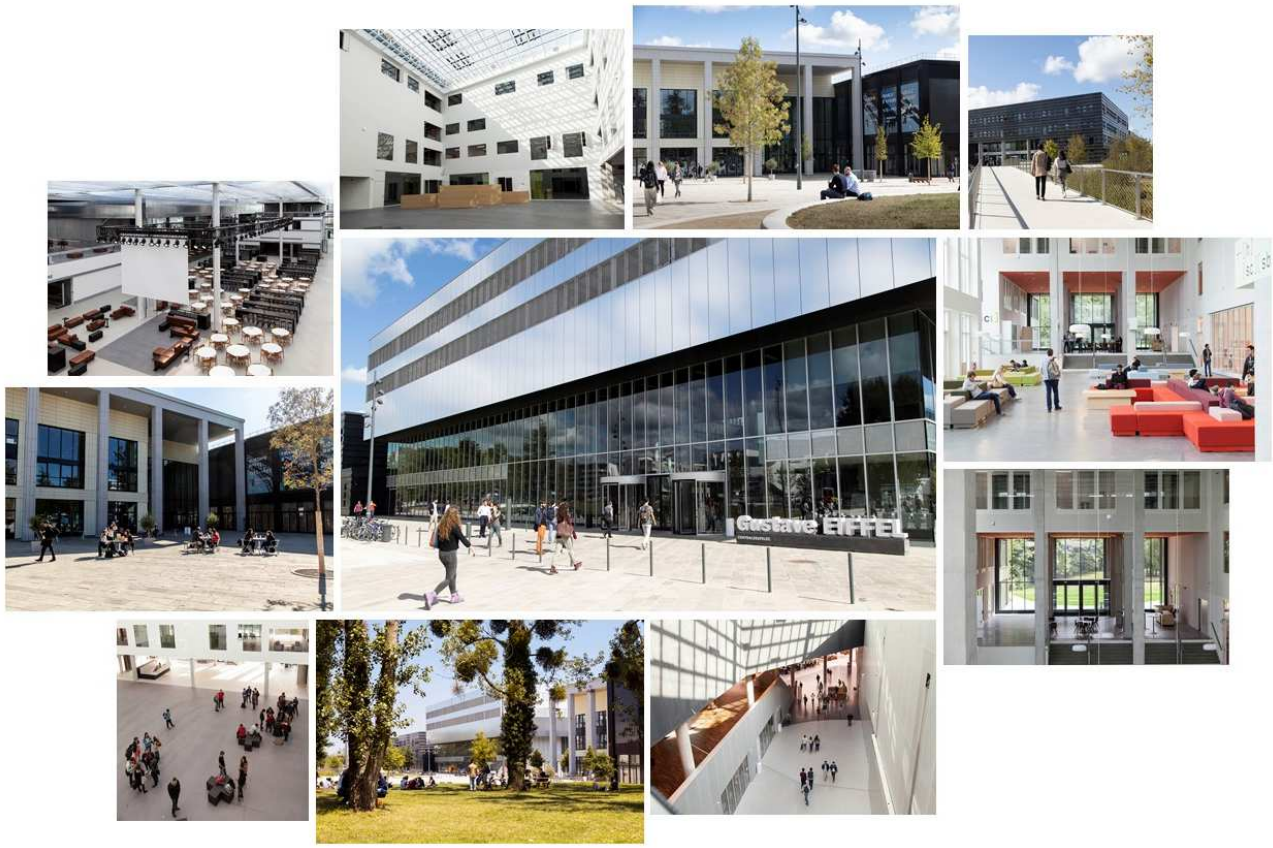
IFAC CAO 2022

18th IFAC Workshop on Control Applications of Optimization

Gif-sur-Yvette, France, 18-22 July 2022

https://cao2022.sciencesconf.org/



Organized by L2S -- Laboratory of Signals and Systems

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I. Welcome Address from IPC and NOC Chairs

Dear IFAC CAO 2022 Participants,

We are pleased to welcome you to IFAC Workshop CAO 2022, the 18th IFAC Workshop on Control Applications and Optimization.

CAO 2022 will be held in Gif-sur-Yvette, France, from 18 to 22 of July 2022, being CentraleSupélec, at the heart of Paris-Saclay University, its venue.

CAO 2022 is foremostly a forum to address the latest developments in Optimal Control Theory and the Optimization-based design in automation and decision-making processes. By building on solid and rich System Theoretic Control and Optimization pillars, it seeks its perpetual rejuvenation and vitality by embracing the current technological developments and societal challenges, thus ensuring its imperative place in the current and future most daring human endeavours.

This entails the openness to novel frameworks to address emerging challenges in the wide range of control, optimization and decision-making problems arising in a vast array of applications in industry, economy, natural and urban environment, agriculture, health, public policies, and other societal services, to name just the few most significant areas. In turn, these application areas encompass emerging systems requiring technological developments, from the very small to the very large scale, in automation, robotics, power and energy, mobility, biology, computational frameworks, and big data processing, among others.

CAO 2022 is a privileged platform to bring together practitioners - engineers, applied economists, and environmental scientists - and researchers in the fields of optimal control, differential games, and optimization, to share their experiences and challenges targeting not only the emergence of research challenges and directions, but also to exploit prospective scientific and commercial applications of optimization for control purposes and for decision-making in the mentioned application areas.

Being the main event of the IFAC Technical Committee on Optimal Control, this edition counts with a strong support of other 12 IFAC Technical Committees which reveals the increasing perception of the relevance of addressing interdisciplinary challenges.

In spite of the uncertainty brought about by extraordinary times the world is going through, 98 contributions were submitted and rigorously peer reviewed by 248 researchers leading to the acceptance of 73 articles. These sessions will be preceded by five Plenary Lectures, and a Key Note Lecture by outstanding researchers, as well as an Invited Talk from Industry by a top industrial leader. The workshop will kick-off in the first day with 3 tutorial sessions and a mini-symposium.

During the week 18-22 July 2022, the same location will welcome the 27th International Conference on Difference Equations and Applications (ICDEA 2022). The participants to IFAC CAO 2022 will have the opportunity to connect and discuss with the participants to this major event of the International Society of Difference Equations (ISDE).

The social and cultural program, together with the charm of the pleasant surrounds of the CAO 2020 venue will be the condiments for an unforgettable productive experience.

We remain looking forward to welcome you in Gif-sur-Yvette
Kind regards,

Sorin Olaru
(General Chair)
Patrick Panciatici
(IPC Co-Chair for Industry)
Tatiana Filippova
(Editor)

Fernando Lobo Pereira
(IPC Chair)
Ionela Prodan
(NOC Co-Chair)

Ilya Kolmanovsky
(IPC Co-Chair)
Jean Maeght
(NOC Co-Chair for Industry)

II. Committees

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Éva Gyurkovics	Budapest University of Technology and Economics, Hungary

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Andrezej Turnau	AGH University of Science and Technology, Poland
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IV. About IFAC CAO History

The workshop will continue the tradition of events of the IFAC Technical Committee on Optimal Control, reaching in 2022 its 18th edition. The past IFAC CAO workshops were:

- 17th, 2018, Yekaterinburg, Russia, October 15-19, 2018, A. Kurzhanski, Stefan Pickl, Alexander Tarasyev and Filippova Tatiana.
- 16th, 2015, Garmisch-Partenkirchen, Germany, October 6-9, 2015, Stefan Pickl, Tarasyev Alexander and Dehmer Matthias.
- 15th, 2012, Rimini, Italy, September 13-16, 2012, Luca Lambertini, Alexander Tarasyev and Stefan Pickl.
- 14th, 2009, Jyväskylä, Finland, May 6-8, 2009, Kaisa Miettinen and Pekka Neittaanmaki.
- 13th, 2006, Cachan-Paris, France, April 26-28, 2006, Hisham Abou-Kandil, Vladimir L. Kharitonov, Frédéric Bonnans, Delfim F. M. Torres and Emmanuel Trélat.
- 12th, 2003, Visegrád, Hungary, June 30 - July 2, 2003, Eva Gyurkovics and Ruth Bars.
- 11th, 2000, Saint Petersburg State University, Saint Petersburg, Russia, July 3-6, 2000, Dmitri Ovsyannikov, Vladimir I. Zubov and Valerïi N. Zakharov.
- 10th, 1995, Technion, Israel Institute of Technology, Haifa, Israel, December 19-21, 1995, Y. Shinar and Faina M. Kirillova.
- 9th, 1992, Fachhochschule München, September 2-4, 1992, D. Kraft and R. Bulitsch.
- 8th IFAC Workshop on Control Applications of Nonlinear Programming and Optimization, Paris, France, June 7-9, 1989, Houria B. Siguerdidjane and Pierre Bernhard.
- 7th IFAC Workshop on Control Applications of Nonlinear Programming and Optimization, Tbilisi, USSR, June 21-25, 1988, V.A. Trapeznikov, Faina M. Kirillova and V. Venets.
- 6th IFAC Workshop on Control Applications of Nonlinear Programming and Optimization, London, UK, July 6-10, 1986, R.W.H. Sargent.
- 5th IFAC Control Applications of Nonlinear Programming and Optimization, Capri, Italy, June 11-14, 1985, G. Di Pillo and A. Miele.
- 4th IFAC Applications of Nonlinear Programming to Optimization and Control, San Francisco, USA, June 20-21, 1983, H. E. Rauch and A. Bryson.
- 3rd IFAC Applications of Nonlinear Programming to Optimization and Control, INRIA, Rocquencourt, France, June 22-25, 1982, J.P. Yvon and J.L. Lions.
- 2nd IFAC Control Applications of Nonlinear Programming and Optimization, Federal Republic of Germany, Oberpfaffenhofen, September 15-17, 1980, Klaus H. Well and A. Bryson.
- 1st IFAC Control Applications of Nonlinear Programming. Denver, Colorado, USA, June 21, 1979, H. E. Rauch.

We thank former organizers: Marc Junger, Tatiana Filippova and Houria Siguerdidjane as well as the IFAC Secretariat (Katharina Willixhofer) for the information provided on these events.

V. Plenary Talks

1- Mean Field Games and Selected Applications

Tamer Başar
Swanlund Endowed Chair Emeritus and CAS Professor Emeritus of ECE
University of Illinois

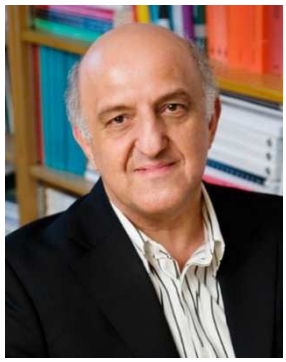
Date and Time: Wednesday, July 20, 08:30-09:30 (Paris time)

Abstract

Perhaps the most challenging aspect of research on multi-agent dynamical systems, formulated as non-cooperative stochastic differential/dynamic games (SDGs) with asymmetric dynamic information structures is the presence of strategic interactions among agents, with each one developing beliefs on others in the absence of shared information. This belief generation process involves what is known as second-guessing phenomenon, which generally entails infinite recursions, thus compounding the difficulty of obtaining (and arriving at) an equilibrium. This difficulty is somewhat alleviated when there is a high population of agents (players), in which case strategic interactions at the level of each agent become much less pronounced. With some structural specifications, this leads to what is known as mean field games (MFGs), which have been the subject of intense research activity during the last fifteen years or so.

This talk will provide a general overview of fundamentals of MFGs approach to decision making in multi-agent dynamical systems, discuss connections to finite-population games and how robustness features can be built into the solution process, and present selected applications drawn from a diverse set of fields, such as opinion dynamics in social networks, networked control systems, swarm formations, and demand response management in the smart grid.

Biography



Tamer Başar has been with University of Illinois Urbana-Champaign since 1981, where he is currently Swanlund Endowed Chair Emeritus; CAS Professor Emeritus of ECE; and Research Professor, CSL and ITI. He has served as Director of the Center for Advanced Study (2014-2020), Interim Dean of Engineering (2018), and Interim Director of the Beckman Institute (2008-2010). He is a member of the US National Academy of Engineering; Fellow of IEEE, IFAC, and SIAM; and past president of the IEEE Control Systems Society (CSS), the International Society of Dynamic Games (ISDG), and the American Automatic Control Council (AACC). He has received several awards and recognitions over the years, including the highest awards of IEEE CSS, IFAC, AACC, and ISDG, the IEEE Control Systems Technical Field Award, Wilbur Cross Medal from his alma mater Yale, and a number of international honorary doctorates and professorships. He was Editor-in-Chief of the IFAC Journal Automatica between 2004 and 2014, and is currently editor of several book series. He has contributed profusely to fields of systems, control, communications, optimization, networks, and dynamic games, and has current research interests in stochastic teams, games, and networks; multi-agent systems and learning; data-driven distributed optimization; epidemics modeling and control over networks; strategic information transmission, spread of disinformation, and deception; security and trust; energy systems; and cyber-physical systems.

2- Reconstructing Optimal Solutions to OCPs from Their Measure-Valued Optimal Solutions

Jean-Bernard Lasserre
Directeur de recherche CNRS
LAAS-CNRS

Date and Time: Tuesday, July 19, 09:30-10:30 (Paris Time)

Abstract

Measure-valued solutions to a weak formulation of optimal control problems (OCP) or certain non-linear PDEs are concerned with measures supported on the graph of optimal state- and control-trajectories (in OCP) or graph of the solution (PDEs). The moment-SOS approach which consists of a hierarchy of semidefinite relaxations of this weak formulation, provides close approximations of finitely many moments of such measure-solutions. Once such moments have been obtained, it then remains to solve the generic inverse problem of reconstructing a function from knowledge of moments of a measure supported on its graph. In some recent work [1] we have been able to provide a numerical scheme to solve this inverse problem, with some convergence guarantees when the number of moments increases. The resulting approximant, based on the Christoffel-Darboux kernel and its associated Christoffel function, is semi-algebraic and not necessarily continuous. This can explain why (at least in some numerical experiments) one avoids a usual Gibbs phenomenon encountered with more traditional approximation schemes when the function to recover is not continuous (as is typical in some OCPs and some non-linear PDEs). Finally, in a subsequent work [2] we also provide a moment-matrix completion scheme (again with some convergence guarantees) to address the case of incomplete moment information, i.e., when some moments are missing. This matrix completion scheme also consists of a hierarchy of semidefinite relaxations of increasing size and with a specific sparsity-inducing criterion.

[1] Marx S., Pauwels E., Weisser T., Henrion D., Lasserre J.B. Semi-algebraic approximation using Christoffel-Darboux kernel, Constructive Approximation (2021)
[2] Henrion D., Lasserre J.B. Graph recovery from incomplete moment information, Constructive Approximation (2021).

Biography

Jean-Bernard Lasserre graduated from “Ecole Nationale Supérieure d'Informatique et Mathématiques Appliquées” (ENSIMAG) in Grenoble, then got his PhD (1978) and “Doctorat d'Etat” (1984) degrees both from Paul Sabatier University in Toulouse (France). He has been at LAAS-CNRS in Toulouse since 1980, where he is currently Directeur de Recherche emeritus. He is also a member of IMT, the Institute of Mathematics of Toulouse, and hold the "Polynomial Optimization" chair at the ANITI Institute (one of the four recently created Artificial Intelligence Institutes in France).
Twice a one-year visitor (1978-79 and 1985-86) at the Electrical Engineering Department of the University of California at Berkeley with a fellowship from INRIA and NSF. He has done several one-month visits to Stanford University (Stanford, California), the Massachusetts Institute of Technology (MIT, Cambridge), the Mathematical Sciences Research Institute (MSRI, Berkeley), the Fields Institute (Fields, Toronto), the Institute for Mathematics and its Applications (IMA, Minneapolis), the Institute for Pure and Applied Mathematics (IPAM, UCLA), Cinvestav-IPN (Cinvestav, Mexico), Leiden University (Leiden, The Netherlands), the Tinbergen Institute (Tinbergen, Amsterdam, The Netherlands), the University of Adelaide (Adelaide, Australia), the University of South Australia (UniSA, Adelaide), the University of New South Wales (UNSW, Sydney), the University of British Columbia (UBC, Vancouver).

3- Socio-Technological Networks and Decision Making

Angelia Nedich
Professor
School of Electrical, Computer and Energy Engineering, Arizona State University

Date and Time: Tuesday, July 19, 13:00-14:00 (Paris Time)

Abstract

We will overview the role of DeGroot's opinion dynamic model for learning and decision making in a system of agents communicating over a network. We start with the classical DeGroot model and, then, use it as the main mechanism for solving optimization problems and games on networks. We then consider DeGroot's model in presence of malicious agents and consider a trust-based approach for reaching an agreement among legitimate agents via statistical learning.

Biography

Angelia Nedich has a Ph.D. from Moscow State University, Moscow, Russia, in Computational Mathematics and Mathematical Physics (1994), and a Ph.D. from Massachusetts Institute of Technology, Cambridge, USA, in Electrical and Computer Science Engineering (2002). She has worked as a senior engineer in BAE Systems North America, Advanced Information Technology Division at Burlington, MA. Currently, she is a faculty member of the school of Electrical, Computer, and Energy Engineering at Arizona State University at Tempe. Prior to joining Arizona State University, she has been a Willard Scholar faculty member at the University of Illinois at Urbana-Champaign. She is a recipient (jointly with her co-authors) of the Best Paper Award at the Winter Simulation Conference 2013 and the Best Paper Award at the International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt) 2015. Her general research interest is in optimization, large-scale complex systems dynamics, variational inequalities, and games.

4- Modeling and Control of Lithium-ion Battery Systems

Simona Onori
Assistant Professor
Stanford University

Date and Time: Thursday, July 21, 14:30-15:30 (Paris Time)

Abstract

Lithium-ion battery technology has enabled electrification of the transportation sector and is projected to dominate the grid-storage in the coming years. Lithium-ion battery systems require sophisticated battery management systems (BMS) to ensure proper charging and discharging and optimize safety and performance through advanced monitoring of critical variables. In this talk, we present recent research on modeling, estimation and optimization of lithium-ion BMS from the Stanford Energy Control Laboratory at Stanford University. In the first part of the talk, we discuss practical identification of electrochemical battery models followed by the description of a degradation model based on capacity and power fade relation. We then introduce the electrode-based interconnected adaptive observer scheme for state of charge (SOC) and state of health (SOH) estimation. Nonlinear observability analysis shows that the new estimation framework outperforms the traditional one – based on battery voltage measurement only- for different current excitations and battery chemistry. In the second part of the talk, we focus on battery pack optimization. Specifically, we present a multi-objective optimization strategy developed to extend battery life while accounting for intrinsic heterogeneity in the parameters of the cells within the pack. Finally, we conclude the talk by providing an overview of research efforts currently done in our group to tackle health estimation and life prediction of second-life battery applications.

Biography

Dr. **Simona Onori** is an Assistant Professor in Energy Resources Engineering at Stanford University where she also holds a courtesy appointment in Electrical Engineering. Upon joining the Stanford faculty, she funded and currently directs the Stanford Energy Control lab where she leads a team of graduate/undergraduate students, postdocs and international visiting scholars conducting research on experiments, modeling, control and optimization algorithms of energy storage and conversation systems for transportation and grid-storage applications. She is the recipient of the 2020 U.S. DoE Clean Energy Education & Empowerment (C3E) Award, Category Research, the 2019 Board of Trustees Award for Excellence, Clemson University, the 2018 Global Innovation Contest Award by LG Chem, the 2018 SAE Ralph R. Teetor Educational Award and the 2017 NSF CAREER award. She is Editor in Chief of the SAE International Journal of Electrified Vehicles, a distinguished lecturer for the IEEE Vehicular Technology Society (2020-2022) and IEEE Senior Member (2015). She is serving as a technical advisory of a number of battery start-ups and she consults for major companies on the topic of BMS. She earned a Laurea Degree in Electrical and Computer Engineering from University of Rome “Tor Vergata”, an M.S. in Electrical Engineering from University of New Mexico, and a PhD. in Control Engineering from University of Rome “Tor Vergata”. Prior to joining Stanford University, she was a faculty at Clemson University International Center of Automotive Research and before that research scientist at the Ohio State University.

5- Feedback Design in Control as Optimization Problem

Boris Polyak
Chief Researcher
Institute for Control Sciences, Russian Academy of Sciences

Date and Time: Friday, July 22, 08:30-09:30 (Paris Time)

Abstract

We can consider feedback gain in linear control systems as an independent matrix variable in the related unconstrained optimization problem. Such approach becomes highly popular in recent researches. We focus on properties of the arising performance functions (smoothness, convexity, connectedness of sublevel sets, gradient domination property) and provide gradient-like methods for optimization. The following examples are addressed: linear quadratic regulator; static output feedback; design of low-order controllers, peak-to-peak gain minimization. Numerical examples confirm the advantages of the approach.

Biography

Boris T. Polyak received Ph.D. degree in mathematics from Moscow State University in 1963 and Doctor of Science degree in engineering from Institute for Control Science, Moscow, in 1977. He has been Head of Ya. Z. Tsypkin Laboratory, Institute for Control Science of Russian Academy of Sciences, Moscow, Russia (where he is currently Chief Researcher) and Professor of Moscow University of Physics and Engineering. He is the author of more than 250 papers in peer-review journals and 4 monographs, including *Introduction to Optimization*, Russian and English editions, and *Robust Stability and Control*, coauthored with P. S. Scherbakov. He is IFAC Fellow, recipient of EURO-2012 Gold Medal and INFORMS Optimization Society Khyachyan Prize (2021).

VI. CentraleSupélec Foudation's Keynote

New Perspectives for Higher-Order Methods in Convex Optimization

Yurii Nesterov
Professor
CORE/INMA, UCLouvain

Date and Time: Thursday, July 21, 08:30-09:30 (Paris Time)

Abstract

In the recent years, the most important developments in Optimization were related to clarification of abilities of the higher-order methods. These schemes have potentially much higher rate of convergence as compared to the lower-order methods. However, the possibility of their implementation in the form of practically efficient algorithms was questionable during decades. In this talk we discuss different possibilities for advancing in this direction, which avoid all standard fears on tensor methods (memory requirements, complexity of computing the tensor components, etc.). Moreover, in this way we get the new second-order methods with memory, which converge provably faster than the conventional upper limits provided by the Complexity Theory.

Biography

Yurii Nesterov is a professor at Center for Operations Research and Econometrics (CORE) in Catholic University of Louvain (UCL), Belgium. He received Ph.D. degree (Applied Mathematics) in 1984 at Institute of Control Sciences, Moscow. Starting from 1993 he works at Center of Operations Research and Econometrics (Catholic University of Louvain, Belgium).

His research interests are related to complexity issues and efficient methods for solving various optimization problems. The main results are obtained in Convex Optimization. He is an author of 6 monographs and more than 120 refereed papers in the leading optimization journals. He got several international prizes and recognitions, among them there are:

- Dantzig Prize from SIAM and Mathematical Programming society (2000),
- von Neumann Theory Prize from INFORMS (2009),
- SIAM Outstanding paper award (2014),
- Euro Gold Medal from Association of European Operations Research Societies (2016),
- Member of Academia Europaea (2021) and National academy of Sciences (USA, 2022).

VII. Invited Industrial Talk and Panel Discussion

Invited talk "How to Effectively Evaluate the Stability of Large Power Systems, Including Short-Term Stochastic Behaviors"

Patrick Panciatici
Scientific Advisor at RTE (French TSO)

Date and Time: Wednesday, July 20, 11:00-11:30 (Paris Time)

Abstract

Stability assessment of large power systems is usually performed using time domain simulation. Numerical schemes have been developed in the last decades, based on hybrid DAE solvers (with switches) using a predictor-corrector approach (typically IDA from sundials: IDA | Computing (llnl.gov)). They are quite efficient in the deterministic case. But in fact, there are always short-term stochastic effects in large power systems that are neglected in this type of stability assessment, Unfortunately, the deterministic approach does not verify that these stochastic effects do not excite instabilities and our classical predictor-corrector approach seems incompatible with noise addition. In the presentation, we will present an example and a formulation of the problem.

Biography

Patrick Panciatici is a graduate of Supélec. He joined EDF R&D in 1985 and then RTE in 2003 when he participated in the creation of an internal R&D department at RTE. He has more than 35 years of experience in power systems: modeling, simulation, control and optimization. Currently, as a scientific advisor, he inspires and coordinates RTE's long-term research on the "system" dimension. He interacts with a large network of international experts and with academic teams worldwide on these topics. He is a member of CIGRE, Fellow of IEEE, RTE representative in PSERC and Bits & Watts.

Panel discussion "The Interplay between Industrial Challenges and Academic Research"

Dime and Time: Wednesday, July 20, 11:30-12:00 (Paris Time)

Panelists:

- Saber Elaydi (Trinity University, USA)
- Alessio Iovine (CNRS - L2S, France)
- Ernesto Kofman (CIFASIS - CONICET, Agentina)
- Houria Siguerdidjane (CentraleSupélec, France)

VIII. Tutorials and Minisymposium

1- Tutorial: Multiscale Modeling and Control of Infectious Diseases

Date and Time: Monday, July 18, 13:30-18:00 (Paris Time)

Organizers and Speakers

Prof. Esteban A. Hernandez-Vargas
Institute of Mathematics, UNAM, Mexico
Frankfurt Institute for Advanced Studies, Germany
Prof. Alejandro H. González
Argentine National Scientific and Technical Research Council - INTEC (CONICET-UNL), Argentine
Prof. Antonio Ferramosca
University of Bergamo, Italy

Summary

Biomedical engineering is a multidisciplinary field linking the application of engineering principles and tools to medicine and biology for healthcare purposes. Furthermore, pharmaceutical companies have taken a strategic initiative to promote the use of modeling approaches within drug projects. The value of a model- based approach to drug development for improved efficiency and decision-making at preclinical development phases has been largely advocated. Drug administration is classically divided into two phases, a so-called pharmacokinetic (PK) phase that relates dose, frequency, and route of administration to drug level-time relationships in the body, and a pharmacodynamics (PD) phase that relates the concentration of the drug at the sites of action of the magnitude of the effects produced.

This workshop aims to provide the basic principles of control, modeling, and biology to:

- understand biomedical engineering
- provide a vision of the applicability to infectious diseases
- develop mathematical models and control strategies in medical applications

These contributions are meaningful because they allow building a systematic framework that can be applied to simulate, emulate, and control other diseases. Furthermore, recent modeling advances will be presented in different viral infections dissecting detailed contributions of key players to severe viral infections as well as their respective interactions are crucial for developing treatment strategies. In the same manner, advances in fully-automated systems for insulin release are discussed, as well as current challenges in COVID-19.

The results that will appear in the workshop include simulations as well as rigorous mathematical analyses that guarantee control engineering strategies properties. Ultimately, simulations of PK/PD are introduced and discussed to evaluate dose-concentration-response and predict the effect-time courses resulting from the treatment.

Content

- Introduction to biomedical systems and control
- Mathematical Modeling and Parameter fitting with differential evolution algorithm
- Optimal and suboptimal control strategies for infectious diseases at the host level
- Optimal control for SIR-type systems
- Concluding Remarks

The intended audience of this workshop consists of researchers, control practitioners, MSc and Ph.D. candidates as well as any scientist who wants to get in touch with this field.

2- Tutorial: UNICORN - A Unified Control Framework for Real-Time Power System Operation

Date and Time: Monday, July 18, 13:30-18:00 (Paris Time)

Organizers and Speakers

M. Sc. Lukas Ortmann
ETH Zurich

Dr. Saverio Bolognani
ETH Zurich

Dr. Jean Maeght
RTE France

Summary

Due to unprecedented changes in power systems, new real-time approaches that enable optimal operation are essential. Feedback Optimization is such a method that turns optimization algorithms into feedback controllers. Utilizing the advantages of both optimization and control provides us with a real-time compatible controller which make (power) systems track the optimum of an optimization problem, while satisfying constraints. We present the theoretical basis and the results of a three-year project between ETH Zurich and the French transmission grid operator RTE. The tutorial aims at theoretical researchers interested in new research directions in the field of Feedback Optimization as well as practitioners who would like to learn how to apply Feedback Optimization in power systems.

Content

- Introduction to the theory of Feedback Optimization (Saverio Bolognani)
- Experimental validation of Feedback Optimization for power systems including the Unicorn 4-bus benchmark (Lukas Ortmann)
- Statistical analysis of Feedback Optimization vs state-of-the-art control including the Unicorn 56-bus benchmark (Saverio Bolognani)
- Transmission Grid Operation with Feedback Optimization including the Unicorn 7019-bus benchmark (Lukas Ortmann & Jean Maeght)
- Panel Discussion and Q&A

The Unicorn project is a three-year research collaboration between the French transmission grid operator RTE and ETH Zurich funded by the Swiss Federal Office of Energy. More details can be found at www.unicorn.control.ee.ethz.ch. There, we will also publish the code for the benchmarks.

3- Tutorial: Mean-Field-Type Games for Engineers

Date and Time: Monday, July 18, 13:30-18:00 (Paris Time)

Organizers and Speakers

Julian Barreiro-Gomez
NYUAD Research Institute, New York University Abu Dhabi
Center on Stability, Instability and Turbulence (SITE)

Hamidou Tembine
NYUAD Research Institute, New York University Abu Dhabi
Center on Stability, Instability and Turbulence (SITE)

Summary

A class of stochastic differential games, known as mean-field-type games, incorporates the distribution of the variables of interest, e.g., the strategies and/or the system state, into the analysis. This feature allows us to take into consideration risk terms such as the variance or even higher-order terms. In general, the solution for this kind of stochastic game problems is complex and requires solving a backward partial integro-differential equation (PIDE), corresponding to the Hamilton-Jacobi-Bellman equation, coupled with a forward partial differential equation describing the evolution of the distribution of the states, known as the Fokker-Plank-Kolmogorov equation. In this tutorial session, we avoid addressing such complex PIDE system and solve the underlying stochastic differential game in a semi-explicit way by proposing an appropriate ansatz for the value function and following the so-called verification/direct method. This tutorial session is mainly designed for new researchers on the topic and beginners in the area. The topic will be addressed in a friendly way trying to present the contents in a quite easy manner.

Content

- Introduction to Mean-Field-Type Games
- Semi-Explicit Solution for LQ Mean-Field-Type Games: Non-cooperative, Cooperative and the Coopetitive Solutions
- Semi-Explicit Solution for Some Non-Linear Mean-Field-Type Games
- Engineering Applications

4- Minisymposium: Constraints in Dynamical Systems and Control

Date and Time: Monday, July 18, 13:30-18:00 (Paris Time)

Organizers

Sorin Olaru
CentraleSupélec (France)

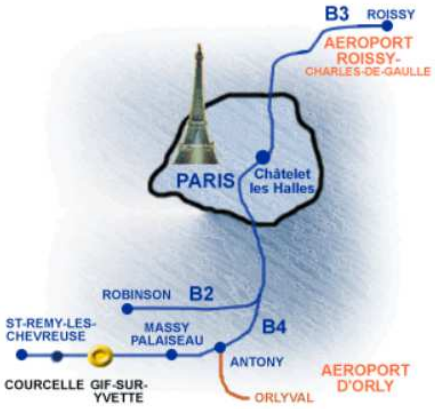
Spilios Theodoulis
ISL (France)

This session will be dedicated to **Prof. George Bitsoris' 70+2 anniversary.** It will host talks by Nikolaos Athanasopoulos, Florin Stoican, Franco Blanchini: “Set-invariance and other stories”, Ionela Prodan, Sorin Olaru, Pedro Rodriguez, Carlos Eduardo Trabuco Dorea and Spilios Theodoulis.

IX. Local Information

Location

CentraleSupélec is a French graduate engineering school of Paris-Saclay University, located 30km to the south of Paris.

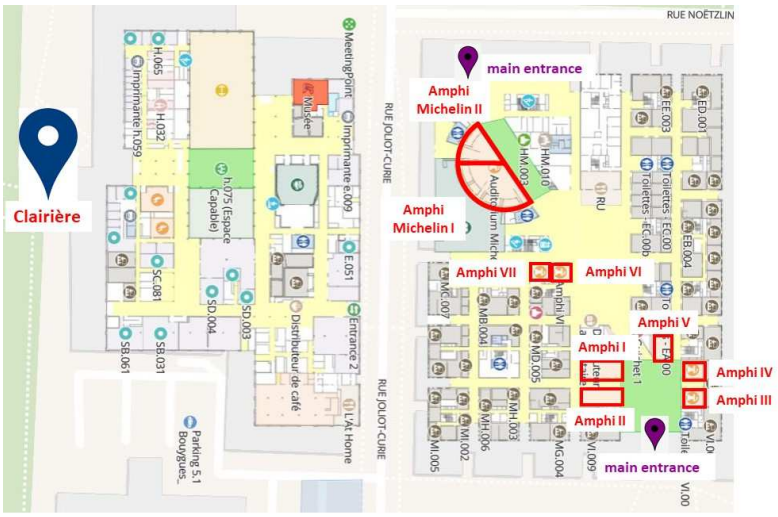


IFAC CAO will be held in the Eiffel Building of CentraleSupélec, located at 8-10 rue Joliot-Curie, 91190 Gif-sur-Yvette (GPS Map 48°42'36.1"N 2°10'02.9"E).

Map of the Eiffel Building

Social events

- **Opening Gala**: Monday, July 18 at 6:00 pm, Clairière CentraleSupélec.



A series of visits and social events will be organized at:

- **Synchrotron SOLEIL**: Tuesday, July 19, starting from 4:00 pm. Further information will be provided soon.

- [Château de Versailles]: Wednesday, July 20, starting from 2:15 pm.

Schedule

- **2:15 pm** Meeting at the bus at the conference place
- **3:00 pm** Arrival at Versailles, group photo and short walk around the castle
- **4:15 pm**: Meeting point with the guide(s) in front of the gate of the chapel of Palace of Versailles

- **4:30 pm**: Guided Tour of the Grands Apartments of the Versailles Palace (1h30)
  A guide is assigned to each group of 30 people maximum, including the accompanying persons. Subject to changing health conditions. Respect for social distancing and barrier gestures. Earphones are mandatory.
  Self-guided tour of the French gardens with the musical gardens
  End of the visit - Walk to the restaurant
- **7:00 pm**: Dinner at the hotel Le Louis M Gallery by Sofitel, in Versailles

- **Banquet -- Dinner cruise on the River Seine**: Thursday, July 21, starting from 6:15 pm.

  Discover or rediscover Paris during a cruise of about 2h30 while enjoying a dinner. The cruise allows you to discover the Parisian monuments along the Seine from the Ile aux Cygnes to Bercy.



Schedule

- **6:15 pm**: Convocation of the participants: CentraleSupélec campus, in front of the Eiffel Building, 8-10 rue Joliot-Curie 91190 Gif-sur-Yvette,
- **6:30 pm**: Departure from Gif-sur-Yvette to Paris, by bus (about 1h30),
- **7:45-8:00 pm**: Arrival at the pier of the Paris cruises,
- **8:30 pm**: Departure of the cruise. Enjoy the charm of the illuminated monuments of Paris and savor a sumptuous dinner prepared on board by the Chef.

  Taste French gastronomy: The Chef proposes a traditional French cuisine, elegant and refined, prepared daily on board with fresh and seasonal products. It favors taste, simplicity and respect for the original flavors of the ingredients. A mastered culinary technique and a meticulous presentation of the dishes sublimate each plate served on board each plate served on board our cruises.

X. IFAC Information

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XI. Program at a Glance

CAO 2022 Technical Program Monday July 18, 2022

Track 1	Track 2	Track 3	Track 4
13:30-18:00 MoTutA Amphi I Tutorial Session: "Multiscale Modeling and Control of Infectious Diseases"	13:30-18:00 MoTutB Amphi II Tutorial Session: "UNICORN - a Unified Control Framework for Real-Time Power System Operation"	13:30-18:00 MoTutC Amphi VI Tutorial Session: "Mean-Field-Type Games for Engineers"	13:30-18:00 MoTutD Michelin II Minisymposium: "Constraints in Dynamical Systems and Control" -- Anniversary George Bitsoris 70+2

CAO 2022 Technical Program Tuesday July 19, 2022

Track 1	Track 2
09:00-09:30 TuOpnP Amphi Michelin I Opening Ceremony	
09:30-10:30 TuP1P Amphi Michelin I Jean-Bernard Lasserre -- "Reconstructing Optimal Solutions to OCPs from Their Measure-Valued Optimal Solutions"	
11:00-12:00 TuR1A Amphi I Theoretical and Numerical Advances on the Optimal Control of Complex Systems 1	11:00-12:00 TuR1B Amphi II Applications in Transportation
13:00-14:00 TuP2P Amphi Michelin I Angelia Nedich -- "Socio-Technological Networks and Decision Making"	
14:00-16:00 TuR2A Amphi I Theoretical and Numerical Advances on the Optimal Control of Complex Systems 2	14:00-16:00 TuR2B Amphi II Application in Energy and Power Applications

CAO 2022 Technical Program Wednesday July 20, 2022

Track 1	Track 2
08:30-09:30 WeP1P Amphi Michelin I Tamer Başar -- "Mean Field Games and Selected Applications"	
10:00-11:00 WeR1A Amphi I Differential Games and Uncertainty	10:00-11:00 WeR1B Amphi II Optimization for Infrastructure Network Resilience
11:00-12:00 WeI1P Amphi Michelin I Invited Industrial Talk "How to Effectively Evaluate the Stability of Large Power Systems, Including Short-Term Stochastic Behaviors" by Patrick Panciatici Followed by a Panel Discussion: "The Interplay between Industrial Challenges and Academic Research	
12:00-13:00 WeR2A Amphi I Data-Based Optimal Control	12:00-13:00 WeR2B Amphi II Computational Methods for Optimal Control

CAO 2022 Technical Program Thursday July 21, 2022

Track 1	Track 2
08:30-09:30 ThK1P Amphi Michelin I CentraleSupélec Foundation's Keynote: "New Perspectives for Higher-Order Methods in Convex Optimization" -- Yurii Nesterov	
10:00-12:00 ThR1A Amphi I Optimization and Control of Biological Systems	10:00-12:00 ThR1B Amphi II Topics in Optimal Control
13:30-14:30 ThR2A Amphi I Path Planning and Routing	13:30-14:30 ThR2B Amphi II Optimization Methods for Time-Delay Systems
14:30-15:30 ThP1P Amphi Michelin I Simona Onori - "Modeling and Control of Lithium-Ion Battery Systems"	
16:00-18:00 ThR3A Amphi I MPC	16:00-18:00 ThR3B Amphi II Optimization-Based Applications

CAO 2022 Technical Program Friday July 22, 2022

Track 1	Track 2
08:30-09:30 FrP1P Amphi Michelin I (CANCELED) Boris Polyak -- Feedback Design in Control as Optimization Problem	
10:00-12:20 FrR1A Amphi I Optimization-Based Decision Making	10:00-12:20 FrR1B Amphi II Computational and Robustness Topics in Optimization-Based Design
12:20-12:45 FrClsP Amphi Michelin I Closing Ceremony	

XII. Content List

Content List of 18th IFAC Workshop on Control Applications of Optimization

Technical Program for Tuesday July 19, 2022

TuR1A	Amphi I
Theoretical and Numerical Advances on the Optimal Control of Complex Systems 1 (Invited Session)	
Chair: Pfeiffer, Laurent	Inria
Co-Chair: Bonalli, Riccardo	Université Paris-Saclay, CNRS, CentraleSupélec, Laboratoire Des Signaux Et Systèmes
Organizer: Pfeiffer, Laurent	Inria
Organizer: Bonalli, Riccardo	Université Paris-Saclay, CNRS, CentraleSupélec, Laboratoire Des

TuR1B	Amphi II
Applications in Transportation (Regular Session)	
Chair: Stoica Maniu, Cristina	CentraleSupélec/Laboratoire De Signaux Et Systèmes
Co-Chair: Naidja, Nouhed	CentraleSupelec

TuR2A	Amphi I
Theoretical and Numerical Advances on the Optimal Control of Complex Systems 2 (Invited Session)	
Chair: Bonalli, Riccardo	Université Paris-Saclay, CNRS, CentraleSupélec, Laboratoire Des Signaux Et Systèmes
Co-Chair: Pfeiffer, Laurent	Inria
Organizer: Pfeiffer, Laurent	Inria
Organizer: Bonalli, Riccardo	Université Paris-Saclay, CNRS, CentraleSupélec, Laboratoire Des

14:00-14:20 TuR2A.1

On the Asymptotic Behavior of the Value Function in Large Time Optimal Control Problems (I), pp. 38-43.

Askovic, Veljko (Sorbonne Université), Trelat, Emmanuel (University Pierre Et Marie Curie (Paris 6)), Zidani, Hasnaa (ENSTA ParisTech)

14:20-14:40 TuR2A.2

A Mayer Optimal Control Problem on Wasserstein Spaces Over Riemannian Manifolds (I), pp. 44-49.

Jean, Frederic (ENSTA ParisTech), Jerhaoui, Othmane (ENSTA PARIS), Zidani, Hasnaa (ENSTA ParisTech)

14:40-15:00 TuR2A.3

Time Minimal Syntheses in the Abnormal Case Using Geometric and Computational Techniques (I), pp. 50-55.

Assainova, Olga (L@bISEN), Rouot, Jérémy (L@bIsen)

15:00-15:20 TuR2A.4

Multilevel Selective Harmonic Modulation by Duality (I), pp. 56-61.

Biccari, Umberto (Fundación Deusto), Zuazua, Enrique (Universidad Autónoma De Madrid)

15:20-15:40 TuR2A.5

Stability of Solutions for Controlled Nonlinear Systems under Perturbation of State Constraints (I), pp. 62-67.

Aubin-Frankowski, Pierre-Cyril (INRIA)

15:40-16:00 TuR2A.6

Optimal Control Problems with Non-Control Regions: Necessary Optimality Conditions (I), pp. 68-73.

Bayen, Terence (Avignon University), Bouali, Anas (Avignon University), Bourdin, Loïc (University of Limoges)

TuR2B	Amphi II
Application in Energy and Power Applications (Regular Session)	
Chair: Siguerdidjane, Houria	CentraleSupelec
Co-Chair: Pham, Thanh Hung	CNRS - CentraleSupelec

14:00-14:20 TuR2B.1

Nonlinearity Handling in MPC for Power Congestion Management in Sub-Transmission Areas, pp. 74-79.

Pham, Thanh Hung (CNRS - CentraleSupelec), Iovine, Alessio (CNRS, CentraleSupélec), Olaru, Sorin (CentraleSupelec), Maeght, Jean (RTE France Réseau De Transport D'Electricité), Panciatici, Patrick (RTE), Ruiz, Manuel (RTE)

14:20-14:40 TuR2B.2

Maximum Power Point Tracking of a Photovoltaic System Using State Feedback Gain Fuzzy Control, pp. 80-85.

Chaibi, Redouane (Industrial Technologies and Services Laboratory, Higher School O), El Bachtiri, Rachid (Industrial Technologies and Services Laboratory, Higher School O), El Hammoumi, Karima (Industrial Technologies and Services Laboratory, Higher School O), Mohamed Yagoubi, Mohamed (IMT Atlantique LS2N)

14:40-15:00 TuR2B.3

Scalable Optimal Control Allocation: Linear and Quadratic Programming Methods Applied to Active Capacitor Balancing in Modular Multilevel Converters, pp. 86-91.

Le Goff, Gregoire (LAPLACE, University of Toulouse, CNRS, INPT, UPS), Fadel, Maurice (LAPLACE/ENSEEIHT), Bodson, Marc (Univ. of Utah)

15:00-15:20 TuR2B.4

Nonlinear Internal Model Control of Wind Farm Power Optimization under Wake Effect, pp. 92-97.

Siguerdidjane, Houria (CentraleSupelec), Hammami, Asma (Automatic Research Laboratory, National Engineering Scool, Tunis)

15:20-15:40 TuR2B.5

Linear Parameter-Varying Model for Prediction of Charge / Discharge Behavior of Tri-Electrode Zinc-Air Flow Battery, pp. 98-103.

Lao-atiman, Woranunt (Chulalongkorn University), Olaru, Sorin (CentraleSupelec), Kheawhom, Soorathep (Chulalongkorn University)

15:40-16:00 TuR2B.6

Optimal Control of Wave Energy Devices with Nonlinear Reactive Power Constraints, pp. 104-109.

Jain, Jitendra Kumar (Centre for Ocean Energy Research, Maynooth University), Mason, Oliver (Maynooth University), Peña-Sanchez, Yerai (University of the Basque Country), Ringwood, John (Maynooth University)

Technical Program for Wednesday July 20, 2022

WeR1A	Amphi I
Differential Games and Uncertainty (Regular Session)	
Chair: Le Menec, Stephane	MBDA France
Co-Chair: Mo, Huadong	University of New South Wales

10:00-10:20 WeR1A.1

Interval Invariance in the Evolutionary Game of Coordination, pp. 110-115.

Le Menec, Stephane (MBDA France)

10:20-10:40 WeR1A.2

Approximating Solution of Stochastic Differential Games for Distributed Control of a Water Network, pp. 116-121.

Misra, Rahul (Aalborg University), Wisniewski, Rafal (Aalborg University), Kallesøe, Carsten Skovmose (Grundfos)

10:40-11:00 WeR1A.3

Alternating Direction Method of Multipliers for Solving Joint Chance Constrained Optimal Power Flow under Uncertainties, pp. 122-127.

Qin, James (University of New South Wales), Yan, Yifan (Fudan University), Jiang, Rujun (Fudan University), Mo, Huadong (University of New South Wales), Dong, Daoyi (University of New South Wales)

WeR1B	Amphi II
Optimization for Infrastructure Network Resilience (Invited Session)	
Chair: Barros, Anne	CentraleSupelec, University of Paris-Saclay
Co-Chair: Fang, Yi-Ping	CentraleSupelec, University of Paris-Saclay
Organizer: Fang, Yi-Ping	CentraleSupelec, University of Paris-Saclay
Organizer: Barros, Anne	CentraleSupelec, University of Paris-Saclay

10:00-10:20 WeR1B.1

A Distributionally Robust Approach for the Optimal Protection of Power Networks with Endogenous Uncertainty (I), pp. 128-133.

Bellè, Andrea (CentraleSupélec, Université Paris-Saclay), Fang, Yi-Ping (CentraleSupelec, University of Paris-Saclay), Zeng, Zhiguo (CentraleSupélec, Université Paris-Saclay), Barros, Anne (CentraleSupelec, University of Paris-Saclay)

10:20-10:40 WeR1B.2

Maintenance Planning under Imperfect Monitoring: An Efficient POMDP Model Using Interpolated Value Function (I), pp. 134-141.

Roux, Matthieu (Univ. Paris-Saclay, CentraleSupélec), Fang, Yi-Ping (CentraleSupelec, University of Paris-Saclay), Barros, Anne (CentraleSupelec, University of Paris-Saclay)

10:40-11:00 WeR1B.3

Resilience Optimization of Wide-Area Control in Smart Distribution Grids (I), pp. 142-147.

Nait Belaid, Youba (CentraleSupélec), Fang, Yi-Ping (CentraleSupelec, University of Paris-Saclay), Zeng, Zhiguo (CentraleSupélec, Université Paris-Saclay), Legendre, Anthony (EDF R&D), Coudray, Patrick (EDF R&D), Barros, Anne (CentraleSupelec, University of Paris-Saclay)

WeR2A	Amphi I
Data-Based Optimal Control (Regular Session)	
Chair: Stoican, Florin	Politehnica University of Bucharest
Co-Chair: Shokry, Ahmed	Ecole Polytechnique

12:00-12:20 WeR2A.1

Health-Constrained Explicit Model Predictive Control Based on Deep-Neural Networks Applied to Real-Time Charging of Batteries, pp. 148-153.

Shokry, Ahmed (Ecole Polytechnique), Moulines, Eric (Ecole Polytechnique, Centre De Mathématiques Appliquées (CMAP))

12:20-12:40 WeR2A.2

Generalized Feedforward Control Using Physics-Informed Neural Networks, pp. 154-159.

Bolderman, Max (Eindhoven University of Technology), Fan, Daiwei (Eindhoven University of Technology), Lazar, Mircea (Eindhoven Univ. of Technology), Butler, Hans (Eindhoven University of Technology)

12:40-13:00 WeR2A.3

Investigation of Alternative Measures for Mutual Information, pp. 160-165.

Kuskonmaz, Bulut (Aalborg University), Gundersen, Jaron Skovsted (Aalborg University), Wisniewski, Rafal (Aalborg University)

WeR2B	Amphi II
Computational Methods for Optimal Control (Regular Session)	
Chair: Fantuzzi, Giovanni	Imperial College London
Co-Chair: Mykhailiuk, Ivan	University of Bremen

12:00-12:20 WeR2B.1

Lyapunov Function Computation for Periodic Linear Hybrid Systems Via Handelman, Polya and SoS Approaches: A Comparative Study, pp. 166-171.

Toso, Leonardo Felipe (Laboratoire Des Signaux Et Systèmes (L2S)), Valmorbida, Giorgio (L2S, CentraleSupelec)

12:20-12:40 WeR2B.2

Verification of Some Functional Inequalities Via Polynomial Optimization (I), pp. 172-177.

Fantuzzi, Giovanni (Imperial College London)

12:40-13:00 WeR2B.6

Parametric Stability Score and Its Application in Optimal Control, pp. 178-183.

Mykhailiuk, Ivan (University of Bremen), Schäfer, Kai (University of Bremen), Büskens, Christof (Univ of Bremen)

Technical Program for Thursday July 21, 2022

ThR1A Amphi I

Optimization and Control of Biological Systems (Invited Session)

Chair: Gonzalez, Alejandro, Hernan — Institute of Technological Development for the ChemicalIndustry (INTEC), CONICET-UNL

Co-Chair: Ferramosca, Antonio — Univeristy of Bergamo

Organizer: Hernandez Vargas, Esteban A. — UNAM

Organizer: Gonzalez, Alejandro, Hernan — Institute of Technological Development for the ChemicalIndustry

Organizer: Ferramosca, Antonio — Univeristy of Bergamo

10:00-10:20 ThR1A.1

Parameter Estimation in Hybrid Machine Learning and Mechanistic Models of Infectious Diseases (I), pp. 184-189.

Jhutty, Suneet Singh (Goethe University Frankfurt, Frankfurt Institute for Advanced St), Hernandez Vargas, Esteban A. (UNAM)

10:20-10:40 ThR1A.2

Permanence Regions for Switched Linear Systems under Waiting-Time Constraints (I), pp. 190-195.

Perez, Mara (Intec - Conicet - Unl), Anderson, Alejandro (INTEC-CONICET-UNL), Hernandez Vargas, Esteban A. (UNAM), Gonzalez, Alejandro, Hernan (Institute of Technological Development for the ChemicalIndustry), Actis, Marcelo Jesús (CONICET-FIQ-UNL)

10:40-11:00 ThR1A.3

Optimal Responses to Constrained Bolus Inputs to Models of T1D (I), pp. 196-201.

Townsend, Christopher (University of Newcastle), Seron, Maria (The Univ of Newcastle), Magdelaine, Nicolas (L@bISEN)

11:00-11:20 ThR1A.4

Artificial Pancreas under Periodic MPC for Trajectory Tracking: Handling Circadian Variability of Insulin Sensitivity (I), pp. 202-207.

Abuin, Pablo (CONICET-UNL), Ferramosca, Antonio (Univeristy of Bergamo), Toffanin, Chiara (University of Pavia), Magni, Lalo (Univ. of Pavia), Gonzalez, Alejandro, Hernan (Institute of Technological Development for the ChemicalIndustry)

11:20-11:40 ThR1A.5

Optimal Single-Interval Control for SIR-Type Systems (I), pp. 208-213.

Gonzalez, Alejandro, Hernan (Institute of Technological Development for the ChemicalIndustry), Ferramosca, Antonio (Univeristy of Bergamo), Hernandez Vargas, Esteban A. (UNAM)

11:40-12:00 ThR1A.6

Optimal Control of Microbial Production in the Chemostat, pp. 214-219.

Bayen, Terence (Avignon University), Cazenave-Lacroutz, Henri (Avignon Université), Coville, Jerome (INRAE Avignon Centre De Recherche PACA), Mairet, Francis (Ifremer)

ThR1B Amphi II

Topics in Optimal Control (Regular Session)

Chair: Bonalli, Riccardo — Université Paris-Saclay, CNRS, CentraleSupélec, L2S

Co-Chair: Courtial, Estelle — Université D'Orléans

10:00-10:20 ThR1B.1

High-Fidelity Quantum State Transfer by Pontryagin Maximum Principle, pp. 220-225.

Binandeh Dehaghani, Nahid (University of Porto), Pereira, Fernando Lobo (Porto University)

10:20-10:40 ThR1B.2

Control Strategies with Multiple Closing Instants for Linear Optimal Control Problems with Disturbances, pp. 226-231.

Dmitruk, Natalia (Belarusian State University), Kastsiukevich, Dzmitry (Belarusian State University)

10:40-11:00 ThR1B.3

On Some Regularization of the Control Problem for a Tracked Mobile Robot in a Steady Flow Field under State Constraints, pp. 232-236.

Chertovskih, Roman (Porto University), Daryina, Anna (Federal Research Center «Computer Science and Control» of Russia), Karamzin, Dmitry (Federal Research Center), Pereira, Fernando Lobo (Porto University)

11:00-11:20 ThR1B.4

Some Remarks on the Issue of Second-Order Optimality Conditions in Control Problems with Mixed Constraints, pp. 237-241.

Arutyunov, Aram V. (Peoples Friendship Univ.of Russia), Karamzin, Dmitry (Federal Research Center), Pereira, Fernando Lobo (Porto University)

11:20-11:40 ThR1B.5

First-Order Constrained Optimization: Non-Smooth Dynamical System Viewpoint, pp. 242-247.

Schechtman, Sholom (École Polytechnique), Tiapkin, Daniil (HSE University), Moulines, Eric (ENST-Paris), Jordan, Michael I. (University of California, Berkeley), Muehlebach, Michael (ETH Zurich)

11:40-12:00 ThR1B.6

Ensemble Control of Dynamic Systems with Square Impulses, pp. 248-253.

Staritsyn, Maxim (Faculdade De Engenharia, Universidade Do Porto, Porto, Portugal), Goncharova, Elena (Institute for System Dynamics and Control Theory SB RAS), Pereira, Fernando Lobo (Porto University)

ThR2A Amphi I

Path Planning and Routing (Regular Session)

Chair: Bertrand, Sylvain — ONERA

Co-Chair: Iovine, Alessio — CNRS, CentraleSupélec

13:30-13:50 ThR2A.1

Vessel Passage Scheduling through Cascaded Bridges Using Mixed-Integer Programming, pp. 254-259.

Segovia, Pablo (Delft University of Technology), Negenborn, Rudy (Delft University of Technology), Reppa, Vasso (Delft University of Technology)

13:50-14:10 ThR2A.2

Polyhedral Potential Field Constructions for Obstacle Avoidance in a Receding Horizon Formulation, pp. 260-265.

Nicu, Theodor-Gabriel (Politehnica University of Bucharest), Stoican, Florin (Politehnica University of Bucharest, Associate Researcher LOS), Prodan, Ionela (INP Grenoble)

14:10-14:30 ThR2A.3

Path Generation Based on Convex Lifting: Optimization of the Corridors, pp. 266-271.

Mirabilio, Marco (University of L'Aquila), Olaru, Sorin (CentraleSupelec), Dorea, Carlos E. T. (Universida Federal Do Rio Grande Do Norte), Iovine, Alessio (CNRS, CentraleSupélec), Di Benedetto, M. Domenica (Univ of L'Aquila)

ThR2B Amphi II

Optimization Methods for Time-Delay Systems (Regular Session)

Chair: Dorea, Carlos E. T. Universidade Federal Do Rio Grande Do Norte

Co-Chair: Morato, Marcelo Menezes Universidade Federal De Santa Catarina

13:30-13:50 ThR2B.1

Computation of Low Complexity Invariant Sets for Time-Delay Systems: An Optimization-Based Approach, pp. 272-277.

Dorea, Carlos E. T. (Universidade Federal Do Rio Grande Do Norte), Olaru, Sorin (CentraleSupelec)

13:50-14:10 ThR2B.2

TDS-CONTROL: A MATLAB Package for the Analysis and Controller-Design of Time-Delay Systems, pp. 278-283.

Appeltans, Pieter (KU Leuven), Silm, Haik (KU Leuven), Michiels, Wim (KU Leuven)

14:10-14:30 ThR2B.3

Explicit Dead-Time Compensation in Linear Parameter Varying Model Predictive Control, pp. 284-289.

Morato, Marcelo Menezes (Universidade Federal De Santa Catarina), Santos, Tito (Federal University of Bahia), Normey-Rico, Julio Elias (Federal Univ of Santa Catarina)

ThR3A Amphi I

MPC (Regular Session)

Chair: Girard, Antoine CNRS

Co-Chair: Rodriguez-Ayerbe, Pedro Supelec

16:00-16:20 ThR3A.1

Approximating Optimal Control by Shrinking Horizon Model Predictive Control for Spacecraft Rendezvous and Docking, pp. 290-295.

Ye, Mingfei (University of Michigan), Kolmanovsky, Ilya V. (University of Michigan)

16:20-16:40 ThR3A.2

Predictive and Symbolic Control: Performance and Safety for Non-Linear Systems, pp. 296-301.

Azaki, Zakeye (Université Grenoble Alpes), Girard, Antoine (CNRS), Olaru, Sorin (CentraleSupelec)

16:40-17:30 ThR3A.3

A Tree-Based Multi-Scenario Approach to Networked MPC under Packet Losses and Disturbances, pp. 302-307.

Arauz, Teresa (Universidad De Sevilla), Maestre, Jose M. (University of Seville), Cetinkaya, Ahmet (National Institute of Informatics), Stoica Maniu, Cristina (CentraleSupélec/Laboratoire De Signaux Et Systèmes)

17:00-17:20 ThR3A.4

Predictive Control Based on Stochastic Disturbance Trajectories for Congestion Management in Sub-Transmission Grids, pp. 308-313.

Dkhili, Nouha (CentraleSupélec - Université Paris-Saclay), Olaru, Sorin (CentraleSupelec), Iovine, Alessio (CNRS, CentraleSupélec), Ruiz, Manuel (RTE), Maeght, Jean (RTE France Réseau De Transport D'Electricité), Panciatici, Patrick (RTE)

17:20-17:40 ThR3A.5

On the Link between Explicit MPC and the Face Lattice of the Lifted Feasible Domain, pp. 314-319.

Mihai, Sergiu-Stefan (Politehnica University of Bucharest), Stoican, Florin (Politehnica University of Bucharest, Associate Researcher LOS), Ciubotaru, Bogdan D. (Faculty of Automatic Control and Computers, Polytechnic Universi)

17:40-18:00 ThR3A.6

Robustness of PWA Control Based on a Coupled Vertex Sensitivity Analysis, pp. 320-325.

Yang, Songlin (CentraleSupele, Paris Saclay University), Olaru, Sorin (CentraleSupelec), Rodriguez-Ayerbe, Pedro (Supelec), Dorea, Carlos E. T. (Universidade Federal Do Rio Grande Do Norte)

ThR3B Amphi II

Optimization-Based Applications (Regular Session)

Chair: Klauco, Martin Slovak University of Technology in Bratislava

Co-Chair: Sandou, Guillaume SUPELEC

16:00-16:20 ThR3B.1

Moving Horizon Estimator with Filtering and Adaptive Sampling, pp. 326-331.

Oliva, Federico (Tor Vergata University of Rome), Carnevale, Daniele (Universita' Di Roma , Tor Vergata)

16:20-16:40 ThR3B.2

Nearly Optimal Tunable MPC Strategies on Embedded Platforms, pp. 332-337.

Kiš, Karol (Slovak University of Technology in Bratislava), Bakaráč, Peter (Slovak University of Technology in Bratislava), Klauco, Martin (Slovak University of Technology in Bratislava)

16:40-17:30 ThR3B.3

Optimization of Start-Up Operation for Centrifugal Chiller, pp. 338-343.

Okazaki, Hirotaka (Mitsubishi Heavy Industries, Ltd), Ono, Hitoi (Mitsubishi Heavy Industries), Yanai, Noritaka (Mitsubishi Heavy Industries)

17:00-17:20 ThR3B.4

Model Predictive Control Prototyping and Validation for a Large Central Cooling System, pp. 344-349.

Heidari, Rahmat (University of Newcastle), Braslavsky, Julio H. (Commonwealth Scientific and Industrial Research Organisation (CS)

17:20-17:40 ThR3B.5

Four MPC Implementations Compared on the Quadruple Tank Process Benchmark : Pros and Cons of Neural MPC, pp. 350-355.

Blaud, Pierre (IMT Atlantique), Chevrel, Philippe (IMT Atlantique / LS2N), Claveau, Fabien (Ecole Des Mines De Nantes), Haurant, Pierrick (IMT Atlantique), Mouraud, Anthony (CEA)

17:40-18:00 ThR3B.6

Controllability and Optimal Control Design for an Elastic Rod Actuated by Piezoelements, pp. 356-361.

Kostin, Georgy (Ishlinsky Institute for Problems in Mechanics RAS), Gavrikov, Alexander (Ishlinsky Institute for Problems in Mechanics RAS)

Technical Program for Friday July 22, 2022

FrR1A	Amphi I
Optimization-Based Decision Making (Regular Session)	
Chair: Hoffmann, Matthias K.	Saarland University
Co-Chair: Dkhili, Nouha	CentraleSupélec - Université Paris-Saclay

10:00-10:20 FrR1A.1

Integrating Customer Portfolio Theory and the Multiple Sources of Risk Approaches to Model Risk-Adjusted Revenue, pp. 362-369.

Machado, Marcos Roberto (University of Twente), Karray, Salma (Ontario Tech University)

10:20-10:40 FrR1A.2

Data Driven Logistics-Oriented Value Stream Mapping 4.0: A Guideline for Practitioners, pp. 370-375.

Muehlbauer, Konstantin (Landshut University of Applied Sciences), Wuennenberg, Max (Technical University of Munich), Meißner, Sebastian (Technology Centre for Production and Logistics Systems), Fottner, Johannes (Technical University of Munich)

10:40-11:00 FrR1A.3

Application of Optimization Method for Identifying Human Operator Model Parameters, pp. 376-381.

Zaitceva, Iuliia (LUT University), Andrievsky, Boris (Saint Petersburg State University), Kuznetsov, Nikolay (Saint-Petersburg State Univ), Shestakov, Ivan (St.Petersburg State University of Civil Aviation)

11:00-11:20 FrR1A.4

I'll Tell You What I Want: Categorization of Pareto Fronts for Automated Rule-Based Decision-Making, pp. 382-387.

Hoffmann, Matthias K. (Saarland University), Schmitt, Thomas (Technische Universität Darmstadt), Flaßkamp, Kathrin (Saarland University)

11:20-11:40 FrR1A.5

Modeling the Choice of an Optimal Educational Trajectory in the Conditions of Digital Transformation of the Economy, pp. 388-393.

Tarasyeva, Tatiana (Ural Federal University Named after the First President of Russi), Agarkov, Gavriil (Ural Federal University Named after the First President of Russi), Tarasyev, Alexandr A. (Ural Federal University Named after the First President of Russi), Koksharov, Viktor (Ural Federal University Named after the First President of Russi)

11:40-12:00 FrR1A.6

Dynamic Modeling of Professional Mobility in the Context of Labor Market Precarization, pp. 394-399.

Tarasyev, Alexandr A. (Ural Federal University Named after the First President of Russi), Agarkov, Gavriil (Ural Federal University Named after the First President of Russi), Sushchenko, Anastasia (Ural Federal University), Tarasyev, Alexander M. (Krasovskii Institute of Mathematics and Mechanics of Ural Branch)

FrR1B	Amphi II
Computational and Robustness Topics in Optimization-Based Design (Regular Session)	
Chair: Nicolau, Florentina	Ensea Cergy
Co-Chair: Colin, Guillaume	Univ. Orléans

10:00-10:20 FrR1B.1

An Optimization-Based Algorithm for Simultaneous Shaping of Poles and Zeros for Non-Collocated Vibration Suppression, pp. 400-405.

Saldanha, Adrian (KU Leuven), Silm, Haik (KU Leuven), Michiels, Wim (KU Leuven), Vyhlidal, Tomas (Czech Technical Univ in Prague, Faculty of Mechanical Engineerin)

10:20-10:40 FrR1B.2

Automatic Weighting Filter Tuning for Robust Flight Control Law Design, pp. 406-411.

Alcolea Perez, Carlos (Capgemini Engineering), Theodoulis, Spilios (ISL), Sève, Florian (Dassault Aviation), Goerig, Laurent (Dassault Aviation)

10:40-11:00 FrR1B.3

Tracking Control for a Flat System under Disturbances: A Fixed-Wing UAV Example, pp. 412-417.

Do, Huu Thinh (University Grenoble Alpes, Grenoble INP), Nicolau, Florentina (Ensea Cergy), Stoican, Florin (Politehnica University of Bucharest), Prodan, Ionela (INP Grenoble)

11:00-11:20 FrR1B.4

Simulation and Comparison between Fuzzy Harmonic Search and Differential Evolution Algorithm: Type-2 Fuzzy Approach, pp. 418-423.

Patel, Himanshukumar (Dharmsinh Desai University), Shah, Vipul (DDU, Nadiad)

11:20-11:40 FrR1B.5

Nonlinear Optimal Control for Maglev Platform Roll Motion, pp. 424-429.

Melnikov, Dmitrii (Saint Petersburg State University), Sakamoto, Noboru (Nanzan University), Zavadskiy, Sergey (Saint Petersburg State University), Golovkina, Anna (Saint Petersburg State University)

11:40-12:00 FrR1B.6

On the Use of Frequency Analysis Tools to Minimize the Calculation Complexity of Optimal Control Problems, pp. 430-435.

Cottin, Willy (Stellantis), Colin, Guillaume (Univ. Orléans), Charlet, Alain (Univ. Orléans), Houillé, Sébastien, Sébastien Houillé (STELLANTIS)

12:00-12:20 FrR1B.7

A Distributed Approach to Economic Dispatch in Power Systems, pp. 436-441.

Jahvani, Mohammad (Queen's University), Guay, Martin (Queen's Univ)

XIII. Book of Abstracts

Book of Abstracts of 18th IFAC Workshop on Control Applications of Optimization

Technical Program for Tuesday July 19, 2022

TuR1A	Amphi I
Theoretical and Numerical Advances on the Optimal Control of Complex Systems 1 (Invited Session)	
Chair: Pfeiffer, Laurent	Inria
Co-Chair: Bonalli, Riccardo	Université Paris-Saclay, CNRS, CentraleSupélec, Laboratoire Des Signaux Et Systèmes
Organizer: Pfeiffer, Laurent	Inria
Organizer: Bonalli, Riccardo	Université Paris-Saclay, CNRS, CentraleSupélec, Laboratoire Des

11:00-11:20 TuR1A.1

Reinforcement Learning with Function Approximation for 3-Spheres Swimmer (I), pp. 1-6

Berti, Luca (Université De Strasbourg), El Khiyati, Zakarya (INRIA, CALISTO), Essousy, Youssef (Université Mohammed VI Polytechnique), Prud'Homme, Christophe (Université De Strasbourg, IRMA), Giraldi, Laetitia (Université Cote d'Azur, LJAD, INRIA Sophia-Antipolis)

We study the swimming strategies that maximize the speed of the 3-spheres swimmer using reinforcement learning methods. First of all, we ensure that for a simple model with few actions, the Q-learning method converges. However, tabular methods like the previous one are not suitable for generalization to more complex environments where states or actions have to be continuous to obtain all directions in the swimmer's reachable set. This is the case, for instance, in the presence of a boundary. To overcome this issue, we investigate another method from reinforcement learning which uses function approximation, and benchmark its results in absence of walls.

11:20-11:40 TuR1A.2

Considerations on Two-Phase Averaging of Time-Optimal Control Systems (I), pp. 7-12

Caillau, Jean-Baptiste (Université Côte d'Azur, CNRS, Inria, LJAD), Dell'Elce, Lamberto (Inria), Pomet, Jean-Baptiste (INRIA)

Averaging is a valuable technique to gain understanding of the long-term evolution of dynamical systems characterized by slow dynamics and fast periodic or quasi-periodic dynamics. Averaging the extremal flow of optimal control problems with one fast variable is possible if a special treatment of the adjoint to this fast variable is carried out. The present work extends these results by tackling averaging of time optimal systems with two fast variables, that is considerably more complex because of resonances. No general theory is presented, but rather a thorough treatement of an example, based on numerical experiments. After providing a justification of the possibility to use averaging techniques for this problem ``away from resonances'' and discussing compatibility conditions between adjoint variables of the original and averaged systems, we analyze numerically the impact of resonance crossings on the dynamics of adjoint variables. Resonant averaged forms are used to model the effect of resonances and cross them without loosing the accuracy of the averaging prediction.

11:40-12:00 TuR1A.3

Ct: Control Toolbox – Numerical Tools and Examples in Optimal Control (I), pp. 13-18

Caillau, Jean Baptiste (University of Nice Sophia-Antipolis), Cots, Olivier (Toulouse-Inp), Martinon, Pierre (Inria)

Combining direct and indirect methods to have the best of both worlds is an efficient method to solve numerically optimal control problems. A direct solver will typically provide information on the structure of the optimal control, allowing an educated guess for shooting. The control toolbox ct offers such possibilities and is presented on two examples. The first example has a bang-singular solution and is solved by chaining direct and indirect solvers. The second one consists in computing conjugate and cut loci on an ellipsoid of revolution, which is performed using a more advanced combination of indirect methods with differential continuation.

TuR1B	Amphi II
Applications in Transportation (Regular Session)	
Chair: Stoica Maniu, Cristina	CentraleSupélec/Laboratoire De Signaux Et Systèmes
Co-Chair: Naidja, Nouhed	CentraleSupelec

11:00-11:20 TuR1B.1

A Unified MPC Envelope Control Formulation for Toyota Guardian and Chauffeur, pp. 19-24

Bobier-Tiu, Carrie (Toyota Research Institute), Koehler, Sarah (Toyota Research Institute), Brown, Matthew (Toyota Research Institute), Ahumada, Manuel (Toyota Research Institute)

For a vehicle that can execute safety and autonomy technologies in two paradigms --- shared control (Guardian) and autonomous control (Chauffeur) --- we present a unified formulation for chassis control in both paradigms. The primary goal for both is to maintain the vehicle within a safe state space, and secondarily track either a human driver's intention through shared control, or a desired trajectory in autonomous operation. We introduce the notion of a pseudo-driver when in the autonomous mode, which mathematically mimics the human driver by using the desired path to generate a ``driver's'' steering angle and acceleration commands. This pseudo-driver allows for an identical controller formulation between both modes. Quantified experimental results are presented.

11:20-11:40 TuR1B.2

Optimal Driving under Traffic Signal Uncertainty, pp. 25-31

Gaspard, Mallory (Cornell University), Vladimirsky, Alexander (Cornell University)

We study driver's optimal trajectory planning under uncertainty in the duration of a traffic light's green phase. We interpret this as an optimal control problem with an objective of minimizing the expected cost based on the fuel use, discomfort from rapid velocity changes, and time to destination. Treating this in the framework of dynamic programming, we show that the probability distribution on green phase durations gives rise to a sequence of Hamilton-Jacobi-Bellman PDEs, which are then solved numerically to obtain optimal acceleration/braking policy in feedback form. Our numerical examples illustrate the approach and highlight the role of conflicting goals and uncertainty in shaping drivers' behavior.

11:40-12:00 TuR1B.3

Optimization in a Traffic Flow Model As an Inverse Problem in the Wasserstein Space, pp. 32-37

Chertovskih, Roman (Porto University), Pereira, Fernando Lobo (Porto University), Pogodaev, Nikolay (Matrosov Institute

for System Dynamics and Control Theory of Sib), Staritsyn, Maxim (Faculdade De Engenharia, Universidade Do Porto, Porto, Portugal)

We address an inverse problem for a dynamical system in the space of probability measures, namely, the problem of restoration of the time-evolution of a probability distribution from certain given statistical information. The dynamics of the distribution is described by a nonlocal continuity equation in the Wasserstein space of probability measures. For the simplest version of this problem, associated with a toy one-dimensional model of traffic flow, we derive a necessary optimality condition and design, on its base, a numerical algorithm of the type of gradient descent. We also discuss some technical aspects of the realization of the elaborated algorithm, and present the results of computational experiments implementing an eloquent numeric scenario.

TuR2A Amphi I

Theoretical and Numerical Advances on the Optimal Control of Complex Systems 2 (Invited Session)

Chair: Bonalli, Riccardo	Université Paris-Saclay, CNRS, CentraleSupélec, Laboratoire Des Signaux Et Systèmes
Co-Chair: Pfeiffer, Laurent	Inria
Organizer: Pfeiffer, Laurent	Inria
Organizer: Bonalli, Riccardo	Université Paris-Saclay, CNRS, CentraleSupélec, Laboratoire Des

14:00-14:20 TuR2A.1

On the Asymptotic Behavior of the Value Function in Large Time Optimal Control Problems (I), pp. 38-43

Askovic, Veljko (Sorbonne Université), Trelat, Emmanuel (University Pierre Et Marie Curie (Paris 6)), Zidani, Hasnaa (ENSTA ParisTech)

We investigate the large time behavior of the value function associated to an optimal control problem in the finite dimensional case. We first establish the large time asymptotic expansion in the linear quadratic (LQ) case using the Hamiltonian structure of the Pontryagin Maximum Principle (PMP) extremal equations and some basic results of LQ theory. We then state, without proof, a general result for dissipative nonlinear systems.

14:20-14:40 TuR2A.2

A Mayer Optimal Control Problem on Wasserstein Spaces Over Riemannian Manifolds (I), pp. 44-49

Jean, Frederic (ENSTA ParisTech), Jerhaoui, Othmane (ENSTA PARIS), Zidani, Hasnaa (ENSTA ParisTech)

This paper concerns an optimal control problem on the space of probability measures over a compact Riemannian manifold. The motivation behind it is to model certain situations where the central planner of a deterministic controlled system has only a probabilistic knowledge of the initial condition. The lack of information here is very specific. In particular, we show that the value function verifies a dynamic programming principle and we prove that it is the unique viscosity solution to a suitable Hamilton Jacobi Bellman equation. The notion of viscosity is defined using test functions that are directionally differentiable in the the space of probability measures.

14:40-15:00 TuR2A.3

Time Minimal Syntheses in the Abnormal Case Using Geometric and Computational Techniques (I), pp. 50-55

Assainova, Olga (L@bISEN), Rouot, Jérémy (L@bIsen)

This article deals with the optimization of chemical network in the frame of geometric optimal control and singularity theory. The objective is to classify the generic syntheses for analytic systems of the form $\dot{q}(t) = X(q(t))+u(t) Y (q(t))$, where the aim is to reach in minimum time a terminal manifold of codimension one. We restrict the study to the three dimensional case considering the McKeithan network for which situations up to codimension 3 have to investigated. We develop symbolic algorithms to derive semi-normal forms and to compute approximations of the strata of the singular set to obtain classification in the generic cases and to illustrate the role of singularity theory in geometric control, in relation with abnormal geodesics and regularity of the value function.

15:00-15:20 TuR2A.4

Multilevel Selective Harmonic Modulation by Duality (I), pp. 56-61

Biccari, Umberto (Fundación Deusto), Zuazua, Enrique (Universidad Autónoma De Madrid)

We address the Selective Harmonic Modulation (SHM) problem in power electronic engineering, consisting in designing a multilevel staircase control signal with some prescribed frequencies to improve the performances of a converter. In this work, SHM is addressed through an optimal control methodology based on duality, in which the admissible controls are piece-wise constant functions, taking values only in a given finite set. To fulfill this constraint, the cornerstone of our approach is the introduction of a special penalization in the cost functional, in the form of a piece-wise affine approximation of a parabola. In this manner, we build optimal multilevel controls having the desired staircase structure.

15:20-15:40 TuR2A.5

Stability of Solutions for Controlled Nonlinear Systems under Perturbation of State Constraints (I), pp. 62-67

Aubin-Frankowski, Pierre-Cyril (INRIA)

This paper tackles the problem of unbounded nonlinear systems under perturbation of some time-varying state constraints. It is shown that, given a trajectory to be approximated, one can find a neighboring one that lies in the interior of the constraints, and which can be made arbitrarily close to the reference trajectory both in L^infty-distance and L^2-control cost. This result is an important tool to prove the convergence of approximation schemes of state constraints based on interior solutions.

15:40-16:00 TuR2A.6

Optimal Control Problems with Non-Control Regions: Necessary Optimality Conditions (I), pp. 68-73

Bayen, Terence (Avignon University), Bouali, Anas (Avignon University), Bourdin, Loïc (University of Limoges)

We consider a smooth control system that is subject to loss of control in the sense that the state space is partitioned into several disjoint regions and, in each region, either the system can be controlled, as usual, in a permanent way (that is, one can change the value of the control at any real time), or, on the contrary, the control has to remain constant from the entry time into the region until the exit time. The latter case corresponds to a non-control region. The objective of this paper is to state the necessary optimality conditions for a Mayer optimal control problem in such a setting of loss of control. Our main result is based on a hybrid maximum principle that takes into account a regional switching parameter.

TuR2B Amphi II

Application in Energy and Power Applications (Regular Session)

Chair: Siguerdidjane, Houria	CentraleSupelec
Co-Chair: Pham, Thanh Hung	CNRS - CentraleSupelec

14:00-14:20 TuR2B.1

Nonlinearity Handling in MPC for Power Congestion Management in Sub-Transmission Areas, pp. 74-79

Pham, Thanh Hung (CNRS - CentraleSupelec), Iovine, Alessio (CNRS, CentraleSupélec), Olaru, Sorin (CentraleSupelec), Maeght, Jean (RTE France Réseau De Transport D'Electricité), Panciatici, Patrick (RTE), Ruiz, Manuel (RTE)

This paper proposes congestion management solutions based on Model Predictive Control (MPC) principles for transmission network

zones. The contribution resides in the use of logical variables for describing the nonlinearities related to the modelling of the physical aspects in power curtailment, or some desired control goals. This allows for the representation of the nonlinear model of a sub-transmission zone with a storage device in a linear Mixed Logical Dynamical (MLD) formulation, then paving the way to the utilisation of linear mixed integer programming for the optimization problem. Moreover, part of the contribution considers supplementary temporal specifications for the energy storage device utilisation. This is modelled using additional temporal and logical variables as part of the system state and control signal. Consequently, the extended model of the power network zone is formulated as a linear MLD system and integrated to the MPC design. The proposed controllers are validated through simulations on an industrial case-study.

14:20-14:40 TuR2B.2

Maximum Power Point Tracking of a Photovoltaic System Using State Feedback Gain Fuzzy Control, pp. 80-85

Chaibi, Redouane (Industrial Technologies and Services Laboratory, Higher School O), El Bachtiri, Rachid (Industrial Technologies and Services Laboratory, Higher School O), El Hammoumi, Karima (Industrial Technologies and Services Laboratory, Higher School O), Mohamed Yagoubi, Mohamed (IMT Atlantique LS2N)

An effective Maximum Power Point Tracking (MPPT) technique, that can be used in a variety of environmental conditions, is tackled with in this note. To this aim, an MPPT control based on a T--S fuzzy model is applied improving thus the performance and the efficiency of a solar photovoltaic (PV) generator. The nonlinear system's dynamics are embedded in a T--S fuzzy model. Sufficient criteria for designing such fuzzy control policy are presented in terms of linear matrix inequalities based on a quadratic Lyapunov function combined with some helpful slack variables (i.e. dilated quadratic LMI conditions). The proposed method reduces tracking time while overcoming the oscillation that usually appear near the maximum powerpoint. Besides, the simulation of a photovoltaic system using the proposed control policy demonstrates the efficiency of the approach even in the case of climate changes.

14:40-15:00 TuR2B.3

Scalable Optimal Control Allocation: Linear and Quadratic Programming Methods Applied to Active Capacitor Balancing in Modular Multilevel Converters, pp. 86-91

Le Goff, Gregoire (LAPLACE, University of Toulouse, CNRS, INPT, UPS), Fadel, Maurice (LAPLACE/ENSEEIHT), Bodson, Marc (Univ. of Utah)

The paper introduces a novel, scalable control allocation (CA) formulation for active capacitor balancing of the Modular Multilevel Converter (MMC). The formulation is obtained by introducing a converter arm model that is also scalable and accommodates an MMC with any number of phases and any number of submodules (SM). The CA algorithm involves the fast real-time minimization of an error cost function formalized as linear programming (LP) and quadratic programming (QP) problems. The real-time coding is implemented in both cases using an interior-point method. A hardware-in-the-loop (HIL) test procedure is used to demonstrate the ability of the CA to perform active capacitor voltage balancing. The influence of QP vs LP on the system behavior is also evaluated, and tracking errors using QP are found to be more evenly distributed than with LP.

15:00-15:20 TuR2B.4

Nonlinear Internal Model Control of Wind Farm Power Optimization under Wake Effect, pp. 92-97

Siguerdidjane, Houria (CentraleSupelec), Hammami, Asma (Automatic Research Laboratory, National Engineering Scool, Tunis)

This paper is dealing with the efficiency of wind power under the wake effect. In our previous work, the efficiency is shown to be first depending on the wind turbine's applied control strategy, besides the influence of the environment topology. It is also widely demonstrated that the wind turbine performance decreases under sudden wind profile variations. Therefore, the first main control objective was to perform an optimal wind power capture, particularly below-rated wind speed, while avoiding substantial loads on the drive train shafts. Herein, the focus is on the wake effect in wind farms. Indeed, a wind farm is often subject to wake effect in addition to wind disturbance, in consequence, the wind turbines may fail in respecting the optimal power production as expected. The second main objective is then to maximize the power extraction under the wake effect. So, as an extension of our previous work, this present one aims to apply nonlinear internal model control to each turbine within a small wind farm and to point out that, it is indeed essential to consider the wake phenomenon to determine the real performance of a wind farm power production. Validation results using a wind farm simulator are provided to illustrate the theoretical developments applied on a single turbine in comparison with our previous work performed without wake effect, as well as using a small windfarm comprising 5 machines.

15:20-15:40 TuR2B.5

Linear Parameter-Varying Model for Prediction of Charge / Discharge Behavior of Tri-Electrode Zinc-Air Flow Battery, pp. 98-103

Lao-atiman, Woranunt (Chulalongkorn University), Olaru, Sorin (CentraleSupelec), Kheawhom, Soorathep (Chulalongkorn University)

Recently, energy storage systems have been a hot topic of research due to their potential to enable the use and integration of renewable energy into a power grid. Zinc-air flow batteries (ZAFBs) are viewed as having significant promise for usage as renewable energy storage devices due to their high energy density and low cost. The battery management system (BMS) for ZAFBs, on the other hand, is still in its infancy, as a precise prediction of their nonlinear behavior is necessary. To address this shortcoming, a linear parameter varying (LPV) model is constructed via a multiple linear time-invariant (LTI) model using charge/discharge current and state of charge (SOC) as scheduling parameters. The model created is validated using a variety of battery data from several experimental batches. According to the discharge current and state of charge, the results reveal that the established LPV model can accurately predict the nonlinear behavior of the ZAFBs. Thus, it is determined that in terms of local accuracy, the LPV model is comparable to the linear model. Furthermore, global accuracy demonstrates that the LPV model outperforms the linear model. This result shows the LPV model's capacity to anticipate the dynamics of ZAFBs and their suitability for usage in the BMS.

15:40-16:00 TuR2B.6

Optimal Control of Wave Energy Devices with Nonlinear Reactive Power Constraints, pp. 104-109

Jain, Jitendra Kumar (Centre for Ocean Energy Research, Maynooth University), Mason, Oliver (Maynooth University), Peña-Sanchez, Yerai (University of the Basque Country), Ringwood, John (Maynooth University)

This paper proposes an optimal control strategy for wave energy devices subject to physical and nonlinear reactive power constraints. Using a pseudospectral Legendre method, optimization is carried out with energy maximization as a target. Physical limitations are applied to the WEC position, velocity, and controller, while a reactive power constraint is added to reduce the negative peaks in the system output power. The optimized velocity of the WEC is used as a reference input to a velocity-following control loop, which tracks it. Since wave energy converters are subjected to parametric uncertainties in stiffness, radiation force coefficients, and physical disturbances, robust backstepping control is employed in the lower-loop to handle these. The proposed control scheme is validated numerically on a cylindrical buoy wave energy converter system.

WeR1A	Amphi I
Differential Games and Uncertainty (Regular Session)	
Chair: Le Menec, Stephane	MBDA France
Co-Chair: Mo, Huadong	University of New South Wales

10:00-10:20 WeR1A.1

Interval Invariance in the Evolutionary Game of Coordination, pp. 110-115

Le Menec, Stephane (MBDA France)

The object of this article is the study of invariant sets in evolutionary games. Proving the invariance of a dynamic system to an invariant set consists in proving that if the system is initialized in the invariant set, then the state of the system remains forever in the invariant set. A (dynamically) invariant system must verify system of equations. Interval analysis makes it possible to prove (exactly) that the contraposition of this system of equations has no solutions. Solving the contraposition of this system consists in proving that there is no state of the invariant set leaving the invariant set (in positive time) according to the dynamics of the system. The studied dynamical systems are evolutionary game theory learning algorithms such as Replicator Dynamic and Best Response. Evolutionary algorithms (differential equations) like Replicator Dynamic allow to calculate Nash evolutionary equilibria (stable Nash under certain conditions) of evolutionary games such as the evolutionary game of coordination that is used for illustration purpose. Evolutionary games can converge to different equilibria depending on the initial condition. It is therefore important to study the invariance of such systems to predict the fixed points of learning algorithms.

10:20-10:40 WeR1A.2

Approximating Solution of Stochastic Differential Games for Distributed Control of a Water Network, pp. 116-121

Misra, Rahul (Aalborg University), Wisniewski, Rafal (Aalborg University), Kallesøe, Carsten Skovmose (Grundfos)

In this work, our objective is to design a distributed optimal control for pumping stations operating in a Water Distribution Network (WDN), where we would like to satisfy consumer demands with minimum energy consumption. The WDN has been modeled using graph theory and stochastic differential equations. This leads to a non-zero sum stochastic differential game. We have approximated the solution of the aforementioned game using Markov chain approximation and combined it with Shapley's algorithm so as to obtain Minimax mixed strategies. Minimax solution can be obtained as a distributed computation at the pumping stations without any knowledge of costs incurred by the other pumping stations. Simulation results on the water network show convergence to an approximate Minimax solution.

10:40-11:00 WeR1A.3

Alternating Direction Method of Multipliers for Solving Joint Chance Constrained Optimal Power Flow under Uncertainties, pp. 122-127

Qin, James (University of New South Wales), Yan, Yifan (Fudan University), Jiang, Rujun (Fudan University), Mo, Huadong (University of New South Wales), Dong, Daoyi (University of New South Wales)

The increasing penetration of renewable energy sources in power system introduces additional load fluctuations. Lack of awareness on them may lead to high risk of system failure. This paper uses joint chance constraints to formulate the optimal power flow (OPF) problem such that all the constraints are satisfied with a predetermined probability. Existing approaches that solve the joint chance constrained (JCC) OPF problem are either over conservative that provide solutions with high economical cost or lack of scalability that incur more computational cost. This paper presents an alternating direction method of multipliers (ADMM) with convex optimization subproblem to solve the JCC OPF, where the computational burden is reduced. In addition, to avoid making assumptions on the uncertainties, the chance constraints are approximated with sample-based approach.

WeR1B	Amphi II
Optimization for Infrastructure Network Resilience (Invited Session)	
Chair: Barros, Anne	CentraleSupelec, University of Paris-Saclay
Co-Chair: Fang, Yi-Ping	CentraleSupelec, University of Paris-Saclay
Organizer: Fang, Yi-Ping	CentraleSupelec, University of Paris-Saclay
Organizer: Barros, Anne	CentraleSupelec, University of Paris-Saclay

10:00-10:20 WeR1B.1

A Distributionally Robust Approach for the Optimal Protection of Power Networks with Endogenous Uncertainty (I), pp. 128-133

Bellè, Andrea (CentraleSupélec, Université Paris-Saclay), Fang, Yi-Ping (CentraleSupelec, University of Paris-Saclay), Zeng, Zhiguo (CentraleSupélec, Université Paris-Saclay), Barros, Anne (CentraleSupelec, University of Paris-Saclay)

Power networks are among the most important infrastructures in any society, and protecting them from a large variety of disruptive events is an essential task. Finding an optimal protection plan often takes the form of a multilevel optimization problem. Recently, approaches based on distributionally robust optimization (DRO) have gained the attention of many scholars. In fact, DRO allows protecting the decision-maker from the ambiguity arising from the imprecisely identified probability distributions of the failure scenarios. In this framework, the probability distribution of the failure scenarios is assumed to be known ambiguously, and contained in an ambiguity set defined by moment-based conditions. In practice, some decisions taken in the protection plan affect the conditions of the ambiguity set. We refer to this situation as DRO with endogenous uncertainty. In this paper, we study the impact of the endogenous uncertainty on the optimal protection plan of a power network, using a numerical example built upon the IEEE 14-bus system with a traditional moment-based ambiguity set.

10:20-10:40 WeR1B.2

Maintenance Planning under Imperfect Monitoring: An Efficient POMDP Model Using Interpolated Value Function (I), pp. 134-141

Roux, Matthieu (Univ. Paris-Saclay, CentraleSupélec), Fang, Yi-Ping (CentraleSupelec, University of Paris-Saclay), Barros, Anne (CentraleSupelec, University of Paris-Saclay)

We develop in this paper a partially observable Markov decision process (POMDP) model for a maintenance planning problem and solve it with an efficient point-based value iteration (PBVI) algorithm. We consider a single-unit system, subjected to random degradation and failures, and for which the current degradation state can be partially observed via an imperfect monitoring system. The system state space is finite, and we model the following maintenance operations: i) perfect inspection, ii) preventive maintenance and iii) corrective maintenance. The goal is to optimize the maintenance policy by taking into account the imperfect monitoring data in order to minimize the expected discounted maintenance cost over an infinite time horizon. We formulate the problem as a POMDP where, at each time step, it should be decided whether or not to conduct a maintenance operation, and if so, which one. To keep the model general and flexible, we suppose that monitoring data are collected every K time steps (i.e. one observation epoch). The model is completed by a constraint imposing that only one maintenance operation can be conducted per observation epoch. Eventually, we solve it using a PBVI algorithm. The value function is approximated by interpolation of grid data points, and new relevant points are dynamically added into the grid where they most improve the value function. This approach is compared to an approximate POMDP modeling based on sample paths; when evaluated in different cost scenarios, the proposed approach systematically finds better maintenance policies for a comparable computation time. The computation of a lower bound

finally proves that we are able to get the optimal value of the problem with satisfying precision.

10:40-11:00 WeR1B.3

Resilience Optimization of Wide-Area Control in Smart Distribution Grids (I), pp. 142-147

Nait Belaid, Youba (CentraleSupélec), Fang, Yi-Ping (CentraleSupelec, University of Paris-Saclay), Zeng, Zhiguo (CentraleSupélec, Université Paris-Saclay), Legendre, Anthony (EDF R&D), Coudray, Patrick (EDF R&D), Barros, Anne (CentraleSupelec, University of Paris-Saclay)

Large-scale power distribution networks rely on the wide-area control (WAC) function to conduct daily grid operations. Grid control is even more critical during extreme events as the WAC function is required to orchestrate the response to contingencies and enhance the power system resilience through failure localization, isolation, and service restoration. Both power and telecommunication domains are involved in control applications, giving rise to multiple cyber-physical interdependencies. This paper proposes a resilience-based optimization of the distribution service restoration (DSR) by coordinating strategies of crew dispatch and manual/remote switches operation. The telecommunication service and underlying infrastructure are identified as main enablers of the co-optimization as all considered resilience strategies communicate with the control center that collects crisis management information. Therefore, the availability of telecom points in terms of power supply is examined in this work. Failure propagation in the coupled power-telecom network is highlighted, and differences in failure propagation between overhead and underground power lines are explored. The proposed approach is formulated as a mixed-integer linear programming (MILP) model, evaluated under a multi-feeder interdependent power-telecom test network. Results show that combined scheduling of resilience strategies as well as prioritization of power supply to telecom points-of-interest, yield an enhanced recovery strategy. Keywords: Wide Area Control, Resilience, Distribution Service Restoration, Extreme Event, MILP.

WeR2A Amphi I

Data-Based Optimal Control (Regular Session)

Chair: Stoican, Florin — Politehnica University of Bucharest

Co-Chair: Shokry, Ahmed — Ecole Polytechnique

12:00-12:20 WeR2A.1

Health-Constrained Explicit Model Predictive Control Based on Deep-Neural Networks Applied to Real-Time Charging of Batteries, pp. 148-153

Shokry, Ahmed (Ecole Polytechnique), Moulines, Eric (Ecole Polytechnique, Centre De Mathématiques Appliquées (CMAP))

The application of Model Predictive Control (MPC) for optimal real-time battery charging is attracting growing interest due to its advantages over empirical charging protocols. However, the high complexity and nonlinearity of physics-based models of batteries can hinder MPC applications due to the large computational resources required online. To overcome this challenge, this paper proposes a machine learning (ML) based explicit MPC method for battery charging subjected to health constraints. The method uses deep artificial neural networks (DANNs) to construct offline control laws that describe the optimal charging current as a function of the state of the battery. These DANN-based control laws are developed using data generated by solving the MPC problem using the physics-based model of the battery and considering different expectations for the initial state of the battery. These control laws can then be used online to control the charging process by calculating the optimal closed-loop current via simple and inexpensive predictions. The method is applied to a case study of battery charging based on MPC, and the results prove the capabilities of the DANN-based control laws in terms of i) very high prediction accuracy of the closed-loop profiles of the charging current, ii) good ability to learn the constraints imposed on the MPC problem from the data, and iii) significant reduction in the required computation time compared to traditional MPC.

12:20-12:40 WeR2A.2

Generalized Feedforward Control Using Physics-Informed Neural Networks, pp. 154-159

Bolderman, Max (Eindhoven University of Technology), Fan, Daiwei (Eindhoven University of Technology), Lazar, Mircea (Eindhoven Univ. of Technology), Butler, Hans (Eindhoven University of Technology)

The improvements in tracking performance resulting from inversion-based feedforward controllers are limited by the accuracy of the available model describing the inverse system dynamics. For this reason, the use of neural networks (NNs) as a model parameterization is growing in popularity. However, training black-box NNs to represent a general description of the inverse dynamics while respecting physical laws turns out to be troublesome, especially in situations where the training data does not cover the full domain of interest. In order to solve this, this paper adopts physics-informed neural networks (PINNs) for identification of the inverse system dynamics. Additionally, a method is proposed that enables a form of graceful degradation by having the PINN feedforward controller obey an a priori known physical model when it is operated on conditions that were not present in the training data.

12:40-13:00 WeR2A.3

Investigation of Alternative Measures for Mutual Information, pp. 160-165

Kuskonmaz, Bulut (Aalborg University), Gundersen, Jaron Skovsted (Aalborg University), Wisniewski, Rafal (Aalborg University)

Mutual information I(X;Y) is a useful definition in information theory to estimate how much information the random variable Y holds about the random variable X. One way to define the mutual information is by comparing the joint distribution of X and Y with the product of the marginals through the KL-divergence. If the two distributions are close to each other therewill be almost no leakage of X from Y since the two variables are close to being independent. In the discrete setting the mutual information has the nice interpretation of how many bits Y reveals about X and if I(X;Y) = H(X) (the Shannon entropy of X) then X is completely revealed. However, in the continuous case we do not have the same reasoning. For instance the mutual information can be infinite in the continuous case. This fact enables us to try different metrics or divergences to define the mutual information. In this paper, we are evaluating different metrics or divergences such as Kullback-Liebler (KL) divergence, Wasserstein distance, Jensen-Shannon divergence and total variation distance to form alternatives to the mutual information in the continuous case. We deploy different methods to estimate or bound these metrics and divergences and evaluate their performances.

WeR2B Amphi II

Computational Methods for Optimal Control (Regular Session)

Chair: Fantuzzi, Giovanni — Imperial College London

Co-Chair: Mykhailiuk, Ivan — University of Bremen

12:00-12:20 WeR2B.1

Lyapunov Function Computation for Periodic Linear Hybrid Systems Via Handelman, Polya and SoS Approaches: A Comparative Study, pp. 166-171

Toso, Leonardo Felipe (Laboratoire Des Signaux Et Systèmes (L2S)), Valmorbida, Giorgio (L2S, CentraleSupelec)

We propose a method for the stability analysis of linear hybrid systems with periodic jumps. The method relies on the solution to polynomial inequalities based on the Handelman decomposition. Compared to existing approaches, such as sum-of-squares (SoS) and Polya's theorem, the proposed method reduces the computation time to obtain stability certificates.

12:20-12:40 WeR2B.2

Verification of Some Functional Inequalities Via Polynomial Optimization (I), pp. 172-177

Fantuzzi, Giovanni (Imperial College London)

Motivated by the application of Lyapunov methods to partial differential equations (PDEs), we study functional inequalities of the form f(I_1(u),...,I_k(u))⩾0 where f is a polynomial, u is any function satisfying prescribed constraints, and I_1(u),...,I_k(u) are integral functionals whose integrands are polynomial in u, its derivatives, and the integration variable. We show that such functional inequalities can be strengthened into sufficient polynomial inequalities, which in principle can be checked via semidefinite programming using standard techniques for polynomial optimization. These sufficient conditions can be used also to optimize functionals with affine dependence on tunable parameters whilst ensuring their nonnegativity. Our approach relies on a measure-theoretic lifting of the original functional inequality, which extends both a recent moment relaxation strategy for PDE analysis and a dual approach to inequalities for integral functionals.

12:40-13:00 WeR2B.6

Parametric Stability Score and Its Application in Optimal Control, pp. 178-183

Mykhailiuk, Ivan (University of Bremen), Schäfer, Kai (University of Bremen), Büskens, Christof (Univ of Bremen)

Optimization problems in the context of real-world applications often suffer from having multiple local solutions. When parameters within such a problem change, the corresponding solutions might differ significantly. However, it can be of interest for a practitioner to remain close to a nominal solution. In this work, we propose a novel concept to evaluate and compare the quality of local solutions with respect to parameter perturbations. We introduce the parametric stability score, which represents the largest possible perturbation magnitude such that the solution of a perturbed problem remains within user-defined bounds. It is defined as a global solution of a nonlinear bilevel program. In addition to a formal definition, we provide an efficient way to approximate the score numerically based on parametric sensitivity analysis. As an application scenario, we consider the optimal control of a pendulum on a cart. The model equations feature physical parameters that undergo perturbations. We obtain two different local solutions of the optimal control problem and calculate their stability scores. Our results indicate that a solution with a better cost does not necessarily have a better stability score. Finally, we validate the results by showing numerically that our approximations predict the actual stability score sufficiently well.

ThR1A Amphi I

Optimization and Control of Biological Systems (Invited Session)

Chair: Gonzalez, Alejandro, Hernan	Institute of Technological Development for the ChemicalIndustry (INTEC), CONICET-UNL
Co-Chair: Ferramosca, Antonio	Univeristy of Bergamo
Organizer: Hernandez Vargas, Esteban A.	UNAM
Organizer: Gonzalez, Alejandro, Hernan	Institute of Technological Development for the ChemicalIndustry
Organizer: Ferramosca, Antonio	Univeristy of Bergamo

10:00-10:20 ThR1A.1

Parameter Estimation in Hybrid Machine Learning and Mechanistic Models of Infectious Diseases (I), pp. 184-189

Jhutty, Suneet Singh (Goethe University Frankfurt, Frankfurt Institute for Advanced St), Hernandez Vargas, Esteban A. (UNAM)

Infectious diseases are one of the biggest public health threats. The development of new avenues to integrate the complex interactions between pathogens and the host immune system is central to tackle outbreaks and pandemics. In the last two decades, mathematical modeling by differential equations has played an important role to interpret experimental results on quantitative grounds providing relevant insights to understand several infectious diseases. However, abstracting the complex mechanisms of the immune system can result in models with a large number of equations and consequently parameters to be estimated. Parameter fitting consists on the estimation of model parameters based on experimental data from the studied process, which can be considered as a nonlinear optimization problem. Hybrid models with machine learning methods have the potential to incorporate data sets of different immune mechanisms and scales in a black-box manner, while the well-known process-related principles are represented by mechanistic models. However, identifiability can be a key obstacle to overcome towards mathematical models with predictive value. Based on the differential evolution algorithm, this paper evaluates the potential use of hybrid models while keeping the capacity to recover the parameters in the mechanistic models to represent viral infections at a host level.

10:20-10:40 ThR1A.2

Permanence Regions for Switched Linear Systems under Waiting-Time Constraints (I), pp. 190-195

Perez, Mara (Intec - Conicet - Unl), Anderson, Alejandro (INTEC-CONICET-UNL), Hernandez Vargas, Esteban A. (UNAM), Gonzalez, Alejandro, Hernan (Institute of Technological Development for the ChemicalIndustry), Actis, Marcelo Jesús (CONICET-FIQ-UNL)

Switched systems provide a suitable framework for a wide variety of biological and biomedical systems where each mode refers to a different control measure. The waiting-time constraints - bounds on the maximal and minimal time of permanence in a mode - are critical limitations to be considered in these kind of applications, since they modify their intrinsic dynamics. As a result, some basic concepts such as equilibria, stability regions and invariant regions need to be updated. In this work some novel concepts concerning generalized permanence regions for these dynamics are proposed and three different algorithms that compute permanence regions out of the origin are presented. The theoretical results are tested via simulation examples, one of them concerning a population ecological system.

10:40-11:00 ThR1A.3

Optimal Responses to Constrained Bolus Inputs to Models of T1D (I), pp. 196-201

Townsend, Christopher (University of Newcastle), Seron, Maria (The Univ of Newcastle), Magdelaine, Nicolas (L@bISEN)

We characterise the bolus insulin input which minimises the maximum plasma glucose concentration predicted by the Magdelaine and Bergman minimal models in response to any positive bounded disturbance whilst remaining above a fixed lower plasma glucose concentration. This characterisation is in terms of the maxima and minima of the plasma glucose concentration and limits the controllability of such systems. Any further attempt to lower the maximum plasma glucose concentration will result in hypoglycaemia.

11:00-11:20 ThR1A.4

Artificial Pancreas under Periodic MPC for Trajectory Tracking: Handling Circadian Variability of Insulin Sensitivity (I), pp. 202-207

Abuin, Pablo (CONICET-UNL), Ferramosca, Antonio (Univeristy of Bergamo), Toffanin, Chiara (University of Pavia), Magni, Lalo (Univ. of Pavia), Gonzalez, Alejandro, Hernan (Institute of Technological Development for the ChemicalIndustry)

Closed-loop glycemic control algorithms have demonstrated the ability to improve glucose regulation in patients with type 1 diabetes mellitus (T1D), both in silico and clinical trials. Many of the proposed control strategies have been developed, based on time-invariant linear models, without considering the parametric variations of T1DM subjects. In this work, a pulsatile Zone Model Predictive Control (pZMPC) is proposed, which explicitly considers patterns of intra-day insulin sensitivity (SI), according to the latest updates of the FDA-approved UVA/Padova simulator. Results show a significant improvement in the performance, which a-priori justifies the increment in the controller complexity.

11:20-11:40 ThR1A.5

Optimal Single-Interval Control for SIR-Type Systems (I), pp. 208-213

Gonzalez, Alejandro, Hernan (Institute of Technological Development for the ChemicalIndustry), Ferramosca, Antonio (Univeristy of Bergamo), Hernandez Vargas, Esteban A. (UNAM)

Although modeling studies are focused on the control of SIR-based systems describing epidemic data sets (recently coming from the different variants of the SARS-CoV-2), few of them present a formal dynamic characterization in terms of the two main indexes: the infected peak prevalence (IPP), and the final epidemic size (EFS). These indices are directly related to equilibrium sets and stability, which are crucial concepts to understand what the government can (and cannot) do to handle an epidemic, by means of non-pharmaceutical interventions such as social distancing, isolation measures, mask-wearing, among others. The objective of this work is to provide a theoretical single interval control strategy that simultaneously minimizes the EFS while maintaining the IPP arbitrary low, according to health system capacity limitations. Several simulations illustrate the true role of the herd immunity threshold and provide new insight into the way authorities may act.

11:40-12:00 ThR1A.6

Optimal Control of Microbial Production in the Chemostat, pp. 214-219

Bayen, Terence (Avignon University), Cazenave-Lacroutz, Henri (Avignon Université), Coville, Jerome (INRAE Avignon Centre De Recherche PACA), Mairet, Francis (Ifremer)

In this work, we study the problem of maximizing microbial production within a continuous stirred-tank reactor with many species competing over a same substrate. The interaction between species is described by the chemostat system including a mutation factor. The optimization problem falls into an optimal control problem of Lagrange type in which the control parameter is the

dilution rate of the reactor. Thanks to the Pontryagin Maximum Principle, we obtain necessary conditions on optimal controls that involve a singular arc. These computations are highlighted thanks to numerical simulations via a direct method. We also study the related optimization problem at steady-state which provides an insight into optimal solutions of the optimal control problem in terms of turnpike phenomenon.

ThR1B	Amphi II
Topics in Optimal Control (Regular Session)	
Chair: Bonalli, Riccardo	Université Paris-Saclay, CNRS, CentraleSupélec, Laboratoire Des Signaux Et Systèmes
Co-Chair: Courtial, Estelle	Université D'Orléans

10:00-10:20 ThR1B.1

High-Fidelity Quantum State Transfer by Pontryagin Maximum Principle, pp. 220-225

Binandeh Dehaghani, Nahid (University of Porto), Pereira, Fernando Lobo (Porto University)

High-fidelity quantum state transfer is an essential part of quantum information processing. In this regard, we address the problem of maximizing the fidelity in a quantum state transformation process subjected to Liouville-von Neumann equation. By introducing fidelity as the performance index, we aim at maximizing the similarity of the final state density operator with the one of the desired target state. Optimality conditions in the form of a Maximum Principle of Pontryagin are given for the matrix-valued dynamic control systems propagating the probability density function. These provide a complete set of relations enabling the computation of the optimal control strategy.

10:20-10:40 ThR1B.2

Control Strategies with Multiple Closing Instants for Linear Optimal Control Problems with Disturbances, pp. 226-231

Dmitruk, Natalia (Belarusian State University), Kastsiukevich, Dzmitry (Belarusian State University)

This paper deals with an optimal control problem for a linear discrete system subject to input and state constraints and unknown bounded disturbances, where the control goal is to minimize a cost function used in linear explicit model predictive control. Since open-loop worst-case solution is conservative or may suffer feasibility problems and dynamic programming solution is computationally demanding, we propose a compromise between those solutions. This compromise is an optimal control strategy that takes into account the state measurements of the system at several future time instants (closing instants). We define control strategies with one and multiple closing instants and propose efficient numerical methods for their construction.

10:40-11:00 ThR1B.3

On Some Regularization of the Control Problem for a Tracked Mobile Robot in a Steady Flow Field under State Constraints, pp. 232-236

Chertovskih, Roman (Porto University), Daryina, Anna (Federal Research Center «Computer Science and Control» of Russia), Karamzin, Dmitry (Federal Research Center), Pereira, Fernando Lobo (Porto University)

In this article, we consider the time-optimal motion for a tracked mobile robot in the presence of state constraints. The complexity of the problem statement is due to a steady vector flow field in which the motion is examined. The difficulty of the considered model is also constituted by a non-regular dynamics with respect to the state constraints. A method for regularisation is proposed. Such a method uses specific eps-perturbations of the original problem, regular in the needed sense.

11:00-11:20 ThR1B.4

Some Remarks on the Issue of Second-Order Optimality Conditions in Control Problems with Mixed Constraints, pp. 237-241

Arutyunov, Aram V. (Peoples Friendship Univ.of Russia), Karamzin, Dmitry (Federal Research Center), Pereira, Fernando Lobo (Porto University)

A smooth optimal control problem with mixed constraints is considered. Under the normality assumption some proof of second-order necessary optimality conditions based on the Robinson stability theorem is proposed. The main feature of the obtained result is that the local regularity with respect to the mixed constraints is assumed, that is, a regularity in an eps-tube about the minimizer, but not the conventional global regularity hypothesis. This impacts the maximum condition. Therefore, the normal set of Lagrange multipliers fulfills the Legendre-Clebsch condition and the maximum principle. At the same time, the maximum condition is modified as the maximum is taken over a reduced feasible set. Further, the case of abnormal minimizers is considered. The same type of reduced maximum condition is obtained along with a refined Legendre-Clebsch condition which is meaningful in the abnormal case.

11:20-11:40 ThR1B.5

First-Order Constrained Optimization: Non-Smooth Dynamical System Viewpoint, pp. 242-247

Schechtman, Sholom (École Polytechnique), Tiapkin, Daniil (HSE University), Moulines, Eric (ENST-Paris), Jordan, Michael I. (University of California, Berkeley), Muehlebach, Michael (ETH Zurich)

In a recent paper, Muehlebach et al. proposed a novel algorithm for constrained optimization based on the ideas of nonsmooth dynamical systems. In this work, we extend these ideas in several important directions: (i) we provide existence and convergence results for continuous-time trajectories and (ii) we provide a convergence guarantee for a perturbed version of the discrete-time version of the algorithm (covering stochastic gradient updates), for non-convex and non-smooth objective functions. Our analysis framework rationalizes the continuous-time and discrete-time cases, which not only provides an important intuition, but could also enable convergence proofs for accelerated or Newton-like versions of our algorithm.

11:40-12:00 ThR1B.6

Ensemble Control of Dynamic Systems with Square Impulses, pp. 248-253

Staritsyn, Maxim (Faculdade De Engenharia, Universidade Do Porto, Porto, Portugal), Goncharova, Elena (Institute for System Dynamics and Control Theory SB RAS), Pereira, Fernando Lobo (Porto University)

In the article, the basic mathematical concepts of quadratic-impulse control are extended to dynamical systems in the space of probability measures (local continuity equations) representing dynamic ensembles of (infinitely many) homotypic individuals. Starting from a model with quadratic dependence on an unbounded control, we constructively design its impulsive trajectory extension, which, as a byproduct, ensures also the well-posedness of an associated optimal control problem. The main attention is paid to the characteristic control ODE whose extension combines a discontinuous time change with a convexification of the velocity set via generalized controls. Finally, we show that it is possible to exclude the generalized controls and represent extended states as impulsive solutions of a measure-driven ODE. The resulting impulsive continuity equation can be viewed as a measure-driven equation in the space of measures.

ThR2A	Amphi I
Path Planning and Routing (Regular Session)	
Chair: Bertrand, Sylvain	ONERA
Co-Chair: Iovine, Alessio	CNRS, CentraleSupélec

13:30-13:50 ThR2A.1

Vessel Passage Scheduling through Cascaded Bridges Using

Mixed-Integer Programming, pp. 254-259

Segovia, Pablo (Delft University of Technology), Negenborn, Rudy (Delft University of Technology), Reppa, Vasso (Delft University of Technology)

This paper addresses the problem of guaranteeing efficient inland waterway transport in the presence of sequential movable bridges, which must be operated to grant vessel passage. The main contribution is the formulation of the vessel passage scheduling problem as a mixed-integer programming problem. The scheduling algorithm receives vessel widths and voyage plans, and determines feasible vessel passage through bridges that best matches vessel plans. Process optimization is carried out using a rolling horizon implementation to keep the problem computationally tractable in real-time applications. Finally, a realistic case study based on the Rhine-Alpine corridor is used to test the approach and demonstrate its effectiveness.

13:50-14:10 ThR2A.2

Polyhedral Potential Field Constructions for Obstacle Avoidance in a Receding Horizon Formulation, pp. 260-265

Nicu, Theodor-Gabriel (Politehnica University of Bucharest), Stoican, Florin (Politehnica University of Bucharest, Associate Researcher LOS), Prodan, Ionela (INP Grenoble)

We revisit and enhance previous work pertaining to the use of polyhedral potential fields for motion planning in a receding horizon framework. We adapt the standard vertex-based mixed-integer (MI) representations of piecewise affine functions and propose three equivalent formulations which balance the complexity of the geometric representation with the size of the associated MI representation. In all cases, we arrive at formulations whose polyhedral support comes (either directly or as a refinement of it) from an associated hyperplane arrangement induced by the hyperplanes bounding the polyhedral obstacles.

14:10-14:30 ThR2A.3

Path Generation Based on Convex Lifting: Optimization of the Corridors, pp. 266-271

Mirabilio, Marco (University of L'Aquila), Olaru, Sorin (CentraleSupelec), Dorea, Carlos E. T. (Universidade Federal Do Rio Grande Do Norte), Iovine, Alessio (CNRS, CentraleSupélec), Di Benedetto, M. Domenica (Univ of L'Aquila)

The capability to compute a partition of a cluttered environment starting from the obstacles that lie in it enables the construction of a route connecting an initial point to a desired final one. In this paper, we revisit the convex lifting method for the computation of a suitable partition of the cluttered environment with the objective to propose a systematic procedure of reorganization of the cells within the partition in order to repel their boundaries from the obstacles. The ultimate goal is the construction of a connecting-path between an initial point and a final point characterized by a corridor with improved width guaranteeing the collision avoidance. The qualities of the corridors will impact the constraints on the motion of the controlled agent and consequently the real-time performance and robustness of the navigation in a cluttered environment.

ThR2B Amphi II

Optimization Methods for Time-Delay Systems (Regular Session)

Chair: Dorea, Carlos E. T. — Universidade Federal Do Rio Grande Do Norte

Co-Chair: Morato, Marcelo Menezes — Universidade Federal De Santa Catarina

13:30-13:50 ThR2B.1

Computation of Low Complexity Invariant Sets for Time-Delay Systems: An Optimization-Based Approach, pp. 272-277

Dorea, Carlos E. T. (Universidade Federal Do Rio Grande Do Norte), Olaru, Sorin (CentraleSupelec)

In this paper we propose an optimization approach to compute low-complexity polyhedral invariant sets for discrete-time linear systems affected by delay, based on structural properties related to set factorization. A similarity transformation is conceived as a design tool to bring the dynamic matrix of an augmented representation of the delay difference equation to a block companion form for which low dimensional polyhedral invariant sets with fixed complexity can be found. An optimization problem is formulated to simultaneously compute the similarity transformation and the invariant polyhedron of pre-defined complexity. Numerical experiments illustrate the efficiency of the proposed approach.

13:50-14:10 ThR2B.2

TDS-CONTROL: A MATLAB Package for the Analysis and Controller-Design of Time-Delay Systems, pp. 278-283

Appeltans, Pieter (KU Leuven), Silm, Haik (KU Leuven), Michiels, Wim (KU Leuven)

This paper presents TDS-CONTROL, a MATLAB package for the analysis and design of controllers for linear time-invariant systems with discrete delays. The code is based on a state-space representation of such systems in terms of delay-differential algebraic equations with input, output, and state delays. As such, a broad class of (interconnected) systems can be considered, including neutral systems. The controller design algorithms are based on optimizing a certain objective function, such as the spectral abscissa, the H-infinity norm, or the pseudo-spectral abscissa, with respect to the controller parameters. For example, to design a stabilizing controller the spectral abscissa, i.e., the real part of the right-most characteristic root, is minimized. As a strictly negative spectral abscissa is a necessary and sufficient condition for stability, the presented design method is not conservative and a stabilizing controller can be computed whenever it exits. This comes however at the cost of having to solve a non-smooth, non-convex optimization problem. The class of considered controllers consists of static and dynamic output-feedback controllers. By allowing to fix certain entries in the controller matrices, it is also possible to design structured controllers such as decentralized, overlapping and PID controllers. Finally, as a wide-range of delay systems can be considered, the software package takes the sensitivity of certain quantities, such as the spectral abscissa and the H-infinity norm, with respect to infinitesimal delay perturbations explicitly into account.

14:10-14:30 ThR2B.3

Explicit Dead-Time Compensation in Linear Parameter Varying Model Predictive Control, pp. 284-289

Morato, Marcelo Menezes (Universidade Federal De Santa Catarina), Santos, Tito (Federal University of Bahia), Normey-Rico, Julio Elias (Federal Univ of Santa Catarina)

Model Predictive Control (MPC) is able to directly deal with dead-time (DT) phenomena. Yet, implicit delay compensation heavily affects computational aspects of these algorithms, and stability and feasibility analyses become numerically tougher. The Linear Parameter Varying (LPV) framework has been shown suitable to model complex, nonlinear dynamics, with corresponding MPC algorithms being developed over the last few years. Thus, we propose a novel MPC method for DT LPV systems, using a DT-free model. The scheme explicitly accounts for the DT via a compensation loop, thus avoiding augmented state-space models. The algorithms is able to ensure input-to-state stability, recursive feasibility, and robust constraint satisfaction w.r.t. model-mismatches and delay estimation uncertainties. A solar collector benchmark example is used to illustrate the advantages of the method, which is compared against a regular LPV MPC algorithm (with standard implicit DT compensation).

ThR3A Amphi I

MPC (Regular Session)

Chair: Girard, Antoine — CNRS

Co-Chair: Rodriguez-Ayerbe, Pedro — Supelec

16:00-16:20 ThR3A.1

Approximating Optimal Control by Shrinking Horizon Model Predictive Control for Spacecraft Rendezvous and Docking, pp. 290-295

Ye, Mingfei (University of Michigan), Kolmanovsky, Ilya V. (University of Michigan)

The paper considers shrinking horizon model predictive control (MPC) as an approximation to the optimal finite horizon control. Recent theoretical results bounding the error of such an approximation in terms of the discretization time-step and accuracy of the preview are discussed, and illustrated/confirmed through a computational case study of spacecraft rendezvous and docking. In addition, we consider the effects of inexactness in solving the optimization problem in the shrinking horizon MPC and examine properties and benefits of the implementation based on a gradient descent method with warm-starting and a varying number of iterations per time step.

16:20-16:40 ThR3A.2

Predictive and Symbolic Control: Performance and Safety for Non-Linear Systems, pp. 296-301

Azaki, Zakeye (Université Grenoble Alpes), Girard, Antoine (CNRS), Olaru, Sorin (CentraleSupelec)

Although Model Predictive Control (MPC) has proven its efficiency in the process operation and it is known for its high performance, it also suffers from design limitation. One of the fundamental issues for such an optimization-based technique is the difficulty to guarantee recursive feasibility in the absence of terminal constraints, or alternatively, the complexity of design when a certain basin of attraction or a controlled invariant set needs to be certified for the closed loop in the most general nonlinear setting. Based on symbolic control techniques, this paper proposes a simple and guaranteed solution for such problems. As a main result, a Symbolically guided Model Predictive Control scheme is developed. This controller is an improved version of the generic MPC approach such that the recursive feasibility is guaranteed through appending time-varying terminal constraints, carefully designed using the symbolic control approach, to the optimization problem of the original MPC formulation.

16:40-17:30 ThR3A.3

A Tree-Based Multi-Scenario Approach to Networked MPC under Packet Losses and Disturbances, pp. 302-307

Arauz, Teresa (Universidad De Sevilla), Maestre, Jose M. (University of Seville), Cetinkaya, Ahmet (National Institute of Informatics), Stoica Maniu, Cristina (CentraleSupélec/Laboratoire De Signaux Et Systèmes)

Systems with elements linked via a communication network are vulnerable to communication problems and attacks of malicious agents, with potentially harmful consequences for performance and stability. This paper proposes a stochastic Model Predictive Control (MPC) scheme to deal with two different sources of uncertainties simultaneously, namely, packet losses and external disturbances. In particular, the controller deals with packet losses using a tree-based approach and is robustified against external disturbances using a multiple scenario approach. Finally, the algorithm performance is compared via simulation with other MPC alternatives and a feedback control law.

17:00-17:20 ThR3A.4

Predictive Control Based on Stochastic Disturbance Trajectories for Congestion Management in Sub-Transmission Grids, pp. 308-313

Dkhili, Nouha (CentraleSupélec - Université Paris-Saclay), Olaru, Sorin (CentraleSupelec), Iovine, Alessio (CNRS, CentraleSupélec), Ruiz, Manuel (RTE), Maeght, Jean (RTE France Réseau De Transport D'Electricité), Panciatici, Patrick (RTE)

The energy transition of power grids is accompanied by a slew of new challenges arising at the design, deployment and operation levels. From the control viewpoint, the integration of renewable-energy-based power generation sources into the power grid translates into emerging uncertainties which compromise the system's stability and performance. In this paper, the main goal is to propose a model-based predictive controller that incorporates the stochastic nature of these sources into its decision-making, in order to balance upholding operational constraints with smart power generation curtailment and energy storage strategies.

17:20-17:40 ThR3A.5

On the Link between Explicit MPC and the Face Lattice of the Lifted Feasible Domain, pp. 314-319

Mihai, Sergiu-Stefan (Politehnica University of Bucharest), Stoican, Florin (Politehnica University of Bucharest, Associate Researcher LOS), Ciubotaru, Bogdan D. (Faculty of Automatic Control and Computers, Polytechnic Universi)

The paper provides a geometric interpretation for the explicit solution of the quadratic cost, linear-constrained MPC (model predictive control) problem. We link the face lattice of the lifted feasible domain (defined in the input and parameter space) with the critical regions which partition the parameter space and serve as polyhedral support for the piecewise affine explicit MPC solution. We provide geometric (face visibility) and algebraic (polyhedron emptiness) tests for the pruning of the candidate sets of active constraints.

17:40-18:00 ThR3A.6

Robustness of PWA Control Based on a Coupled Vertex Sensitivity Analysis, pp. 320-325

Yang, Songlin (CentraleSupele, Paris Saclay University), Olaru, Sorin (CentraleSupelec), Rodriguez-Ayerbe, Pedro (Supelec), Dorea, Carlos E. T. (Universidade Federal Do Rio Grande Do Norte)

Under the vertex representation for the state partitions, this paper studies the robustness of PWA control for constrained discrete-time linear systems. In particular, the aim is to evaluate the impact of uncertainty in the representation of state-space partition. Practically, the notion of coupled vertex sensitivity (CVS) is defined to inscribe the joint uncertainty in the vertex positioning. This novel concept reduces the computational complexity and the conservativeness of the construction compared to the use of independent vertex perturbation through the iterative procedure using the existing results. A numerical example illustrated the effectiveness of our work.

ThR3B Amphi II

Optimization-Based Applications (Regular Session)

Chair: Klauco, Martin — Slovak University of Technology in Bratislava

Co-Chair: Sandou, Guillaume — SUPELEC

16:00-16:20 ThR3B.1

Moving Horizon Estimator with Filtering and Adaptive Sampling, pp. 326-331

Oliva, Federico (Tor Vergata University of Rome), Carnevale, Daniele (Universita' Di Roma , Tor Vergata)

Optimisation based algorithms known as Moving Horizon Estimator (MHE) have been developed through the years. In this work, we propose two solutions to decrease the computational cost of MHE, limiting its applicability in real-time applications. The proposed solutions rely on output filtering and adaptive sampling. The use of filters reduces the total amount of data by shortening the length of the moving window (buffer) and consequently decreasing the time consumption for plant dynamics integration. The proposed adaptive sampling policy allows for discarding data that do not yield significant improvements in the estimation error. Simulations on several cases are provided to corroborate the effectiveness of the proposed strategies.

16:20-16:40 ThR3B.2

Nearly Optimal Tunable MPC Strategies on Embedded Platforms, pp. 332-337

Kiš, Karol (Slovak University of Technology in Bratislava), Bakaráč, Peter (Slovak University of Technology in Bratislava), Klauco, Martin (Slovak University of Technology in Bratislava)

We present an embeddable optimization-free application of a near-optimal MPC implementation with continuous tuning capabilities. We propose a strategy combining the advantages of explicit model predictive control with tunable properties that are implementable on embedded platforms with limited memory and computational resources. We consider a neural network (NN) learning procedure to mimic the control actions of an MPC strategy. While acknowledging limited guarantees on the constraints satisfaction with just the NN-based controller, we introduce an optimization-based corrector of the mimicked control action. Such a corrector then steers the control authority of the mimicked controller such that constraints on manipulated and process variables are enforced. To demonstrate the efficacy of the proposed control strategy, a case study implemented on an embedded platform is shown.

16:40-17:30 ThR3B.3

Optimization of Start-Up Operation for Centrifugal Chiller, pp. 338-343

Okazaki, Hirotaka (Mitsubishi Heavy Industries, Ltd), Ono, Hitoi (Mitsubishi Heavy Industries), Yanai, Noritaka (Mitsubishi Heavy Industries)

In this study, we derived an operating profile that minimizes startup time using a rigorous physical model that takes into account the characteristics of the compressors and heat exchangers that make up a centrifugal chiller, as well as the phase change and flow of the refrigerant. As an optimization method, we used the direct method of transforming the original infinite optimal control problem into a finite-dimensional nonlinear programming problem. We were able to derive an operation profile that reduces the startup time while satisfying the constraints compared to conventional operations and confirmed that the model and optimization method are effective for optimal design of equipment and control logic.

17:00-17:20 ThR3B.4

Model Predictive Control Prototyping and Validation for a Large Central Cooling System, pp. 344-349

Heidari, Rahmat (University of Newcastle), Braslavsky, Julio H. (Commonwealth Scientific and Industrial Research Organisation (CS)

In this paper we present an application of Model Predictive Control (MPC) to a commercial building cooling system. The MPC models are a combination of white, grey and black box models derived from the experimental dataset and ensure energy and mass conservation is the system. Individual equipment models as well as the whole-system model are validated against the actual measurements to ensure they accurately represent the physical system. Results and the lessons learnt in this practice are summarised.

17:20-17:40 ThR3B.5

Four MPC Implementations Compared on the Quadruple Tank Process Benchmark : Pros and Cons of Neural MPC, pp. 350-355

Blaud, Pierre (IMT Atlantique), Chevrel, Philippe (IMT Atlantique / LS2N), Claveau, Fabien (Ecole Des Mines De Nantes), Haurant, Pierrick (IMT Atlantique), Mouraud, Anthony (CEA)

This study aims to aid understanding of Model Predictive Control (MPC) alternatives through comparing most interesting MPC implementations. This comparison will be performed intrinsically and illustrated using the four-tank benchmark, widely studied by academics taking care of industrial perspectives. Although MPC provides advanced control solutions for a wide class of dynamical systems, challenges arise in managing the compromise between accuracy, computational cost and resilience, depending on the type of model used. In this study, linear, linear time-varying and non-linear MPCs are compared to MPC that uses a neural network based predictive model identified from data. The tuning and implementation methods considered are discussed, and accurate simulation results provided and analyzed. Precisely, the performance of each method (linear, linear time-varying, non-linear MPC) are compared to the neural MPC. Pros and cons of neural MPC are highlighted.

17:40-18:00 ThR3B.6

Controllability and Optimal Control Design for an Elastic Rod Actuated by Piezoelements, pp. 356-361

Kostin, Georgy (Ishlinsky Institute for Problems in Mechanics RAS), Gavrikov, Alexander (Ishlinsky Institute for Problems in Mechanics RAS)

The study is aimed at the optimal control design of longitudinal motions for a rectilinear elastic rod with free ends. Several piezoelectric actuators are attached along its axis. The control is carried out by piezoelectric normal force acting in the cross section. We assume that this force changes piecewise constantly in space, and the intervals of constancy have no gaps and are equal in length. Given an arbitrary initial state and periodic terminal conditions, the optimal control problem is to minimize the mean mechanical energy stored in the rod over a fixed time horizon. For a uniform rod, the minimal admissible horizon is found, and the exact optimal control law is presented.

FrR1A Amphi I

Optimization-Based Decision Making (Regular Session)

Chair: Hoffmann, Matthias K. Saarland University

Co-Chair: Dkhili, Nouha CentraleSupélec - Université Paris-Saclay

10:00-10:20 FrR1A.1

Integrating Customer Portfolio Theory and the Multiple Sources of Risk Approaches to Model Risk-Adjusted Revenue, pp. 362-369

Machado, Marcos Roberto (University of Twente), Karray, Salma (Ontario Tech University)

This study proposes new methods to formulate customers' risk-adjusted revenue (RAR) metrics applied to the financial industry. Using a customer dataset provided by a loan company, we compute RAR using benchmark approaches presented in the literature and new formulas that combine the Customer Portfolio Theory and the Multiple Sources of Revenues approaches. We validate the efficiency and originality of our formulations by implementing statistical tests to check for differences across the different RAR measures. We find that the proposed RAR models are unique and can be implemented in the industry to account for multiple sources of risk, hence providing managers with ways to improve their valuation of customers' portfolios.

10:20-10:40 FrR1A.2

Data Driven Logistics-Oriented Value Stream Mapping 4.0: A Guideline for Practitioners, pp. 370-375

Muehlbauer, Konstantin (Landshut University of Applied Sciences), Wuennenberg, Max (Technical University of Munich), Meißner, Sebastian (Technology Centre for Production and Logistics Systems), Fottner, Johannes (Technical University of Munich)

Abstract: The use of data-oriented approaches like data mining or machine learning has an increasing potential for application in the planning and control of production and logistics systems. The growing amount of digital process information helps to expand the existing process understanding in order to determine weaknesses in the process landscape. Due to the extensive complexity within production and logistics systems, a comprehensive approach is required to ensure a systematic analysis. This article presents an extension of the value stream method based on the existing approaches that is intended to support operators of logistics systems in the company. This methodology collects all relevant process information and validates the data maturity. Hence, indications for the use of data-oriented approaches can be given and potential machine learning-based analysis scenarios can be derived.

10:40-11:00 FrR1A.3

Application of Optimization Method for Identifying Human Operator Model Parameters, pp. 376-381

Zaitceva, Iuliia (LUT University), Andrievsky, Boris (Saint Petersburg State University), Kuznetsov, Nikolay (Saint-Petersburg State Univ), Shestakov, Ivan (St.Petersburg State University of Civil Aviation)

The development of automation technologies in various fields of human life poses the problem of studying human-machine systems interaction and the influence of human on machine actions. The varied human behavior and the complexity of his central nervous system organization are a disability to his mathematical description. However, despite this, the human operator has efficient properties of trainability, adaptation to task variables, and optimization of system parameters. These properties allow researchers to introduce various assumptions in modeling and use them to identify the human model parameters. The purpose of this paper is to propose an approach to human operator model parameters identification by systems optimization methods. The paper is aimed to obtain a model of the human operator, which acts as a closed-loop feedback controller. The human operator model is taken in the form of the delayed lead-lag filter. Based on the assumption that the human operator optimizes system quality index, employing the optimization procedure to obtain/identify the human operator dynamics. The controlled plant model is assumed to be known and its parameters are fixed. The paper presents the results of the optimization-based identification procedure where the McRuer model in the compensatory control system was used. The proposed algorithm for calculation of the cost function is described mathematically and presented in pseudocode. Its reliability is demonstrated by comparing the numerical values of the human operator model parameters with the experimental results given in the literature.

11:00-11:20 FrR1A.4

I'll Tell You What I Want: Categorization of Pareto Fronts for Automated Rule-Based Decision-Making, pp. 382-387

Hoffmann, Matthias K. (Saarland University), Schmitt, Thomas (Technische Universität Darmstadt), Flaßkamp, Kathrin (Saarland University)

The application of Pareto optimization in control engineering requires decision-making as a downstream step since one solution has to be selected from the set of computed Pareto optimal points. Economic Model Predictive Control (MPC) requires repeated optimization and, in multi-objective optimization problems, selection of Pareto optimal points at every time step. Thus, designing an automated selection strategy is favorable. However, it is challenging to come up with a measure – possibly based on a Pareto front analysis – that characterizes preferred Pareto optimal points uniformly across different Pareto fronts. In this work, we first discuss these difficulties for application within MPC and then suggest a solution based on unsupervised machine learning methods. The approach is based on categorizing Pareto fronts as an intermediate step. This allows generating an individual set of rules for every category. Thereby, the human decision-maker's preferences can be modeled more accurately and the selection of a Pareto optimal solution becomes less time-consuming while breaking down the decision-making process into a selection solely based on the Pareto front's shape. Here, the measures act as anchor points for the decision rules. Lastly, a novel knee point measure, i.e. an approximation of the Pareto front's curvature, is presented and used for a knee point-focused categorization. The proposed algorithm is successfully applied to a case study for an energy management system. Moreover, we compare our method to using singular measures for decision-making in order to show its higher flexibility leading to better performance of the controller.

11:20-11:40 FrR1A.5

Modeling the Choice of an Optimal Educational Trajectory in the Conditions of Digital Transformation of the Economy, pp. 388-393

Tarasyeva, Tatiana (Ural Federal University Named after the First President of Russi), Agarkov, Gavriil (Ural Federal University Named after the First President of Russi), Tarasyev, Alexandr A. (Ural Federal University Named after the First President of Russi), Koksharov, Viktor (Ural Federal University Named after the First President of Russi)

The processes of transformation of the modern economy taking place in recent decades encourage researchers to determine the place of higher education in general and of sets of educational programs in particular, in the new conditions of the educational services market. In the context of significant changes in the processes of market structures interaction, employers are forced to impose new requirements on university graduates, whose qualifications should be relevant to the current market. Since the university in this case is an intermediary between enterprises and skilled labor, its goal is to solve the shortage of personnel with a level of training that meets the new objectives of employers in the regional labor market. In these conditions, optimizing recruitment of students for the areas necessary for the market becomes relevant. To solve these problems, the following tools can be used: identifying value orientations and incentives for applicants in the process of choosing bachelor's degree programs, and admission of master's degree applicants who have shown an inclination for professional activity related to their undergraduate degree field. Thus, there is a

need to study the applicants' educational trajectories in relation to their economic incentives, such as the amount of expected income after graduation. The method of this study combines an agent-based model with econometric modeling to determine the maximum expected salary after graduation. The first stage of modeling involves the use of an econometric model to adapt students' educational trajectories to their preferences. At the second stage of modeling, an agent-based model is used, which allows determining the behavior of students within the overall sample. To determine the probability of a student changing their educational trajectory, a fuzzy logical model was developed.

11:40-12:00 FrR1A.6

Dynamic Modeling of Professional Mobility in the Context of Labor Market Precarization, pp. 394-399

Tarasyev, Alexandr A. (Ural Federal University Named after the First President of Russi), Agarkov, Gavriil (Ural Federal University Named after the First President of Russi), Sushchenko, Anastasia (Ural Federal University), Tarasyev, Alexander M. (Krasovskii Institute of Mathematics and Mechanics of Ural Branch)

The pandemic has become a catalyst for the inevitable process of digitalization of communications, significantly changing the organization and technology of professional activity around the world. There has been a radical change in labor market trends due to the digital transformation of the economy, changes in the unemployment rate, the transition of professional groups to the remote work format due to the external need for isolation to minimize the spread of Covid-19. The uncertainty of the labor market development conditions, as well as changes in the unemployment rate among the young subset of employable population, cause the emergence of various forms of unstable employment. The presence of high social risks, the need to develop mechanisms to increase the level of protection of the population, ensuring the growth of youth welfare and the formation of an energy saving policy aimed, inter alia, at the innovative development of the labor economy, determine the relevance of developing a set of models for predicting precarization of the labor market. To describe the dynamics of the labor market development, we constructed a model for assessing the risks for young professionals from key sectors of the economy who enter the precariat during the pandemic. Based on the provisions of the theory of positional games and behavioral economics, we have developed a multifactorial dynamic model for predicting professional mobility and precarization of the labor market, considering the fulfillment of Nash equilibrium conditions. The model allows you to track and predict the professional mobility of qualified youth depending on the intensity of the labor market, wage levels and the degree of digital maturity of companies in the region.

FrR1B Amphi II

Computational and Robustness Topics in Optimization-Based Design (Regular Session)

Chair: Nicolau, Florentina — Ensea Cergy

Co-Chair: Colin, Guillaume — Univ. Orléans

10:00-10:20 FrR1B.1

An Optimization-Based Algorithm for Simultaneous Shaping of Poles and Zeros for Non-Collocated Vibration Suppression, pp. 400-405

Saldanha, Adrian (KU Leuven), Silm, Haik (KU Leuven), Michiels, Wim (KU Leuven), Vyhlidal, Tomas (Czech Technical Univ in Prague, Faculty of Mechanical Engineerin)

This article presents a control design method for simultaneous shaping of the poles and zeros of linear time-invariant systems, motivated by the application of non-collocated vibration suppression of flexible multi-body systems. An entire suppression of vibrations of a target mass at given excitation frequencies can be recast into the assignment of zeros of the transfer function from the excitation force to the target mass' position. The design requirement of achieving sufficient damping in the closed loop system, combined with vibration suppression at the target, leads us to the minimization of the spectral abscissa function of the closed loop system as a function of the controller parameters, subject to zero location constraints. These constraints exhibit polynomial dependence on the controller parameters. We present two approaches to solve the optimization problem, which are both based on constraint elimination followed by application of an algorithm for non-smooth unconstrained optimization. The design approach is applicable to delay-free models as well as time-delay models of retarded and neutral type. Simulations results illustrate its applicability to a spring-mass-damper system.

10:20-10:40 FrR1B.2

Automatic Weighting Filter Tuning for Robust Flight Control Law Design, pp. 406-411

Alcolea Perez, Carlos (Capgemini Engineering), Theodoulis, Spilios (ISL), Sève, Florian (Dassault Aviation), Goerig, Laurent (Dassault Aviation)

This article presents a practical framework for the co-design of weighting filter parameters and controller gains in the context of multi-objective/multi-model tuning of flight control laws. A non-smooth optimization-based procedure is proposed aiming to reduce the complexity of the control design process, evolving from a rather classical manual filter selection all the way to a fully automatic one. A normal acceleration Control Augmentation System (CAS), designed by making use of non-smooth optimization software, for the linearized dynamics of an agile autonomous aerospace vehicle is used as an illustrative example. Several performance indexes are compared in the context of the developed framework as well as against more classical tuning methods such as pole placement, demonstrating that the proposed approach may lead to improved results and potentially benefit the flight control engineer via an easier handling of conflicting design requirements, model uncertainty and application-tailored control structures.

10:40-11:00 FrR1B.3

Tracking Control for a Flat System under Disturbances: A Fixed-Wing UAV Example, pp. 412-417

Do, Huu Thinh (University Grenoble Alpes, Grenoble INP), Nicolau, Florentina (Ensea Cergy), Stoican, Florin (Politehnica University of Bucharest), Prodan, Ionela (INP Grenoble)

This paper considers a class of systems admitting several flat representations and proposes a trajectory tracking controller design which accounts for disturbance rejection. Set invariance is used for characterizing the tracking and estimation error dynamics. Furthermore, some insights on the disturbance propagation in case of different flat representations for a fixed-wing Unmanned Aerial Vehicle (UAV) system are highlighted via simulations and comparisons.

11:00-11:20 FrR1B.4

Simulation and Comparison between Fuzzy Harmonic Search and Differential Evolution Algorithm: Type-2 Fuzzy Approach, pp. 418-423

Patel, Himanshukumar (Dharmsinh Desai University), Shah, Vipul (DDU, Nadiad)

The harmony search (HS) and differential evolution (DE) algorithms are compared in this study. Additionally, an interval type-2 fuzzy logic system (IT2FLS) allowing dynamic change of the key parameters is offered for each algorithm. The use of fuzzy systems to dynamically alter the primary parameters for each algorithm seeks to improve the performance of the associated algorithms. The optimal design of fuzzy systems for benchmark control issues, particularly in fuzzy controller design, is used to evaluate and compare each algorithm (IT2FHS and IT2FDE). Simulation results demonstrate that the FHS method outperforms the FDE approach when it comes to fuzzy controller optimization. The better errors are found with the application of fuzzy systems to enhance each proposed algorithm, according to statistics.

11:20-11:40 FrR1B.5

Nonlinear Optimal Control for Maglev Platform Roll Motion, pp. 424-429

Melnikov, Dmitrii (Saint Petersburg State University), Sakamoto, Noboru (Nanzan University), Zavadskiy, Sergey (Saint Petersburg State University), Golovkina, Anna (Saint Petersburg State University)

The stable manifold method is applied to construct a nonlinear real-time feedback optimal control system for the roll motion and vertical position of a certain maglev platform. The chosen platform uses combined electromagnetic suspensions consisting of permanent magnets and upper and lower electromagnets. Within the given technical gaps between the platform and guideway, the magnetic forces provide highly nonlinear effects. This makes this object a multi-input multi-output (MIMO) nonlinear control system. The stable manifold method is applied to construct an optimal nonlinear stabilizing controller. The benefit of the nonlinear control in comparison with a linear regulator is illustrated on an ensemble of perturbed motions caused by a set of initial deviations covering the necessary engineering stabilization range.

11:40-12:00 FrR1B.6

On the Use of Frequency Analysis Tools to Minimize the Calculation Complexity of Optimal Control Problems, pp. 430-435

Cottin, Willy (Stellantis), Colin, Guillaume (Univ. Orléans), Charlet, Alain (Univ. Orléans), Houillé, Sébastien, Sébastien Houillé (STELLANTIS)

Transport domain is currently facing the challenge of reducing its CO2 emissions. To do so, hybrid electric vehicles have been developed. Having several power sources offer the possibility to reach an optimal use of power systems. This can be considered as Optimal Control Problem (OCP). Various methods exist to solve such problems. Since the 1960s and the Dynamic Programming (DP) developed by Bellman, it is possible to get the optimal solution for a constrained nonlinear system. This method is used to solve OCPs. However, the computational effort of DP is exponential and depends on the number of state and control variables. The present study used the frequency analysis tools Relative Gain Array and Column Diagonal Dominance Degree to dissociate states and control variables that are not linked and on the contrary pair those that are linked. This enables a large Multi Input Multi Output (MIMO) DP to be built from a succession of smaller MIMO DP that will successively solve the OCP. Since there is sub optimality by not solving problems at the same time, a trade-off between accuracy and computational time has to be done. The methodology reduces the calculation complexity and memory, making it possible to use a better mesh-grid to recover lost optimality.

12:00-12:20 FrR1B.7

A Distributed Approach to Economic Dispatch in Power Systems, pp. 436-441

Jahvani, Mohammad (Queen's University), Guay, Martin (Queen's Univ)

This paper proposes a distributed dynamics to solve the economic dispatch problem in electric power systems. The approach can be implemented in a fully decentralized manner and it does not require any central control unit. It is assumed that the participating entities can exchange information over a potentially asymmetric communication network. In particular, when the local generation cost functions are quadratic and the communication network is strongly connected, we establish the exponential convergence of the proposed dynamics to the optimal solution of the dispatch problem. We also provide simulation studies on an IEEE benchmark to demonstrate the performance of the proposed dynamics.

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