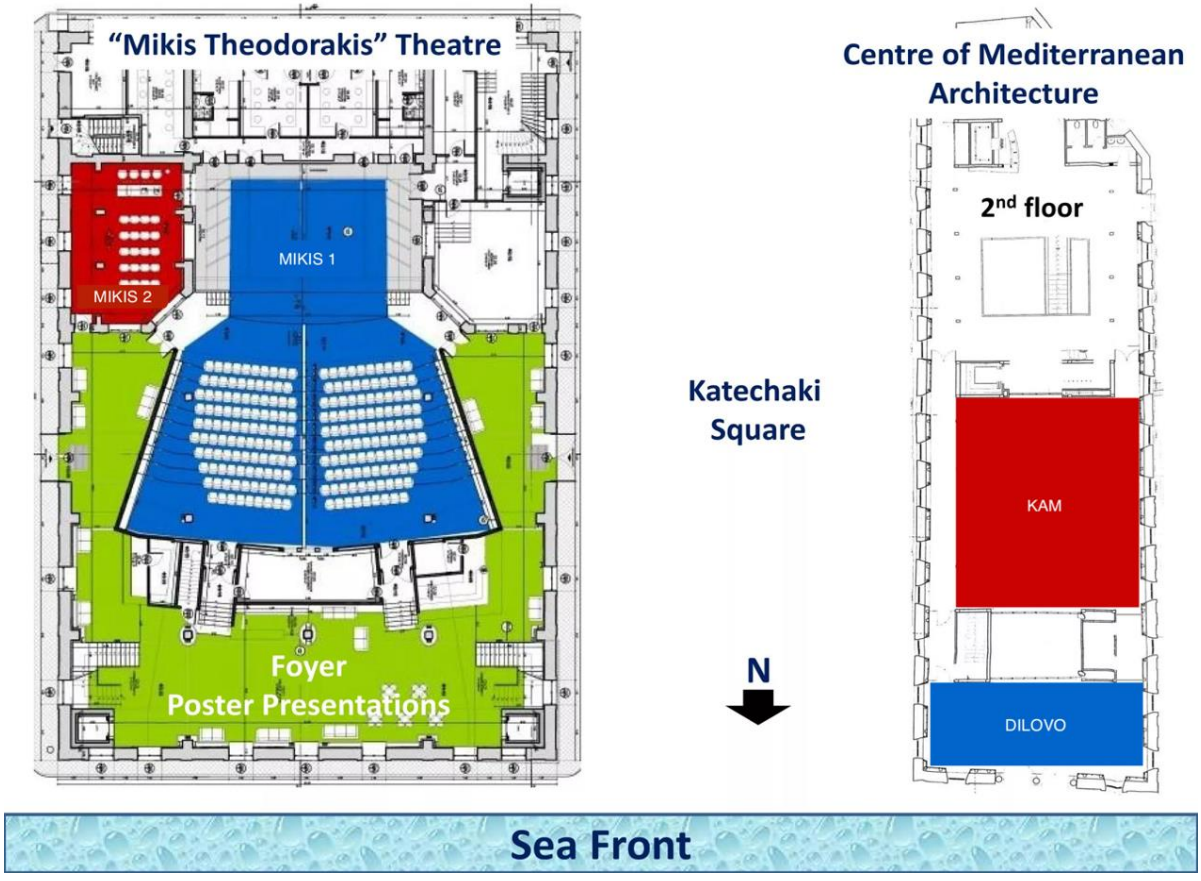


Mikis Theodorakis Theatre



Centre of Mediterranean Architecture -KAM

The layout of the venues is shown below. The Conference will take place in both buildings, which are next to each other. ***MIKIS 1*** is the large Auditorium where all three Plenary talks will take place. Workshops / Tutorials and the parallel technical sessions are scheduled in ***MIKIS 1***, ***MIKIS 2***, ***KAM*** and ***DILOVO***. The Foyer of the *Mikis Theodorakis* Theatre will be used as a free area for interactions and discussions.



Traveling to Chania

Chania (also spelled Hania) is located on the northwest coast of the Greek island of Crete. Crete is about 160 km (99 mi) south of the Greek mainland.

Arriving by Air: The Chania Airport (IATA code: CHQ) is located on the peninsula of Akrotiri (or Souda), which is about 20 minutes (14 km) from the town of Chania. The Chania Airport operates domestic flights to and from Athens Airport, Thessaloniki Airport, and other airports in Greece. From April to early November, there are many direct charter flights to the Chania Airport from the UK, Germany, Italy, Scandinavia, and other European countries. More information may be found on the web site https://www.chania-airport.com/.

Traveling to Chania via Athens: The Athens International Airport "Eleftherios Venizelos" (IATA code: ATH) is serviced by all major airlines, offering direct non-stop flights from/to most of the major European cities, New York, Philadelphia, Montreal/Toronto, North Africa, Gulf States, South Africa, and easy connections to the rest of the world. ATH is also serviced by low-cost and/or charter airlines that offer attractive packages. More information: https://www.aia.gr/traveler/. There are several direct, non-stop flights between ATH and CHQ, serviced by Aegean Airlines, www.aegeanair.com, and Sky Express, https://skyexpress.gr.

Arriving by Sea: There is a ship/ferry from Piraeus (the port of Athens) to Souda Bay (Chania) every day. The route Piraeus to Chania is operated (all year round) by two companies: ANEK-Superfast and Minoan Lines. The trip duration is between 5 - 9 hours depending on the type of vessel.

Language and Currency

The official and national language of Greece is Greek, which is written in the Greek alphabet. In some tourist areas, you will also find street names and signs transliterated into the Latin script. Almost all Greeks speak English, French, German or Italian as a foreign language. Greece uses the Euro (EUR) as currency. Major debit and credit cards are accepted in cities and tourist areas in Greece. When shopping, however, you may get better deals with merchants with cash than debit or credit cards. You may withdraw Euros from all ATM machines. If you have a permanent non-EU residence and you plan to do shopping while in Greece, you may want to learn some tips and guidelines for tax free shopping.

Electricity, Plugs and Sockets

Electrical supply is 230 V, 50 Hz AC. Greece uses the standard European (round-pronged) plugs and power sockets. In technical terms, sockets are "type C" or "type F" (also known as "Schuko"), and they work with corresponding plugs (type C, E, F).

Visa Requirements

Citizens of some countries need an entry visa for Greece. For more information, check out the detailed visa information page.

CONFERENCE LOGISTICS

MED 2024 is a four-day event, starting with Workshops and Tutorials on Tuesday, June 11, followed by a three-day technical Conference on June 12-14. The Conference includes three Keynote Lectures. The meeting rooms in which all technical sessions will take place are ***MIKIS 1***, ***MIKIS 2***, ***KAM*** and ***DILOVO***. The Registration Desk is in the *Centre of Mediterranean Architecture* (KAM) building, on the main floor. Exhibit booths will also be on the main floor for maximum traffic.

Conference Registration

All Conference attendees must register by using the online registration when they upload the final version of their papers. This is the preferred option. Late and onsite registration is also available for non-authors who want to attend the Conference. It is not required to present a paper in the Conference

program to register and to attend the Conference. All registered participants must check in at the Registration Desk to pick up their registration packages. Personal badges will be provided to all registered participants. Attendees must always wear their badges when attending any MED'24 event (workshops, tutorials, technical sessions, and social functions). Conference details will be posted and updated daily in the registration area. To register, follow the steps:

- ✓ Go to https://controls.papercept.net
- ✓ Scroll down the list until you find MED'24 - Choose MED'24 (from the list of Conferences)
- ✓ Click on Register for MED 2024
- ✓ Login with your PIN/Password. *First time users, create a 'profile', to get a PIN and Password.*
- ✓ After you Log in, choose **Registree**.
- ✓ Follow the self-explained screens to register.

You may register through www.icuas.com, too. The Registration schedule is provided next.

TUESDAY, JUNE 11:	***Workshop/Tutorial Registration only*** Note that morning registration is for Workshops and Tutorials only.	8:30 AM – 10:00 AM
	Conference Registration	3:00 PM – 5:00 PM
WEDNESDAY, JUNE 12:		8:00 AM – 4:00 PM
THURSDAY, JUNE 13:		8:30 AM – 2:30 PM
FRIDAY, JUNE 14:		8:30 AM – 11:00 AM

Onsite Conference registration policy & fees

Attendees can register for the Conference under the following registration categories/rates:

Attendee Status	Registration Fee
Full Regular Registration	$700
Student Registration	$380
Retiree Registration	$200
IEEE Life Member	$0
T1: Topics in Control for Aircrafts	$240
T2: Modeling and Control of Multirotor UAVs: A Comprehensive Framework	$140
T3: Technologies and Digital Transformation in Industry 4.0/5.0	$140
T4: Bounded control theory for power converter and microgrid control design	$140
Guest Registration (All Social Events)	$200
Extra Welcome Reception Ticket	$50
Extra Banquet Ticket	$100

Internet Access

All registered attendees will have complementary internet access.

Lunch for Registered Participants

Lunch will be served to registered Conference participants. Lunch tickets will be provided for Wednesday, Thursday and Friday, June 12 to 14.

Coffee Breaks with Snacks

There will be two coffee breaks per day for all registered participants, one in the morning and one in the afternoon.

Events, Reception and Banquet

The MED 2024 social agenda includes two *Coffee Breaks* per day, with snacks, *Lunch* on Wednesday, Thursday and Friday, a *Welcome Reception* on Tuesday, June 11, and *Banquet* on Thursday, June 13. Student Registration does not include the *Banquet*.



MED 2024 Tutorials and Workshops

MED'24 offers four pre-Conference Workshops/Tutorials addressing current and future topics in unmanned aircraft systems from experts in academia, national laboratories, and industry. Interested participants may find details on www.uasconferences.com, and they may use the online system for registration. Tutorials/Workshops will take place on Tuesday, June 11. Duration is either *Full-Day* (09:00 - 18:00) or *Half-Day* (09:00 - 13:00, or 14:00 – 18:00).

TUTORIALS / WORKSHOPS - Tuesday, June 11		
Location	**Time**	**Title**
MIKIS 1	Full-Day 9:00-18:00	T1*: Topics in Control for Aircrafts*
KAM	Half-Day 9:00 – 13:00	T2*: Modeling and Control of Multirotor UAVs: A Comprehensive Framework*
DILOVO	Half-Day 9:00 – 13:00	T3*: Technologies and Digital Transformation in Industry 4.0/5.0*
MIKIS 2	Half-Day 9:00 – 13:00	T4*: Bounded Control Theory for Power Converter and Microgrid Control Design*

MED 2024 Plenary Lectures

MED'24 includes three Plenary Lectures given by leading authorities in their fields. We are proud to include them in the Technical Program. All Plenary Lectures will be in the ***MIKIS 1 Auditorium***. The schedule for the lectures is shown next.

PLENARY LECTURES		
Day	**Time**	**MIKIS 1 AUDITORIUM**
Wednesday June 12	09:00 – 10:00	***Addressing Complexity in Contemporary Applications via Data-driven and Distributed Optimization***, *Dr. Prof. Maria Prandini, Politecnico di Milano*
Thursday June 13	09:00 - 10:00	***Human-Level Performance with Autonomous Vision-based Drones***, *Dr. Prof. Davide Scaramuzza, University of Zurich*
Friday June 14	09:00 - 10:00	***Video Games: The Ultimate Launchpad for Automation and Control***, *Dr. Prof. Georgios N. Yannakakis, University of Malta,* *modl.ai (Malta), Co-founder and Research Director*

MED 2024 Panel Discussion

MED 2024 includes a Panel Discussion on Wednesday afternoon, June 12. Details are provided next.

Title: ***Opportunities and Challenges for Control in the Current AI Era***

Organizer: ***Maria Prandini***, *Politecnico di Milano*

Panelists: ***Frank Allgower***, *University of Stuttgart*
Panos J. Antsaklis, *University of Notre Dame*
Kostas Kyriakopoulos, *NTU Athens, Professor Emeritus* and *New York University, Abu Dhabi*
Kimon P. Valavanis, *University of Denver*

MED' 24 TECHNICAL PROGRAM AT A GLANCE

Workshops / Tutorials: Tuesday June 11

T1-MIKIS 1 09:00 – 18:00	T2 – KAM 09:00 – 13:00	T3 – MIKIS 2 09:00-13:00	T4 – DILOVO 09:00-13:00
Topics in Control for Aircrafts	*Modeling and Control of Multirotor UAVs: A Comprehensive Framework*	*Bounded Control Theory for Power Converter and Microgrid Control Design*	*Technologies and Digital Transformation in Industry 4.0/5.0*

Technical Program: Wednesday, June 12

Coffee Breaks: **10:00 – 10:30**
16:00 – 16:30
Lunch: **12:30 – 14:00**

08:30-09:00
MIKIS 1
MED 2024 Opening Ceremony

09:00-10:00
MIKIS 1 - Plenary Session
Addressing Complexity in Contemporary Applications via Data-driven and Distributed Optimization

MIKIS 1	MIKIS 2	KAM	DILOVO
10:30-12:30 WeA1 Intelligent Transportation Systems	10:30-12:30 WeA2 Industrial Automation	10:30-12:30 WeA3 Robotics I	10:30-12:30 WeA4 Adaptive Control
14:00-16:00 WeB1 Autonomous Systems	14:00-16:00 WeB2 Unmanned Systems	14:00-16:00 WeB3 Biomedical Engineering	14:00-16:00 WeB4 Robotics and System Identification in Education

KAM
16:30-18:30
WeC1
Panel Discussion: ***Opportunities and Challenges for Control in the Current AI Era***

Technical Program: Thursday, June 13

Coffee Breaks: **10:00 – 10:30**
16:00 – 16:30
Lunch: **12:30 – 14:00**

09:00-10:00
MIKIS 1 – Plenary Session
Human-Level Performance with Autonomous Vision-based Drones

MIKIS 1	MIKIS 2	KAM	DILOVO
10:30-12:30 ThuA1 Automotive Control	10:30-12:30 ThuA2 Control	10:30-12:30 ThuA3 Education and Training	10:30-12:30 ThuA4 Intelligent Data Processing in Control and Decision Support Systems (SENSYS 24)

14:00-16:00 ThuB1 Aerospace Control	14:00-16:00 ThuB2 Navigation	14:00-16:00 ThuB3 Optimisation I
16:30-18:30 ThuC1 Technological Challenges I	16:30-18:30 ThuC2 Image Processing	16:30-18:30 ThuC3 Linear Systems

Technical Program: Friday, June 14

Coffee Breaks: **10:00 – 10:30**
16:00 – 16:30
Lunch: **12:30 – 14:00**

09:00-10:00 **MIKIS 1 - Plenary Session** ***Video Games: The Ultimate Launchpad for Automation and Control***			
MIKIS 1	**MIKIS 2**	**KAM**	**DILOVO**
10:30-12:30 FriA1 Robotics II	10:30-12:30 FriA2 Multi-Agent Systems	10:30-12:30 FriA3 Neural Networks	
14:00-16:00 FriB1 Technological Challenges II	14:00-16:00 FriB2 Optimisation II	14:00-16:00 FriB3 Power Systems and Smart Grid	
16:30-18:10 FriC1 Renewable Energy and Sustainability	16:30-18:10 FriC2 Robust Control	16:30-18:10 FriC3 System Identification	

MED'24 Content List and Paper Abstracts

Technical Program for Wednesday June 12, 2024

WeA1 **MIKIS1**

Intelligent Transportation Systems (Regular Session)

Chair: Papamichail, Ioannis ***Technical University of Crete***

10:30-10:50 WeA1.1

Safe Lane Change Aborting Maneuver for Autonomous Vehicle, pp. 1-6

Benoit, Vigne IRIMAS

Giuliani, Pio Michele Ohio State University

Orjuela, Rodolfo Université De Haute-Alsace

Lauffenburger, Jean-Philippe University of Haute-Alsace

Basset, Michel Université De Haute Alsace - ENSISA

Rizzoni, Giorgio Ohio State University

This paper deals with autonomous-driving vehicle trajectory planning. It introduces a trajectory planning approach that allows aborting a lane change maneuver during an overtaking process for safety reasons. In detail, this method consists of two main tasks: on the one hand, it generates a path that leads the vehicle to the initial lane starting from its current position and, on the other hand, it generates a speed profile capable of adapting the vehicle's speed to the velocity of the overtaken vehicle. Furthermore, some geometrical and dynamic constraints are considered to ensure the stability of the vehicle. The algorithm is validated by an experimental campaign carried out through an instrumented drive-by-wire car. The different functions have been integrated into the ROS-Autoware architecture and the online-generated trajectories are tested in real-time on the track. The experimental results show the effectiveness of the proposed planning method in the field of autonomous-driving vehicle control.

10:50-11:10 WeA1.2

A Fault Detection and Isolation Scheme for Autonomous Car Vehicle Subjected to Uncertainties and External Disturbance, pp. 7-12

Ferraro, Alessia Università Mediterranea

De Capua, Claudio Università Mediterranea of Reggio Calabria

This work aims to enhance the reliability and safety of intelligent transportation vehicles through an integrated system of control and diagnostics. Specifically, a Fault Detection and Isolation (FDI) system is proposed, which proves to be efficient and robust, capable of distinguishing between sensor and actuator faults even in the presence of external disturbances affecting the system. This system employs a set-based approach to establish a real-time fault detection threshold logic. The effectiveness of the proposed approach has been tested through numerical simulations involving a car vehicle simulator implemented in the MATLAB/Simulink environment.

11:10-11:30 WeA1.3

Feedforward Extension to Improve LQR Performance in Internal Boundary Control, pp. 13-18

Malekzadeh, Milad Technical University of Crete

Papamichail, Ioannis Technical University of Crete

Papageorgiou, Markos Technical University of Crete

A new concept called TrafficFluid proposes that autonomous vehicles do not need to drive on traffic lanes, and this allows for sharing of the capacity of the road in real-time between the two traffic directions using Internal Boundary Control (IBC). This new traffic control measure was demonstrated to be very effective in improving traffic flow efficiency when evaluated through macroscopic traffic flow models using LQR (Linear Quadratic Regulator). In this study, to enhance the performance of LQR, a feedforward term, accounting for external disturbances, i.e. entering and on-ramp flows, is designed, leading to an augmented LQR-FF control scheme. To evaluate the effectiveness of the LQR and LQR-FF controllers, a realistic demand scenario is considered and the two control schemes are tested and compared, indicating benefits for the LQR-FF scheme.

11:30-11:50 WeA1.4

Performance Comparison between Constrained Cooperative Adaptive Cruise Controllers of Homogeneous Vehicle Platoons, pp. 19-24

Gaagai, Ramzi Helmut Schmidt University

Horn, Joachim Helmut-Schmidt-University / University of the Federal Armed Forces

This paper compares a novel distributed synchronization-based controller using Euclidean contraction metrics, that guarantees exponential synchronization of the vehicle platoon with modified versions of renown PD and consensus-based controllers from the literature. Inter-vehicle spacing of the ego vehicle relative to the preceding vehicle is realized by utilizing a Predecessor-Follower (PF) communication topology. Furthermore, to account for the system constraints, avoid unreasonable accelerations/decelerations, and prevent collisions between vehicles, safety features are incorporated, using the concept of control barrier functions (CBFs). Finally, the performance of the three controllers is compared in a simulation study using different scenarios.

11:50-12:10 WeA1.5

Numerical Investigation of Head-To-Tail String Stability and Performance of Predictor-Based ACC in a Mixed Traffic Scenario, pp. 25-30

Samii, Amirhossein — Technical University of Crete
Karafotis, Panagiotis — Technical University of Crete
Bekiaris-Liberis, Nikolaos — Technical University of Crete

We illustrate the performance of predictor-based adaptive cruise control (ACC) with integral action in a scenario of traffic consisting of both ACC-equipped and human-driven vehicles. We consider a linearized optimal velocity model (OVM) with input delay for human-driven vehicles, while for the ACC-equipped vehicle we consider linear, second-order dynamics with input delay. We demonstrate that a single ACC-equipped vehicle, located at the tail of the platoon, under the predictor-based ACC law, is capable of guaranteeing head-to-tail string stability, despite the presence of input delay and the string unstable behavior of the human-driven vehicles. We further analyze numerically the effect of the tuning parameters of the ACC law to three metrics quantifying performance in terms of fuel consumption, safety, and comfort, providing recommendations for their choice. The ACC law also guarantees individual vehicle stability and zero steady-state tracking errors, which is demonstrated in simulation, considering a platoon of four vehicles.

12:10-12:30 — WeA1.6

The Effects of Cruise Controlled Vehicles on Traffic Density, pp. 31-36

Titakis, George — Technical University of Crete
Karafyllis, Iasson — National Technical University of Athens
Theodosis, Dionysios — Technical University of Crete
Papamichail, Ioannis — Technical University of Crete
Papageorgiou, Markos — Technical University of Crete

In this paper we study the performance of a class of cruise controllers for automated vehicles on a macroscopic scale. To approximate the solutions of the corresponding macroscopic traffic model, a particle method is used, in which the vehicles are considered as “self-driven” particles of a fluid, to provide a link between the macroscopic model and the underlying microscopic cruise controllers. This allows to determine the physical properties of the “traffic-fluid” by changing the functions or the parameter values included in the cruise controllers. Finally, a traffic simulation scenario and a comparison with the Aw-Rascle-Zhang (ARZ) model are provided, illustrating the advantages of the use of automated vehicles.

WeA2 — **MIKIS2**

Industrial Automation (Regular Session)

Chair: Tsourveloudis, Nikos — ***Technical University of Crete***

Co-Chair: Koumboulis, Fotis N. — ***National and Kapodistrian University of Athens***

10:30-10:50 — WeA2.1

Holistic Risk Assessment in Industrial Control Systems: Combining Multiple Bayesian Networks with Multi-Criteria Decision Making, pp. 37-42

Guarino, Simone — University Campus Bio-Medico of Rome
Faramondi, Luca — Università Degli Studi Roma Tre
Oliva, Gabriele — Università Campus Bio-Medico Di Roma
Del Prete, Ernesto — INAIL
Setola, Roberto — University Campus BioMedico of Rome

In recent years, the increase in cyber-attacks on Industrial Control Systems (ICS) due to open industrial protocols has highlighted the vulnerability of critical infrastructures to such threats. Notable incidents like Stuxnet and BlackEnergy3 have demonstrated the potential for significant operational disruptions. Such a new situation calls for a successful risk assessment approach that can address the multifaceted nature of cyber threats. Addressing such need, this paper introduces a novel holistic risk assessment framework combining Bayesian Networks (BNs) with Multi-Criteria Decision Making (MCDM) to compute and integrate heterogeneous risk values into a single, comprehensive risk metric. In more detail, a set of heterogeneous risk metrics, derived by resorting to an array of risk specific BNs, is combined through the Incomplete Analytic Hierarchy Process (AHP) technique. Briefly, a set of experts is asked to compare the relevance of pairs of risks, and this relative information is translated into a weight associated to each metric. The effectiveness of the proposed risk assessment technique is evaluated against a real hardware-in-the-loop case study in a laboratory environment, namely the Water Distribution Testbed (WDT) for cyber-physical security testing.

10:50-11:10 — WeA2.2

Input-Output Supervisor Design for Systems Analyzed in Cooperating Pairs of Subsystems, pp. 43-49

Koumboulis, Fotis N. — National and Kapodistrian University of Athens
Fragkoulis, Dimitrios — National and Kapodistrian University of Athens

The problem of supervisor design for systems analyzed in cooperating pairs of subsystems is studied. The supervisors realize the cooperation using only sensor and actuator data of each pair of subsystems. The analysis of the system in cooperating pairs of subsystems covers a wide range of applications. Each cooperating ordered pair forms a master/slave relation between the sensor signals of the second element of the pair and the actuator of the first element of the pair. All possible cooperation relations are determined and investigated with respect to the avoidance of blocking and stuck to the initial states of the actuators. The system properties of the cooperation are formulated in a set theoretic scheme that allows the determination of the set of admissible cooperation rules. The present theoretical results are illustrated through one manufacturing application and one infrastructure application.

11:10-11:30 — WeA2.3

Detection of Novel Asset Failures in Predictive Maintenance Using Classifier Certainty, pp. 50-56

Fathi, Kiavash	ZHAW, Zurich University of Applied Sciences
Ristin, Marko	Zurich University of Applied Sciences (ZHAW)
Sadurski, Marcin	ZHAW
Kleinert, Tobias	RWTH Aachen
van de Venn, Hans Wernher	Zurich University of Applied Sciences ZHAW

Model reliability is one of the main building blocks of trustworthy AI where models can indicate their prediction with certainty given the provided input data. Despite the numerous model calibration techniques available to gauge the reliability of trained models, it has been shown that even well-calibrated classification models cannot properly represent their uncertainty for data points outside the training distribution. Such models, therefore, cannot be used in industrial settings to find previously unidentified failures in an asset, leaving the maintenance crews in the dark. To counter that, we analyze the sequence of the predicted probability values from a condition monitoring classification sub-model of a predictive maintenance solution. We demonstrate that the data points from unknown regions of the asset parameter space can be flagged by simply analyzing such sequences. The flagged failure instances of the asset are consequently sent for thorough inspection to the maintenance crew. Furthermore, we demonstrate on a practical real-world scenario the effectiveness of our proposed method (mean accuracy of 94.35%) by comparing it with models trained only on pre-processed data (mean accuracy of 27.96%) or models based on autoencoder reconstruction error (mean accuracy of 51.09%). We finally show how the predicted probability values from different regions of the parameter space exhibit a higher degree of separability between normal working condition, known and unknown failure modes compared to signal readings of the system or reconstruction errors of an anomaly detection model.

11:30-11:50 WeA2.4

Traceability in Engineer-To-Order Manufacturing SMEs, pp. 57-62

Bründl, Patrick	Friedrich-Alexander Universität Erlangen-Nürnberg
Stoidner, Micha	Friedrich-Alexander Universität Erlangen-Nürnberg
Nguyen, Huong Giang	Friedrich-Alexander Universität Erlangen-Nürnberg
Abrass, Ahmad	Rittal GmbH & Co. KG
Franke, Jörg	Friedrich-Alexander Universität Erlangen-Nürnberg

This paper examines the implementation and impact of component traceability within small and medium-sized enterprises (SMEs) in the control cabinet manufacturing industry. Through a detailed examination of expert interviews, this study addresses four critical research questions regarding the current state of traceability practices, motivational factors for implementation, challenges faced by companies, and the expected impact on selected business criteria. Our findings reveal a diverse landscape of traceability implementation among the SMEs surveyed. The primary motivators for adopting traceability include quality assurance and defect analysis, customer requirements and regulatory compliance, and product and warranty liability, highlighting the intrinsic and extrinsic factors that drive companies to adopt traceability practices. Conversely, significant barriers preventing SMEs from implementing traceability were identified, including cost-benefit considerations, administrative burden, IT infrastructure challenges, employee resistance to change, and the complexity of managing a diverse range of items and suppliers. The impact of traceability on quality, time-to-market, competitiveness, customer satisfaction, product cost and other business processes was also assessed. In addition, the study highlights the potential for traceability to indirectly impact product costs and facilitate improvements in other operational areas through the strategic use of collected data. This research contributes to a deeper understanding of component traceability in the control cabinet manufacturing sector and provides valuable insights for SMEs considering the implementation and optimization of traceability systems within their operations.

11:50-12:10 WeA2.5

Efficiency and Sustainability in Manufacturing: Simultaneous Work-In-Progress Control and Energy Consumption Management, pp. 63-68

Ioannidis, Stratos	Technical University of Crete
Doitsidis, Lefteris	Technical University of Crete
Tsourveloudis, Nikos	Technical University of Crete

Work-in-process (WIP) control and energy consumption management are two important aspects of modern manufacturing systems. This paper proposes a bi-objective strategy that controls WIP and energy consumption simultaneously. The strategy is based on production scheduling that meets the demand for finished products while keeping WIP and energy consumption to a minimum. The control strategy avoids energy peaks throughout the operation of the manufacturing system. The effectiveness of the approach is demonstrated via simulation in production lines with random demand and machines' failures.

12:10-12:30 WeA2.6

Validation of a Digital Platform for Intrafactory Logistics Optimization, pp. 69-74

Alexopoulos, Kosmas	Univ of Patras
Ntoulmperis, Michail	Laboratory for Manufacturing Systems & Automation (LMS)
Angelopoulos, John	Laboratory for Manufacturing Systems and Automation, Department
Kanellopoulos, Giannis	Laboratory for Manufacturing Systems & Automation (LMS)
Kaimenopoulos, Apostolos	Halcor Copper and Alloys Extrusion Division of ElvalHalcor
Ziata, Efstathia	Halcor Copper and Alloys Extrusion Division of ElvalHalcor

Due to recent advancements in manufacturing, in-house logistics have become significantly more complicated, particularly in large-scale production lines, making the optimization of waste management a critical challenge. This study introduces a digital platform designed to enhance waste management through real-time monitoring using sensors and cameras. Our objective is to evaluate the platform's performance in optimizing waste management through comparing different scenarios of forklift routing in a copper factory setting.

Employing a Discrete Event Simulation model, we examined two distinct scenarios to assess the impact of the digital platform on internal logistics. The results demonstrate a substantial decrease in both the total distance travelled by forklifts and the duration waste bins remain full, indicating a significant improvement in operational efficiency. These findings validate the effectiveness of the digital platform, highlighting its potential as a valuable tool in modern digital manufacturing.

WeA3	**KAM**
Robotics I (Regular Session)	
Chair: Papadopoulos, Evangelos	***National Technical University of Athens***
Co-Chair: Papageorgiou, Dimitrios	***Hellenic Mediterranean University***

10:30-10:50 WeA3.1

Multicamera Visual SLAM for Vineyard Inspection, pp. 75-80

Kokas, Christos-Vasileios — National Technical University of Athens
Mastrogeorgiou, Athanasios — National Technical University of Athens
Machairas, Konstantinos — National Technical University of Athens
Koutsoukis, Konstantinos — National Technical University of Athens
Papadopoulos, Evangelos — National Technical University of Athens

Automating the process of collecting samples (e.g. images) from a vineyard can help to monitor the condition of the grapes with precision and prevent the spread of diseases. A critical part in this task is the development of a robust localisation algorithm so that (a) a robot can carry out the inspection process and (b) the vine-grower knows exactly which part of the vineyard has been inspected. In this paper, we propose a novel approach for enhancing the robustness of vSLAM by utilising multiple stereo cameras, and a novel method for detecting loops in homogeneous environments based on AprilTags, where state-of-the-art approaches may find it difficult to detect them. We test the accuracy of our method using a wheeled Robotic Platform (RP) in simulation and in a synthetic vineyard developed at CSL, NTUA. The developed method achieves high accuracy in the localization of the RP in the vineyard and robustness even when a featureless object covers a large part of the Field of View of one camera. The developed software is available for testing at the CSL's bitbucket repository.

10:50-11:10 WeA3.2

Modeling and Control of an Underwater Calibration Arm, pp. 81-87

Voskakis, Dimitris — Norwegian University of Science and Technology
Kelasidi, Eleni — SINTEF Ocean
Papandroulakis, Nikos — Hellenic Center for Marine Research

Automating calibration process is a crucial task for imaging technologies especially in an aquaculture domain, where novel camera-based technologies are utilized to provide valuable information about the performance of the reared organisms. To target this open research question, this paper presents modelling and control concepts of a specially designed underwater calibration arm (UCA) in a simulation environment. In particular, we present a calibration arm model with the kinematics assessed in various scenarios in an aquatic environment, precisely simulating the pertinent physical forces acting upon it. The model's design is based on an actual calibration arm and the simulation has been achieved through DAVE, an open-source aquatic virtual environment that provides the capability to develop and evaluate robotic applications in different underwater scenarios. The motion of the calibration arm has been achieved using a trajectory planner and an Inverse Kinematics solver, which provides the joint angles for the desired state of the end-effector. The results are promising to indicate the potential for automated camera calibration technologies in simulated aquaculture conditions. The proposed control framework can be adapted to carry out various simulation scenarios, offering valuable insights into camera calibration procedures to the unique demands of aquaculture operations.

11:10-11:30 WeA3.3

On Vision and Distance Based, Object Specific, Grasp Strategy Selection for Simplified Electromyography Control of Prosthetic Hands, pp. 88-93

Owen, Mahonri — The University of Waikato
Au, Chi Kit — The University of Waikato
August, Luke — The University of Waikato
Guan, Bonnie — The University of Auckland
Liarokapis, Minas — The University of Auckland

Numerous individuals experience the detrimental consequences of amputation arising from incidents such as muscle trauma, cancer, and disease. Amputees see decreased efficiency in performing activities of everyday life, additionally suffering from the psychological effects stemming from feelings of grief and depression. As such, research into human-machine interfaces for the control of prostheses serves as a pivotal pathway to help them regain their lost dexterity. Autonomous technologies have the potential to improve the quality of life of amputees, supporting the growth and development of better, more simplified control interfaces for prosthetic devices. The research presented herein combines vision and distance sensors to derive object specific grasp strategies for the simplified Electromyography-based control of humanlike prosthetic hands, allowing amputees to efficiently handle a plethora of everyday life objects with ease. The integration of the proposed vision and distance sensor aided grasp strategy selection scheme can increase the efficiency of prosthetic control while simultaneously reducing the cognitive load a user experiences while operating a prosthetic device. Such approaches have the potential to increase prostheses acceptance rates and improve the quality of life for amputees.

11:30-11:50 WeA3.4

ActIVO: An Active Perception Framework for Skill Transfer through Iterative Visual Observations, pp. 94-100

Papageorgiou, Dimitrios — Hellenic Mediterranean University

Kounalakis, Nikolaos — Hellenic Mediterranean University,
Efstathopoulos, Nikolaos — Hellenic Mediterranean University
Fasoulas, John — Hellenic Mediterranean University
Sfakiotakis, Michael — Hellenic Mediterranean University

Learning by demonstration (LbD) through visual observation is widely used in literature for tackling the problem of robot programming. However, identification and exact localization of the point of interest (e.g. human hand) during the demonstration, in most of the cases, comes with a non-negligible uncertainty, introduced by the detection algorithm and the sensor characteristics. In this work, we propose an active perception framework for gaining the maximum information during iterative demonstrations performed by a human, towards LbD. The method is based on a covariance weighted pseudo-inverse estimator that accounts for the non-homogeneous uncertainty of the sensor. The proposed framework, coined as "ActIVO", is experimentally validated in two scenarios, utilizing a UR5e robotic manipulator and an in-hand RealSense RGB-D camera.

11:50-12:10 — WeA3.5

BOX3D: Lightweight Camera-LiDAR Fusion for 3D Object Detection and Localization, pp. 101-106

Valdes Saucedo, Mario Alberto — Luleå University of Technology
Stathoulopoulos, Nikolaos — Luleå University of Technology
Sumathy, Vidya — Luleå University of Technology
Kanellakis, Christoforos — Luleå University of Technology
Nikolakopoulos, George — Luleå University of Technology, Sweden

Object detection and global localization play a crucial role in robotics, spanning across a great spectrum of applications from autonomous cars to multi-layered 3D Scene Graphs for next-level scene understanding. This article proposes BOX3D, a novel multi-modal and lightweight scheme for localizing objects of interest by fusing the information from RGB camera and 3D LiDAR. BOX3D is structured around a three-layered architecture, building up from the local perception of the incoming sequential sensor data to the global perception refinement that covers for outliers and the general consistency of each object's observation. More specifically, the first layer handles the low-level fusion of camera and LiDAR data for initial 3D bounding box extraction. The second layer converts each LiDAR's scan 3D bounding boxes to the world coordinate frame and applies a spatial pairing and merging mechanism to maintain the uniqueness of objects observed from different viewpoints. Finally, BOX3D integrates the third layer that supervises the consistency of the results on the global map iteratively, using a point-to-voxel comparison for identifying all points in the global map that belong to the object. Benchmarking results of the proposed novel architecture are showcased in multiple experimental trials on public state-of-the-art large-scale dataset of urban environments.

12:10-12:30 — WeA3.6

Localization and Offline Mapping of High-Voltage Substations in Rough Terrain Using a Ground Vehicle, pp. 107-112

Alamanos, Ioannis — National Technical University of Athens
Moustris, George — National Technical University of Athens
Tzafestas, Costas — National Technical University of Athens

This paper proposes an efficient hybrid localization framework for the autonomous navigation of an unmanned ground vehicle in uneven or rough terrain, as well as techniques for detailed processing of 3D point cloud data. The framework is an extended version of FAST-LIO2 algorithm aiming at robust localization in known point cloud maps using Lidar and inertial data. The system is based on a hybrid scheme which allows the robot to not only localize in a pre-built map, but concurrently perform simultaneous localization and mapping to explore unknown scenes, and build extended maps aligned with the existing map. Our framework has been developed for the task of autonomous ground inspection of high-voltage electrical substations residing in rough terrain. We present the application of our algorithm in field trials, using a pre-built map of the substation, but also analyze techniques that aim to isolate the ground and its traversable regions, to allow the robot to approach points of interest within the map and perform inspection tasks using visual and thermal data.

WeA4 — DILOVO

Adaptive Control (Regular Session)

Chair: Ruderman, Michael — ***University of Agder***
Co-Chair: Glushchenko, Anton — ***V. A. Trapeznikov Institute of Control Sciences of RAS***

10:30-10:50 — WeA4.1

Kalman Filter Based Adaptive Control Allocation, pp. 113-118

Hafner, Simon Franz — Technical University of Munich
Ryals, Andrea Dan — University of Pisa
Li, Hangxu — Technical University of Munich
Pollini, Lorenzo — University of Pisa
Holzapfel, Florian — Technische Universität München

In recent years, various approaches for adaptive control allocation have been published with the goal of enabling fault tolerance and improving flight performance of over actuated vehicles. Most of the presented methods are based on Model Reference Adaptive Control (MRAC) techniques and/or recursive least squares. In this study, we present a novel strategy combining concurrent learning MRAC and Kalman filtering to adapt the control effectiveness vector. The proposed strategy incorporates short term updates of the direct update as well as stationary correction through the Kalman filter. The adaptive control allocation has been evaluated using a hexacopter high fidelity simulation model. The hexacopter is controlled by an Incremental Nonlinear Dynamic Inversion (INDI) velocity controller and by a backstepping controller. In the simulation, we demonstrated the advantages of the adaptive control allocation for partial loss of effectiveness of one rotor and in nominal conditions. The adaptive control allocation avoided the crash of the hexacopter and improved

tracking in forward flight compensating for effectiveness changes.

10:50-11:10 WeA4.2

Adaptive FRIT-Based Recursive Robust Controller Design Using Forgetting Factors, pp. 119-124

Tsuruhara, Satoshi — Shibaura Institute of Technology
Ito, Kazuhisa — Shibaura Institute of Technology

Adaptive FRIT (A-FRIT) with exponential forgetting (EF) has been proposed for time-varying systems to improve the data dependence of FRIT, which is a direct data-driven tuning method. However, the EF-based method is not a reliable controller because it can cause significant degradation of the control performance and instability unless the persistent excitation (PE) condition is satisfied. To solve this problem, we propose a new A-FRIT method based on directional forgetting (DF) and exponential resetting that can forget old data without instability regardless of the PE condition. To confirm the effectiveness of the proposed method, we applied it to artificial muscle control with strong asymmetric hysteresis characteristics and evaluated its robust performance against load changes during the experiment. The experimental results show that the proposed method based on DF achieves high control performance and is robust against changes in the characteristics and/or target trajectory. The proposed method is also practical because it does not require system identification, model structure, or prior experimentation.

11:10-11:30 WeA4.3

Adaptive Time Delay Based Control of Non-Collocated Oscillatory Systems, pp. 125-130

Ruderman, Michael — University of Agder

Time delay based control, recently proposed for non-collocated fourth-order systems, has several advantages over an observer-based state-feedback compensation of the low-damped oscillations in output. In this paper, we discuss the practical infeasibility of such observer-based approach and bring forward application of the time delay-based controller, which is simple in both the structure and design. Moreover, robust estimation of the output oscillation frequency is used and extended by bias canceling. The latter is required for positioning the oscillatory passive loads. This way, an adaptive version of time delay-based control is realized that does not require prior knowledge of the mass and stiffness parameters. The results are demonstrated on the oscillatory experimental setup with constraints in the operation range and control value.

11:30-11:50 WeA4.4

Generalized Saddle Points Seeking Algorithms for Convex Optimization Problems, pp. 131-136

Grushkovskaya, Victoria — University of Klagenfurt
Ebenbauer, Christian — RWTH Aachen University

The paper focuses on convex optimization problems, assuming that the cost and constraint functions are not analytically known, and only the values of the associated Lagrangian are available. One of the main contributions is the introduction of a general family of dynamical systems, whose trajectories converge to an arbitrarily small neighborhood of a saddle point of the associated Lagrangian. The vector fields of the proposed systems exploit only the values of the Lagrangian and thus are derivative-free. Unlike previous derivative-free saddle point seeking methods, this approach utilizes a generalized Lagrangian, which provides certain advantages like driftless dynamics, convergence for almost all initial conditions, and others. It is proven that, in general, the set of saddle points is practically asymptotically stable for the obtained systems. Additionally, it is demonstrated that a special choice of vector fields leads to asymptotic stability in the sense of Lyapunov. The obtained results are illustrated with several examples.

11:50-12:10 WeA4.5

Exact Asymptotic Estimation of Unknown Parameters of Perturbed LRE with Application to State Observation, pp. 137-142

Glushchenko, Anton — V. A. Trapeznikov Institute of Control Sciences of RAS
Lastochkin, Konstantin — V.A. Trapeznikov Institute of Control Sciences of RAS

Most identification laws of unknown parameters of linear regression equations (LRE) ensure only boundedness of a parametric error in the presence of additive perturbations, which is almost always unacceptable for practical scenarios. In this paper, a new identification law is proposed to overcome this drawback and guarantee asymptotic convergence of the unknown parameters' estimation error to zero in case the mentioned additive perturbation meets special averaging conditions. Such law is successfully applied to state reconstruction problems. Theoretical results are illustrated by numerical simulations.

12:10-12:30 WeA4.6

Parameter Estimation-Based Extended Observer for Linear Systems with Polynomial Overparameterization, pp. 143-148

Glushchenko, Anton — V. A. Trapeznikov Institute of Control Sciences of RAS
Lastochkin, Konstantin — V.A. Trapeznikov Institute of Control Sciences of RAS

We consider a class of uncertain linear time-invariant overparametrized systems affected by bounded disturbances, which are described by a known exosystem with unknown initial conditions. For such systems an exponentially stable extended adaptive observer is proposed, which, unlike existing solutions, simultaneously: (i) allows one to reconstruct original (physical) states of the system represented in arbitrarily chosen state-space form rather than virtual states of the observer canonical form; (ii) ensures convergence of the state observation error to zero under weak requirement of the regressor finite excitation; (iii) does not include Luenberger correction gain and forms states estimate using algebraic rather than differential equation; (iv) additionally reconstructs the unmeasured external disturbance. The proposed solution is based on the new parametrizations to identify the observer parameters obtained with the help of the heterogeneous mappings and the dynamic regressor extension and mixing procedure. Illustrative simulations support obtained theoretical results.

WeB1	MIKIS1
Autonomous Systems (Regular Session)	
Chair: Theodosis, Dionysios	***Technical University of Crete***
Co-Chair: Mohammadpour Velni, Javad	***Clemson University***

14:00-14:20 WeB1.1

Cruise Controllers for General Lane-Free Driving Conditions, pp. 149-154

Karafyllis, Iasson — National Technical University of Athens
Theodosis, Dionysios — Technical University of Crete
Papageorgiou, Markos — Technical University of Crete

In this paper we present cruise controllers for automated vehicles with two-dimensional lane-free movement. The derived cruise controllers (feedback laws) are decentralized (per vehicle) and can account for collision avoidance, roads of variable width, on-ramps and off-ramps, as well as different desired speed for each vehicle. Demonstration examples and videos illustrate the cruise controller capabilities.

14:20-14:40 WeB1.2

Local Trajectory Planning Using Dynamic Random Tree Search, pp. 155-160

Akhmadeev, Konstantin — MCQ-Scan, Lille, France
Khomutenko, Bogdan — MCQ-Scan, Lille, France

Mobile robots operating in dynamic environments require computationally efficient solutions to the trajectory planning problem that respect kinematic limits and minimize the navigation cost. In this work, we present an approach to plan local trajectories that incrementally advances the robot along a global path, considering its kinematic constraints and changes in the environment. The key idea of the presented approach is to combine space discretization and heuristic-based search into a single algorithm. To explore the local neighborhood, the algorithm generates a heuristic-driven trajectory tree by iteratively expanding the most promising vertex with randomly sampled control inputs. Then, the robot advances along the best local trajectory and the process are repeated from the new configuration. The approach was successfully applied in a real differential drive robot. Here, we demonstrate the efficacy of our method through tests performed in simulation. The results highlight our approach's suitability for mobile robot navigation in complex dynamic environments.

14:40-15:00 WeB1.3

Safe MPC-Based Motion Planning of AUVs Using MHE-Based Approximate Robust Control Barrier Functions, pp. 161-166

Nejatbakhsh Esfahani, Hossein — Clemson University
Mohammadpour Velni, Javad — Clemson University

This paper presents a safety-critical motion planning approach for Autonomous Underwater Vehicles (AUVs). To this end, we formulate a safe Model Predictive Control (MPC) scheme by leveraging the benefits of MPC with a discrete-time Control Barrier Function (CBF). To address the truncation errors associated with the discretized CBF, we then adopt a Moving Horizon Estimation (MHE) approach to approximate these errors. To cope with both the model mismatch in the CBF and unknown external disturbances, we also leverage the MHE scheme to formulate an approximate Robust CBF (RCBF). Finally, to demonstrate the efficacy of the proposed safety-critical robust control scheme, simulation studies are conducted for path planning of AUVs, and the results confirm the superiority of the proposed method compared to few other methods.

15:00-15:20 WeB1.4

Partial System Identification and Sensor Fusion with the Jaiabot Micro Autonomous Underwater Vehicle, pp. 167-172

Tanner, Herbert G. — University of Delaware
Gane Achchillage, Chanaka Thushitha Bandara — University of Delaware
Gyves, Matthew — U.S. Geological Survey

This paper reports on the first approach to dynamical system modeling, identification, control, and environmental quantity estimation with a new, commercially available, micro-AUV named Jaiabot. The Jaiabot is a small and relatively inexpensive marine robotic sensor platform that dives vertically to collect measurements of quantities related to water quality, such as salinity and temperature. The paper presents (i) the first dynamical model for Jaiabot's dive motion estimated based on field-data, (ii) a controller redesign given mission specifications associated with vertical environmental quantity profiling, and (iii) a first underwater implementation of a cooperative Kalman filter that fuses measurements from several Jaiabots to yield a confident estimate of an environmental quantity of interest along a path within the convex closure of the vehicle formation.

15:20-15:40 WeB1.5

Distributed Bearing-Based Control of Three-Link Planar Redundant Manipulators, pp. 173-178

Paliwal, Pulkit — Indian Institute of Technology, Bombay
Hazarika, Hemanta — Indian Institute of Technology, Bombay
Mukherjee, Dwaipayan — Indian Institute of Technology Bombay
Pal, Debasattam — Indian Institute of Technology Bombay

Redundant manipulators find applications in various tasks and possess more degrees of freedom (DOF) than are required to perform a particular task. Centralized control of such manipulators may result in high computational complexity due to high degrees of freedom. We propose a distributed control strategy for a redundant manipulator to control the manipulator's end-effector and to drive it to a desired goal point. We use only two angle measurements to design the control commands for every link, which has the added advantage of using cheaper sensors. We further analyze the local stability of our control law applied to a 3-link planar manipulator and validate the efficacy of our proposed strategy through several simulations.

15:40-16:00 WeB1.6

Range-Based Wireless Sensor Network Localization by a Circumnavigating Mobile Anchor without Position Information, pp. 179-184

Guler, Samet — Abdullah Gul University

Typical range-based wireless sensor network (WSN) localization approaches aim at estimating the sensor node positions by using a set of anchors with known positions. In some applications, assuming the knowledge of the anchors' positions may be impractical, and estimation of the sensors' positions in an arbitrary fixed frame may be sufficient. Considering such scenarios, we propose a WSN localization algorithm by single mobile anchor without self-location information. The mobile anchor obtains distance measurements from the sensors while tracking a custom trajectory which is shown to improve the localization performance over time for high signal-to-noise ratio cases. By utilizing two stationary reference nodes within the WSN, the proposed framework generates sensor node position estimation up to translation and rotation with sufficient precision in the absence of global positioning aids. We foresee that the proposed framework can demonstrate benefits in several WSN applications ranging from internet-of-things to service robotics.

WeB2 **MIKIS2**

Unmanned Systems (Regular Session)

Chair: Kyriakopoulos, Kostas J. ***National Tech. Univ. of Athens***

14:00-14:20 WeB2.1

Ensuring Safety for UAVs through Event-Triggered Predictive Control, pp. 185-190

Aspragkathos, Sotiris — National Technical University of Athens
Karras, George — University of Thessaly
Kyriakopoulos, Kostas J. — National Tech. Univ. of Athens

This paper presents a control system for unmanned aerial vehicles (UAVs) that track deformable objects. Using Event-Triggered (ET) principles and Image Moments-Based Nonlinear Model Predictive Control (NMPC), the suggested approach improves flexibility by triggering control changes in response to specific occurrences. The incorporation of Barrier Functions (BFs) enforces safety requirements, which are critical for negotiating uncertain terrains. The framework's implementation and testing on a UAV tracking deformable coastlines are intended to demonstrate its effectiveness in adapting to dynamic situations while adhering to safety limitations.

14:20-14:40 WeB2.2

Fault Detection Algorithm of INS of Parametrically Uncertain Unmanned Vessel, pp. 191-196

Bazylev, Dmitry — ITMO University
Margun, Alexey — ITMO University
Dobriborsci, Dmitrii — Deggendorf Institute of Technology

This paper addresses the problem of fault detection and localization of an inertial navigation system (INS) of an unmanned surface vessel (USV) with unknown parameters. The INS under consideration includes angular and linear velocity measurement units. The proposed approach is based on full-order Luenberger observers that are used to synthesize directional generators of residual signals. To estimate the unknown parameters of the USV a dynamic regressor extension and mixing (DREM) technique is applied. Developed algorithm ensures finite-time convergence of parameter estimation errors to zero under some reasonable assumptions. Simulation results demonstrate the efficiency and performance of the developed algorithm for correct fault detection of each sensor.

14:40-15:00 WeB2.3

Approaches Enabling Underwater Autonomy and Sensing in Sea-Based Aquaculture Settings, pp. 197-202

Skaldebø, Martin — SINTEF Ocean
Schellewald, Christian — SINTEF Ocean
Evjemo, Linn Danielsen — SINTEF Ocean
Amundsen, Herman Biørn — Norwegian University of Science and Technology
Xanthidis, Marios — Sintef Ocean
Kelasidi, Eleni — SINTEF Ocean

Aquaculture is of increasing importance as an alternative food supply that mitigates climate change, and an industrial domain with surprising growth as of lately. Unfortunately, due to the notorious logistics of industrial-focused large scale underwater research, and the potential problems that introduces to state-of-the-art methods, only minor focus has been given by the robotics community. This paper aspires to increase the interest in aquaculture robotics, by exposing some major unique challenges this domain poses to relative localization and mapping. Robots are expected to operate in highly dynamic and uncertain environments with no static visual reference, absence of GNSS signals, and interference from a livestock of up to 200,000 units. With this goal in mind, we provide the community a dataset gathered from an industrial-scale fish farm, including monocular cameras, stereo cameras, and acoustics to promote further research. Furthermore, we apply three known state-of-the-art methodologies to demonstrate its value and experiment with different sensing modalities. The first method exploits the net pattern of fish cages to estimate the relative distance via Fourier transformation (FT) on frames collected with a monocular camera, the second method utilizes stereo vision for both acquiring disparity maps and relative pose estimation, and finally acoustic relative localization is shown with a 360° scanning sonar. The contributions are accompanied with relevant analysis and discussion regarding feasibility and potential limitations in aquaculture robotics.

15:00-15:20 WeB2.4

Local Bidding Strategies for Reactive and Scalable Auction-Based Multi-Agent Coordination, pp. 203-208

Dahlquist, Niklas — Luleå University of Technology
Saradagi, Akshit — Luleå University of Technology

Nikolakopoulos, George — Luleå University of Technology

This article proposes local bidding strategies for autonomous agents participating in an auction-based multi-agent coordination system, to improve the scalability and reactivity of the architecture in large-scale coordination scenarios. Based on a careful analysis of the reactivity requirements and the computational costs of the central auctioneer (costs for solving Linear Integer Programs) and the local agents (costs for path-planning and task execution), this article explores the idea of each agent bidding for a subset of available tasks that are locally relevant to the agent. Each agent first employs a computationally light Euclidean distance-based and percentile-based screening method to choose a subset of available tasks, followed by a more computationally complex, but realistic path-planning based cost-estimation and bidding for the chosen subset. The proposed strategy not only reduces the overall computational cost at the agents, but also at the central auctioneer, by reducing the size of the combinatorial optimization problems and the overall communication requirements of the architecture, thereby improving the scalability and reactivity of the overall system. It is shown that, through a one-time simulation-guided design of the bidding parameters, the improved reactivity and scaling is achieved while retaining the optimality or near-optimality of the resulting task-allocation. The performance of the proposed bidding strategies is evaluated in two large-scale simulation scenarios and the reduction in computational costs and the near optimality of the task allocation is demonstrated.

15:20-15:40 — WeB2.5

A GAN-Based Domain Adapted Deep Learning Pipeline for Object Detection in an Intralogistics Warehouse Environment, pp. 209-214

Rashed, Mohammad — German Jordanian University
Bakr, Mohamed — KION Group AG
ElMoaqet, Hisham — The German Jordanian University

Perception is crucial for Autonomous Mobile Robots (AMRs) operating in warehouses to recognize load carriers using vision-based guiding systems. Convolutional Neural Networks (CNNs), while frequently utilized in object detection networks, exhibit significant performance degradation when evaluated in new environments. Although creating computer simulations is a straightforward option, their usefulness in real-world applications is restricted by stylistic disparities between simulated and real data. Recently, Generative Adversarial Networks (GANs) have demonstrated improved performance in Unpaired Image-to-Image Translation (UNIT) tasks, indicating that they might be a viable choice for reducing the stylistic difference between simulated and actual data. This work proposes a domain adaptation-based deep learning pipeline for object detection in a warehouse setting. The detection pipeline is trained with synthetic data and then tested on a real warehouse dataset. A UNIT GAN model is used to bridge the gap between the synthetic and real worlds. The GAN model was evaluated for its overall efficacy in recognizing pallets in a real-world warehouse testing dataset. The findings indicate that the GAN model is effective in bridging the synthetic-real domain gap. Finally, the study gives fresh insight on the potential performance enhancements that may be achieved by training the detection network using both adapted and non-adapted synthetic data.

15:40-16:00 — WeB2.6

Robust Deep RL-Based Aerial Transportation of Suspended Loads, pp. 215-220

Panetsos, Fotis — National Tech. Univ. of Athens
Karras, George — University of Thessaly
Kyriakopoulos, Kostas J. — National Tech. Univ. of Athens

In this work, a robust policy, trained using deep Reinforcement Learning (RL), is presented for the aerial transportation of cable-suspended loads with simultaneous minimization of the swinging motion of the cable. More precisely, domain randomization is applied throughout the learning procedure in a simulation environment to develop a policy which is robust to varying model parameters, e.g., load mass and cable length, as well as system dynamics that differ from the ones encountered during the training. Based on our approach, the gap between simulation and real-world conditions is bridged and the successful transfer of the policy, trained exclusively in simulation, to a real Unmanned Aerial Vehicle (UAV) is attained. The performance of the learned policy is demonstrated through both simulation and real-world experiments in an outdoor environment.

WeB3 — KAM

Biomedical Engineering (Regular Session)

Chair: Tzemanaki, Antonia — ***University of Bristol***
Co-Chair: Tzafestas, Costas — ***National Technical University of Athens***

14:00-14:20 — WeB3.1

Deep Reinforcement Learning Control of Type-1 Diabetes with Cross-Patient Generalization, pp. 221-226

Atanasious, Mohab Mahdy Helmy — Sapienza University of Rome
Becchetti, Valentina — Sapienza University of Rome
Baldisseri, Federico — Sapienza University of Rome
Menegatti, Danilo — Sapienza University of Rome
Wrona, Andrea — Sapienza University of Rome

Type 1 diabetes is one of the major concerns in current medical studies, as the World Health Organisation plans to reduce mortality due to such disease by one third by 2030. Standard clinical practice involves self-administered injections of insulin, while current research in the field of automatic control of blood glucose concentration mostly focuses on model-based control techniques. This work presents an application of a Deep Reinforcement Learning-based controller for autonomous treatment of type 1 diabetes, building on the Deep Deterministic Policy Gradient algorithm. Such control framework is applied for the first time on the Python implementation of the UVA/Padova simulator, named Simglucose. The proposed methodology is validated through in-vitro simulations on an inter-cluster cross-generalization group of virtual adult patients, showing that normoglycemia is successfully preserved while assuring cross-patient generalization and outperforming clinical practice, without the direct knowledge of the amount of ingested carbohydrates.

14:20-14:40 WeB3.2

Design of Impulsive Feedback Controller for Dosing, pp. 227-232

Medvedev, Alexander V. Uppsala University

Proskurnikov, Anton Politecnico Di Torino

Zhusubaliev, Zhanybai South-West State University

This paper proposes a pulse-modulated controller that generates, under stationary conditions, a desired sequence of uniform and equidistant impulsive control actions from continuous measurements of the output of a smooth nonlinear time-invariant positive single-input single-output plant of Wiener structure. The proposed controller is applied to the dosing of the drug atracurium in closed-loop neuromuscular blockade and its performance is studied on a database of patient-specific pharmacokinetic-pharmacodynamic models previously estimated from clinical data.

14:40-15:00 WeB3.3

Personalized LSTM-Based Alarm Systems for Hypoglycemia Prevention in an Intraperitoneal Artificial Pancreas, pp. 233-238

Drecogna, Martina University of Padova, Department of Women's and Children's Health

Cobelli, Claudio University of Padova

Toffanin, Chiara University of Pavia

Prevention of hypoglycemia is a key aspect for efficient management of Type I diabetes. Alarm systems (ASs) are very useful to alert the patient in advance in case of hypoglycemia, allowing early intervention to avoid or mitigate the potential critical situation. Model-based ASs use patient models to predict the future glucose concentration and trigger alarms. In recent years neural networks, in particular Personalized Long Short-Term Memory Networks (PLSTMs) have shown very promising performances in glucose prediction. In this work, PLSTM-based AS for the prevention of hypoglycemia for an Artificial Pancreas is proposed. Preliminary results on a subgroup of 71 patients show that this system can predict almost all the potentially critical events (median TPR = 100%) with a precision of 57%. These promising techniques are under study to include also the remaining 29 problematic patients.

15:00-15:20 WeB3.4

Dynamic Mode Decomposition for Individualized Model Predictive Control with Application to Type 1 Diabetes, pp. 239-244

Becchetti, Valentina Sapienza University of Rome

Atanasious, Mohab Mahdy Helmy Sapienza University of Rome

Menegatti, Danilo Sapienza University of Rome

Baldisseri, Federico Sapienza University of Rome

Giuseppi, Alessandro Sapienza University of Rome

Type 1 diabetes is one of the main issues in current medical research. If not properly managed, it can lead to serious long-term complications such as blindness, stroke, coma and, ultimately, death. In recent years, research endeavors have focused on the development of a fully automated system for glucose control through automated insulin injections, known as Artificial Pancreas, which, however, is not yet robust enough for practical use. Currently, the UVA/Padova simulator provides the most accurate model for effectively representing the insulin-glucose dynamics of individual diabetic patients. As it is highly complex, consisting of 18 strongly nonlinear and time-varying equations, the objective of this work is to linearize it and reduce its dimensionality exploiting Dynamic Mode Decomposition with Control. This allows for the synthesis of a controller based on Linear Model Predictive Control to be applied to the original model. This is justified by the need to integrate the control algorithm into portable devices with limited computational capabilities. The proposed dimensionality reduction method is validated through in-vitro simulations showing that an accurate representation of the system dynamics is effectively preserved, while conveniently reducing required computational power.

15:20-15:40 WeB3.5

Automation in Pleural Aspiration: Design, Development and Verification, pp. 245-250

Jiang, Anxing University of Bristol

Martsopoulos, Athanasios University of Bristol

Walker, Steven University of Bristol

Tzemanaki, Antonia University of Bristol

This paper introduces a novel automated system for small-volume pleural effusion aspiration procedures. The traditional reliance on clinician experience in manual pleural aspiration can lead to fatigue, insufficient medical resources, as well as variability in outcomes due to human errors and complications during the procedure. The proposed system uses automation to ensure a consistent and standardised approach, aiming at improving procedure efficacy and safety. The setup includes a medical syringe supplemented by 3D-printed components, driven by a linear actuator, and an infrared proximity sensor for the closed-loop system. We controlled the fluid aspirated speed, achieving a minimum plunger movement speed of about 2 mm/s and measuring plunger displacement as a proxy for aspirated liquid volume. Experiments verified the system's performance across different speeds, with a mean error of 2 mm in the closed-loop tests.

15:40-16:00 WeB3.6

Straight Walking Gait Parameter Prediction with a Reduced Number of Sensors, pp. 251-256

Maniacco, Maximilian Free University of Bolzano

Tzafestas, Costas National Technical University of Athens

Peer, Angelika TU München

The correct prediction of gait parameters is crucial in hip exoskeleton-assisted walking tasks, which can reduce the fall rate of individuals wearing these devices. Current prediction methods focus primarily on the foot and shank segments and do not consider the lower back and thigh segments. This paper introduces a novel LSTM-based gait parameter prediction model for straight walking paths that uses data from IMU sensors mounted on the lower back and thigh to predict three key gait parameters: step distance, swing height, and swing velocity. Two approaches were tested: individual LSTM models for each gait parameter and a unified LSTM model that predicted all three gait parameters at once. Results in a 10% accuracy range demonstrate sufficient estimation accuracy, even when using a reduced number of sensors and highlight the superior performance of individual LSTM models over the unified LSTM model.

WeB4	**DILOVO**
Robotics and System Identification in Education (Invited Session)	
Chair: Fagiolini, Adriano	***Università Degli Studi Di Palermo***
Co-Chair: Varagnolo, Damiano	***NTNU - Norwegian University of Science and Technology***
Organizer: Screpanti, Laura	***Università Politecnica Delle Marche***
Organizer: Fagiolini, Adriano	***Università Degli Studi Di Palermo***
Organizer: Varagnolo, Damiano	***NTNU - Norwegian University of Science and Technology***
Organizer: Scaradozzi, David	***Università Politecnica Delle Marche***

14:00-14:20 WeB4.1

Sharing and Collaborating When Teaching Automatic Control: An Experience-Based Needs Analysis (I), pp. 286-291

Knorn, Steffi — Technische Universität Berlin
Garone, Anja — Vrije Universiteit Brussel
Varagnolo, Damiano — NTNU - Norwegian University of Science and Technology
Garone, Emanuele — Université Libre De Bruxelles

We discuss two specific issues that affected the workflows in our career as automatic control teachers and that are related to how teachers may establish teaching-oriented collaborations with colleagues from the same or different institutions. The first issue we identify is the systematic difficulty that one encounters when wanting to exchange instructional material with colleagues, while the second is the complexity of establishing students exchange programs across different institutions and nations. We discuss the nature and structure of the two problems, discuss why and how they are connected, and draw practical examples of how these problems may affect workflows. We then present a strategy that aims at solving these issues based on the introduction of an opportune indexing of instructional material in terms of contents and complexity of such contents, and how this information may be graphically displayed so to ease human and machine interpretability. We further discuss how this approach was used on a smaller scale to ease collaborations among close colleagues, and how it may be extended and adopted on a larger scale.

14:20-14:40 WeB4.2

Social Robotics and Intercultural Pedagogy (I), pp. 292-297

Joy, Jerin — Università Degli Studi Di Genova
Bartolini, Alessia — Università Di Perugia
Milella, Marco — Università Di Perugia
Sgorbissa, Antonio — University of Genova
Recchiuto, Carmine Tommaso — Università Degli Studi Di Genova

Culturally Sustaining Pedagogy has emerged in recent years as a fundamental theoretical approach to incorporating children's different languages, cultures, and identities into the teaching process, leading to the consolidation of the concept of Intercultural Education. On the other hand, social robotics has recently shown its potential applications both as a powerful tool in the educational sector, to help children learn a second language or to deal with children's special needs, also being an instrument for inclusion. This paper introduces the project SONRIE, which has the primary goal of defining a software framework for social robots able to operate in kindergartens and primary schools with children of different cultures. The presented work represents the initial phase of this project, aimed at analyzing some of the technical and scientific issues that may arise when deploying a social robot in such contexts, also proposing possible solutions to these challenges.

14:40-15:00 WeB4.3

Teaching of Robot Arm Programming - Tasks with Increasing Difficulty (I), pp. 298-303

Chodnicki, Marek — Gdańsk University of Technology
Guzik, Alina — Gdańsk University of Technology
Galewski, Marek — Gdańsk University of Technology
Sieklicki, Wiktor — Gdańsk University of Technology
Mazur, Michał — Gdańsk University of Technology

The article describes educational techniques using robotics. For example, educational exercises on programming the Nachi MZ04 robotic arm are presented. The exercises use a wooden railroad toy model and elements printed in additive manufacturing technology. The exercises have increasing difficulty and can be used to educate young people in high school and specialized higher engineering studies.

15:00-15:20 WeB4.4

Designing Courses in Modeling and Identification of Dynamic Systems for Real-Time Assessment (I), pp. 304-309

Screpanti, Laura — Università Politecnica Delle Marche
Morano, Martina — Università Politecnica Delle Marche

Scaradozzi, David Università Politecnica Delle Marche

In undergraduate engineering education, particularly in control systems, it is vital for students to gain knowledge on the identification of linear systems. Undergraduate students need to be equipped with both theoretical understanding and practical skills in this field. The key to achieving this goal is creating an effective course design that maximizes student learning outcomes by promoting active learning and integrating diverse instructional strategies and resources. In response to this educational requirement, the present work aims at describing the design of an undergraduate course on the modeling and identification of dynamic systems based on a blended learning approach. Thanks to the course design, the traditional educational experience allows for additional practice exercises and laboratory experiments exploiting the virtual learning environment. Moreover, the integration of the online environment also enables the personalization of learning by means of automated formative and summative assessments of student learning. Initial findings from the course implementation underscore the efficacy of the blended learning approach in eliciting student engagement, offering promising implications for educational practices and pedagogical strategies.

Technical Program for Thursday June 13, 2024

ThuA1 **MIKIS1**

Automotive Control (Regular Session)

Chair: Koutsoukos, Xenofon ***Vanderbilt University***

10:30-10:50 ThuA1.1

An Improved Lateral Vehicle Control Design Using Ultra-Local Model-Based Slip Estimation, pp. 310-315

Fenyes, Daniel — Institute for Computer Science and Control (SZTAKI)

Nemeth, Balazs — SZTAKI Institute for Computer Science and Control

Gaspar, Peter — SZTAKI

In the paper, a complex estimation and control algorithm is presented for autonomous vehicles. The algorithm has an observer layer that aims to estimate the slip of the vehicle on both the front and rear axles. The observer design is based on the combination of the Linear Parameter Varying (LPV) approach and the ultra-local model technique. The goal of the ultra-local model is to update the cornering stiffness for the lateral dynamics of the vehicle model to be updated. A Model Predictive Control (MPC) is developed based on the updated model and the estimated slips, that can maintain the lateral stability of the vehicle even under extreme circumstances, e.g., moving on a surface with a low adhesion coefficient. This stabilization is achieved by limiting the slips of the vehicle. The proposed algorithm is tested through a complex test scenario using a high-fidelity simulation software, CarMaker.

10:50-11:10 ThuA1.2

Observer-Controller Based Reference Model of Lateral Dynamics of Four-Wheel Steered Vehicles, pp. 316-321

El Youssfi, Naoufal — Royal School of Aeronautics

Zoulagh, Taha — Department of Electrical Engineering, University of Santiago De

El AISS, Hicham — Universidad De Santiago De Chile

Barbosa, Karina A. — Universidad De Santiago De Chile

This article presents an observer-based control framework designed for four-wheel steering (4WS) vehicles, aimed at improving lateral stability and handling. Relying on active front/rear steering and direct yaw moment control, the system guides the vehicle to closely follow the desired lateral sideslip angle and yaw rate of the reference model. Different from previous approaches, this work considers longitudinal speed variations within a given range, adopting the Takagi-Sugeno (T-S) fuzzy method to deal with the resulting non-linearities and build an appropriate T-S fuzzy model. The design of the control and observer is based on the common Lyapunov function method, with stability conditions expressed as linear matrix inequalities (LMIs). Simulation results validate the effectiveness of the proposed method in achieving the main objectives of this study.

11:10-11:30 ThuA1.3

Improving Graph Machine Learning Performance through Feature Augmentation Based on Network Control Theory, pp. 322-327

Said, Anwar — Vanderbilt University

Ahmad, Obaid Ullah — University of Texas at Dallas

Abbas, Waseem — University of Texas at Dallas

Shabbir, Mudassir — Vanderbilt University

Koutsoukos, Xenofon — Vanderbilt University

Network control theory (NCT) offers a robust analytical framework for understanding the influence of network topology on dynamic behaviors, enabling researchers to decipher how certain patterns of external control measures can steer system dynamics towards desired states. Distinguished from other structure-function methodologies, NCT's predictive capabilities can be coupled with deploying Graph Neural Networks (GNNs), which have demonstrated exceptional utility in various network-based learning tasks. However, the performance of GNNs heavily relies on the expressiveness of node features, and the lack of node features can greatly degrade their performance. Furthermore, many real-world systems may lack node-level information, posing a challenge for GNNs. To tackle this challenge, we introduce a novel approach, NCT-based Enhanced Feature Augmentation (NCT-EFA), that assimilates average controllability, along with other centrality indices, into the feature augmentation pipeline to enhance GNNs performance. Our evaluation of NCT-EFA, on six benchmark GNN models across two experimental settings solely employing average controllability and in combination with additional centrality metrics—showcases an improved performance reaching as high as 11%. Our results demonstrate that incorporating NCT into feature enrichment can substantively extend the applicability and heighten the performance of GNNs in scenarios where node-level information is unavailable.

11:30-11:50 ThuA1.4

Vehicle Dynamics and Suspension Design Using Systems Engineering, pp. 328-333

Georgios, Gatos — Technical University of Crete

Karakostas, Spyridon — Technical University of Crete

Agiotis, Andreas — Technical University of Crete

Katzourakis, Diomidis — Technical University of Crete

This paper summarizes the methodology for developing a Formula Student (FS) vehicle based on Systems Engineering principles. It showcases a condensed version of an automotive Development Process focused on Vehicle Dynamics and Suspension Design. It highlights key vehicle Goals, System, and subsystem level Requirements in the form of vehicle attributes and finally the Verification and Validation method. The intent is to offer a compass for teams and individuals building mechatronic prototypes (not limited to FS vehicles),

where the tools and methods are not production ready and are on tight resource constraints (financial and time) as we normally see in FS competitions.

11:50-12:10 ThuA1.5

Nussbaum Function Based PID Approach for Tracking Control of Robot Manipulators, pp. 334-339

Rahimi Nohooji, Hamed — Curtin University, Perth, Australia
Voos, Holger — University of Luxembourg

This paper introduces a novel Nussbaum function based PID control for robotic manipulators. The integration of the Nussbaum function into the PID framework provides a solution with a simple structure that effectively tackles the challenge of unknown control directions. Stability is achieved through a combination of neural network-based estimation and Lyapunov analysis, facilitating automatic gain adjustment without the need for system dynamics. Our approach offers gain determination with minimum parameter requirements, significantly reducing the complexity and enhancing the efficiency of robotic manipulator control. The paper guarantees that all signals within the closed-loop system remain bounded. Lastly, numerical simulations validate the theoretical framework, confirming the effectiveness of the proposed control strategy in enhancing robotic manipulator control.

12:10-12:30 ThuA1.6

Introducing a Yaw Rate-Based Control System for Adjusting the Camber Angle of the Front Wheels on a Prototype Vehicle, pp. 340-345

Tzortzis, Ioannis — National Technical University of Athens
Papalamprou, George — National Technical University of Athens
Katzourakis, Diomidis — Technical University of Crete

In this paper, we present the design and the development of an active control system for adjusting the front wheels' camber angle of an electric prototype vehicle according to the instant yaw rate measurement. The vehicle is equipped with a simple independent suspension structure, where each wheel is attached to the vehicle body through an upper and a lower arm. With the proposed mechanism in place, the upper arms of the front wheels can be translated horizontally, adjusting the camber angle of the front wheels. Conforming to the theory, the proper camber angle adjustment can reduce the camber thrust, improving the yaw rate and accordingly the lateral acceleration of the vehicle, which are directly associated with its stability and traction. Based on this hypothesis, simple circular maneuvers with constant longitudinal velocity and steering angle were designed for the mathematical proof of concept. In accordance with the experimental results, the proposed system, on average, improves the yaw rate by approximately 10%, enhancing the vehicle capacity to navigate corners at higher speeds.

ThuA2 **MIKIS2**

Control (Regular Session)

Chair: Demetriou, Michael A. ***Worcester Polytechnic Inst***

10:30-10:50 ThuA2.1

Fractional Order Time Delayed Acceleration Feedback Control of Inverted Pendulum System, pp. 346-351

Lazarevic, Mihailo — University of Belgrade, Faculty of Mechanical Engineering
Radojevic, Darko — Dunav Company
Pisl, Stjepko — University of Belgrade Faculty of Mechanical Engineering
Živković, Nikola — Lola Institute Ltd

The issue of human balancing in the sagittal plane using fractional order time delayed acceleration feedback is studied in this contribution. The problem of asymptotic stability of closed-loop fractional order neutral time delay system is solved by applying the D - decomposition approach. Stability regions in the control parameters space are determined using this method. Special attention was focused on the consideration of the influence of the time delay on the asymptotic stability of the system. Finally, simulation results are presented to show the effectiveness of the proposed method.

10:50-11:10 ThuA2.2

Plant Modeling and Estimation Framework for a Plume-Generating Controlled Underwater Vehicle, pp. 352-357

Orlovsky, Nicholas — Worcester Polytechnic Institute
Demetriou, Michael A. — Worcester Polytechnic Inst
Gatsonis, Nikolaos A. — Worcester Polytechnic Institute

The use of autonomous underwater vehicles (AUVs) for the real-time estimation of a plume generated by an underwater stationary or moving source finds important applications. A mathematical estimation framework is presented that includes the process-state (plume) model described by the 3D advection-diffusion partial differential equation and the exosystem (moving source) with a 6 DOF dynamical model and a guidance scheme. The process-state model is discretized using a non-overlapping domain decomposition finite volume method with Runge-Kutta integration. The source is following a physics-based prescribed trajectory with a PID controller. Numerical results show grid sensitivity analysis for the process-state under realistic underwater tidal currents and diffusivities. Plant data are shown for a typical case of a moving source in a large simulation domain and realistic ambient conditions.

11:10-11:30 ThuA2.3

Preliminary Control Design by Simulation of a Marine Engine Turbine, pp. 358-363

Maione, Francesco — Politecnico Di Bari
Giannino, Giuseppe — Isotta Fraschini Motori S.p.A
Lino, Paolo — Technical University of Bari

Maione, Guido — Politecnico Di Bari

Simulation can be useful to the marine engine designer in identifying necessary improvements. During the initial design of a complex engine, even inaccurate physical modelling can give important information to quickly change configuration and parameters, if necessary, without waiting for experimental tests. This paper considers supercharged diesel engines that are widely used in marine applications. It reports the preliminary design of the speed control system for one turbine of a more complex engine based on a sequential turbine architecture. The authors show how to improve a speed PID controller by using a simplified model to represent an engine turbine in simulation. An accurate physical representation is not required to choose the control scheme and set the parameters. Namely, the specifications on the minimum turbine speed and the limitation of speed oscillations are met, and performance is improved compared to a first control scheme.

11:30-11:50 — ThuA2.4

Stabilization of a Nonholonomic Car Model with Off-Hooked Trailers, pp. 364-369

Zuyev, Alexander — Max Planck Institute for Dynamics of Complex Technical Systems
Grushkovskaya, Victoria — University of Klagenfurt

We consider a kinematic model of a controlled car with two trailers by assuming that each trailer is attached at some distance from the preceding axle ("off-hooked trailers"). For this model, we derive the transformation towards privileged coordinates and present the corresponding nilpotent quasihomogeneous approximate system. The components of this nilpotent approximation are written explicitly in terms of mechanical parameters of the original system. The constructed system does not satisfy the Brockett necessary stabilizability condition, and the design of time-varying feedback controllers with oscillating components is proposed. It is proved that these controllers ensure the exponential convergence of solutions to the trivial equilibrium, and simulation results are presented to illustrate the behavior of the closed-loop system.

11:50-12:10 — ThuA2.5

Safety-Critical Combustion Control for Gas Boilers Using Control Barrier Functions, pp. 370-376

Deisling, Regina — Bergische Universität Wuppertal
Ackerschott, Laura — University of Wuppertal
Dehnert, Robert — Wuppertal University
Rosik, Michelle — University of Wuppertal
Tibken, Bernd — Wuppertal University

Besides the efficient operation of a gas boiler, ensuring safe combustion across the operating range is essential. This becomes even more critical when burning hydrogen instead of natural gas. The distinct characteristics of hydrogen and their effects on flame behavior necessitate stricter safety requirements. This paper investigates a novel method to contribute to the safe operation of a gas boiler by using control barrier functions (CBFs). Thereby, it demonstrates the potential of CBFs in the heating industry as a novel field of application. The system is represented by a Hammerstein model. To ensure the operation remains within a safe range, two CBFs and a high order control barrier function (HOCBF) are set up. The resulting safety filter is integrated into the combustion control loop and verified in simulation.

12:10-12:30 — ThuA2.6

Adaptive Robust Control of Atmospheric Pressure Plasma Jets in Linear Parameter-Varying Framework, pp. 377-382

GhafGhanbari, Pegah — Clemson University
Mohammadpour Velni, Javad — Clemson University

Atmospheric pressure plasma jets (APPJs) hold significant promise in biomedical applications, where safe and efficient operation is critical. In this study, a new data-driven robust control paradigm is proposed for APPJs in the Linear Parameter-varying (LPV) framework. By leveraging Bayesian Neural Networks (BNNs), a state space LPV model is identified to capture the intricate nonlinear dynamics of APPJs while providing statistical insights into the system's behavior. This approach allows for the adaptation of the uncertainty region at each time step, enhancing closed-loop control adaptability, and alleviating the conservativeness of the control design compared to the conventional robust controllers. The proposed robust Model Predictive Control (MPC) design method operates through an online process, where an optimization problem, formulated using Linear Matrix Inequalities (LMIs), computes a time-varying feedback control law. Through extensive simulations, the LPV-based robust control's efficacy in handling modeling discrepancies and external disturbances is assessed. Furthermore, a comparison is made with an alternative control scheme employing MPC with a given LTI model, demonstrating the superior robustness and tracking capabilities of the proposed LPV-MPC-based approach. These findings underscore the potential of the proposed technique to enhance APPJ control across diverse practical scenarios.

ThuA3 — KAM

Education and Training (Regular Session)

Co-Chair: Uppalapati, Venkata Prashanth — ***Schmalkalden University of Applied Science***

10:30-10:50 — ThuA3.1

Model of a Rotating Disc Driven by Two Solenoids for Teaching Mechatronic Systems Engineering, pp. 383-387

Roskam, Rolf — Ostfalia University of Applied Sciences, Department of Mechanica

Teaching mechatronic systems engineering should include theories as well as real world experiments. A rotating disc driven by two solenoids is presented as a new experimental setup. Mathematical equations for modelling of the system are given. Quantization and simplification are considered in the model. A validation of the model is carried out and checks the correctness but also the limitation of operation for the model. Finally, the use of the setup in education is presented.

10:50-11:10 — ThuA3.2

A Professional Remote Interface Battery Management System for Remote Testing or Remote Education Laboratories, pp. 388-393

Luwes, Nicolaas	Central University of Technology, Free State
Hienle, Lukas	Technische Hochschule Ulm
Commerell, Walter	Technische Hochschule Ulm

The proliferation of technological advancements, coupled with the introduction of electric vehicles (EVs), has led to a substantial surge in battery utilization. Battery systems represent intricate multi-domain systems with a significant potential for hazards. Effectively mitigating these hazards necessitates rigorous supervision. This supervision is orchestrated by battery management systems (BMS) to ensure the safe and optimal operation of the battery systems. Design engineers must be educated on hazards, diagnostic, and fault protection solutions. The hazardous conditions inherent in testing or researching new battery technologies create an environment that is conducive to remote testing. The purpose of this paper is to demonstrate and discuss the development of a graphics-based operating battery management system instrument. This system can manage several battery packs in a safe operation and can be controlled and supervised via a remote human interface. It is used as an educational tool to demonstrate the operation of a battery management system with various functions such as unsafe operation diagnostic, controller failure, safe switch, battery charge, discharge, battery balancing, etc. These characteristics also designate it as a remote testing tool for hazardous environments). This remote-control system is constructed of various “off the shelf” laboratory and industrial equipment that is specialized in one of the building block functions. Thus, the paper demonstrates how different manufactured modular components that consist of a variable energy source, variable electronic load, and BMS were assembled, and then interconnected via one main operations controller, running one GUI.

11:10-11:30 ThuA3.3

Evaluating Student Acceptance and Engagement with a Humanoid Robot Tutor in a Formal Learning Environment, pp. 394-399

Karousou, Alexandra	Democritus University of Thrace
Makris, Nikolaos	Democritus University of Thrace
Sarafis, Ilias	Democritus University of Thrace
Chatzichristofis, Savvas	Democritus University of Thrace
Amanatiadis, Angelos	Democritus University of Thrace

In this paper we explore the use of a humanoid robot named LINA as an educational tutor in primary schools. The study focuses on understanding student acceptance and engagement with LINA within a formal classroom setting, examining their reactions to both the robot itself and the educational activities it facilitated. Utilizing a combination of questionnaires, we investigated students' perceptions of LINA's appearance, voice, and instructional methods. The results demonstrate a positive overall picture, with students expressing appreciation for LINA's physical design, clear communication, and interactive learning activities. Despite finding some tasks moderately challenging, they reported high levels of engagement and enjoyment. The findings highlight the potential of social robots in education but emphasizes the importance of considering design and social capabilities for effective implementation.

11:30-11:50 ThuA3.4

ColourBot: A New Modular Tool for STEM Education, pp. 400-405

Giannoulaki, Chrysi	Technical University of Crete
Sioutis, Alexandros	Technical University of Crete
Kypraios, George	Technical University of Crete
Tsinarakis, George	Technical University of Crete
Doitsidis, Lefteris	Technical University of Crete

STEM education is of great importance and although ideally adopted in the last decades it still lacks affordable tools with extended capabilities. In this work we introduce an enhanced and significantly modified version of the system proposed by Kakkaras et al. in [1]. The new systems present a low-cost solution, where custom hardware is enclosed into functional shells designed and developed using a 3D printing approach. These shells are connected using a custom connection mechanism with enhanced capabilities, which allow the design and development of various working prototypes. The system is accompanied by custom software adapted to the age, educational level and skills of the end users, which in our case are students of primary and secondary education. An autonomous mobile robot was developed using the approach to highlight the robustness and ease of use of our approach.

11:50-12:10 ThuA3.5

MicroROS Based Controller and RViz Visualization for Robot Manipulation As an Educational Module, pp. 406-411

Krushnan, Jayabadhrinath	Schmalkalden University of Applied Sciences
Schrödel, Frank	University of Applied Science Schmalkalde
Thangaraj, Hariharan	Schmalkalden University of Applied Sciences
Balasubramanian, Srinivasan	Schmalkalden University of Applied Sciences
Thiruvalluvan, Keerthibaalan	Schmalkalden University of Applied Sciences
Uppalapati, Venkata Prashanth	Schmalkalden University of Applied Science

The increasing adoption of ROS-based control systems across diverse industries can be attributed to its middleware functionalities and open-source accessibility, prompting educational institutions to integrate comprehensive robot programming courses into their curricula. The students lack the necessary programming skills but there are plenty of tools such as MOOL (Massive Open Online Laboratories) and MOOC (Massive Open Online Courses) available which can support this. They still lack traditional hands-on learning experience which has proven to improve the pedagogical approach to teaching and learning. Programming with embedded systems has always piqued the interest of students to develop their hands-on skills and the learning experience. On the other hand, the embedded systems are cost-effective and highly energy efficient making it an affordable option to control most electrical and electronic devices. Since

embedded systems are seeing rapid integration in industries, and ROS-based support to control the embedded systems, microROS (micro–Robot Operating System) was introduced. This paper focuses on controlling a 4 DOF (Degree Of Freedom) self-made robotic arm using the microROS framework of ROS2, visualization performed through RViz and motion planning performed using the MoveIt framework. Overall, this paper discusses various educational advantages and the control engineering aspects devised as an education module.

ThuA4 **DILOVO**

Intelligent Data Processing in Control and Decision Support Systems (SENSYS 24) (Invited Session)

Chair: Popescu, Dan ***University POLITEHNICA of Bucharest***

Co-Chair: Ichim, Loretta ***Politehnica University of Bucharest***

Organizer: Popescu, Dan ***University POLITEHNICA of Bucharest***

Organizer: Ichim, Loretta ***Politehnica University of Bucharest***

10:30-10:50 ThuA4.1

Detection and Identification of Unexploded Ordnance Using a Two-Step Deep Learning Methodology (I), pp. 257-262

Craioveanu, Gheorghe — Politehnica Bucuresti National University for Science and Techno

Stamatescu, Grigore — University Politehnica of Bucharest

Localisation and disposal of unexploded ordnance (UXO) is a crucial task that can save the lives of both military personnel and civilians. In comparison to immediate post-war intervention situations, EOD (Explosive Ordnance Disposal) teams can now leverage emerging technologies based on computer vision architectures, mitigating the perceived risks associated with hands-on inspection of ammunition. The paper analyzes the use of new convolutional neural network architectures, in detection and identification of unexploded ordnance by combining specialised domain knowledge with computer vision models and methods. Additionally, it presents image preprocessing methods, research techniques, results, and conclusions. Moreover, we propose a complementary approach to previous research, often based on the interpretation of external sensor signals, representing the missing link in a com- prehensive and extensive identification. Standardized metrics such as mean average precision, precision, recall, and F1-score are reported to evaluate the outcomes. Results, using the YOLOv8 architecture, achieve up to 80.8% mAP for the binary classification task (detection problem) and up to 81.4% mAP performance for the subsequent identification task. The work aims to offer a baseline study and new perspective on addressing a highly significant issue: mitigating by computer vision the risks associated with unexploded ordnance.

10:50-11:10 ThuA4.2

Texture Analysis of Breast US Images Using Morphological Transforms, Hausdorff Dimension and Bagging Ensemble Method (I), pp. 263-267

Tăbăcaru, Gigi — "Dunarea De Jos" University of Galati

Moldovanu, Simona — Dunarea De Jos University

Barbu, Marian — Dunarea De Jos University of Galati

In this work, an attempt is made for the first time to use the measurement pattern generated by morphological transformation quantified by Hausdorff fractal dimension (HFD) and classified with ensemble learning based on bagging. The proposed work uses three morphological transformations for image preprocessing: hit-and-miss transform (HMT), white (WHT), and black top-hat (BHT). The pattern texture of US breast images is described by extracting the HFD from the regions of interest (ROI) after the ultrasound (US) images have been preprocessed. The main objective of this study was achieved by comparatively analyzing the classification performance of features using the Random Forest (RF), Extra Trees (ET) classifier, and bagging ensemble method based on XGBoot classifier. In the presented study, the XGBoost classifier and BHT image processing method give an accuracy of 89.8% in a binary classification, benign versus malignant breast cancer.

11:10-11:30 ThuA4.3

Automated Waste Sorting: A Comprehensive Approach Using Deep Learning for Detection and Classification (I), pp. 268-273

Ogrezeanu, Iulian Alexandru — Transilvania University of Brasov

Suciu, Constantin — SC Siemens SRL

Itu, Lucian — Transilvania University of Brasov

The increasing challenges associated with waste management necessitate advanced technologies to enhance the efficiency of recycling processes. In this work, we present a comprehensive study utilizing the WaRP (Waste Recycling Plant) dataset for waste detection and classification within an industrial waste sorting plant. The dataset is available on Kaggle, and it encompasses 28 recyclable waste categories, including plastic and glass bottles, cardboard, detergents, canisters, and cans. Notably, objects in the dataset exhibit complexities such as overlap, deformation, and varying lighting conditions. For the classification task, we leverage the WaRP-C dataset, consisting of cut-out image areas from the WaRP-D set with class labels. Employing diverse deep learning architectures, including CNN, Le-Net5, AlexNet, VGG16, Mobile-Net-v2, Inception, and DenseNet, we explore the efficacy of each of them in accurately classifying the waste. For the task of waste detection, we focus on the WaRP-D dataset, comprising images with full HD resolution. The YOLO v8 architecture is employed for its efficiency in detecting waste items in cluttered and complex scenes. The dataset includes 2452 training images and 522 test images, each annotated with bounding boxes for precise object localization. The integration of both classification and detection tasks contributes to a holistic approach in automating waste sorting processes, fostering advancements in sustainable waste management practices.

11:30-11:50 ThuA4.4

System Based on Efficient Neural Network Fusion for Negative Emotion Classification (I), pp. 274-279

Bustan, Raluca — National University of Science and Technology Politehnica Buchar

Boriceanu, Roxana — National University of Science and Technology Politehnica Buchar

Popescu, Dan — University POLITEHNICA of Bucharest
Ichim, Loretta — Politehnica University of Bucharest

Face emotion recognition is an important subject in fields such as psychology and cognitive sciences, as well as in applications that use machine learning methods to create intelligent models capable of understanding human behavior. This paper addresses the challenge of negative facial emotion recognition by employing a comprehensive framework. Our approach leverages 68 facial landmarks and integrates three pre-trained convolutional neural network models (VGG19, DenseNet201, Inception V3) into a unified weighted voting system. The efficacy of our system is evaluated using the Extended Cohn-Kanade (CK+) and Karolinska Directed Emotional Faces (KDEF) databases. The results showcase the effectiveness of our approach in accurately identifying negative facial emotions. This research contributes to the advancement of emotion recognition systems, offering a promising methodology with implications for fields such as psychology, cognitive sciences, and the broader spectrum of intelligent systems reliant on facial expression analysis.

11:50-12:10 — ThuA4.5

On the Energy Consumption of a Quadcopter Navigating in an Orchard Environment (I), pp. 280-285

Stoican, Florin — Politehnica University of Bucharest
Marguet, Vincent — Universite Grenoble Alpes
Popescu, Dan — University POLITEHNICA of Bucharest
Prodan, Ionela — Grenoble INP, Univ. Grenoble Alpes
Ichim, Loretta — Politehnica University of Bucharest

The problem of efficient motion planning is of significant interest in precision agriculture. We propose a mechanism to estimate it via Bezier function parametrization of the position, velocity, and acceleration profiles for a quadcopter system. This is done by providing closed-form descriptions of the cost components, which are further incorporated into the overall motion planning problem to analyze the effect of various tuning parameters (such as total flight time, maximum velocity, and acceleration). The ideas are tested over a proof-of-concept orchard navigation setup (challenging due to the close grouping of the waypoints) with the final goal being the comparison between horizontal-first and vertical-first path construction.

ThuB1 — MIKIS1

Aerospace Control (Regular Session)

14:00-14:20 — ThuB1.1

Trajectory Planning Using Dubins-Like Paths with Approach Angle and Terminal Time Constraints, pp. 412-417

Dubey, Avinash Kumar — Indian Institute of Technology Bombay
Mukherjee, Dwaipayan — Indian Institute of Technology Bombay
Kumar, Shashi Ranjan — Indian Institute of Technology Bombay

In this paper, we introduce a trajectory planning method based on a modification of the well-known Dubins path. The goal is to ensure the interception of a stationary target at both a desired impact or approach angle and a desired impact or terminal time. We satisfy these constraints of impact time and angle simultaneously by appropriately selecting the radius of a relevant circle. This work outlines the range of values over which this radius (design parameter) may vary, highlighting its dependence on the initial engagement geometry. The simplicity of the proposed strategy lies in the requirement for constant levels of lateral acceleration to be applied over three distinct time intervals during the engagement. Additionally, we present a closed-loop implementable version of the control law, and simulation results demonstrate the superiority of our proposed strategy over some existing methods.

14:20-14:40 — ThuB1.2

Super-Twisting Sliding Mode Design for Spacecraft Attitude Control with Actuators Constraints, pp. 418-423

Mancini, Mauro — Politecnico Di Torino

This paper considers robust Sliding Mode Control (SMC) methods for spacecraft attitude maneuvers. The quaternions representation is used to describe the spacecraft attitude dynamics, while the actuation system consists of a cluster of four reaction wheels in pyramidal configuration. The saturation values of the cluster are used to design the control law, which is based on the Super-Twisting (STW) SMC algorithm. A novel strategy is proposed to design the parameters of the STW control law so that it does not overload the actuator limits while maneuvering the spacecraft. The proposed control strategy is validated through extensive Monte Carlo simulations, aimed at testing the robustness of the controller under a wide range of initial conditions, external disturbances, and values of system parameters.

14:40-15:00 — ThuB1.3

Identification of Aerodynamic Parameters Using Improved Physics-Informed Neural Network Framework, pp. 424-429

Chen, Jungu — Beijing Institute of Technology
Liu, Junhui — Beijing Institute of Technology
Shan, Jiayuan — Beijing Institute of Technology
Wang, Jianan — Beijing Institute of Tehcnology
Meng, Xiuyun — Beijing Institute of Technology

An on-line aerodynamic parameters identification method is proposed based on improved Physics-Informed Neural Network (PINN) to address aerodynamic parameters error problem during flight control. An integration-based loss function is utilized to ensure that the neural network can learn the correct physical equation information and adopts a parallel neural network architecture to reduce network complexity. To ensure the feasibility of the network, the input and output data are measurable by the Integrated Navigation System. The improved PINNs is used to identify the aerodynamic parameters of the Reentry Gliding Vehicle in numerical simulation. Simulation results demonstrate that the network can effectively identify aerodynamic parameters during the flight process and the proposed method is insensitive to measurement noise. The proposed method can provide information for the design of multi constraints guidance laws for

flight vehicle.

15:00-15:20 ThuB1.4

Deep Neural Network Based Cooperative Guidance Law for Speed-Varying Interceptors, pp. 430-435

Xiangjun, Ding — Beijing Institute of Technology
Liu, Junhui — Beijing Institute of Technology
Wang, Jianan — Beijing Institute of Tehcnology
Shan, Jiayuan — Beijing Institute of Technology
Yu, Qingbo — Beijing Institute of Technology
Meng, Xiuyun — Beijing Institute of Technology
Ding, Yan — Beijing Institute of Technology

This paper studies the problem of three-dimensional (3-D) cooperative guidance for speed-varying interceptors. A 3-D cooperative guidance strategy is designed by adding a cooperative term to proportional navigation guidance (PNG). First, a deep neural network (DNN) is constructed for predicting the time-to-go of the speed-varying interceptor under PNG. Then, a cooperative term is derived based on predicted time-to-go information. Moreover, the time-to-go consensus error system is proven to be input-to-state stable (ISS) under the designed guidance law. Finally, numerical simulations are conducted to illustrate the validity of the proposed method.

15:20-15:40 ThuB1.5

Nonlinear Optimal Impact-Time-Control Guidance against Maneuvering Targets, pp. 436-443

Li, Haojian — National University of Defense Technology
Yuanhe, Liu — National University of Defense Technology
Li, Kebo — National University of Defense Technology
Liang, Yan'gang — National University of Defense Technology
Luo, Yazhong — National University of Defense Technology

Aiming to cope with the problem of impact-time control (ITC) for engaging maneuvering targets, a nonlinear optimal guidance method is proposed in this paper. Utilizing the classical differential geometric curve theory and the relative virtual frame, the ITC is realized by the combination of the relative trajectory-length control and the relative speed prediction. The characteristics of the ideal proportional navigation (IPN) guidance law is fully leveraged in this paper: 1) with the series solution of the relative trajectory length-to-go under IPN, the guidance law is derived using the optimal error dynamic method; 2) to provide the real-time and stable estimation of the future relative speed profile, the implementation framework of ITC is developed based on IPN. Besides, the linear solutions of the relative lead angle and the relative guidance curvature are derived, which are compared with the exact numerical solutions to explore the properties of the proposed law. Finally, numerical simulations are conducted to substantiate the effectiveness of guidance method and the validity of relevant theoretical findings.

15:40-16:00 ThuB1.6

Correlated Process and Measurement Noise in Kalman Filtering Revisited: A Case Study on Initialization and Leveling in Inertial Navigation Systems, pp. 444-451

Bryne, Torleiv Håland — Norwegian Univ. of Science and Technology
Basso, Erlend A — Norwegian University of Science and Technology
Schmidt-Didlaukies, Henrik M. — Norwegian University of Science and Technology

Derivations of the Kalman filter that ensure optimality with respect to minimum variance typically assume that the process and measurement noise are uncorrelated. However, several works have presented generalized formulations of the Kalman filter where correlated measurement and process noise is permitted. This paper revisits the problem of correlated noise in the context of initialization and leveling for inertial navigation systems. We show how the discretized process and measurement noise covariance matrices can be calculated and applied in a discrete-time Kalman filter. These results are used in an error-state extended Kalman filter implementation which is experimentally tested using a data set from a fixed-wing unmanned aerial vehicle flight together with a simulation study. The simulation and experimental results both indicate that formally addressing the process and the measurement noise correlation during inertial navigation system initialization has little to no impact in our use case.

ThuB2 **MIKIS2**

Navigation (Regular Session)

Chair: Doitsidis, Lefteris ***Technical University of Crete***

14:00-14:20 ThuB2.1

Two-Dimensional Target Following Using Discrete Waypoints Via Artificial Vector Field, pp. 452-457

Zhao, Longze — Beijing Institute of Technology
Liu, Junhui — Beijing Institute of Technology
Wang, Jianan — Beijing Institute of Tehcnology
Shan, Jiayuan — Beijing Institute of Technology
Yu, Qingbo — Beijing Institute of Technology
Meng, Xiuyun — Beijing Institute of Technology
Ding, Yan — Beijing Institute of Technology

This paper investigates the guidance issue of the two-dimensional target following of a general robot with only discrete waypoints information of the target. A velocity guidance strategy is proposed by introducing an artificial vector field. First, thin plate spline

interpolation is employed to fit the waypoints into a continuous curve in real time. Due to the spatial relationship between the robot and the target, a guiding vector field and an additional vector field are proposed separately to ensure the convergence of the robot onto the target curve. Finally, the velocity signal is obtained by combining the two vector fields to an artificial vector field. Simulation results show that the proposed strategy achieves target following with ultimate bound.

14:20-14:40 ThuB2.2

Delay Compensation through Dynamic Behavior Estimation of an Automated Vehicle in View of Its Remote Teleoperation, pp. 458-463

Bellamri, Ikram — Laboratoire De l'Intégration Du Matériau Au Système
Benine-Neto, André — Laboratoire De l'Intégration Du Matériau Au Système
Bel Haj Frej, Ghazi — University of Bordeaux
Moreau, Xavier — Université Bordeaux 1
Aioun, Francois — STELLANTIS

The remote control of automated vehicles introduces various challenges, with communication latency being a prominent concern. The mitigation of this latency is crucial for ensuring safe and effective mobility. Within this context, this paper aims to address the impact of communication latency by introducing the Vehicle Dynamics Estimator (VDE). This approach is designed to enhance the accuracy of vehicle trajectory estimation and contribute to the overall improvement of remote-control systems for automated vehicles. To validate the effectiveness of the proposed approach, comprehensive simulations have been conducted. The results of these simulations demonstrate the successful enhancement of vehicle trajectory estimation through the application of the VDE.

14:40-15:00 ThuB2.3

Bounded Control Mobile Robot Navigation Functions, pp. 464-469

Ravina, Leeor-Assaf — Technion, Israel Institute of Technology
Rimon, Elon — Technion
Loizou, Savvas — Cyprus University of Technology

Navigation functions combine geometric path planning and control of mobile robots in the presence of obstacles. This paper extends the theory of mobile robot navigation functions by proposing a navigation function feedback control law that ensures safe navigation of a point mass robot under bounded control inputs. Simulations describe the robot state variables navigating under bounded control in planar environments populated by disc obstacles.

15:00-15:20 ThuB2.4

Towards Developing a Framework for Autonomous Electric Vehicles Using CARLA: A Validation Using the Deep Deterministic Policy Gradient Algorithm, pp. 470-475

Matsioris, Georgios — School of Production Engineering and Management, Technical Unive
Theocharous, Alexandros — TUDelft
Tsourveloudis, Nikos — Technical University of Crete
Doitsidis, Lefteris — Technical University of Crete

As the world of transportation goes towards fundamental transformations, urban mobility experiences the dawn of autonomous electric vehicles. Under this scope we aim to develop a framework which will facilitate research around digital twins, autonomous agents, and efficient electrified transportation. This effort is built around a two-seat compact electric vehicle, which is currently being modified to act as an autonomous platform. The current work has a twofold purpose. Initially to describe the simulated approach towards building a realistic model of the proposed vehicle, which will allow realistic experimentation. Subsequently, we validate our approach by implementing a two-step procedure towards an autonomous agent, which will be able to follow a predefined path in an urban environment. Initially we use a standard path planner, namely the A$*$ algorithm, and once we have the desired trajectory, we train an autonomous agent to perform the navigation task. The whole process is integrated in CARLA simulator by using a tailored GYM environment.

15:20-15:40 ThuB2.5

Robust Prescribed-Time Predictive Control for Mobile Robot Navigation, pp. 476-481

Sharifi, Maryam — ABB Corporate Research
Nikou, Alexandros — Ericsson AB
Heshmati Alamdari, Shahab — Aalborg University

This paper presents a robust control strategy for point-to-point navigation of mobile robotic systems under prescribed time specifications and with state and input constraints. Based on the concept of Nonlinear Model Predictive Control (NMPC), we propose a stable dynamically decreasing horizon robust optimal control strategy that achieves the task while considering state and input constraints as well as system uncertainties and disturbances. We guarantee that, under the proposed control scheme, the mobile robotic system reaches the desired set in the specific given time, provided an upper bound of the disturbances. This can have great applications in collaborative tasks including a team of mobile robots, where in addition to mobility and flexibility, the mobile robots are required to be enhanced individually with abilities to satisfy time-constrained navigation tasks, to fulfill high-level planning specifications. Finally, simulation results verify the performance of the proposed framework.

15:40-16:00 ThuB2.6

Robust Multisensor Localization Using Sparse Landmarks for Autonomous Driving, pp. 482-487

Ellinoudis, Dimitrios — Democritus University of Thrace
Doitsidis, Lefteris — Technical University of Crete
Amanatiadis, Angelos — Democritus University of Thrace

The advent of autonomous driving technology highlights the crucial need for reliable and real-time localization, which is essential for ensuring vehicle safety and efficient driving. Techniques relying solely on traditional sensors like GNSS and IMU often present significant challenges in localization accuracy. Moreover, LiDAR-based point cloud localization methods demand extensive storage and computational resources. To address these issues, this paper introduces a map-based localization system for autonomous vehicles that integrates LiDAR, GNSS, and IMU data within an Extended Kalman Filter framework together with sparse map-based features, offering a more efficient and robust solution for vehicle positioning and navigation. Real-world experiments and comparison results demonstrate the efficiency of our proposed method in urban and suburban environments.

ThuB3 **KAM**

Optimisation II (Regular Session)

Co-Chair: Mavridis, Christos ***KTH Royal Institute of Technology***

14:00-14:20 ThuB3.1

Constructive Function Approximation with Local Models, pp. 488-493

Mavridis, Christos KTH Royal Institute of Technology
Johansson, Karl H. KTH Royal Institute of Technology

We introduce a constructive function approximation approach as a general tool, particularly useful in adaptive and data-driven methods for perception and control. The key idea is to estimate a collection of simple local models as opposed to a single and complex regression model trained in the entire input space. We use principles from the Online Deterministic Annealing (ODA) optimization framework to construct an adaptive partition of the input space, which enables the introduction of local function approximation models within each subset of the partition. We show that both the partitioning and the local model training algorithms are stochastic approximation algorithms that operate online, and with the same observations, as part of a two-timescale stochastic approximation scheme. This process constitutes a heuristic method to gradually increase the complexity of the function approximation framework in a task-agnostic manner, giving emphasis to regions of the input space where the regression error is high. As a result, this framework has inherent explainability properties, and is suitable for continuous learning applications where regression improvement without re-training from scratch is crucial. Simulation results illustrate the properties of the proposed approach.

14:20-14:40 ThuB3.2

Scalable Approximate Optimization of Objective Functions Represented by Random Forests, pp. 494-499

Leonesio, Marco National Research Council (CNR) & Politecnico of Milan (DEIB)
Fagiano, Lorenzo Politecnico Di Milano

The problem of global optimization of an objective function represented by a Random Forest (RF) is considered. A method to obtain an approximate solution at low computational complexity is proposed, resorting to the inherent structure of an RF, which is a non-parametric model that partitions the feature space in convex polytopes according to the training data. The approach selects the optimal solution inside the polytopes corresponding to the best data points. It is shown that the proposed approximate method is significantly more efficient, thus applicable at large scale, than extensive global search algorithms, such as gridding and Mixed Integer Linear Programming (MILP), which in turn provide exact solutions. The efficiency and sub-optimality of the approach are evaluated on RFs trained on a dataset generated by sampling a bivariate, discontinuous and non-convex benchmark function from the literature.

14:40-15:00 ThuB3.3

Lyapunov Iterations for Linear-Quadratic Differential Games with Assigned Local Behavior, pp. 500-505

Possieri, Corrado Università Di Roma “Tor Vergata”
Sassano, Mario University of Rome, Tor Vergata

An algorithm that locally converges to all the feedback Nash equilibria (F-NE) of a two-player, linear-quadratic (LQ) differential game is proposed. This objective is pursued by modifying classic Lyapunov iterations, which naturally arise by a straightforward interpretation of the coupled Algebraic Riccati Equations, and which converge only to a subset of all the F-NE, so to enforce local asymptotic stability of all the F-NE of the underlying differential game.

15:00-15:20 ThuB3.4

Generalized Bang-Bang Control for Multivariable Feedforward Regulation, pp. 506-511

Consolini, Luca University of Parma
Laurini, Mattia University of Parma
Piazzi, Aurelio University of Parma

In control engineering, effective implementations require to consider the constraints for both the inputs and the outputs of the controlled system. A feedforward regulation problem is then set out to achieve a minimum-time rest-to-rest output transition for square MIMO (multi-input multi-output) linear time-invariant systems. The found time-optimal solution extends the well-known bang-bang control to a generalized bang-bang control in which some amplitude constraints on the outputs are active. A straightforward sufficient condition to have a solution is provided. The structure of the time-optimal input-output pair is also investigated. A feasibility linear programming approach to compute an approximate solution is proposed. An example highlights the found results.

15:20-15:40 ThuB3.5

State Observer Design for a Class of Rational Nonlinear Systems, pp. 512-517

Saraiva, Eduardo S Saraiva Universidade Federal Do Rio Grande Do Sul
Salton, Aurelio Tergolina Universidade Federal Do Rio Grande Do Sul (UFRGS)
Cristofaro, Andrea Sapienza University of Rome

This paper presents a novel methodology for the synthesis of state observers for a class of systems subject to rational nonlinearities. The key idea is to represent both the system and the observer in the so-called differential-algebraic representation to obtain the error dynamics. Once achieved, design conditions can be formulated through optimization problems subject to constraints in the form of linear matrix inequalities. This approach enables the development of a systematic observer design framework with formal theoretical guarantees, including the asymptotic stabilization of the error within a specified exponential decay rate along with constraints on the observer gains. A post-synthesis analysis is presented to ensure the stability of the plant considering the feedback of the estimated states. An illustrative example is provided to showcase the proposed method.

15:40-16:00 ThuB3.6

Model Predictive Control Based Reference Generation for Optimal Proportional Integral Derivative Control, pp. 518-524

Gashi, Fatos — Technische Universität Kaiserslautern
Abuibaid, Khalil — Rheinland-Pfälzische Technische Universität Kaiserslautern-Landa
Ruskowski, Martin — Technische Universität Kaiserslautern
Wagner, Achim — German Research Center for Artificial Intelligence

We introduce an alternative approach towards optimal proportional integral derivative (PID) control, consisting of model predictive control (MPC) based reference generation. To this end, we have integrated the reference as part of optimization variables of the resulting problem, where a deliberate sequence of errors is induced to obtain an optimal PID control action. In addition, the desired behavior of the PID controller is achieved without the need for internal modification of the PID gains. To better highlight the ability of coping with poor PID tuning, several test cases consisting of progressively degraded PID gains are presented. Validation of the proposed strategy is displayed by comprehensive simulations using two different plants.

ThuC1 **MIKIS1**

Technological Challenges I (Regular Session)

Chair: Susto, Gian Antonio ***University of Padova***

16:30-16:50 ThuC1.1

Predictor-Based Gas Flow Rate Control with Event-Triggered Corrections, pp. 525-530

Stanger, Lukas — TU Wien
Bartik, Alexander — TU Wien
Schirrer, Alexander — Technische Universität Wien
Jakubek, Stefan M. — Vienna Univ. of Technology, Austria
Kozek, Martin — Vienna University of Technology

This paper proposes a solution for controlling a gas flow rate using a diaphragm gas meter as a measuring device that emits a pulse after a certain volume of gas has passed through it, instead of relying on continuous flow rate measurement. The proposed method combines a continuous-time predictor with an event-triggered corrector, considering that the interval at which measurements are received is significantly larger than the time constant of the process. The presented algorithm demonstrates the ability to achieve offset-free reference tracking at steady state, as supported by both simulation and experimental results. Additionally, a stability proof is provided.

16:50-17:10 ThuC1.2

Fault Prognosis Approach Using Data-Driven Structurally Generated Residuals, pp. 531-536

Fang, Xin — UPC
Blesa, Joaquim — Institut De Robòtica I Informàtica Industrial (CSIC-UPC)
Puig, Vicenç — Universitat Politècnica De Catalunya (UPC)

This paper presents a fault prognosis approach using data-driven structurally generated residuals. The proposed approach assumes that a set of residuals generated using structural analysis (SA) and identified using data-driven approach are available. Residuals are used for fault detection purposes activating fault signals when residual values reach anomalous values. In addition, it is possible to predict future faults by means of the detection of anomalous residual deviations. Once an anomalous change in the residual trend has been detected, it is proceeded to estimate when this residual deviation will result in fault detection and therefore what will be the Remaining Useful Life (RUL) time of the system. For this purpose, the future residual evolution is estimated by means of a regressor function. Nominal and interval parameters of regressor function are estimated with available residual data providing nominal and interval values of the RUL of the system. A brushless direct current (BLDC) motor is used as the application case study to illustrate the performance of proposed method.

17:10-17:30 ThuC1.3

Fault Tolerant Static Output Feedback H∞ Control for Diesel Engine System in the Finite Frequency Domain, pp. 537-542

El-Amrani, Abderrahim — LIS Laboratory (UMR CNRS 7020), Aix-Marseille University, 13397
Noura, Hassan — LIS Laboratory (UMR CNRS 7020), Aix-Marseille University, 13397
Ananou, Bouchra — LIS Laboratory (UMR CNRS 7020), Aix-Marseille University, 13397
Ouladsine, Mustapha — LIS Laboratory (UMR CNRS 7020), Aix-Marseille University, 13397

This study focuses on the design of H∞ finite frequency (FF) fault tolerant (FF) static output feedback (SOF) problem of Diesel engine air-path system with consideration of actuator faults. The state space model of air-path system, firstly, is linearized around average an operating point of the Diesel engine. The aim is to regulate intake and exhaust manifold pressures to the desired reference pressures by controlling the Geometry Turbine (VGT) and Exhaust Gas Recirculation (EGR) valves. Then, the robust integrator-based control strategy is developed to track the desired reference signals despite the presence of disturbances and actuator faults. By constructing

the Generalized Kalman Yakubovich Popov GKYP lemma, projection lemma and Lyapunov functions, sufficient conditions are established to ensure both the reference signal tracking and H∞ performance with FF domain. To corroborate the theoretical findings, a simulation results is employed, demonstrating the applicability of the proposed theorems.

17:30-17:50 ThuC1.4

Mitigating Measurement Noise in Event-Triggered Distributed Control: Infinite and Finite Horizon Architectures, pp. 543-548

Kurtoglu, Deniz — University of South Florida
Yucelen, Tansel — University of South Florida

This paper addresses the problem of measurement noise in event-triggered distributed control of multiagent systems. In the considered setup, each agent receives the state information from neighboring agents through a fixed, connected, and undirected graph, and the state of each agent is corrupted by measurement noise. To address this challenge, new and novel distributed control architectures predicated on local state observers are proposed in a leader-follower setting for both the infinite and finite horizon cases. The goal of these architectures is to effectively mitigate the effect of measurement noise while reducing agent-to-agent information exchange through event-triggering. The system-theoretical findings for both the infinite and finite horizon cases are presented, which are also numerically validated by two illustrative examples.

17:50-18:10 ThuC1.5

Addressing Trust Issues in Vehicle to Building Enabled Demand Response Using Blockchains, pp. 549-554

Saxena, Shivam, Shivam — University of New Brunswick
Yip, Amanda, Amanda — Volta Research

Power system operators incentivize large consumers of electricity to reduce their demand during peak periods, where consumers can promise a fixed demand reduction in the form of a contract known as demand response (DR). Commercial building owners, particularly those who have electric vehicle (EV) charging infrastructure, can utilize vehicle to building (V2B) technology to participate in DR, while also aggregating other on-site distributed energy resources (DERs) such as solar and batteries. However, the provision of V2B-enabled DR creates trust issues between EV owners, building owners, and power system operators in ensuring that the contracted DR capacity is delivered, and that operational preferences, such as the minimum state of charge of EVs participating, is respected. Thus, this paper proposes a blockchain-based system to create a shared ledger that stores contract details, including contract bids and EV state of charge, and executes automated smart contracts to record, monitor, and dispatch the DERs to ensure that the contracted capacity is realized without violating constraints. Through real-world scalability testing and DR event demonstration, the proposed system shows that it can support up to 10,000 DERs and deliver 20 kW of contracted capacity for a 4-hour DR event.

18:10-18:30 ThuC1.6

Extended B-ALIF: Improving Anomaly Detection with Human Feedback, pp. 555-560

Zaccaria, Valentina — Università Degli Studi Di Padova
Sartor, Davide — Università Degli Studi Di Padova
Susto, Gian Antonio — University of Padova

Anomaly Detection is a task in engineering aiming at identifying deviations from expected patterns in data. Data-driven approaches have emerged in past recent years due to the fact that a model of complex system may be hard or impossible to be derived in many scenarios. Moreover, unsupervised approaches have been particularly appealing for practitioners and scientists given the typical unavailability of tagged data.

Such approaches are often integrated in frameworks, like Decision Support Systems, that assist domain experts and operators in the monitoring task. Human presence, by providing a limited amount of feedback, can be leveraged as a valuable source of information to iteratively enhance detection performance. In this work we introduce Extended B-ALIF, a framework designed to incrementally select and integrate expert feedback into the Extended Isolation Forest anomaly detection model. This study extends B-ALIF, which originally proposed the same theoretical principles for another anomaly detection model, the Isolation Forest.

ThuC2 **MIKIS2**

Image Processing (Regular Session)

16:30-16:50 ThuC2.1

ARIES: An Intelligent System for Landslide and Wildfire Risk Management, pp. 561-566

Giuseppi, Alessandro — La Sapienza
Di Paola, Antonio — Sapienza University of Rome
Santopaolo, Alessandro — University of Rome "La Sapienza"
Saif, Syed Saad — La Sapienza
Fiorini, Federico — La Sapienza
Pietrabissa, Antonio — Consorzio Per La Ricerca nell'Automatica E Nelle Telecomunicazioni

With the rise in frequency of catastrophic events, environmental protection and risk management have become critical challenges for assuring both the safety of human populations and the sustainability of ecosystems. In this direction, the ARIES project has developed a suite of functionalities and software solutions to support emergency operators in all phases of emergency management, from risk estimation to environmental monitoring, early detection, and response. The present paper provides an overview of the main functionalities that constitute the building blocks of the environmental monitoring system developed by the project through a combination of dynamical systems, digital twins, and convolutional neural networks, also reporting on its early validation activities.

16:50-17:10 ThuC2.2

Framework for Automated Wound Detection and Tracking in Industrial Scale Fish Farms, pp. 567-572

Nissen, Oscar SINTEF
Evjemo, Linn Danielsen SINTEF Ocean
Ohrem, Sveinung Johan SINTEF Ocean
Haugaløkken, Bent Oddvar Arnesen SINTEF Ocean
Kelasidi, Eleni SINTEF Ocean

Preserving fish welfare is of major priority for fish farming companies and essential for the sustainability and future growth of the aquaculture industry. Wounds represent a serious welfare issue for the fish, both as a symptom of existing problems and a precursor to potential future vulnerabilities. Existing static or moving vision-based sensor systems paired with computer vision methods offer promise for monitoring different welfare indicators but have not yet been well adapted for wound detection. Targeting this challenge, this paper introduces a computer vision framework that leverages object detection and tracking algorithms to automate wound detection and tracking in video recordings. Tested on unseen video images from operational salmon fish farms, the model achieves 90% accuracy and showcases enhanced robustness in highly complex and dynamic scenarios due to the added tracking capabilities. Currently an assistive tool for detecting wounds during manual camera inspections, the framework has the potential for future development into a fully autonomous, data-driven approach to fish welfare monitoring.

17:10-17:30 ThuC2.3

High-Speed One-Shot Detection and Recognition of Low-Resolution Text Trained on Synthetic Data, pp. 573-578

Huynh, Le Duy MCQ-Scan
Dorosenko, Mihhail MCQ-Scan
Khomutenko, Bogdan MCQ-Scan, Lille, France

In this study, we address the challenge of text detection and recognition in low-resolution images. Addressing the dual constraints of limited training data and the necessity for real-time processing, we adopt a twofold strategy. Firstly, we introduce a pipeline for the generation of synthetic datasets that requires minimal manual annotation and is specifically designed for the context of low-resolution real-life text images. Secondly, we employ a streamlined neural network architecture based on the U-Net model, which concurrently executes text detection and recognition across multiple contextual layers. Our method demonstrates superior performance, achieving real-time processing speeds exceeding 120 fps, and is accurate even in challenging conditions where text characters are as small as five pixels in width. Our findings suggest that both the synthetic dataset generation pipeline and the neural network model are highly adaptable and can be easily modified for a broad range of applications.

17:30-17:50 ThuC2.4

Implementation of a Camera System for the Application of Artificial Intelligence in Monitoring the Cold Atmospheric Plasma Spray Process, pp. 579-583

Ockel, Manuela Friedrich-Alexander-Universität Erlangen-Nürnberg
Meier, Sven Friedrich-Alexander-Universität Erlangen-Nürnberg
Stelter, Oliver Georg Friedrich-Alexander-Universität Erlangen-Nürnberg
Thielen, Nils Friedrich-Alexander-Universität Erlangen-Nürnberg
Bründl, Patrick Friedrich-Alexander Universität Erlangen-Nürnberg, Institute For
Franke, Jörg Friedrich-Alexander Universität Erlangen-Nürnberg, Institute For

Monitoring of the complex cold atmospheric plasma spraying process currently relies on technologically advanced systems, that often measure only a single parameter. This research introduces a more integrated approach, that uses a comprehensive set of parameters, consolidated in the characteristics of the plasma flame, is used to accurately classify particle temperature and coating materials. A simple optical camera system and image analysis based on a transfer learning model predicts an 85% success rate. This approach simplifies and complements the monitoring process. Accuracy could be increased by using additional machine data already recorded, which could allow a complete replacement of additional the plasma flame monitoring.

17:50-18:10 ThuC2.5

Sub-Millimetric Fiducial Localization for Intralogistics Robotics, pp. 584-589

Vidal, Daniel Technical University of Munich
Fottner, Johannes Technical University of Munich

This study presents a novel approach to achieve sub-millimetric localization in intralogistics robotic applications by combining the simplicity of ArUco code detection with the enhanced accuracy of pose estimation using a structured light 3D camera. By evaluating the point cloud generated by the depth camera, the cartesian pose of the ArUco code can be directly extracted, eliminating the need for prior knowledge about camera intrinsics or calibration. This method enhances the accuracy of relative robot localization within warehouse environments up to 0.1 mm at a 1 m distance. To the best of our knowledge, this accuracy has not been reported in any previous work in the literature.

ThuC3 **KAM**

Linear Systems (Regular Session)

Chair: Cristofaro, Andrea ***Sapienza University of Rome***

16:30-16:50 ThuC3.1

Some Remarks on Fault-Tolerant Dynamic Control Allocation for Weakly Redundant Systems, pp. 590-595

Cristofaro, Andrea — Sapienza University of Rome
Faleschini, Michelangelo — University of Camerino

We consider the problem of control allocation for weakly redundant systems subject to actuator faults. In particular, the design of a suitable allocator will be devised with the aim of compensating for the fault effects while, at the same time, keeping the control burden as low as possible. To this goal, two approaches can be followed for the synthesis of the allocation servomechanism: direct allocation using orthogonal projection and optimization-based allocation. Some numerical examples illustrate and highlight advantages, disadvantages, and limitations of both strategies.

16:50-17:10 ThuC3.2

Design of Exponentially Stabilizers for Distributed Control Systems Subject to Cyber Disconnections, pp. 596-601

Massenio, Paolo Roberto — Polytechnic University of Bari
Tipaldi, Massimo — Polytechnic University of Bari
Naso, David — Politecnico Di Bari
Rizzello, Gianluca — Saarland University

Distributed control architectures are attractive for large-scale interconnected systems as they provide good trade-offs between control complexity and closed-loop performance. In such a context, it becomes crucial to ensure robustness against variations in the communication topology arising from connectivity failures or cyber-attacks. Based on Linear Matrix Inequalities, this paper introduces a novel design approach for distributed controllers that exhibit robustness to changes in the communication topology. The primary objective is to achieve resilience against potential disconnections of subsystems that may occur within the communication network. The control gains are structured and reflect the nominal communication topology. Exponential stability with a prescribed decay rate is guaranteed within the sub-configurations of the nominal communication topology. The proposed approach does not make any assumptions regarding the connectivity of the communication graph. Moreover, leveraging on the projection lemma, the design of control gains is decoupled from the design of the Lyapunov matrix, thus minimizing the conservativeness of the solution. An illustrative example on a multimachine power system is presented to demonstrate the effectiveness of the proposed approach.

17:10-17:30 ThuC3.3

Observer Design Based on Steady State and Reduced Model Information with Application to Running Gears with Independently Rotating Driven Wheels, pp. 602-609

Posielek, Tobias — German Aerospace Center (DLR)
Heckmann, Andreas — DLR German Aerospace Center

Observer design typically demands a comprehensive understanding of the system's model, necessitating meticulous parameter tuning for each state. In this paper, we introduce an observer design tailored to a class of linear systems, mitigating the need for extensive tuning and intricate model knowledge. Our proposed observer integrates steady-state behavior estimation with dynamic state-based estimation, effectively streamlining the design process. To illustrate its effectiveness, we apply this observer design to the control of running gears with independently rotating and driven wheels within the research project 'Next Generation Train'. This approach demonstrates a significant reduction in the requisite tuning parameters and model intricacy, offering a more practical and efficient solution for control systems.

17:30-17:50 ThuC3.4

Data-Driven Loewner Matrices-Based Modeling and Model Predictive Control of a Single Machine Infinite Bus Model, pp. 610-615

Ionescu, Tudor C. — Politehnica University of Bucharest & Romanian Academy
Iftime, Orest V. — University of Groningen
Necoara, Ion — Politehnica University of Bucharest

In this paper, we consider the problem of data-driven modelling and model predictive control (MPC) of a single machine infinite bus system (SMIB). When a linear state-space model of the plant is not available, a pair of Loewner matrices is constructed from a set of measured input-output data and a set of prescribed poles. We prove that the Loewner matrices are the solutions of two Sylvester equations. We compute the unique linear model of an order equal to the dimension of the data sets, that interpolates the input-output data and that has all the poles prescribed at the selected locations. As an application we perform MPC on both the original system and its approximant. The simulation show that the linear data-driven model is a good approximation of the SMIB and achieves good closed-loop MPC performance.

17:50-18:10 ThuC3.5

Impact of Delay-Difference Approximation on PID Controllers: Stability and Performance Insights, pp. 616-621

Torres-García, Diego — Universite Paris-Saclay
Méndez-Barrios, César Fernando — Universidad Autónoma De San Luis Potosí
Niculescu, Silviu-Iulian — University Paris-Saclay, CNRS, CentraleSupelec, Inria

This paper aims to explore the advantages and disadvantages associated with implementing derivative action in a PID controller using a delay-difference approximation scheme in continuous time. Despite the simplicity of the approximation, the characteristic function of the closed-loop system is a quasipolynomial including delay-dependent coefficients, which results in a challenging task. The proposed study primarily focuses on the way the controller gains and the delay affect the key characteristics of the dynamics such as asymptotic stability, noise rejection, and closed-loop performance for linear-time-invariant (LTI) minimum-phase second-order systems. Additionally, the paper provides some results concerning the delay margin of the delay-difference approximation of the closed-loop system. Finally, the proposed results are illustrated via numerical examples.

18:10-18:30 ThuC3.6

Perturbation Attenuation in Load Frequency Control, pp. 622-627

Dritsas, Leonidas ASPETE
Tzes, Anthony New York University Abu Dhabi

This article addresses the problem of robust stabilisation of uncertain systems with linear nominal part suffering from perturbations. The proposed composite controller, consisting of a linear state feedback (LQR) and a nonlinear Integral Sliding Mode Control (iSMC), guarantees that despite the presence of unmatched perturbations the closed loop system enters the sliding mode in finite time. The matched perturbations are rejected while the unmatched ones are attenuated in a quantifiable way. The suggested controller is applied on the Load Frequency Control (LFC) of power systems with two and three fully interconnected control areas. Problem specific tuning rules are offered enabling the stabilizing controller to handle also partial stability objectives. The numerical examples corroborate the applicability of the proposed nonlinear methodology.

FriA1 **MIKIS1**

Robotics II (Regular Session)

Chair: Di Lillo, Paolo ***University of Cassino and Southern Lazio***

10:30-10:50 FriA1.1

Design and Prototyping of a Low-Cost Mobile Robot Drive System for Outdoor Autonomous Logistics Solutions, pp. 628-633

Uppalapati, Venkata Prashanth — Schmalkalden University of Applied Sciences
Strigina, Yekaterina — Schmalkalden University of Applied Sciences
Parmar, Tarunkumar — Schmalkalden University of Applied Sciences
Tendulkar, Swaraj — Schmalkalden University of Applied Sciences
Busireddy, Harshavardhan — Schmalkalden University of Applied Sciences
Schrödel, Frank — University of Applied Science Schmalkalde

The paper focuses on the development of a drive system for outdoor autonomous logistics robots, emphasizing cost-effectiveness, modularity, and adaptability through open-source software (ROS). The design process includes selecting components for the drive system, building a hardware prototype using an affordable microcontroller, and implementing closed-loop control using a PI controller. The PI gains are derived from system dynamic modelling using a black box modelling approach with Matlab/Simulink and the microcontroller. The robot is integrated with ROS and can be maneuvered using ROS commands from the onboard PC, facilitating integration with high-level sensors and advanced algorithms.

10:50-11:10 FriA1.2

Remote Control of a Flexible Robotic Cell As a Cyber Physical System for Assembly and Disassembly Based on SCADA and Industry 4.0, pp. 634-639

Filipescu, Adrian — Lower Danube University of Galati
Simion, Georgian — "Dunărea De Jos" University of Galați
Ionescu, Dan — "Dunarea De Jos" University of Galati
Filipescu, Adriana — Low Danube University of Galati

This paper aims to design a remote-controlled Flexible Robotic Cell (FRC) equipped with an ABB 120 industrial robotic manipulator (IRM) as Cyber Physical System (CPS) for assembly and disassembly (A/D) of two workpieces (WP1, WP2) with 5 parts each, based on SCADA and Industry 4.0 concepts. CPS involves integrating various digital devices, connected in a local array network (LAN) and Internet for enhanced automation, connectivity, and intelligence, The digital devices are: PLC, 3D cameras, video processing unit (VPU), powerful, embedded computer, Wi Fi router, remote and local Human Machine Interface (HMI), ethernet switch, servo drive and IoT, the last one being an edge device that allows remote connection via VPN. Synchronized timed Petri nets (STPN), for assembly and disassembly, are used for modeling and simulation. The design of CPS was subordinated to the concept of "Digital Twin", by integrating, and synchronizing task planning and the simulation results of the STPN models, with real-time control in a supervisory control and data acquisition (SCADA) system connected remotely.

11:10-11:30 FriA1.3

Towards a Reconfigurable Manufacturing System for Control Cabinet Manufacturing: A Systematic Literature Review and Research Agenda, pp. 640-645

Stoidner, Micha — Friedrich-Alexander Universität Erlangen-Nürnberg
Bründl, Patrick — Friedrich-Alexander Universität Erlangen-Nürnberg
Nguyen, Huong Giang — Friedrich-Alexander Universität Erlangen-Nürnberg
Abrass, Ahmad — Rittal GmbH & Co. KG
Franke, Jörg — Friedrich-Alexander Universität Erlangen-Nürnberg

In response to the challenges of Industry 4.0 and global competition, this study introduces a research agenda towards an innovative concept for automation tailored to small and medium-sized enterprises (SMEs) in the control and switchgear manufacturing sector. These companies, crucial to machinery and plant engineering industries, face the dilemma of needing increased product customization and shorter delivery times without sacrificing quality, despite cost pressures and a shortage of skilled workers. The proposed solution is outlined based on a systematic literature review on Reconfigurable Manufacturing Systems (RMS) and aims to automate a wide range of manual manufacturing and assembly steps, making it a feasible option for SMEs to adopt manufacturing automation economically. The technical and economic requirements of the control and switchgear cabinet production process chain were analyzed, leading to the conceptualization of a system that significantly reduces lead times and manufacturing times by up to 30 % and 60 %, respectively. Further research needs to validate the possible savings and further detail the functional modules of the concept. Working towards this research goal will not only enhance operational efficiency and competitiveness for SMEs in control cabinet production but will also take a significant step towards industrialization and digitalization in high-wage countries.

11:30-11:50 FriA1.4

A Simple and Effective Human-Robot Shared Control Approach for Agricultural Robots Employed in Table-Grape Vineyards, pp. 646-651

Palmieri, Jozsef — University of Cassino and Southern Lazio
Di Lillo, Paolo — University of Cassino and Southern Lazio

Chiaverini, Stefano — Università Di Cassino
Marino, Alessandro — Università Degli Studi Di Cassino

This paper introduces a simple yet effective shared control architecture to enable a human operator to enhance robot autonomy in complex scenarios, such as those encountered in agriculture. Specifically, the proposed approach foresees to dynamically exchange the control between the robotic system and a human operator depending on the uncertainty in the environment perception. This is achieved by envisioning three control modes that exhibit varying levels of autonomy for the robot: i) autonomous, ii) teleoperation and iii) hand-guiding control modes. The approach is embedded into a Hierarchical Quadratic Programming (HQP) control framework, that allows the robot to simultaneously address different control objectives with different priorities. Remarkably, experimental results conducted as part of the EU-funded CANOPIES project, involving a mobile robot equipped with a mobile base and a dual-arm torso engaged in harvesting operations, demonstrate the effectiveness of the proposed method in real-world conditions.

11:50-12:10 FriA1.5

High-Continuity Path Smoothing Along Obstacle Boundaries Applied to Agricultural Headland Planning with Kinematic Constraints, pp. 652-657

Schönnagel, Adrian — Fraunhofer Institute for Transportation and Infrastructure Systems
Dunkelberg, Nils — Fraunhofer Institute for Transportation and Infrastructure Systems
Keppler, Felix — Fraunhofer Institute for Transportation and Infrastructure Systems
Janschek, Klaus — TU Dresden

High-continuity paths are a major topic of research, especially for vehicles with kinematic constraints. In this paper, we propose an approach for computing highly continuous (C^{5+}) paths along complex polyline boundaries. The paths are restricted in their curvature, curvature derivative and minimum obstacle clearance. Unlike previous research, we minimize the gap between path and boundary. By doing so, paths for kinematic constrained vehicles that need to work near walls, fences or other obstacles can be planned. We showcase the functionality of the NURBS-based approach for the topic of agricultural headland path planning and extend the current research in this topic to organic-shaped fields. Additionally, we introduce a complexity measure for constrained smoothing of polygon outlines and rank our algorithm's performance.

12:10-12:30 FriA1.6

Control Aspects in Programming by Demonstration for Robotic Deep-Micro-Hole Drilling, pp. 658-663

Maric, Bruno — University of Zagreb
Petric, Frano — University of Zagreb
Orsag, Matko — University of Zagreb, Faculty of Electrical Engineering and Comp

This paper explores control aspects in a collaborative robotic system designed to replicate human operators' drilling skills in deep-micro-hole tasks, focusing on the glass-container mould industry. To replicate human performance, we develop a single-DOF Impedance-based drill controller for a standard industrial position-controlled robot, enhancing safe and smooth interactions between the drill bit and the mould. To address high feed rates observed in worker demonstrations and prevent bit breaks, we focus on minimizing non-axial motion during drilling on an off-the-shelf available industrial manipulator KUKA KR 10. This involves analyzing the impact of joint dynamics on drill motion and designing a control system for the robot's low-level control to achieve axial drill motion. We show that the proposed joint control system that considers relationship between joint and tool dynamics outperforms available robot low-level control in minimizing non-axial motion, leading to the robot being able to outperform the human in deep-micro-hole drilling.

FriA2 — MIKIS2

Multi-Agent Systems (Regular Session)

Chair: Verginis, Christos — ***Uppsala University***
Co-Chair: Pierri, Francesco — ***Universita` Degli Studi Della Basilicata***

10:30-10:50 FriA2.1

A MILP Scheduling Problem for Multi-Robot Logistics Systems in a Precision Farming Application and a Polynomial Time Optimal Algorithm, pp. 664-669

Furchi', Antonio — Roma Tre
Franceschelli, Mauro — University of Cagliari, Italy
Gasparri, Andrea — Università Degli Studi Roma Tre

In this paper, we present an innovative use of multi-robot systems in a precision farming application proposed in the European project ``CANOPIES". The considered scenario is then formalized identifying a real-time scheduling problem that needs to be solved for the efficient use of the multi-robot platform. A solution to the proposed real-time scheduling problem is first identified by proposing a mixed integer linear programming (MILP) problem formulation which is iteratively solved within a receding horizon time window. Then, we propose a polynomial time optimal algorithm able to solve a simplified but relevant scenario of the proposed multi-robot scheduling problem. Numerical examples are presented to corroborate the formal analysis of the proposed algorithm.

10:50-11:10 FriA2.2

Robust Coordination of Uncertain Multi-Agent Systems under Transient Constraints and Prescribed Performance, pp. 670-675

Verginis, Christos — Uppsala University

This paper develops a novel decentralized algorithm for the coordination of multi-agent systems with uncertain 2nd-order dynamics under collision, connectivity, and prescribed-performance constraints. More specifically, we consider that a leader agent aims at tracking a time-varying reference trajectory with prescribed performance, where the tracking performance is dictated by user-defined functions of

time; at the same time, the entire multi-agent team needs to avoid collisions with each other and retain its communication connectivity. The proposed algorithm is based on the integration of prescribed-performance control techniques with reciprocal barrier functions and compensates for the uncertainties of the dynamics, which consist of structural and parametric uncertainty as well as exogenous disturbances. Simulation results verify the theoretical findings.

11:10-11:30 FriA2.3

Exploring Resilient Operation of Multi-Robot Fleet in Various Attack Scenarios, pp. 676-681

Papanikolaou, Athanasios — SingularLogic
Rizou, Stamatia — SingularLogic
Sotiropoulos, Iason — SingularLogic
Ramdani, Nacim — Université D'Orléans
Fraile, Francisco — Universitat Politecnica De Valencia
Julia, Raquel — Robotnik Automation

In the era of autonomous robotics and the proliferation of robot fleets, the reliability of these systems in the face of potential disruptions becomes a critical consideration. This paper focuses on examining the resilience of robotic fleets, specifically at the communication layer. Through a systematic exploration of various communication-based attack scenarios, the study seeks to unravel vulnerabilities and challenges in maintaining seamless communication within the fleet. The findings aim to contribute insights into fortifying the communication infrastructure of robotic fleets, thereby enhancing their overall resilience in dynamic and potentially adversarial environments. This research aims towards advancing the robustness of autonomous systems and ensuring their dependable operation across diverse applications.

11:30-11:50 FriA2.4

Consensus of Multi-Agent Singular Systems by Using an Algebraic Transformation, pp. 682-687

Zarei, Fatemeh — Northeastern University
Shafai, Bahram — Northeastern University

This paper delves into the consensus problem for singular multi-agent systems with a fixed communication topology whereby each agent is represented by a linear singular dynamic system. First, it is shown that singular systems can be described by standard input derivative systems. Then, due to the presence of input derivatives, an algebraic transformation is applied to eliminate the derivative inputs and to obtain an equivalent standard state space representation for multi-agent singular systems. This elimination transfers the input derivative in the output equation, which does not interfere with the consensus process. Thus, when the algebraic transformation is employed, the consensus protocol for the available network of linear dynamic agents is accommodated, which allows the agents to agree in a distributed and cooperative fashion. An example is provided to demonstrate the effectiveness of our theoretical results.

11:50-12:10 FriA2.5

Allocation of Formation Control Tasks Using Delaunay Triangulation and Tetrahedralization, pp. 688-693

Babazadeh, Reza — Concordia University
Selmic, Rastko — Concordia University
Fidan, Baris — University of Waterloo

This paper studies the task allocation for the formation control of multi-agent systems with directed graph topologies, where agents are required to form and preserve a specific geometric shape. A directed graph is said to be persistent if it is constraint-consistent and the underlying undirected graph is rigid. A formation of agents is constraint-consistent if every agent can satisfy all its distance constraints. In this context, based on Delaunay triangulation in 2-D and Delaunay tetrahedralization in 3-D space, we propose a novel task allocation algorithm applicable to distance-based formation topologies that guarantees constraint consistency of a desired formation of agents. Given the desired shape -- a framework in space -- the algorithm uses the Delaunay operations to build a network of rigid triangles/tetrahedrons representing the desired formation topology. The algorithm uses the shortest Euclidean distance-based task assignment to establish a desired topology in the form of directed triangulated or directed trilateral Laman graphs. The source agent of each edge is responsible for preserving the desired distance to the sink agent. The output of the proposed algorithm is a minimally persistent graph in 2-D or a minimally structurally persistent graph in 3-D. Examples are provided to demonstrate and verify the effectiveness of the proposed method.

12:10-12:30 FriA2.6

A Discrete-Time Decentralized Estimation Scheme, pp. 694-699

Caccavale, Fabrizio — Universita Degli Studi Della Basilicata
Pierri, Francesco — Universita` Degli Studi Della Basilicata

This paper investigates a discrete-time distributed estimation approach for multi-agent systems. A given signal is assumed to be sampled by only a subset of agents, named sources, while the other agents, the users, are required to estimate it in a distributed way. Each agent communicates only with a subset of neighbors and the communication topology is described by a directed graph with relatively weak connectivity properties. The problem is solved by resorting to a bank of discrete-time distributed estimators run by each user agent. Convergence properties are then assessed for two classes of signals characterized, respectively, by a null or a uniformly bounded difference of a given order. Simulations are run to show the effectiveness of the approach and assess its performance.

FriA3 **KAM**

Neural Networks (Regular Session)

Chair: Lekkas, Anastasios ***Norwegian University of Science and Technology***

10:30-10:50 FriA3.1

Explaining Deep Reinforcement Learning Policies with SHAP, Decision Trees, and Prototypes, pp. 700-705

Eikså, Kristoffer — Norwegian University of Science and Technology
Vatne, Jan Erlend — Norwegian University of Science and Technology
Lekkas, Anastasios — Norwegian University of Science and Technology

The increasing use of complex and uninterpretable Artificial Intelligence (AI) models has led to a growing demand for AI model transparency. In response, the research field of Explainable AI (XAI) is growing, intending to increase trust in black box models by explaining the decisions made.

In this paper, we apply the XAI methods SHAP, decision trees, and ProtoDash to Deep Reinforcement Learning (DRL) policies trained in software environments simulating road vehicle traffic cases of different complexity. The SHAP algorithms Deep SHAP and Kernel SHAP allowed us to assess the rationality of the DRL agents' policy by assigning feature attributions to their decisions. Limitations were found in manipulating the input of Deep SHAP, while Kernel SHAP demonstrated more flexibility. Decision trees provided insight into the agents' behavior by splitting and classifying policy decisions, revealing rational tendencies in their overall behavior. ProtoDash was used to select states representative of each action, which highlighted weaknesses in the trained policy.

The capabilities these XAI methods demonstrated in terms of insight and transparency can be used to increase trust in black-box decision-making, facilitating for industrial adaptation of AI models.

10:50-11:10 FriA3.2

Identification of Tire Characteristics Using Physics-Informed Neural Network for Road Vehicles, pp. 706-711

Hegedus, Tamas — Institute for Computer Science and Control
Nemeth, Balazs — SZTAKI Institute for Computer Science and Control
Gaspar, Peter — SZTAKI

In this paper, a technique is presented for estimating tire characteristics using a Physics-Informed Neural Network (PINN). By integrating physics-based information during the training process the accuracy of the network is enhanced. Utilizing a probabilistic approach, not only individual parameters are identified but also a confidence interval is determined. Additionally, the paper outlines an iterative algorithm for the case when one of the input signals is not measurable or cannot be estimated accurately. Finally, the approach is validated through simulated and real-world test scenarios.

11:10-11:30 FriA3.3

Low-Frequency Load Identification Using CNN-BiLSTM Attention Mechanism, pp. 712-717

Azzam, Amanie — Concordia University
Sanami, Saba — Concordia University
Aghdam, Amir G. — Concordia University

Non-intrusive load monitoring (NILM) is a technique for effective and cost-efficient electricity consumption management. The method is used to estimate appliance-level power consumption from aggregated power measurements. This paper presents a hybrid learning approach, consisting of a convolutional neural network (CNN) and a bidirectional long short-term memory (BiLSTM), featuring an integrated attention mechanism, all within the context of disaggregating low-frequency power data. While prior research has been mainly focused on high-frequency data disaggregation, our study takes a distinct direction by concentrating on low-frequency data. The proposed hybrid CNN-BiLSTM model is adept at extracting both temporal (time-related) and spatial (location-related) features, allowing it to precisely identify energy consumption patterns at the appliance level. This accuracy is further enhanced by the attention mechanism, which aids the model in pinpointing crucial parts of the data for more precise event detection and load disaggregation. We conduct simulations using the existing low-frequency REDD dataset to assess our model's performance. The results demonstrate that our proposed approach outperforms existing methods in terms of accuracy and computation time.

11:30-11:50 FriA3.4

Deep Reinforcement Learning Behavioral Mode Switching Using Optimal Control Based on a Latent Space Objective, pp. 718-723

Remman, Sindre Benjamin — Norwegian University of Science and Technology (NTNU)
Kristiansen, Bjørn Andreas — Norwegian University of Science and Technology (NTNU)
Lekkas, Anastasios — Norwegian University of Science and Technology

In this work, we use optimal control to change the behavior of a deep reinforcement learning policy by optimizing directly in the policy's latent space. We hypothesize that distinct behavioral patterns, termed behavioral modes, can be identified within certain regions of a deep reinforcement learning policy's latent space, meaning that specific actions or strategies are preferred within these regions. We identify these behavioral modes using latent space dimension-reduction with ac*{pacmap}. Using the actions generated by the optimal control procedure, we move the system from one behavioral mode to another. We subsequently utilize these actions as a filter for interpreting the neural network policy. The results show that this approach can impose desired behavioral modes in the policy, demonstrated by showing how a failed episode can be made successful and vice versa using the lunar lander reinforcement learning environment.

11:50-12:10 FriA3.5

Direct Biologically-Inspired Sliding-Mode Control of a Rotorcraft System, pp. 724-729

Alvarez Muñoz, Jonatan Uziel — EXTIA
Escareno Castro, Juan Antonio — XLIM Research Institute - University of Limoges
Garcia Carrillo, Luis Rodolfo — New Mexico State University
Rubio Scola, Ignacio Eduardo — CIFASIS / CONICET - National University of Rosario
Labbani Igbida, Ouiddad — Picardie Jules Verne University

In the context of nonlinearity and uncertainty in the control systems, this work presents a novel control strategy based on a biologically inspired learning robust controller for the attitude stabilization of a Vertical-Take-Off and Landing (VTOL) rotorcraft. Initially, the attitude's VTOL model based on quaternion formalism is detailed to subsequently develop the corresponding control law. Such controller consists of a Brain Emotional Learning-Based Intelligent Control (BELBIC) mechanism, combined with a Super-Twisting Sliding-Mode Control (STSMC) law. By using this architecture, the nonlinear sliding-mode equivalent control term is estimated via the BELBIC model, which allows the controller not to be fully dependent on the system model. Furthermore, closed loop stability is verified through Lyapunov's theory. Finally, for validation and assessment purposes of the overall control strategy, an extensive numerical simulation stage is conducted.

FriB1 **MIKIS1**

Technological Challenges II (Regular Session)

Chair: Di Lillo, Paolo ***University of Cassino and Southern Lazio***

14:00-14:20 FriB1.1

Anomalous Vessel Behavior Detection Via Offline Clustering of Regular Trajectories, pp. 730-735

Di Berto Mancini, Giulia — University Campus Bio-Medico of Rome
Fioravanti, Camilla — Università Campus Bio-Medico Di Roma
Sacchetti, Marco — IPS
Oliva, Gabriele — Università Campus Bio-Medico Di Roma
Setola, Roberto — University Campus BioMedico of Rome

This paper presents a novel method for detecting anomalous vessel behavior in maritime traffic using unsupervised clustering techniques like K-Means and Self-Organizing Maps (SOM). Our approach, differing from traditional methods, initially clusters regular trajectories to provide a stronger foundation for anomaly detection. This approach is grounded in the observation that certain trajectories, while not evidently anomalous if compared against a heterogeneous dataset of regular paths, become easily noticeable when compared against clustered regular trajectories. By clustering standard maritime routes, we establish a baseline for normal traffic patterns, identifying anomalies through their deviation from these clusters. Our approach has the potential to be particularly effective in an online setting, as the clustering of regular trajectories is conducted offline. This avoids the necessity of executing clustering algorithms online, simplifying the process and enhancing operational efficiency. The paper includes an experimental analysis using real Automatic Identification System (AIS) data and synthetic anomalous vessel trajectories, demonstrating the method's effectiveness.

14:20-14:40 FriB1.2

Actuator and Sensor Attacks Detection Method Based on Attack Reconstruction, pp. 736-743

Nguyen, Dinh Duy Kha — INSA Lyon
Escudero, Cédric — Université De Lyon, France
Dumitrescu, Emil — INSA-Lyon
Zamai, Eric — Institut National Polytechnique De Grenoble, Laboratoire

This paper outlines a method for designing Sliding Mode Observer (SMO) to detect and reconstruct attacks, demonstrating robustness against system uncertainty. Additionally, a strategy for selecting protection is developed to meet the demands of real-world systems. This method showcases the effectiveness of SMO in the field of attack detection and explores its practical application.

14:40-15:00 FriB1.3

Optimal Stealthy Attack Design Using Sequential Linear Programming, pp. 744-751

Nguyen, Dinh Duy Kha — INSA Lyon
Escudero, Cédric — Université De Lyon, France
Zamai, Eric — Institut National Polytechnique De Grenoble, Laboratoire
Dumitrescu, Emil — INSA-Lyon

This article presents a novel methodology based on Sequential Linear Programming (SLP) for designing optimal (stealthy) attack sequences aimed at maximizing a nonlinear attack function. Our investigation extends to scenarios where adversaries can inject attack signals into both control input and sensor measurement channels through an unsecured communication network. Through a simulation example, we substantiate the effectiveness of our proposed approach. The proposed method emerges as a relevant tool for designing attack sequences tailored for injection into control systems, offering valuable insights for testing detection mechanisms.

15:00-15:20 FriB1.4

Delayed Decision Guidance in an Integrated Midcourse-Terminal Engagement for Conventional Interceptors, pp. 752-757

Shalumov, Vitaly — Technion
Merkulov, Gleb — Technion
Shima, Tal — Technion

In this paper we develop an integrated midcourse-terminal guidance methodology for a trailing interceptor in a many-on-many intercept scenario. The interceptor acts upon the engagement outcomes of the preceding interceptor group and can dynamically engage one of the evaders at the specified decision time, which separates the scenario in midcourse and terminal phases. We propose a methodology based on reachability analysis and adjoint mathematics tools for selecting an optimal decision (handover) point between the engagement phases. The handover point optimizes the trade-off between the expected miss distance and control effort over all possible allocations. The proposed approach facilitates computationally efficient solutions for online operation in a salvo-attack scenario. The methodology is exemplified for minimum-time midcourse trajectories and proportional navigation terminal guidance law.

15:20-15:40 FriB1.5

Frequency-Based Coupling Method for Modeling of Mechatronic Machine Axis, pp. 758-764

Ackerschott, Laura — University of Wuppertal
Deisling, Regina — Bergische Universität Wuppertal (Fellowship from Vaillant GmbH)
Rosik, Michelle — University of Wuppertal
Dehnert, Robert — Wuppertal University
Tibken, Bernd — Wuppertal University

To meet the high accuracy requirements of machine tools, models for mapping the behavior of machine axes are becoming increasingly important. The individual machine axes consist of mechanical components and a servo control system. To ensure precision, it is necessary to evaluate the interaction between both components through a coupled mechatronic simulation. Because the measuring systems and the motor are at different positions, a new coupling method is introduced, which takes this into account. Using the overall created model, the disturbance frequency response is calculated. Furthermore, the same system is modeled in state-space representation, and the resulting frequency responses are compared. Moreover, the influence of the control on the system is examined using two examples.

15:40-16:00 FriB1.6

Distributed Underwater Bearing-Only Multi-Sensor Acoustic Source Position-Velocity Estimation with Latency and Packet Loss, pp. 765-770

Di Lillo, Paolo — University of Cassino and Southern Lazio
Bazzarello, Lorenzo — Naval Support and Experimentation Centre
Chiaverini, Stefano — Università Di Cassino
Antonelli, Gianluca — University of Cassino and Southern Lazio

Multiple underwater moving sensors are deployed to estimate the position and velocity of an acoustic source based on bearing-only measurements. With the given constraints, the measurements are characterized by poor observability. Communication of the data with the other sensors is thus needed which, in turn, adds to the problem communication latency and packet loss. A solution based on the pseudo-linear formulation is proposed based on an iterative optimization for each measurement. Validation on numerical simulations based on realistic underwater communication validates the proposed approach.

FriB2 **MIKIS2**

Optimisation I (Regular Session)

14:00-14:20 FriB2.1

Fast Adaptive First-Order Semidefinite Programming for Data-Driven Linear Quadratic Regulation, pp. 771-776

Rahimi Baghbadorani, Reza — Delft University of Technology
Mohajerin Esfahani, Peyman — TU Delft
Grammatico, Sergio — Delft University of Technology

We study the data-driven finite-horizon linear quadratic regularization (LQR) problem reformulated as a semidefinite program (SDP). Our contribution is to propose two novel accelerated first-order methods for solving the resulting SDP. Our methods enjoy adaptive step size and adaptive smoothing parameters that speed up convergence and in turn, enhance scalability. Finally, we compare our accelerated first-order methods and show their benefits via numerical simulations on a benchmark LQR example.

14:20-14:40 FriB2.2

Control Allocation in the Presence of Actuator Dynamics and Limitations, pp. 777-782

Sayssouk, Wissam — Université De Haute-Alsace
Orjuela, Rodolfo — Université De Haute-Alsace
Roos, Clément — ONERA
Basset, Michel — Université De Haute Alsace - ENSISA

A novel linear control allocation method is presented in this paper. It combines an extended version of the classical weighted pseudo-inverse technique to account for actuator dynamics, and reference governors to cope with actuator limitations and maximize their use. Additionally, daisy-chaining is used to allow interconnection between different actuator groups of increasing priority. A comparative analysis is conducted to examine the effects of the algorithm parameters on the transient and steady-state responses of the system.

14:40-15:00 FriB2.3

Machine Learning by Symbolic Regression for Automatic Synthesis of Universal Stabilization System of Motion, pp. 783-788

Diveev, Askhat — Federal Research Center «Computer Science and Control» of Russia
Barabash, Artem Dmitrievich — Federal Research Center "Computer Science and Control" of the Ru

This work describes automatization of creation process of automatic control systems. This needs not only for faster construction of control systems, but also to attract the machine to the solving the control problems, to computer found some solutions itself and offered them to developers. Here the optimal control problem in the extended statement is considered when its solution can be realized directly in a real object. Here, for this purpose it is proposed to synthesize the universal stabilization system of a control object motion along any trajectory

from enough wide class. The model of control object with stabilization system and with reference model for generation of a trajectory is called extended model of control object. The optimal control problem with the extended model of control object for realization of its solution it is enough to solve in classical form and to find a control function as a function of time. Universal stabilization system will provide quality motion a control object along obtained trajectory. For synthesis of a universal stabilization system machine learning control by symbolic regression is used. A computational example of application considered approach to a control of spatial motion of a quadcopter group is presented.

15:00-15:20 FriB2.4

Exploring Control Co-Design's Versatility in System Optimisation: A Case Study of DC Motors, pp. 789-794

Nazare, Thalita — National University of Ireland Maynooth
Queinnec, Isabelle — LAAS-CNRS
Nepomuceno, Erivelton — National University of Ireland Maynooth

This study explores the integration of Control Co-Design (CCD) with Linear Quadratic Regulator (LQR) optimisation to enhance DC motor performance. Focusing on early design stages, it demonstrates how CCD and LQR can cooperatively improve system parameters, addressing both step and triangular disturbances. Results show significant enhancements, including up to 44.3% overshoot reduction and 62.2% energy consumption decrease, alongside a notable reduction in maximum actuator voltage by 51.1%. These findings underscore the technical advantages of incorporating CCD and LQR optimisation from the outset of system design, offering a comprehensive framework for achieving superior system performance, adaptability, and efficiency. The results contribute valuable technical insights into the application of CCD in system optimisation.

15:20-15:40 FriB2.5

Air Release Point Optimization of Parafoil Airdrop Mission with Multiple Drop Zone Targets, pp. 795-800

Zhang, Mengying — National University of Defence Technology
Liang, Yangang — National University of Defense Technology
Xu, Qin — Academy of Military Science
Wu, Yutong — National University of Defense Technology

To address the optimization of the Computed Air Release Point (CARP) for parafoil systems in mass airdrop missions with multiple targets, a mission planning method that integrates computational geometry and optimal control theory is developed. Based on the kinematic model of a single parafoil, two methods are proposed to determine the ideal feasible release cone for each airdrop target point: the simple cone method and the optimal control method. According to the mission accuracy and the ideal feasible release cone, the discretized maximum feasible release envelope of each airdrop target is automatically generated, and the nonlinear programming problem is constructed to calculate the optimal flight route of the carrier aircraft through the release cone. By minimizing the distance from the airdrop release point to the starting point of the flight into the route, and the energy consumption of each parafoil, the coordinates of the optimal CARP and the navigation control law of individual parafoil are solved. Simulation results show that the algorithm can determine whether an airdrop system can reach the corresponding target, and it can also plan the required airdrop release envelope and even the optimal CARP as well, which plays an important role in real application scenarios.

FriB3 KAM

Power Systems and Smart Grid (Regular Session)

14:00-14:20 FriB3.1

Optimum Control Method of DC Load Placement and Air Conditioners Considering Fluctuations in Electricity Cost, pp. 801-807

Nakazato, Hikotoshi — NTT
Fukuda, Harumoto — NTT NIC
Kaneko, Masashi — NTT

High-performance and energy efficiency are now becoming more important requirements for datacenters (DC). Due to the increasing power density and heat generation of newer equipment, cooling and air-conditioning energy costs account for a large proportion of power consumption costs in DCs. On the other hand, the use of renewable energy is expanding with the goal of reducing greenhouse gas emissions, so the efficiency of renewable energy use needs to be maximized by increasing demand to coincide with peak electricity supply. Since the amount of load in the DC also fluctuates throughout the day, the overall electricity rate efficiency can be maximized by applying an air conditioning control level that considers both the amount of load arriving at the DC and fluctuations in electricity rates. In addition, there is a strong relationship between flexible load placement within a DC and cooling efficiency. In this paper, we propose a new control method that maximizes energy cost efficiency by combining two patterns of load placement between DC rooms and within the DC room, and air conditioning control that optimizes electricity cost efficiency that follows electricity rate fluctuations and load. Experimental results including those measured in an actual DC environment showed that our proposed method has valid electricity cost saving effects following the fluctuations in the electricity price and workload in the DC.

14:20-14:40 FriB3.2

Three-Dimensional Dynamic Wake Model for Real-Time Wind Farm Simulation, pp. 808-815

Kipke, Vile — Ruhr University Bochum
Sourkounis, Constantinos — Ruhr-University Bochum

This paper presents the modeling framework Smart WindPark Laboratory Wind Flow Model for real-time capable and three-dimensional dynamic wind farm simulation. Coupling it to a set of laboratory-scaled wind turbine test benches allows for holistic wind farm simulations, covering dynamics ranging from the aerodynamics domain through mechatronics to power electronics and grid interaction with all relevant cross-couplings. Collective wind farm operation through active wake control, dynamic interactions between wind farms and cluster optimization or grid support by providing frequency restoration reserves are fields of research which require a simulation

environment with the aforementioned capabilities. This work particularly focuses on dynamic wake modeling to predict the impact of wind turbines on ambient flow in terms of velocity deficit, increased turbulence, and wake meandering. Based on model requirements, a modular framework designed for real-time execution is proposed, modeling and implementation aspects are discussed, and simulation results are presented.

14:40-15:00 FriB3.3

*Granular Weighted Fuzzy Approach Applied to Short-Term Load Demand Forecasting**

Züge, Cesar Vinicius — Universidade Federal do Paraná
Coelho, Leandro — Universidade Federal do Paraná
Mariani, Viviana Cocco — Universidade Federal do Paraná

15:00-15:20 FriB3.4

Nonlinear Maximum Torque Control of Reverse-Saliency Permanent Magnet Synchronous Motors for EV Applications, pp. 816-821

Manasis, Apostolos — University of Patras
Konstantopoulos, George — University of Patras

In this paper, a novel nonlinear controller for Reverse- Saliency Permanent Magnet Synchronous Motor (RSPMSM) used in EV applications is proposed to maximize the output torque at the steady state and inherently guarantee the required operating constraints (voltage and current). The torque maximization is achieved by obtaining the optimal stator current, thus implicitly minimizing the motor copper losses. In the conventional torque-maximizing control approaches, the solution of multiple optimization problems is required forming the Maximum Torque Per Ampere, Maximum Power, and Maximum Torque Per Flux controllers, where a continuous update of the reference motor currents is essential, to guarantee the appropriate torque production under all the necessary constraints. In this work, only one simplified optimization problem is required to be solved offline, while the unique nonlinear structure of the proposed controller inherently ensures all necessary current and voltage constraints. This is proven using nonlinear invariant set theory, while the instantaneous values of the motor currents are proven to be bounded within a desired set using nonlinear ultimate boundedness theory. The proposed controller efficiency is validated through extended simulation results under both low and high-speed operation, as required in modern EV applications.

15:20-15:40 FriB3.5

Indirect Model Predictive Control of a Shunt Active Power Filter Using DFT-Based Load Current Prediction, pp. 822-827

Stok, Emmanuel — Eindhoven University of Technology
Roes, Maurice G.L. — Eindhoven University of Technology
Papafotiou, Georgios — Eindhoven University of Technology

A continuous control set model predictive control (CCS-MPC) scheme and discrete Fourier transform (DFT) based load current identification method are proposed for the control of high switching frequency shunt active power filters (SAPFs). To allow for the extremely short computation windows presented by high switching frequency, the proposed CCS-MPC scheme manipulates the applied voltage through an intermediate modulator rather than generating the switching signals for the SAPF directly. Simulation confirms the advantages of MPC: maximum utilization of the available voltage while respecting system constraints, resulting in accurate and effective harmonic cancellation.

15:40-16:00 FriB3.6

A Reinforcement Learning-Based Health-Conscious Energy Management Strategy Considering Flooding and Drying Fault Mitigation for Fuel Cell-Battery Hybrid Electric Vehicles, pp. 828-833

Bäumler, Antoine — ESTACA Lab
Azib, Toufik — LGEP
Benterki, Abdelmoudjib — ESTACA Engineering School
Meng, Jianwen — Université Paris-Saclay, CentraleSupélec, CNRS, GeePs
Boukhnifer, Moussa — Université De Lorraine

One of the main challenges of Fuel Cell Electric Vehicle (FCEV) integration is the Fuel Cell (FC) lifetime preservation, which can be significantly reduced due to the absence of an appropriate mitigation strategy, especially state of health (SOH) monitoring. Typical faults such as membrane drying and flooding, contamination of reactants and mechanical stress have been identified as the main fault that can shore the Proton Exchange Membrane Fuel Cell service time. For that, a proper way of Fuel Cell operation should be carefully designed to avoid this situation. This paper proposes an energy management strategy (EMS) that considers the FC SOH to mitigate FC faults. For that, a proper FC fault modeling is proposed, and associated to an appropriate health-conscious EMS based on Reinforcement Learning (RL) with a proper design of the reward function.

FriC1 **MIKIS1**

Renewable Energy and Sustainability (Regular Session)

Chair: Konstantopoulos, George ***University of Patras***

16:30-16:50 FriC1.1

Validation of a Three-Dimensional Dynamic Wind Farm Flow Model for Real-Time Simulation, pp. 834-841

Kipke, Vile — Ruhr University Bochum
Sourkounis, Constantinos — Ruhr-University Bochum

This paper presents simulation results of a real-time capable three-dimensional wind farm flow model, which provides an environment to simulate aerodynamic conditions in wind farms and turbine interactions. It allows to develop, validate, and improve individual turbine control, collective wind farm flow control and wind farm cluster optimization techniques while taking grid interactions into account. Wind farm optimization and grid integration will gain more interest, as wind energy is expected to strongly increase in the next years, resulting in more wind farms which are clustered and closely located. This work specifically addresses dynamic wake modeling to predict the impact of wind turbines on wind farm flow and power generation of individual turbines within a wind farm through wake interactions. The simulation framework is briefly described, and particular modifications of the implemented wake model are presented. Simulation results are shown to demonstrate the model capabilities and are validated against data from literature to assess its accuracy and to determine further possible improvements.

16:50-17:10 FriC1.2

Dynamic Virtual Inertia Control for Inverter-Interfaced Distributed Energy Resources, pp. 842-847

Kavvathas, Theodoros University of Patras
Konstantopoulos, George University of Patras

In this paper, a novel dynamic virtual inertia control scheme is proposed to improve the frequency dynamic response of grid forming inverters. The proposed controller dynamically calculates the virtual inertia constant as a function of the gradient of the output voltage frequency, to prevent large frequency deviation and large values of rate of change of frequency (RoCoF) after load variations. Meanwhile, without altering the controller dynamics, the proposed control scheme accomplishes short settling times and intercepts frequency oscillations around the equilibrium point. Inspired by the concept of the bounded integral controller, the proposed solution adopts the simple structure of the integral controller to achieve the desired control tasks and to ensure that the inertia constant will remain within predefined limits, independently of the frequency deviation. The boundedness property of the proposed controller is analytically proven using vector field theory and the stability of an inverter-interfaced distributed energy resource (DER) equipped with the proposed controller is proven using the Routh-Hurwitz criterion. Finally, the effectiveness of the proposed controller in achieving the desired control tasks (i.e. RoCoF and frequency deviation restriction, fast convergence to the rated frequency) under scenarios of external disturbances (e.g. variations in load demand) is validated, in a simulation environment created in Typhoon HIL real time simulator for a microgrid consisting of 4 buses and 4 inverter interfaced DERs.

17:10-17:30 FriC1.3

PLL Control Design for Voltage Source Converters with Frequency and Current Limiting Properties, pp. 848-853

Alexakis, Zaint University of Patras
Papageorgiou, Panos University of Patras
Alexandridis, Antonio University of Patras

A novel phase locked loop (PLL) control scheme is introduced for a voltage source converter (VSC) that is connected to the main grid through an LR filter; also, new suitable inner-loop current controllers are implemented. This new approach enables us to accurately limit the ac current value of the VSC, even under hard abnormal conditions whereas its robust synchronizing operation additionally provides enhanced frequency limiting properties. The whole analysis is implemented in the well-known d-q synchronously rotating reference frame, which is widely used in modern power grid studies, especially when distributed generation (DG) from renewable energy sources exists. A fundamental advantage of the proposed methodology constitutes the fact that it allows to prove asymptotic stability and convergence to an equilibrium through large signal analysis. To verify the theoretical results and to evaluate the expected performance, the system under consideration with the proposed controllers is simulated under cumbersome scenarios featuring large current flows and frequency deviations. In all cases, both the current and frequency limiting properties and the improved system dynamic response are fully confirmed.

17:30-17:50 FriC1.4

Advanced Constant Active Power and Inertia Control of Wind Power System with Supercapacitor Energy Storage System, pp. 854-859

Isa, Abubakar Ruhr University Bochum
Sourkounis, Constantinos Ruhr-University Bochum

This paper presents an enhanced approach to manage a fed Induction Generator (DFIG) wind turbine with a Supercapacitor (SC) energy storage system. The focus is on achieving constant active power and inertia control. The technique involves linking the supercapacitor to the DC link of the DFIG converters to achieve the desired constant wind active power control. Moreover, the impact of Virtual Inertia (VI) support through the Energy Storage System (ESS) and rotating mass of DFIG is investigated. The study includes a detailed analysis of two simulation scenarios, highlighting the respective advantages and limitations of each approach.

Index Terms—Wind turbine, Supercapacitor, Converters, Virtual inertia, Wind power control.

17:50-18:10 FriC1.5

Influence of Aerodynamic Couplings on the Support of Reserve Power with Wind Farms, pp. 860-865

Spichartz, Benedikt Ruhr University Bochum
Sourkounis, Constantinos Ruhr-University Bochum

The transformation of the European grid from conventional to climate neutrality leads to power converter dominated grids with changed requirements for grid stability. Especially wind farms must contribute to grid support and grid building due to their high percentage on the total energy supply. While the provision of the required reserve power for stand-alone turbines by pitching or increasing the speed has been widely researched, there is a need for further investigations regarding the supply in wind farms due to the aerodynamic couplings. In this paper, requirements of the future grid are explained, and the influence of wind speed changes caused by the reserve operation point are investigated. In this context, new definitions of sum-MPP and global-MPP are introduced. Based on simulation studies with dynamical wind turbine and wind emulation, advantages, and disadvantages of the reserve strategies in a wind farm are discussed. The dynamic performance of inertia, primary and secondary power supply is investigated in terms of robustness and component stress.

18:10-18:30 FriC1.6

Control of Power Reserves at Wind Farms with Availability for Inertia, Primary and Secondary Power Supply and Thrust Force Reduction, pp. 866-871

Spichartz, Benedikt — Ruhr University Bochum
Sourkounis, Constantinos — Ruhr-University Bochum

The transformation of the European grid from conventional power plants to climate neutrality leads to an increase of regenerative energy sources and to a power converter dominated grid. Grid services like the supply of inertia, primary and secondary power must be delivered by renewable energies and accumulators, whereby wind farms have a central role due to their high contribution to power supply. Despite this, the adjustment of power reserves and their provision in the event of a fault is currently still rarely researched. In this paper a control concept is introduced, that enables a WF to keep robust power reserves and to support it for instantaneous, primary, and secondary power control. Based on a simulation study, advantages of this approach in terms of grid support, reduction of aerodynamic couplings and reduction of thrust forces are shown. The provision of reserves in the event of wind rotation and the dynamical supply in grid faults are also investigated. For the simulation a holistic model with aerodynamic wind field, wind rotor and drive train emulation as well as separation of WT and management area is used. Furthermore, approaches are given for the transfer to a market-ready overall solution.

FriC2 **MIKIS2**

Robust Control (Regular Session)

Chair: Koumboulis, Fotis N. — ***National and Kapodistrian University of Athens***

Co-Chair: Ippoliti, Gianluca — ***Università Politecnica Delle Marche***

16:30-16:50 FriC2.1

Robust Sensorless Control of a PMSM: Experimental Validation on an Appliance, pp. 872-877

Beato, Alessio — Whirlpool Management Emea S.r.l
Fagnano, Luigi — Whirlpool Management EMEA Srl
Gulesin, Rumeysa Nur — Università Politecnica Delle Marche
Ippoliti, Gianluca — Università Politecnica Delle Marche
Moretti, Laura — Università Politecnica Delle Marche
Orlando, Giuseppe — Università Politecnica Delle Marche

Modern home appliances like dishwashers are engineered considering energy-saving features. This requires enhancing the performance and efficiency of the entire drive system and the correct selection and effective control of the main driving motor to meet industry standards in the white goods market. Permanent Magnet Synchronous Motors (PMSMs), combined with vector control strategy, are selected as the driving system for high-efficiency and high-performance smooth torque control applications. Employing such control techniques requires sensors to detect rotor speed and position but the consideration of cost and reliability requires the avoidance of using sensors. In this paper, a sensorless Field Oriented Control (FOC) for PMSM using Sliding Mode Control (SMC) has been studied and implemented in drives for household dishwasher machines. The reported experimental data demonstrates that the considered solution, compared with a PID control policy, achieves effective speed trajectory tracking and maintains robustness in the presence of system disturbances.

16:50-17:10 FriC2.2

μ-Analysis Based Algorithms for Probabilistic Finite-Frequency H2-Performance Analysis of Uncertain Linear Systems, pp. 878-883

Somers, Franca — Onera
Roos, Clément — ONERA
Preda, Valentin — European Space Agency
Sanfedino, Francesco — ISAE-SUPAERO

Current industrial validation and verification (V&V) activities mostly rely on time-consuming Monte Carlo simulations. They can quantify the probability of sufficiently frequent phenomena, but they may fail in detecting rare but critical combinations of uncertainties. In recent years, deterministic model-based worst-case analysis methods have reached a good level of maturity. Without the need for simulations, they explore the entire space of all possible combinations of uncertain parameters and provide guaranteed mathematical bounds on robust stability margins and worst-case performance levels. Identified problematic parameter configurations can then be used to guide the Monte Carlo campaigns and shorten the V&V process. But a limitation of these deterministic methods is that the probability of occurrence of critical parameter combinations is not measured, which means that a control system can be rejected based on an extremely unlikely scenario. Probabilistic μ-analysis has therefore been studied since the 1990s to bridge this analysis gap between traditional simulation-based and deterministic worst-case analysis techniques, by focusing on rare but nonetheless possible situations that may threaten system integrity. In this context, this paper introduces three novel μ-based probabilistic H2-analysis algorithms, which provide guaranteed upper and lower bounds on the probability that an uncertain system violates a desired H2-performance requirement on a fixed frequency range.

17:10-17:30 FriC2.3

A Two-Step Design for Robust Input-Output Decoupling of a Class of Uncertain and Linear Parameter Dependent Systems, pp. 884-890

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

This research delves into the intricacies of achieving input-output decoupling for a class of uncertain linear parameter dependent systems. A combined approach is introduced, involving the utilization of a state feedback controller that incorporates both static and time-varying

elements. The design of this controller aims to maintain insensitivity to uncertainties. The investigation establishes criteria for determining the feasibility of solving the robust input-output decoupling problem. Under these established conditions, a specific class of state feedback controllers is systematically identified as proficient in effectively addressing the stated problem. The proposed methodology entails deriving the controller and formulating solvability conditions to convert the original Parameter Dependent System (PDS) into an uncertain Linear Time-Invariant (LTI) system. Then an analytical presentation of a static state feedback controller is provided as a means to resolve the input-output robust decoupling for the uncertain LTI system. The practical applicability of these findings is exemplified through successful implementation in a two-mass translation system, appropriately linked with a hydraulic actuator.

17:30-17:50 FriC2.4

On the Approximation of Anisotropic Controller by H2-Optimal Controller, pp. 891-895

Belov, Ivan — Institute of Control Sciences RAS

In this paper, the anisotropic control problem for linear discrete time invariant systems is considered. We examined the properties of anisotropic static feedback controller in case of small values of mean anisotropy. The asymptotic formulas of anisotropic controller are obtained in terms of studied system matrices and mean anisotropy parameter and presented in the form of theorem. The numerical example of anisotropic control problem solution for the LDTI system is illustrated by the graphs.

17:50-18:10 FriC2.5

Robust Finite-Time Stabilization of Linear Descriptor Systems, pp. 896-900

Konovalov, Dmitry — ITMO University
Kremlev, Artem — ITMO University
Zimenko, Konstantin — ITMO University
Dobriborsci, Dmitrii — Deggendorf Institute of Technology

The paper is devoted to the problem of robust finite-time control design for linear descriptor systems. The proposed homogeneity-based control does not require system transformation to a canonical form and guarantees finite-time convergence in the presence of additive disturbances. The parameters tuning is based on the solution of linear matrix equations and inequalities.

18:10-18:30 FriC2.6

Joint Design of Disturbance Observer-Based Feedback Controllers for Discrete-Time Systems Subject to Actuator Faults, pp. 901-908

Dehnert, Robert — Wuppertal University
Rosik, Michelle — University of Wuppertal
Deisling, Regina — Bergische Universität Wuppertal
Ackerschott, Laura — University of Wuppertal
Dilji, Ramiz — Bergische Universität Wuppertal
Tibken, Bernd — Wuppertal University

This paper proposes a novel iterative linear matrix inequality (LMI) method for a class of input-affine nonlinear systems. The design method incorporates nonlinearities through convex enclosure techniques, thereby ensuring the stability of the nonlinear control system. Furthermore, the controller gain is optimized through the application of LQ criteria, while the observer gains are optimized to suppress process and sensor noise. The LMI problem is solved by a block-diagonal structure of a common Lyapunov matrix to separate the controller from the observer in the design. The observer is composed of a disturbance observer and a state observer. Thus, the overall control structure suppresses the process and sensor noise and compensates disturbances such as actuator inaccuracies efficiently. An example demonstrates the effectiveness of the method by comparing it to linear-quadratic-Gaussian (LQG) controllers based on the linearized model. Therefore, the closed loop simulation is based on the continuous-time nonlinear plant and the discrete-time linear observer-based state-feedback control structure.

FriC3 **KAM**

System Identification (Regular Session)

Co-Chair: Wei, Hua-Liang ***University of Sheffield***

16:30-16:50 FriC3.1

Uncertainty-Informed Model Selection Method for Nonlinear System Identification and Interpretable Machine Learning, pp. 909-914

Gu, Yuanlin — University of Stirling
Wei, Hua-Liang — University of Sheffield

Modeling uncertainty has been an active and important topic in the fields of data-driven modeling and machine learning. Uncertainty ubiquitously exists in any data modeling process, making it challenging to identify the best models among a huge number of potential candidates. This article proposes an uncertainty-informed method to address the model selection problem. The performance of the proposed method is evaluated on a dataset generated from a complex system model. The experimental results demonstrate the effectiveness of the method and its superiority over conventional approaches. This method has minimal requirements for the length of data and model types, making it applicable for various modeling frameworks.

16:50-17:10 FriC3.2

A Non-Parametric Identification Scheme of SISO-LTI Systems Using Blaschke-Products, pp. 915-920

Ungvári, Gergő — Eötvös Loránd University
Soumelidis, Alexandros — Comp. and Automation Research Inst

Dózsa, Tamás HUN-REN Institute for Computer Science and Control

In this manuscript, a novel algorithm is presented for the identification of single input single output linear time invariant (SISO-LTI) systems. The proposed method can find poles of the transfer function describing the system without any assumptions on the system order. The results presented in this paper generalize earlier identification schemes based on expansions of the transfer function using generalized rational orthogonal basis functions (GOBFs). These previous methods depended on a convergent sequence constructed from the coefficients of the orthogonal GOBF expansion. The first contribution of this study is showing that a wider family of functions may be used to construct similar pole finding algorithms. The previous approaches can be interpreted as special cases of the results presented here. In addition, using this generalization a new pole identification scheme is proposed using finite Blaschke-products. Through experiments, the practical utility of this scheme is verified when compared to earlier variations of the pole finding scheme.

17:10-17:30 FriC3.3

An Empirical Investigation on Variational Autoencoder-Based Dynamic Modeling of Deformable Objects from RGB Data, pp. 921-928

Coleman, Tomás TU Delft
Babuska, Robert Delft Univ. of Technology
Kober, Jens Delft University of Technology
Della Santina, Cosimo TU Delft

Formulating the dynamics of continuously deformable objects and other mechanical systems analytically from first principles is an exceedingly challenging task, often impractical in real-world scenarios. What makes this challenge even harder to solve is that, usually, the object has not been observed previously, and the only information that we can get from it is a stream of RGB camera data. In this study, we explore the use of deep learning techniques to solve this nonlinear identification problem. We specifically focus on extracting dynamic models of simple deformable objects from the high-dimensional sensor input coming from an RGB camera. We investigate a two-stage approach to achieve this goal. First, we train a variational autoencoder to extract an extremely low-dimensional representation of the object configuration. Then, we learn a dynamic model that predicts the evolution of these latent space variables. The proposed architecture can accurately predict the object's state up to one second into the future.

17:30-17:50 FriC3.4

Flatness-Based Identification of Nonlinear Dynamics, pp. 929-934

Kopp, Alexander University of Augsburg
Fuchs, Lisa University of Augsburg
Ament, Christoph University of Augsburg

The identification of a nonlinear system model given only measurement data is a frequently encountered task. Uncovering the structure of differential equations as system model alongside the determination of the optimal parameters is still a problem under investigation. Assuming a differentially flat system under investigation, an algorithm for single input single output systems is proposed that faces this identification task. To find a proper state space model, an iterative strategy is presented expanding an initial solution in every step. Harnessing only the measurement data and not their time derivatives, a criterion is proposed to select promising extensions to the model avoiding extensive simulation studies on possible model structures. Applying a subset selection reduces the complexity of the resulting models and avoids overfitting. To show the capability of the presented approach to identify a nonlinear state space model from data, a simulation example is presented.

17:50-18:10 FriC3.5

On Sparse Nonlinear System Identification Using Orthogonal Matching Pursuit, Orthogonal Least Squares and LASSO, pp. 935-940

Wei, Hua-Liang University of Sheffield

System identification, as a rich and vital discipline, provides a practical and general methodology and tool for quantitatively modelling the input-output relationships of dynamical systems. Sparse nonlinear system identification (SNSI), especially parametric sparse nonlinear system identification (PSNSI), is an important and vital field of research with a wide range of applications. This work is concerned with PSNSI and particular attention is paid to the assessment of three well-known mainstream sparse learning methods, namely, orthogonal least squares (OLS), orthogonal matching pursuit (OMP) and least absolute shrinkage and selection operator (LASSO). The performances of these methods are tested and evaluated through three case studies relating to PSNSI problems. The research results and findings of this work provide practical useful information and guidance for researchers to better choose or adapt methods when solving PSNSI problems.

18:10-18:30 FriC3.6

Zeroing Neural Networks for Unknown Functions, pp. 941-946

Possieri, Corrado Università Di Roma “Tor Vergata”

The main goal of this paper is to propose new classes of zeroing neural networks that allow one to determine the zeros of an unknown function. This objective is pursued by using, both linear–in–parameters and nonlinear–in–parameters, adaptive schemes to estimate the function to be zeroed and a modified version of the Newton method to estimate a zero of the approximated function. If the function to be zeroed is known in parametric form, then the proposed method estimates one of its zeros exponentially fast, whereas if it is completely unknown, then the approximation error can be made arbitrarily small by using a sufficiently good approximation function.

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