Preprints of the

3rd IFAC Conference on Advances in Proportional-Integral-Derivative Control

Book of Abstracts

Ghent, Belgium

May 9-11, 2018

IFAC
INTERNATIONAL FEDERATION OF AUTOMATIC CONTROL

200 JAAR
UNIVERSITEIT GENT

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Welcome Message from the Organizing Committee

On behalf of the National Organizing Committee and of the International Program Committee it is our pleasure to welcome you to the IFAC Conference on Advances in Proportional-Integral-Derivative Control, organized by Ghent University, in Ghent, Belgium, during 9-11 May 2018.

We already knew that PID controllers are the 'working horse' controllers for industry. The previous meetings in Terrassa (Spain) in 2000 and Brescia (Italy) in 2012 confirmed yet again that PID control is not yet to be forgotten. Once again, in 2012, both academia and industry confirmed there are still many problems to be solved with PID control and new challenges to face. Six years later, at PID18 in Ghent, we witness without doubt, a new paradigm as we move forward into the industrial revolution timeline.

The present edition of this flagship conference in control engineering brings together academic and industrial experts in the field worldwide to disseminate, discuss and possibly question the current developments and suggest future trends and research directions.

The first day of the conference is almost entirely dedicated to industry, as several plenary speakers and presentations from well-known leaders in industrial control are setting the focus on what's challenging from manufacturers, developer, end-user, practitioner sides. The second day focuses on academic challenges, with a panel discussion on control education. The third day features among others a benchmark challenge and various student competitions.

We would like to thank all members of the International Program Committee, National Organizing Committee, Sponsors, Associated Editors and Reviewers who did their best to set the scene for a successful event. We would also like to thank our special honorary guests and plenary speakers for their dedication to this event.

Our venue, Ghent, no doubt will prove inspirational and versatile with its medieval architecture. A city with long-standing history since the Stone Age, with Roman sites underneath, once the greatest city of Europe and nowadays trembling with art and culture in its every heartbeat. We are in the region of Flanders of great industrial development and connected, like a heart, by sea, land and air to the rest of Europe and the world.

We are sure you will experience a fruitful and inspiring meeting and you will leave PID18 with enlarged horizons for research and education perspectives.

Clara Ionescu

Conference Chair

Antonio Visioli

IPC Chair

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Co-Sponsors:

TC 6.1. Chemical Process Control (IPC Representatives: D. Rivera and S. Engell)

TC 9.4. Control Education (IPC Representatives already in IPC list)

Sponsors

The conference takes place under the auspices the International Federation of Automatic Control (IFAC), with the support of the IFAC Technical Committee 2.1 Control Design.

The conference is also supported by the University of Ghent, University of Antwerp and KU Leuven.

The conference is also supported by the industrial sponsors ABB, ArcelorMittal, Flanders Make, Gefran, Gibas, MathWorks, Springer, Yazzoom and Yokogawa.

Conference Information

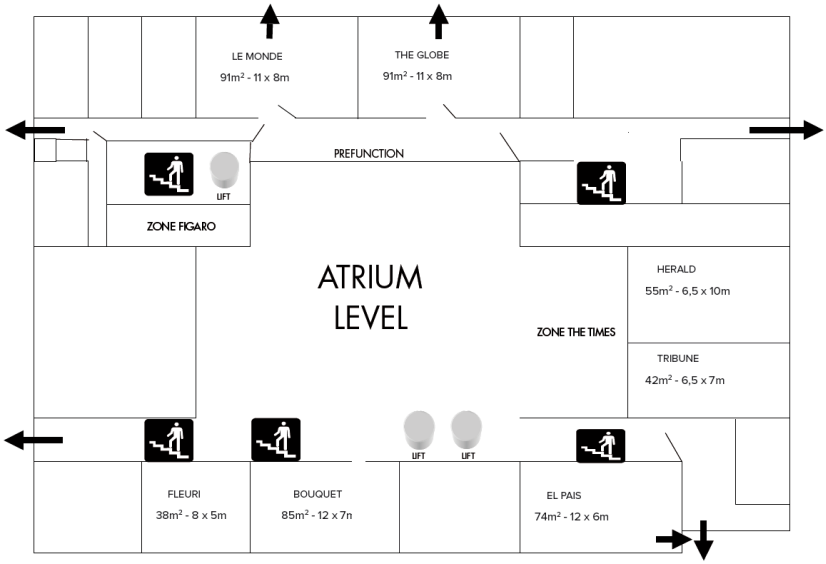
Conference Site

Holiday Inn Gent Expo

Maaltekouter 3, Sint Denijs-Westrem, 9051 Ghent, Belgium

Holiday Inn Gent Expo offers a convenient location next to Flanders Expo and Ikea Ghent, providing a restaurant and a bar, a fitness centre and free wired and wireless internet throughout the hotel. Bicycle rental services are available. Each room comes with its own private bathroom. At the Holiday Inn Gent Expo, every unit features a desk, a TV, a radio and a telephone. The Atrium Restaurant serves contemporary food, combining light and refined meals with inventive Belgian cuisine. In the Atrium bar a selection of fine wines and a variety of the famous Belgian beers are served. At 100 m from Holiday Inn Gent Expo you'll find a tram stop which offers access to the historical centre of Ghent every 10 minutes. The hotel is easily accessible by car via E40, E17 and A17 Motorways. Parking at a reduced rate is possible or free parking at IKEA. Sint Denijs-Westrem is a great choice for travellers interested in city trips, sightseeing and history.

The sessions will be held in the conference facilities of the hotel, as described in the technical program and the following floorplan.



Conference secretariat

The conference secretariat will be located at the Lobby of the conference hotel, at Atrium level. The desk will be open May 8th between 10:00-15:00, May 9th between 08:00-18:00, May 10th between 08:00-16:00 and May 11th between 09:00 to 12:00.

Internet Access

The conference hotel provides free wireless internet access throughout the hotel property. Further information is provided in the participants kit.

Coffee breaks

All the coffee breaks will be served in the Lobby-Atrium, where the poster sessions are also simultaneously held. The coffee break hours will be:

- Wednesday May 9, 10:00-10:30 & 14:30-15:00.
- Thursday May 10, 10:00-10:30 & 14:00-14:30.
- Friday May 11, 10:30-11:00 & 14:30-15:00.

Lunch breaks

The lunch is buffet type and lunch hours will be on May 9th , 12:30-13:30, May 10th , 12:00-13:00 and May 11th , 12:00-12:30.

Social Program

Welcome Reception: Wednesday May 9th , 2018, 19:00 – 21:00.

Location: **The Great Butchers' Hall**. Groentenmarkt, 7, 9000 Ghent.

The Great Butchers' Hall dates back to the 15th century, when meat halls were indoor market places with centralised sales to monitor the freshness and quality of the meat.

The building has a remarkable and splendid open wooden truss roof. If you look up, the sight of Ghent's special Ganda Hams hanging there will whet your appetite.

The impressive medieval and covered Great Butchers' hall houses the centre for the promotion of local East Flemish products. The ideal base to discover the East Flanders' cuisine from appetizer to dessert.

Participants are advised to use tram line 1 to get to the Great Butchers' Hall. The nearest tram stop to the conference hotel is Flanders Expo whereas the Great Butchers' Hall is within walking distance from Gravensteen tram stop.

Conference Banquet and Brugge tour, Thursday May 10th , 2018, 17:00 – 23:00.

Location: **De Halve Maan.** Walplein, 26,8000 Brugge.

The town directory of Bruges mentions Die Maene brewery at Walplein (wall square) as early as 1564. From 1856 onwards, when Leon Maes (also known as Henri I) acquired the building, we can begin to talk about the modern 'Brouwerij De Halve Maan' ('De Halve Maan Brewery') we know today.

The dinner will be preceded by a tour of the brewery with details on its history and beer types. A beer degustation will allow to sample the local beer speciality.

Bus transport service will be provided from the conference hotel to Brugge. The buses will leave the hotel at 16:30-17:00.

Closing Ceremony: Friday, May 11, 16:30 – 18:30.

Location: **Conference Hotel Garden**

A live band will liven up the ceremony. The Young Authors Award and Student Competition Award winners will be announced during the ceremony.

About the city

Belgium's fourth-largest - and most beautiful - city is home to a quarter of a million people and a flourishing flower export trade. An important port, Ghent's city center is a pedestrian area that is like a museum to early Flemish architecture and a testament to the city's medieval might. Impressive Gothic sites, such as dramatic St. Bavo's Cathedral and the Castle of the Counts, inspire awe. The works of Flemish masters are housed in the distinguished Museum voor Schone Kunst.

The Gravensteen

Historic city centre

The city started as a settlement at the confluence of the Rivers Scheldt and Leie and in the Late Middle Ages became one of the largest and richest cities of northern Europe, with some 50,000 people in 1300. With 260,467 inhabitants in the beginning of 2018, Ghent is Belgium's second largest municipality by number of inhabitants. The metropolitan area, including the outer commuter zone, covers an area of 1,205 km2 (465 sq mi) and has a total population of 594,582 as of 1 January 2008, which ranks it as the fourth most populous in Belgium. The port of Ghent, in the north of the city, is the third largest port of Belgium. It is accessed by the Ghent-Terneuzen Canal, which ends near the Dutch port of Terneuzen on the Western Scheldt. The port houses, among others, large companies like ArcelorMittal, Volvo Cars, Volvo Trucks, Volvo Parts, Honda, and Stora Enso. The Ghent University and a number of research oriented companies, such as Ablynx, Innogenetics, Cropdesign and Bayer Cropscience, are situated in the central and southern part of the city.

Getting to the conference site

Arriving at Brussels airport: The airport City Express leaves from within the airport building (floor -2) and takes you to one of the main stations in Brussels (subsequently Noord/Nord, Centraal/Central and Zuid/Midi), where you can switch to one of the many intercity trains (IC) to, or via "Gent-Sint-Pieters", Ghent's main railway station (Directions Brugge, Knokke, Blankenberge, Oostende all stop in Ghent). Some trains run directly from the airport to "Gent-Sint-Pieters".

Arriving at Charleroi Brussels airport: From here a bus shuttle to Gent Sint-Pieters Station is available every 2 hours. More information about tickets and bus schedule can be found here https://www.flibco.com/en#/booking.

Arriving by train in Brussels: Switch to one of the many intercity trains(IC) to, or via "Gent-Sint-Pieters, Ghent's main railway station (Directions Brugge, Knokke, Blankenberghe, Oostende all stop in Ghent). Ghent is on the crossroads of the international lines "London - Brussel - Köln" and "Paris - Lille - Antwerpen"

From the railway station "Gent Sint-Pieters": Take tram 1 from the tunnel under the railway station (every 6 minutes), get off at the "Flanders Expo". The conference venue hotel is 500m from the tram station and is well indicated.

For more information about trains click here http://www.belgianrail.be/en/Default.aspx

For more information about public transport from Gent Sint Pieters station to Conference Venue and city center click here https://www.delijn.be/en/?vertaling=true

Recommended hotels:

Conference venue hotel:

Hotel HOLIDAY INN GENT EXPO****: https://www.higentexpo.com; e-mail: res@higentexpo.com.

Hotels at walking distance to/from train station and 10 minutes direct connection by tram 1 (in direction Flanders Expo):

Hotel TRIANON***: http://www.hoteltrianon.be/home

Hotel BEST WESTERN***: http://www.chamade.be; e-mail: info@chamade.be

Hotel THE LORD***: http://hotelthelord.be; e-mail: info@hotelthelord.be

Hotels in city center directly connected by tram 1 to the conference venue and the train station:

Hotel DE FLANDRE****: http://www.hoteldeflandre.be; e-mail: info@hoteldeflandre.be

Hotel IBIS Ghent Centrum Opera**: http://ibishotel.ibis.com/gb/hotel-1455-ibis-gent-centrum-opera/index.shtml; e-mail: H1455@accor.com

Koestraat:http://www.koestraat46.be; e-mail: info@koestraat46.be; Info

Sandton Hotels****: http://www.sandton.eu/en/gent/; e-mail: nancy.vandenberghe@sandton.eu

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Hotel GHENT-RIVER****: http://www.ghent-river-hotel.be; e-mail: info@ghent-river-hotel.be

Technical Program

Plenary Sessions

Industrial loop tuning in the digital age

Kevin Starr, (ABB, USA)

Time and location: Wednesday May 9, 2018, 09:00-10:00, Herald+Tribune

Abstract: In the industrial world automation expansion has grown at a rate that has passed even the best loop tuner. Plant personnel are being tasked with everything from hard networking, drive space management, control platform stability, loop tuning, field instrumentation, and now even cyber-attacks. The result is spotty maintenance coverage an alarming trend towards control loops being turned off, out of range, or inducing variability. Plants that once had a few 100 wall mounted devices now have 1000's of embedded controllers. The result is the loss of production, quality, and in increase in the cost to produce of industrial clients. Tuning in the digital age means being able to have the right person, at the right time, with the right solution. One cannot guess and check or tune by feel. Expanding the circle of influence of our loop tuners and process control personnel is of key importance. Solutions in the automation space that enable data to be converted to information at the asset and function level are crucial, but we can't stop there, these KPI's need consolidated in heads up dashboards that enable demonstrated proficiency so that answers to are you safe, reliable, and optimized are defined in a systematic manner. Now as plants are being joined around the globe, fleet and enterprise solutions that finally enable the linkage of loop performance at plants and process areas can be linked to production, quality, and cost to produce. The need for loop tuners that can manage 100's or even 1000's of loops in the time we use to tune 1 to 10 loops are required. We can't expect the same growth trajectory in the digital age by doing what we use to always do.

Biography: Kevin Starr is R&D Manager at ABB Process Automation Services. He has worked for ABB for over 26 years and is responsible for the development and implementation of service solutions that result in the increased life cycle and utilization of Industrial Automation systems. He has taught process control techniques in a number of countries in Europe and Asia as well as numerous locations throughout the United States and Canada. His book on process control, Single Loop Control Methods, has sold over 3,000 copies worldwide and Kevin has been a keynote speaker at industry events throughout the world. He currently has 12 patents as a result of his efforts with process control. Kevin holds a master's degree in electrical engineering from Ohio State University, and a bachelor of science degree in electrical engineering from Ohio University, both with an emphasis in process control.

New PID designs for sampling control and batch process optimization

Tao Liu, (Dalian University of Technology, China)

Time and location: Wednesday May 9, 2018, 13:30-14:30, Herald+Tribune

Abstract: Owing to overwhelming development of digital control technologies in modern industrial engineering and manufacturing, advanced PID designs have been widely appealed for implementation in sampled control systems. In this lecture, a few up-to-date PID designs for practical applications subject to operating constraints and measurement noise will be presented, based on our research results explored in the past years. For industrial batch processes and periodic systems, by using historical cycle data, iterative learning type PID control system designs will be introduced to realize perfect tracking of the set-point profile against unknown process uncertainties and repetitive load disturbances, along with robust tuning methods to accommodate for time-varying uncertainties or disturbances from cycle to cycle. Finally, some perspective and challenges on PID design are pointed out, hoping to draw more attentions by scholars and engineers in the field of control engineering.

Biography: Tao Liu received his PhD degree in Control Science and Engineering from Shanghai Jiaotong University, China, in 2006. He had been a postdoc fellow at Hong Kong University of Science and Technology from May 2006 to April 2010, and an Alexander von Humboldt research fellow at RWTH Aachen University in Germany from May 2010 to June 2012. He is a professor with the Institute of Advanced Control Technology at Dalian University of Technology, China, since July 2012. He has published more than 70 international journal papers and a research monograph by Springer. His research interests mainly include chemical and industrial process identification & modeling, model predictive control, PID tuning, robust control, batch process optimization. He serves as an associate editor of ISA Transaction and Systems Science and Control Engineering.

PID control of dead-time process: robustness, dead-time compensation and constraints handing

Julio Normey-Rico, (Federal University of Santa Catarina, Brazil)

Time and location: Thursday May 10, 2018, 13:00-14:00, The Globe+Le Monde

Abstract: PID controllers are widely used to control dead-time processes. As dead time is a dynamic behavior normally found in many industrial plants, to find appropriate tuning rules and operational conditions of PIDs for such processes is very important. This work tackles, using a unified approach, valid for stable, integrating, and unstable dead-time processes, a methodology to tune and configure PID control loops. The main ideas of the proposed approach are to use dead-time compensation concepts to obtain the PID tuning and to consider adequate anti-windup strategies to overcome the effects of saturations of the increments and absolute values of the control action. Robustness aspects, stability analysis and optimal or sub-optimal conditions are analyzed to understand the limitations of the solutions. Model predictive control algorithms are used to show how almost optimal solutions can be obtained with the proposed anti-windup PID controllers under control action constraints. Moreover, the advantages or disadvantages of using the proposed PID strategy instead of more sophisticated dead-time compensation algorithms with anti-windup are discussed. Several case studies are presented to illustrate the main ideas and to compare the obtained results with other existing methods. Experimental results are also included to discuss implementation issues.

Biography: Julio Normey received the Ph.D. degree from the Dept. of System Eng. and Automatic Control, University of Seville, Spain, in 1999. He is currently Full Professor at the Dept. of Automation and Systems Engineering, Federal University of Santa Catarina (UFSC), Brazil; researcher of the Brazilian National Research Council CNPq; Associate Editor of Control Eng. Practice and director of several projects with industry in Brazil. His current research interests include model predictive control, time delay systems and process control applications. He is the author or coauthor of about 260 conference and journal papers, the book Control of Dead-Time Processes (Springer, 2007), and has supervised 60 Ph.D./M.Sc. graduates.

Fractional order PID control: better than the best issue and what's next

YangQuan Chen, (University of California,USA)

Time and location: Friday May 11, 2018, 11:00-12:00, The Globe

Abstract: In fractional order proportional derivative and integral controllers (FOPID), the order of differentiation/integration can be non-integer. It is now being accepted that the additional freedom in tuning the FOPIDs can offer better performance at the cost of extra implementation efforts. Since the embedded computing power and memory are both getting cheaper and cheaper, people are running out of excuses not to attempt FOPID in industry 4.0 era when more optimal performance is being pursued. The only remaining question is: Can the FOPID really outperform IOPID under fairness consideration? This talk will focus on first order plus time-delay (FOPTD) plants to illustrate that, FOPID can do better than the best of its integer order counterpart under fairness comparisons in terms of performance, robustness margins and even control energy consumption. This talk ends with a few future research opportunities in FO-PID such as networked control system with intermittent delays, systems with nonlinearities with memory, human-in-the-loop control of wearables, cyber physical human systems etc.

Biography: YangQuan Chen earned his Ph.D. from Nanyang Technological University, Singapore, in 1998. He joined the University of California, Merced in summer 2012 teaching “Mechatronics”, “Engineering Service Learning” and “Unmanned Aerial Systems” for undergraduates; “Fractional Order Mechanics” & “Nonlinear Controls” for graduates. His research interests include mechatronics, cognitive process control, drones, CPS, DPS & applied fractional calculus.

Advances in Control Education Panel

Thursday, 14:30-16:30.

Chaired by: J.A. Rossiter (Sheffield University, UK)

What is an ideal undergraduate control curriculum?

Panelists:

Ferdinand Kieckhäfer (Hamburg University, Germany)

Tore Hägglund (Lund University, Sweden)

Paulo Moura Oliveira (UTAD, Portugal)

Guy Dumont (The University of British Columbia, Canada)

Tao Liu (Dalian University of Technology, China)

What is an ideal control curriculum? Do we focus on concepts, applications and simple tools such as PID? Alternatively, maybe we should focus on traditional analysis tools such as Bode and Nyquist as these are skills and tools students will not acquire in the workplace. A different alternative notes there is a growing opinion that we should bin all of those classical tools and instead present control solely from a state space framework. Having decided what should be on the curriculum, how do we as an IFAC community (industrialists and academics) provide learning resources and tools which will help students learn what they need to know? Do we have a role in coordinating this or do we leave this to the whim of those who choose to write a control text book?

The panel session will begin with some short speeches from the panelists followed by input and dialogue involving the whole audience.

INDUSTRY DAY

Wednesday 9th May 2018.

The PID 2018 conference is traditionally an opportunity for interaction between academia and industry. To better acknowledge the industry needs and academic solutions, and map them for better synergy, an open panel discussion session will be organized on the second day of the conference. This is accessible for all participants to attend and interact with the panel contributors.

Program at a glance:

9:00 – 10:00 Kevin STARR – ABB, USA, ***Industrial Loop Tuning in the Digital Age.***

10:00 – 10:30 Coffee Break.

10:30 – 12:30 PID Technical Sessions (see technical program for full information).

12:30 – 13:00 Stijn Derammelaere – UAntwerpen, ***Take the fast lane: sophisticated yet accessible motion control techniques.***

13:00 – 13:30 Jan Verhasselt – YAZZOOM, ***A practical approach for integrating and maintaining computational models in control.***

13:30 – 14:30 Tao Liu – Dalian University of Technology, China, ***New PID designs for sampling control and batch process optimization.***

14:30 – 15:00 Coffee Break

15:00 – 17:30 Debate, Chaired by: Karl-Johan Åström, Lund University, Sweden, ***New perspectives in industrial PID control.***

Overview: Ramon Vilanova (UAB, Spain)

Panelists:

Davide Colombo (Gefran, Italy)

Rafael Gonzalez (Repsol, Spain)

Alf Isaksson (ABB, USA)

Jan Verhasselt (YAZZOOM, Belgium)

Sigurd Skogestad (NTNU, Norway)

Yongduan Song (Chongqing University, China)

Massimiliano Veronesi (Yokogawa, Italy)

Jan Verhasselt, YAZZOOM, Belgium: **A practical approach for integrating and maintaining computational models in control**

It is well known that computational models can bring significant improvements to control, for example when used as a virtual sensor, or for real-time production optimization. Nevertheless, the adoption of these techniques by industry is limited. One of the reasons is fear of the lack of understanding and maintainability of the so called “black-box” models that are learned from historical data using machine learning techniques. But also when the mathematical model is “white-box”, i.e. written by a human expert, adoption is slow for another reason: one needs a programmer to implement and integrate the model in a robust fashion with the control layer of the factory. In many cases the human experts that understand the production process and/or the business very well and hence can develop the mathematical model in a spreadsheet like Excel, are not programmers and do not wish to learn a new dedicated development environment. At the same time many production companies struggle to find and keep good programmers. Moreover, there is risk that bugs are introduced when an Excel model is translated into a programming language. In this talk, we demonstrate a novel solution to this problem: the automatic translation of an Excel model into a robust live mathematical model that communicates with the control layer and databases using OPC communication and SQL queries. We also show how with one simple addition to Excel it becomes easy to create dynamic models and introduce time delays, which are often useful in practical applications. We illustrate this with practical use cases from industry.

Stijn Derammelaere, UAntwerpen, Belgium: **Take the fast lane: sophisticated yet accessible motion control techniques**

We provide the necessary tools to achieve a high-performance setting of a motion controller (both PID and advanced torque feedforward). We explain all these using demonstrations on cases as well as utilizing a handy workflow. Participants receive a digital version of this workflow with the necessary calculation tools, best practices and instructional videos. In this way, we want to guarantee the practical usability! We start by studying a cascade control unit, which is standard frequently used in a motion application. In addition, we introduce rapidly applicable techniques to identify dynamic characteristics of the driveline. These measurements (Bode plots) provide a reference for the judicious setting of the PID control parameters. Finally, Digital Twins are used to determine the settings of torque and speed feedforward.

PID 2018 Technical Program Wednesday May 9, 2018

Track T1	Track T2	Track T3
08:30-09:00 WeOS Herald+Tribune Opening Ceremony		
09:00-10:00 WeP1S Herald+Tribune Kevin Starr, "Industrial Loop Tuning in the Digital Age"		
10:00-10:30 WeI1N Lobby PID Control Applications 1		
10:30-12:30 WeAT1 Herald+Tribune Fractional PID Control 1	10:30-12:30 WeAT2 Bouquet PID Control of Biosystems 1	10:30-12:30 WeAT3 Fleuri PID Control of Mechatronic Systems 1
12:30-13:30 WeI2N Lobby PID Tuning		
13:30-14:30 WeP2S Herald+Tribune Tao Liu, "New PID Designs for Sampling Control and Batch Process Optimization"		
14:30-15:00 WeI3N Lobby PID Control Applications 2		
15:00-17:30 WePA Herald+Tribune Panel - New Perspectives in Industrial PID Control		

19:00-21:00 WeWR Welcome Reception

Opening ceremony, plenary sessions and industry day panel will have additional video conferencing in “El País” room.

PID 2018 Technical Program Thursday May 10, 2018

Track T1	Track T2	Track T3	Track T4	Track T5
08:40-10:00 ThAT1 The Globe Control Education 1	08:40-10:00 ThAT2 El Pais PID Control of Mechatronic Systems 2	08:40-10:00 ThAT3 Fleuri PID Control of Energy Systems 1	08:40-10:00 ThAT4 Bouquet PID Design 1	08:40-10:00 ThAT5 Le Monde Optimization in PID Control 1
10:00-10:30 ThI1S Lobby Control Education 2				
10:30-11:50 ThBT1 The Globe Control Education 3	10:30-11:50 ThBT2 El Pais PID Control of Mechatronic Systems 3	10:30-11:50 ThBT3 Fleuri PID Control of Energy Systems 2	10:30-11:50 ThBT4 Bouquet PID Design 2	10:30-11:50 ThBT5 Le Monde PID Control Structures 1

12:00-13:00 ThI2S Lobby PID Control Applications 3
13:00-14:00 ThP1L Le Globe+Le Monde Julio Normey-Rico, "PID Control of Dead-Time Process: Robustness, Dead-Time Compensation and Constraints Handing"
14:00-14:30 ThI3S Lobby Nonlinear Systems
14:30-16:30 ThPA Le Globe+Le Monde Panel - What Is an Ideal Undergraduate Control Curriculum?

17:00-23:00 ThTT Trip to Bruges and Banquet

PID 2018 Technical Program Friday May 11, 2018

Track T1	Track T2	Track T3	Track T4
08:30-10:30 FrAT1 The Globe Benchmark System 1	08:30-10:30 FrAT2 Le Monde Fractional PID Control 2	08:30-10:30 FrAT3 El Pais Optimization in PID Control 2	08:30-10:30 FrAT4 Bouquet PID Design for Load Frequency Control
10:30-11:00 FrI1S Lobby PID Control Applications 4			
11:00-12:00 FrP1L The Globe YangQuan Chen, "Fractional Order PID Control: Better Than the Best Issue and What's Next"			
12:00-12:30 FrI2S Lobby Fractional PID Control 3			
12:30-14:30 FrBT1 The Globe Benchmark System 2	12:30-14:30 FrBT2 Le Monde Fractional PID Control 4	12:30-14:30 FrBT3 El Pais PID Control Structures 2	12:30-14:30 FrBT4 Bouquet PID Control Applications 5
14:30-15:00 FrI3S Lobby Fractional PID Control 5			
15:00-16:20 FrCT1 The Globe Benchmark System 3	15:00-16:20 FrCT2 Le Monde PID Control of Biosystems 2	15:00-16:20 FrCT3 El Pais PID Design 3	15:00-16:20 FrCT4 Bouquet Control Education 4

16:30-18:30 FrFC The Globe Closing Ceremony and Farewell Reception

PID 2018 Book of Abstracts

Technical Program for Wednesday May 9, 2018

WeI1N	Lobby
PID Control Applications 1 (Poster/Interactive Session)	
Chair: Isaksson, Alf J.	Abb Ab
Co-Chair: Bauer, Margret	Univ. of the Witwatersrand

10:00-10:30 WeI1N.1

Proportional-Integral State-Feedback Controller Optimization for a Full-Car Active Suspension Setup Using a Genetic Algorithm, pp. 1-6

Haemers, Michiel (Ghent Univ), Derammelaere, Stijn (Univ. of Antwerp), Ionescu, Clara (Ghent Univ), Stockman, Kurt (Univ. Gent, Campus Kortrijk), De Viaene, Jasper (UGent), Verbelen, Florian (Ghent Univ)

The use of active car suspensions to maximize driver comfort has been of growing interest in the last decades. Various active car suspension control technologies have been developed. In this work, an optimal control for a full-car electromechanical active suspension is presented. Therefore, a scaled-down lab setup model of this full-car active suspension is established, capable of emulating a car driving over a road surface with a much simpler approach in comparison with a classical full-car setup. A kinematic analysis is performed to assure system behaviour which matches typical full-car dynamics. A state-space model is deducted, in order to accurately simulate the behaviour of a car driving over an actual road profile, in agreement with the ISO 8608 norm. The active suspension control makes use of a Multiple-Input-Multiple-Output (MIMO) state-feedback controller with proportional and integral actions. The optimal controller tuning parameters are determined using a Genetic Algorithm, with respect to actuator constraints and without the need of any further manual fine-tuning

10:00-10:30 WeI1N.2

Nonlinear Controllers in the Regulation Problem of the Robots, pp. 7-12

Andreev, Aleksandr (Ulyanovsk State Univ), Peregudova, Olga (Ulyanovsk State Univ)

The report presents the results on the application of nonlinear PI and PID regulators in the position stabilization problem of the robots. As an example the position stabilization problem of a three-wheeled mobile robot with a displaced mass center is considered.

10:00-10:30 WeI1N.3

Dissolved Oxygen Control of Batch Bioreactor Using Model Reference Adaptive Control Scheme, pp. 13-18

Murugan, Chitra (Dept. of Inst. Engineering, MIT Campus, Anna Univ), Natarajan, Pappa (Anna Univ), Abraham, Anuj (Anna Univ)

Bioreactor imparts a significant role in the manufacture of pharmaceuticals, enzymes, food products, etc. as these processes depend on the bio transformation catalyzed by microorganisms. Dissolved Oxygen (DO) is one of the significant parameter in an aerobic fermentation process. DO control is difficult to achieve due to the variations in

process dynamics during batch/fed-batch processes and the complex nonlinear behavior of the Bioreactor. In this paper, design and implementation of Model Reference Adaptive Control (MRAC) scheme based on MIT rule is applied to DO control of the bioreactor using the stirrer speed as control signal. A PC-supported, fully automated, multi-task control system has been designed and built by the authors using Lab VIEW .A comparative study is carried out for the experimental bioreactor with conventional PI controller and proposed MRAC scheme for DO control. Results show that MRAC controller provides good tracking performance in comparison to PI controller.

10:00-10:30 WeI1N.4

Predictive PI Strategy for Hydrographs Control in a Experimental Microscale Flume, pp. 19-24

Alarcon, Ruben (Univ. De Concepcion), Oscar, Briones (Univ. De Concepcion), Link, Oscar (Univ. De Concepcion), Rojas, Alejandro J (Univ. Tecnica Federico Santa María)

Hydraulics, specifically the engineering related to river infrastructure, has had always to deal with issues as floods, erosion debilitating important civil infrastructure (bridges, etc.). In recent years it has been shown that there is predictive value for hydraulics in studying and analyzing these phenomena at a reduced scale. For this reason the microscale experimental canal was build at the Hydraulics Laboratory at the Universidad de Concepci'on, with a second copy for control purposes at the Control Systems Laboratory (LCS). The partial differential equations that govern the process are unnecessarily complex for control purposes. Known literature offers the alternative of a third order linear system, capturing the canal standing wave with a second order system together with an integrator to account for the mass accumulation. However, such a proposal, even when slowing the control to discard the standing wave dynamics is only valid for long canals. The microscale experimental canal does not satisfies that assumption, therefore we propose and adjust a first order structure to the process, which proves adequate for any given operating point selection. Nevertheless, he main three parameters of the plant model (gain, time constant and time delay) vary with the operating point. As a preliminary control approach we consider a plant model selection for a specific operating point as the nominal plant and adjust a PI control using the reaction curve method of Ziegler-Nichols. We compare the previous PI tuning with a predictive PI $lambda$ tuning to achieve robustness, and thus better deal (in this preliminary control approach) with the inherent variability of the plant model parameters.

WeAT1 Herald+Tribune

Fractional PID Control 1 (Regular Session)

Chair: Lanusse, Patrick Bordeaux INP - Univ. De Bordeaux

Co-Chair: Cech, Martin Univ. of West Bohemia in Pilsen

10:30-10:50 WeAT1.1

FOPID Controllers and Their Industrial Applications: A Survey of Recent Results, pp. 25-30

Tepljakov, Aleksei (Tallinn Univ. of Tech), Alagoz, Baris Baykant (Inonu Univ), Yeroglu, Celaleddin (Inonu Univ. Engineering Faculty), Gonzalez, Emmanuel (De

La Salle Univ. - Manila), HosseinNia, Hassan (Delft Univ. of Tech), Petlenkov, Eduard (Tallinn Univ. of Tech)

The interest towards using Fractional-order (FO) PID controllers in the industry is mainly fueled by the fact that these controllers have two additional “tuning knobs” that can be used to adjust the control law in a way that would benefit the control loop. However, there are certain points that are rarely addressed in literature, namely: (1) What are the particular advantages (in concrete numbers) of FOPID controllers versus conventional, integer-order (IO) PID controllers in the light of complexities arising in the implementation of the former? (2) For real-time implementation of FOPID controllers, approximations are used that are equivalent to high order linear controllers. What, then, is the benefit of using FOPID controllers? In the present paper, we attempt to address these issues by reviewing recent literature in the field and by providing relevant analysis and recommendations.

10:50-11:10 WeAT1.2

Benchmark Challenge: A Robust Fractional Order Control Autotuner for the Refrigeration Systems Based on Vapor Compression, pp. 31-36

Muresan, Cristina Ioana (Tech. Univ. of Cluj Napoca), De Keyser, Robin M.C. (Ghent Univ), Birs, Isabela Roxana (Tech. Univ. of Cluj-Napoca), Copot, Dana (Ghent Univ), Ionescu, Clara (Ghent Univ)

This paper proposes fractional order autotuner controller for the benchmark refrigeration system. The method is an extension of a previously presented autotuning principle and produces a robust fractional order PI controller to gain variations. Fractional order PI controllers are generalizations of the integer order PI controllers, which have a supplementary parameter that is usually used to enhance the robustness of the closed loop system. The method is not restricted to robustness to gain variations and can be adapted to obtain robust fractional order controllers to time delay or time constant variations, for example. The autotuning method presented in this paper has several advantages such as the need for a single sine test to be applied to the process to extract the necessary information and the elimination of complex nonlinear equations in the tuning procedure for fractional order controllers. The results obtained on the benchmark system indicate the method has high potential for real-life applications.

11:10-11:30 WeAT1.3

Analysis of Actuator Rate Limit Effects on First-Order Plus Time-Delay Systems under Fractional-Order Proportional-Integral Control, pp. 37-42

Yuan, Jie (Southeast Univ), Chen, YangQuan (Univ. of California, Merced), Fei, Shumin (Southeast Univ)

Actuator rate limit deteriorates control performance, and may even lead to system instability in precision process control. In this paper, a first-order plus time-delay (FOPTD) system class with actuator rate limit is considered. The describing function (DF) of the rate limiter is derived to obtain the describing functions of the closed-loop and open-loop systems, and the onset frequency in the Nichols chart is used to analyze the rate limit effects in frequency domain. A fractional-order proportional-integral (FOPI) controller is first designed based on the flat phase constraint, crossover frequency, and phase margin specifications. Then a traditional integer order PID (IOPID) controller is designed based on the same specifications to compare with the FOPI controller in the presence of actuator rate saturation. A careful simulation study is

presented to validate all the conclusions.

11:30-11:50 WeAT1.4

Discrete-Time Generalized Mean Fractional Order Controllers, pp. 43-47

António, Lopes (Faculty of Engineering of Univ. of Porto), Machado, J.A. Tenreiro (Inst. of Engineering, Pol. of Porto)

This paper studies the performance of discrete-time fractional order controllers. The fractional derivatives and integrals are numerically implemented by means of a generalized mean of discrete generating functions. The two additional degrees of freedom provided by the method, namely the averaging order and the weight of the generating functions, are tuned for increasing the performance of the closed-loop system. Experiments with a fractional PID controller reveal the benefits of the approach.

11:50-12:10 WeAT1.5

Comparing Classical and Fractional Order Control Strategies of a Cardiovascular Circulatory System Simulator, pp. 48-53

Traver, José Emilio (Univ. of Extremadura), Tejado, Inés (Univ. of Extremadura), Prieto, Javier (Univ. of Extremadura), Vinagre, B. M. (Univ. De Extremadura)

This paper compares two strategies, namely, feedback linearization (FBL) and classical proportional-integral-derivative (PID) controller, as well as their fractional versions, for the control of a simulator of the human cardiovascular circulatory system (CVS) in the Matlab/Simulink environment. The simulator is based on a hydraulic model of the system, realizable in practice, in which muscular contraction of the left ventricle is modelled by a pump with piston (tank of variable volume depending on the position of the piston), so that a control strategy is need to control the velocity of the piston in order to emulate the behaviour of the heart. Simulations are given to demonstrate, on the one hand, that all strategies have good tracking and hemodynamic performance and, on the other, that dysfunctions in the CVS can be emulated applying an appropriate control strategy that allows tracking the desired reference waveform. The nal objective of this work is the construction of an experimental platform based on this simulator to test swimming robots of small dimensions that allows to emulate the conditions in which these robots would navigate in the human circulatory system.

12:10-12:30 WeAT1.6

Fractional - Order Modeling and Control for Two Parallel PWM Rectifiers, pp. 54-59

Wang, Xiaohong (South China Univ. of Tech), Hoang, Thi Thu Giang (South China Univ. of Tech), Pan, Zhifeng (South China Univ. of Tech), Chen, Yangquan (School of Engineering , Univ. of California)

For the purpose of improving control quality, fast response, stability and other quality indexes for parallel coupled PWM rectifiers, as well as derived from being able to determine the actual transfer function which is closer to the actual control object, the fractional-order transfer function of the three-phase PWM rectifiers. This paper used a fractional proportional Integral controller instead of a traditional PI controller. The use of the fractional-order controller object will help to design a higher precision fractional-order controller of the system. This paper analyzes the characteristics of the system, constructs the function of the fractional-order controller object, designs the two current

and voltage of the fractional-order controllers, performs the simulations and related experiments. Simulation and experiment results have demonstrated that using the fractional proportional integral controller to control the system of two parallel PWM rectifiers has resulted in ideal control, clearly improved control quality.

WeAT2	Bouquet
PID Control of Biosystems 1 (Regular Session)	
Chair: Kovacs, Levente	Obuda Univ
Co-Chair: Soltesz, Kristian	Lund Univ

10:30-10:50 WeAT2.1

A Nonovershooting Controller with Integral Action for Multi-Input Multi-Output Drug Dosing Control, pp. 60-65

Padmanabhan, Regina (Qatar Univ), Meskin, Nader (Qatar Univ), Ionescu, Clara (Ghent Univ), Haddad, Wassim M. (Georgia Inst. of Tech)

In this paper, a nonovershooting tracking controller is proposed for the continuous infusion of multiple drugs that have interactive effects. The proposed controller design method exploits the freedom of eigenstructure assignment pertinent to the design of feedback controllers for multi-input, multi-output (MIMO) systems. For drug dosing, a nonovershooting tracking controller restricts the undesirable side effects of drug overdosing. The proposed tracking controller is based on an estimate of the full state using a hybrid extended Kalman filter (EKF) that is used to reconstruct the system states from the measurable system outputs. An integral control action is included in the controller design to achieve robust tracking in the presence of patient parameter uncertainty. Simulation results and performance analysis of the proposed control strategy are also presented using 20 simulated patients.

10:50-11:10 WeAT2.2

Optimized PID Tuning for the Automatic Control of Neuromuscular Blockade, pp. 66-71

Merigo, Luca (Univ. of Brescia), Padula, Fabrizio (Curtin Univ), Latronico, Nicola (Univ. OF BRESCIA), Mendonça, Teresa (Faculdade De Ciências Da Univ. Do Porto), Paltenghi, Massimiliano (Spedali Civili Di Brescia), Rocha, Paula (Univ. of Porto), Visioli, Antonio (Univ. of Brescia)

In this paper we propose a PID-based control scheme for the automatic regulation of the neuromuscular blockade level during surgery. In particular, we introduce an optimized tuning of the PID controller parameters based on a standard set of patient models presented in literature. The tuning procedure is based on the solution of a min-max multiobjective optimization problem that takes into account the control performance, the control effort and the robustness. A genetic algorithm is used to solve the optimization problem and to find the optimal tuning. Then, in order to evaluate the control systems robustness, the optimal PID controller is tested in simulation on a database of patient models estimated from real data. The obtained results demonstrate that the performance achieved by considering an optimized PID tuning satises the clinical specications and is robust to the inter-patient variability.

11:10-11:30 WeAT2.3

Two-Degree-Of-Freedom Control Scheme for Depth of Hypnosis in Anesthesia, pp. 72-77

Pawlowski, Andrzej (UNED), Merigo, Luca (Univ. of Brescia), Guzman, Jose Luis (Univ. of Almeria), Dormido, Sebastián (UNED), Visioli, Antonio (Univ. of Brescia)

In this work, a Proportional-Integral-Derivative (PID) controller based two-degree-of-freedom control scheme for Depth of Hypnosis (DoH) in general anesthesia is proposed. This approach uses the Bispectral Index Scale (BIS) as a controlled variable and propofol administration as a control variable. The developed structure applies a new compensation scheme, which reduces the influence of the nonlinear element. In this context, we exploit the linear part of the patient model, that can be obtained from the demographics of each individual patient. The parameters are tuned using the optimization procedure based on a genetic algorithm. The evaluation of the proposed technique is performed using intra-patient variability with a Monte Carlo method. Additionally, the performance of the analyzed system has been verified using several indexes. The simulation results show that desired characteristics are obtained for both induction and maintenance phases.

11:30-11:50 WeAT2.4

Performance of Robust PID and Q-Design Controllers for Propofol Anesthesia, pp. 78-83

van Heusden, Klaske (Univ. of British Columbia), Ansermino, John Mark (Univ. of British Columbia), Dumont, Guy (Univ. of British Columbia)

Control of propofol anesthesia is characterized by large variability in individual responses to drug infusion, relatively simple system dynamics and relatively low performance criteria. Robust PID control can be expected to provide adequate control given these characteristics. While feasibility of robust PID control of propofol anesthesia has been shown in clinical trials, higher-order controllers that use an explicit model might provide additional valuable characteristics. This paper examines the performance achieved with a manually tuned robust PID controller and a higher-order Q-design controller. The additional degrees of freedom in the Q-design allow an increase in the robustness margin, at the cost of decreased gain at low frequencies and corresponding increased time to induction of anesthesia. These results indicate that the uncertainty introduced by interpatient variability is an important factor limiting closed-loop performance. Performance improvement from increased controller complexity may therefore be limited, unless strategies aimed at reducing the uncertainty are implemented.

11:50-12:10 WeAT2.5

Hypnosis Regulation in Presence of Saturation, Surgical Stimulation and Additional Bolus Infusion, pp. 84-89

Copot, Dana (Ghent Univ), Neckebroek, Martine (UZ Gent), Ionescu, Clara (Ghent Univ)

The closed loop regulation of hypnosis implies the mixed effect of the actions dictated by a software based controller, and by the expert knowledge of the anesthesiologist. Other effects such as slew rate limitations due to resolution limits or saturation of the pump infusion system are also present in practice. Almost without exception, the actions of the anesthesiologist and other hardware limitations are not taken into account by the software based controller, hence they are regarded as disturbances. In

this work, a PID controller is implemented to investigate the effects of such additional features in the closed loop dynamics. The results are discussed based on simulation study on a linear patient dynamic model.

12:10-12:30 WeAT2.6

A Simple Positive Control Law for the Rocuronium-Induced Neuromuscular Blockade Level, pp. 90-94

Almeida, Juliana (Faculdade De Ciências Da Univ. Do Porto), Mendonça, Teresa (Faculdade De Ciências Da Univ. Do Porto), Rocha, Paula (Univ. of Porto)

In this paper a new simplied control scheme for the neuromuscular blockade level that only requires the knowledge of one model parameter is proposed. The control law is designed to track a desired target neuromuscular blockade level. Furthermore, the performance of this approach is compared with the results of a PI controller. The results were validated by simulations based on real data collected during surgeries.

WeAT3 Fleuri

PID Control of Mechatronic Systems 1 (Regular Session)

Chair: Beschi, Manuel National Res. Council of Italy (CNR)

Co-Chair: Borisov, Oleg ITMO Univ

10:30-10:50 WeAT3.1

On the Equivalence between PD+DOb and PID Controllers Applied to Servo Drives, pp. 95-100

Garrido-Moctezuma, Rubén Alejandro (Centro De Investigacion Y De Estudios Avanzados Del I.P.N), Luna Pineda, Jose Luis (CINVESTAV)

This work shows that a Proportional Derivative controller with weighted Derivative action plus a Disturbance Observer, is equivalent to a Proportional Integral Derivative (PID) controller with weighted Proportional and Derivative actions, when they are applied to servo drives. A byproduct of this equivalence is a tuning rule for the PID controller, called the DOB tuning, which is expressed in terms of the cutoff frequency of the filter employed in the DOB. Experiments in a laboratory testbed allow assessing the performance of a PID controller under the resulting tuning formulae.

10:50-11:10 WeAT3.2

Adaptive PI Controller for Slip Controlled Belt Continuously Variable Transmission, pp. 101-106

Verbelen, Florian (Ghent Univ), Haemers, Michiel (Ghent Univ), De Viaene, Jasper (UGent), Derammelaere, Stijn (Univ. of Antwerp), Stockman, Kurt (Univ. Gent, Campus Kortrijk), Sergeant, Peter (Ghent Univ)

The control of slip in a belt Continuously Variable Transmission (CVT) has been the subject of many research papers. Optimal control of the belt CVT is of major importance for the efficiency as demonstrated in literature. The challenge in optimizing that efficiency is in the reduction of the necessary clamping forces while the stability of the variable transmission is maintained. Although these problems have already been tackled to a certain extent, mostly fairly complex controllers are proposed. The goal of this paper is to propose a straightforward though effective method to control slip. The

main idea of the paper is to use linearized equations of the slip dynamics to update the controller parameters in function of the operating point. This approach allows to reduce the highly nonlinear system to a first order transfer function which is easily controlled with a PI controller. Results based on extensive simulations show that the controller is robust against torque disturbances and speed ratio variations.

11:10-11:30 WeAT3.3

Current Reduction in Stepping Motor Applications Using an Adaptive PI Controller Based on Linearized Dynamics, pp. 107-112

De Viaene, Jasper (Ghent Univ), Haemers, Michiel (Ghent Univ), Verbelen, Florian (Ghent Univ), Derammelaere, Stijn (Univ. of Antwerp), Stockman, Kurt (Univ. Gent, Campus Kortrijk)

Stepping motors are used in numerous applications because of their low manufacturing cost and simple open-loop position control capabilities. The bulk of the widely used full-step open-loop stepping motor drive algorithms are driven at maximum current to avoid step loss. This non-optimal way of control leads to low eciency. In order to use stepping motors in a more optimal way, closed-loop control is needed. A previously described sensorless load angle estimation algorithm, solely based on voltage and current measurements, is used to provide the necessary feedback without using a mechanical position sensor. In this paper, an adaptive PI controller which optimizes the current level based on the feedback of the estimated load angle is introduced. Although the current - load angle dynamics are highly non-linear, an adaptive PI controller with the settling time of the current reduction as design constraint is worth considering. Especially because few tuning parameters are required. The described method is complimentary to the popular methodology used to drive a stepper motor, which is based on step command pulses. Measurements validate the proposed approach.

11:30-11:50 WeAT3.4

Cascade Attitude Control of a Quadcopter in Presence of Motor Asymmetry, pp. 113-118

Njinwoua, Brice (Univ. of Mons), Vande Wouwer, Alain (Univ. De Mons)

The quadcopter is one of the most popular unmanned aerial vehicles in both military and commercial in- and outdoor applications. In this study, the problem of UAV attitude control is investigated when there are discrepancies in the characteristics of the 4 actuators, i.e., electrical motors and propellers. To tackle this problem in a simple way, a cascade control strategy is proposed with a PD controller in the inner loop to achieve stabilization, and PI controller in the outer loop to ensure disturbance rejection. This way, the external disturbance created by the actuator asymmetry is compensated by the PI loop. The robustness of the control strategy is tested in simulation as well as in real-life tests.

11:50-12:10 WeAT3.5

Designing 3-DOF Hardware-In-The-Loop Test Platform Controlling Multirotor Vehicles, pp. 119-124

Hancer, Muhsin (Necmettin Erbakan Univ), Bitirgen, Rahman (Istanbul Tech. Univ), Bayezit, Ismail (Istanbul Tech. Univ)

Main idea of this paper is the development of Hardware-in-the-Loop test platform in order to flight mechanical modeling and better stabilization of multirotor vehicles via

different feedback control structures, including PID controllers. First, nonlinear mathematical model of the quadrotor platform is built and validated via Matlab/Simulink based simulation environment.Then, Hardware-in-the-Loop (HIL) test scenario is developed to analyze and tune controller parameters with the help of in-house designed testbed mechanism. Next step is observing the quadrotor attitude maneuvers via embedded hardware over the gyroscopic gimballed testbed. The HIL testbed enables us validate and calibrate model and control parameters within real-time environment including inertial and mechanical sensors for multirotor systems. In this study, the particular platform is IRIS cross-type quadrotor vehicle PID based controlled for stable hover flight.

WeI2N	Lobby
PID Tuning (Poster/Interactive Session)	
Chair: Lennartson, Bengt	Chalmers Univ. of Tech
Co-Chair: Birs, Isabela Roxana	Tech. Univ. of Cluj-Napoca

12:30-13:30 WeI2N.1

Tuning PID Controllers from Sampled-Data Relay Feedback Experiments, pp. 125-130

Bazanella, Alexandre S. (Univ. Federal Do Rio Grande Do Sul), Parraga, Adriane (Univ. Estadual Do Rio Grande Do Sul (UERGS))

Existing tuning formulas for PID based on relay feedback experiments are derived from continuous-time systems theory, even though most such systems are implemented digitally. These formulas rely on the fact that, according to this continuous time theory, the relay feedback experiment allows the identification of the ultimate point of the plant's frequency response - the point at which its Nyquist plot crosses the negative real axis. We have shown in a recent paper that a sampled relay feedback experiment may exhibit various limit-cycles at possibly quite different frequencies, even for quite reasonable sampling rates - that is, well within the ranges recommended by sampling theory and control textbooks. In this paper we show the deleterious effect of this reality on the tuning of PID controllers and propose an improvement to the tuning formulas to overcome this limitation.

12:30-13:30 WeI2N.2

PID Tuning Based on Forced Oscillation for Plants without Ultimate Frequency, pp. 131-136

Lorenzini, Charles (Univ. Federal Do Rio Grande Do Sul - UFRGS), Bazanella, Alexandre S. (Univ. Federal Do Rio Grande Do Sul), Pereira, Luís Fernando Alves (Univ. Federal Do Rio Grande Do Sul)

In this article, a method to tune proportional-integral-derivative controllers for the class of plants with relative degree one is proposed, since this class includes plants that are not amenable to application of the traditional Ziegler-Nichols (ZN)-like methods. The method presented here is based on a modified relay feedback experiment with inclusion in the loop of a transfer function of constant phase in a defined range of frequencies. Thus, with a single experiment and simple tuning formulas this method enlarges the class for which the ZN-like methods can be applied.

12:30-13:30 WeI2N.3

Structure-Specific Analytical PID Tuning for Load Disturbance Rejection, pp. 137-142

Leva, Alberto (Pol. Di Milano), Seva, Silvano (Pol. Di Milano)

This paper addresses the important and well studied problem of synthesising PID controllers for load disturbance rejection. The tuning rationale, on which some general words are spent in connection to literature research, is to shape the disturbance-to-output frequency response, together with conveniently assigning the poles of the corresponding transfer function. Analytical tuning formulae are derived, to maximise simplicity and make the presented method applicable on any device. Simulation results support the proposal.

12:30-13:30 WeI2N.4

A Recursive Tuning Approach for the Model-Free PID Controller Design, pp. 143-147

Wang, Jiadong (Zhejiang Supcon Software Ltd), Zhang, Yanhui (Zhejiang Supcon Software Co., Ltd), Jin, Xiaoming (Zhejiang Univ), Su, Hongye (Zhejiang Univ)

This paper presents a new model-free tuning approach for the PID controller tuning with the employment of the refined recursive instrumental variable (RIV) method. The proposed approach can be applied to solve the control loop tuning problem without identification of the plant or process model and it can be implemented in the online manner. Also, the colored measurement noise has been taken into account. For PI and PID control, the implementation details and the step by step procedures are provided respectively. Two simulation examples are provided to validate the effectiveness of the proposed approach.

12:30-13:30 WeI2N.5

IMC PI Control Loops Frequency and Time Domains Performance Assessment and Retuning, pp. 148-153

da Silva Moreira, Lucas José (Univ. Federal De Campina Grande), Acioli Junior, George (Univ. Federal De Campina Grande), Barros, Péricles R. (Univ. Federal De Campina Grande)

This paper is about a performance assessment strategy for IMC PI control systems using collected data from a specific closed-loop experiment. It is used time and frequency indexes to analyze how close or far the closed-loop is from the desired performance. A data-driven PI retuning method is applied to improve the control system for IMC PI specifications and the chosen indexes.

WeI3N Lobby

PID Control Applications 2 (Poster/Interactive Session)

Chair: Sato, Takao Univ. of Hyogo

Co-Chair: Mac Thi, Thoa Ugent

14:30-15:00 WeI3N.1

New Repetitive Current Controller for PWM Rectifier, pp. 154-159

Wang, Xiaohong (South China Univ. of Tech), Pan, Zhifeng (South China Univ. of

Tech), Hoang, Thi Thu Giang (South China Univ. of Tech), Tian, Lianfang (South China Univ. of Tech), Chen, Yangquan (School of Engineering , Univ. of California)

This paper analyzed and designed a new Repetitive Current Controller (New RCC), performing a comparison with a traditional RCC. Based on the tracking performance by the original PI controller, the New RCC uses another PI controller to replace the compensator to achieve better control performance. That is the novel approach of the proposed method. And it has been proved in this paper that the controller is not sensitive to the controlled object, therefore it is suitable for use in complex object model scenarios. Simulations and experimental results demonstrate that the new RCC is effective in improving the AC current quality of the three-phase PWM rectifier, which is the right method of control, with high practical application value.

14:30-15:00 WeI3N.2

Mixed Slip-Deceleration PID Control of Aircraft Wheel Braking System, pp. 160-165

Chen, Mengqiao (Central South Univ), Liu, Wensheng (Central South Univ), Ma, Yunzhu (Central South Univ), Wang, Jian (Central South Univ), Xu, Fengrui (Central South Univ), Wang, Yejian (Central South Univ)

Aircraft antiskid braking system is designed to prevent the main wheels from locking and additionally seeking the optimal braking performance. Wheel deceleration is the traditional controlled target used in antiskid system, since it can be easily measured by angular velocity transducer. However the optimal target value is hard to find due to the changing of road-surface and aircraft velocity. An alternative controlled target is the wheel longitudinal slip which is more robustly controllable under all conditions. But the wheel slip cannot be measured directly, that will definitely result in control error from the poor estimated aircraft speed. In this work a PID control scheme based on mixed slip-deceleration input variable is proposed for aircraft antiskid braking system. This control algorithm is able to stabilize the wheel slip around any equilibrium point. Moreover, it inherits all the appealing characteristics of slip control, while overcoming its sensitivity to slip measurement errors.

14:30-15:00 WeI3N.3

Adaptive PI Control of Bottom Hole Pressure During Oil Well Drilling, pp. 166-171

Zhou, Jing (Univ. of Agder)

In this paper, we studied the bottom hole pressure (BHP) control in an oil well during drilling. Today marginal wells with narrow pressure windows are frequently being drilled. This requires accurate and precise control to balance the bottom hole pressure between the pore and fracture pressure of the reservoir. This paper presents three control schemes to stabilize the BHP profile, including proportional-integral(PI) control, PI with feed-forward control and adaptive PI with feed-forward control. The proposed schemes are carried out through simulations on a high-fidelity hydraulic drilling simulator for flow rate changes and BHP set-point changes. The simulation results illustrate the effectiveness of proposed control schemes.

14:30-15:00 WeI3N.4

New Method to Find Operating Points for Multi-PID Control. Application to Vehicle Lateral Guidance, pp. 172-177

Monot, Nolwenn (IMS Lab), Moreau, Xavier (Univ. of Bordeaux, FRANCE), Benine Neto, André (IMS Lab), Rizzo, Audrey (IMS), Aioun, François (PSA Company)

This paper proposes a new approach to find operating points for gain scheduling control using PID controllers. The operating point are computed with a frequency analysis of the system that gives the number of operating points needed and their values. The PID are weighted in their operating area using continuous functions that depend on the scheduling parameter. A concrete example of an autonomous vehicle lateral guidance shows the effectiveness of the method comparing different configuration of operating points and weights.

Technical Program for Thursday May 10, 2018

ThAT1	The Globe
Control Education 1 (Regular Session)	
Chair: Dormido, Sebastián	UNED
Co-Chair: Saenz, Jacobo	UNED

08:40-09:00 ThAT1.1

M-PaRoLa: A Mobile Virtual Laboratory for Studying the Kinematics of Five-Bar and 3RRR Planar Parallel Robots, pp. 178-183

Peidro, Adrian (Miguel Hernandez Univ), Tendero, Carlos (Miguel Hernández Univ), Marin, Jose Maria (Miguel Hernandez Univ), Gil, Arturo (Miguel Hernández Univ), Paya, Luis (Miguel Hernández Univ), Reinoso, Oscar (Univ. Miguel Hernández)

This paper presents m-PaRoLa, an educational virtual laboratory that consists of Javascript simulations for analyzing parallel robots. These simulations can be run indistinctly on web browsers of desktop computers or mobile devices (smartphones, tablets), which turns m-PaRoLa into a mobile virtual laboratory ready to be integrated in m-learning methodologies for teaching robotics and mechanisms. The presented simulations, which are highly intuitive and visual, allow the user to analyze diverse kinematic problems of parallel robots.

09:00-09:20 ThAT1.2

Next Steps in Supporting More Students in MOOL for Control Education, pp. 184-189

Salzmann, Christophe (Ec. Pol. Fédérale De Lausanne), Gillet, Denis (Ec. Pol. Fédérale De Lausanne (EPFL))

This paper explores the possible steps to support a larger number of students in a Massive Open Online Lab (MOOL) dedicated to control education. The current solutions to support a ratio greater than 1:1 (1 student accessing 1 setup) is either to multiply the setups or to limit the time the students access the setup. This paper first describes the current EPFL MOOL infrastructure and its associate MOOC for control offered to bachelor engineering students. It then provides analysis of students access and activity. Finally based on the analysis, various options to support more students are explored.

09:20-09:40 ThAT1.3

New Interactive Books for Control Education, pp. 190-195

Guzman, Jose Luis (Univ. of Almeria), Piguet, Yves (Calerga Sarl), Dormido, Sebastián (UNED), Berenguel, Manuel (Univ. of Almeria), Costa-Castelló, Ramon (Univ. Pol. De Catalunya (UPC))

This paper presents a ongoing project to develop new interactive books for control education. The novelty of the proposed idea is to merge web-based solutions with LaTex text into a epub format. In such a way, classical interactive tools for control education are combined with static text and thus interactive books are created, being compatible with standard e-book readers. A book chapter about the teaching of second-order processes is presented as example to show the different steps and the

results of the proposed idea.

09:40-10:00 ThAT1.4

A Web Based Support for the Performance Portrait Based Controller Design, pp. 196-201

Huba, Mikulas (Slovak Univ. of Tech. in Bratislava), Žáková, Katarína (Slovak Univ. of Tech. in Bratislava)

The Performance Portrait Method enables to visualize influence of chosen control parameters on the loop performance of the selected dynamical system with given interval parameter uncertainties. The knowledge of this behavior can help to analyze and tune control algorithm and to fulfill expected requirements as far as robustness and control quality. The presented paper introduces a new web tool that in an interactive way enables to design filtered 2DOF PI controller for the integral plus dead time system models on the base of the performance portrait method. For a performance portrait calculated once in the 3-5D parameter space it enables to find optimal robust controller tuning. For given plant parameter uncertainties it yields the fastest possible transient responses satisfying with chosen tolerances the shape related constraints at the plant input and output. A web application developed to illustrate the problem offers much richer visual information than it is possible to offer by standard publications, interactivity and dynamical effects. The backend of the application is driven by Matlab software. This environment is used both for calculation of the performance portrait and for simulation of transients of the considered feedback control structure.

ThAT2 El Pais

PID Control of Mechatronic Systems 2 (Regular Session)

Chair: Copot, Cosmin Univ. of Antwerp

Co-Chair: Chacón, Jesús Univ. Nacional De Educación a Distancia

08:40-09:00 ThAT2.1

Anti-Disturbance Study of Position Servo System Based on Disturbance Observer, pp. 202-207

Sun, Jing (Changchun Univ. of Science and Tech), Wang, Chunyang (Changchun Univ. of Science and Tech), Xin, Ruihao (Changchun Univ. of Science and Tech)

In this paper, the mechanism and method of using disturbance observer (DOB) to eliminate the disturbance are studied and applied to the control of position servo system. The DOB consists of an inverse model of the controlled object and a filter, and suppresses the external disturbance acting on the servo system. Based on the traditional proportional integral derivative (PID) controller, simulations on MATLAB/Simulink and tests on Quanser semi-physical experiment platform are performed for the PID controller with DOB and without DOB. Simulation and experimental results show that the introduction of DOB can effectively suppress the external disturbance and improve the dynamic response performance and stability of the servo system.

09:00-09:20 ThAT2.2

A Fast Autotuning Method for Velocity Control of Mechatronic Systems, pp. 208-213

Giacomelli, Marco (Univ. of Brescia), Colombo, Davide (Gefran Spa), Simoni, Luca (Univ. of Brescia), Finzi, Giovanna (Univ. of Brescia), Visioli, Antonio (Univ. of Brescia)

In this paper a fast automatic tuning methodology for velocity controllers of mechatronic systems is proposed. In order to be applicable in general, the method takes into account the position, velocity and torque constraints of the motion control system and it requires a minimum intervention of the operator. Further, it can be implemented also with small computational capabilities which makes it suitable for industrial drives. Simulation results show the effectiveness of the technique.

09:20-09:40 ThAT2.3

Acceleration Feedback in PID Controlled Elastic Drive Systems, pp. 214-219

Helma, Václav (NTIS Res. Centre, Univ. of West Bohemia, Pilsen), Goubej, Martin (Univ. of West Bohemia), Ježek, Ondřej (Univ. of West Bohemia)

This paper deals with the use of a load acceleration feedback to overcome fundamental performance limitations of elastic servo drive systems that occur when employing a standard PI velocity controller. Structured H-infinity optimization approach is used to develop an optimal control strategy consisting of a PI controller and a static acceleration feedback. Qualitative and quantitative analysis of potential benefits for the case of a two-mass system is provided. Effects of higher resonance modes is studied as well. Experimental results demonstrate the application of the proposed methodology to a flexible arm manipulator.

09:40-10:00 ThAT2.4

Robust Tuning Rules for Series Elastic Actuator PID Cascade Controllers, pp. 220-225

Ghidini, Stefano (Inst. of Industrial Tech. and Automation, CNR, Italy), Beschi, Manuel (National Res. Council of Italy (CNR)), Pedrocchi, Nicola (CNR - National Res. Council of Italy), Visioli, Antonio (Univ. of Brescia)

This paper deals with the control of a collaborative robot manipulator with series elastic actuators. In particular, robust tuning rules for cascade control of the joints are presented. Both the motor velocity and link position control loops are considered. The proposed tuning rules allow the online computation of robust control parameters to cope with the different link reflected inertia. Experimental results show the effectiveness of the method in real applications.

ThAT3 Fleuri

PID Control of Energy Systems 1 (Regular Session)

Chair: Rampazzo, Mirco Univ. Degli Studi Di Padova

Co-Chair: Zhao, Shiquan Harbin Engineering Univ

08:40-09:00 ThAT3.1

Grid Voltage Regulation Using a Reset PI+CI Controller for Energy Storage Systems, pp. 226-231

Raveendran Nair, Unnikrishnan (Univ. Pol. De Catalunya), Costa-Castelló, Ramon (Univ. Pol. De Catalunya (UPC)), Baños, Alfonso (Univ. of Murcia)

Hybrid controllers are capable of improved performance over their linear counterparts. In particular, reset controllers like the PI+CI are capable of fast flat response for lag dominant plants. Grid connected power converters especially interfacing energy storage systems to grids are required to have fast response to varying load demands to ensure minimum variation in grid parameters. Application of PI+CI controllers in such systems can improve their performance. In this work the improvement brought about by use of PI+CI controller employed for energy storage system power converters is highlighted by comparing it with PI controller based system under load variations. A DC microgrid with Fuel cellsupercapacitor based storage elements are considered here. The design criteria and simulation results are presented here.

09:00-09:20 ThAT3.2

An Analysis of Dynamic Lighting Control in Landscape Offices, pp. 232-237

Juchem, Jasper (Ghent Univ), Lefebvre, Stijn (Ghent Univ), Mac Thi, Thoa (Ghent Univ), Ionescu, Clara (Ghent Univ)

This paper makes a discussion on the control of light in landscape offices. This is a feature of modern office buildings, with increasing incidence as the number of employees increase while individual space allocation decreases. This can have already an impact on the efficiency and versatility of coping with stress situations of the employees. Apart from the stress induced by the lack of space and privacy, the light level is yet another important factor. Poor light or extreme illumination, or even more relevant: periodic shadow disturbance (i.e. windmills) are all increasing factors of stress levels. Control of illumination in a closed environment seem to be a feasible solution, but perhaps not very useful for the overall mood of the employee. Windows and possibility to see green patches, sunlight, have significant positive influence on the overall working conditions. Although easy to implement and broadly available in industrial lighting components, PID control has some limitations which we discuss here.

09:20-09:40 ThAT3.3

Collective Pitch Control with Active Tower Damping of a Wind Turbine by Using a Nonlinear PID Approach, pp. 238-243

Gambier, Adrian (Fruanhofer IWES, Fraunhofer Inst. for Wind Energy Systems), Nazaruddin, Yul Yunazwin (Inst. Teknologi Bandung (ITB))

The present work describes the results obtained from a nonlinear PID control (NPID) approach for the pitch control with top tower active damping of a large wind turbine. The control algorithm is implemented by using a well-known approach based on hyperbolic secant functions. A nonlinear PID controller and a nonlinear P controller are used for the collective pitch control and the active tower damping, respectively. As simulation platform, the 5-MW reference turbine developed by NREL and the software FAST are used. Results show that the NPID approach can provide significant improvements in the control performance in comparison to the classic control approach, in particular when the wind speed goes far from its rated value.

ThAT4 Bouquet

PID Design 1 (Regular Session)

Chair: Kinoshita, Takuya Hiroshima Univ

Co-Chair: Hauksdottir, Anna Soffia Univ. of Iceland

08:40-09:00 ThAT4.1

Closed-Loop Data-Driven Trade-Off PID Control Design, pp. 244-249

Kurokawa, Ryo (Univ. of Hyogo), Sato, Takao (Univ. of Hyogo), Vilanova, Ramon (Univ. Autònoma De Barcelona), Konishi, Yasuo (Univ. of Hyogo)

The present study proposes a new approach to a data-driven PID control design method based on one-shot closed-loop input and output data. Even if the proposed controller is designed using only one-shot data, both the prescribed robust stability and tracking performance optimization are attained. The proposed control law is designed by solving a constrained optimization problem, in which the robust stability as a constraint condition is designed by a sensitivity function estimated using the discrete-time Fourier transform, and the performance function defined using a fictitious reference is minimized. As a result, the proposed method provides trade-off design between the tracking performance and robust stability, where the robust stability is arbitrarily selected depending on the model perturbation. The effectiveness of the proposed method is demonstrated through numerical examples.

09:00-09:20 ThAT4.2

When Is PID a Good Choice?, pp. 250-255

Soltesz, Kristian (Lund Univ), Cervin, Anton (Lund Univ)

A new and freely available model-based PID design tool for Matlab is introduced. It can be used to solve Maximal Integral Gain Optimization (MIGO) and (load) Integral Absolute Error (IAE) problems. Robustness is ensured through Hinf constraints on the closed-loop transfer functions. A Youla parameter (Q design) method for comparison with the optimal linear time- invariant (LTI) controller for the considered IAE optimization problem is presented. Several realistic design examples are provided, in which the tool is used to compare achievable PID and optimal LTI controller performance, to illustrate whether PID is a good choice for a given combination of process dynamics and closed-loop robustness requirements.

09:20-09:40 ThAT4.3

A Shifting Pole Placement Approach for the Design of Performance-Varying Multivariable PID Controllers Via BMIs, pp. 256-261

Sánchez, Helem Sabina (Univ. Pol. De Catalunya), Rotondo, Damiano (Univ. Pol. De Catalunya (UPC)), Puig, Vicenç (Univ. Pol. De Catalunya (UPC)), Quevedo, Joseba (Tech. Univ. of Catalonia)

In this paper, the design of a performance-varying multivariable Proportional-Integral-Derivative (PID) controllers is presented. The main objective is to provide a framework for changing online the closed-loop behavior of the controlled system using the shifting pole placement approach. In order to carry out this target, the PID design problem is transformed into a static output feedback design problem which is analyzed through the linear parameter-varying (LPV) paradigm. An academic example is used to

demonstrate the effectiveness of the proposed approach.

09:40-10:00 ThAT4.4

Robust QFT-Based PI Controller for a Feedforward Control Scheme, pp. 262-267

Hoyo, Ángeles (Univ. of Almería), Moreno, Jose Carlos (Univ. OF ALMERIA), Guzman, Jose Luis (Univ. of Almeria), Hagglund, Tore (Lund Univ)

Feedforward control schemes to compensate for disturbances are very well known in process control. In those control approaches, PID controllers are usually considered in the feedback loop, where nominal design for both feedback and feedforward controllers are commonly performed. This paper presents a robustness analysis to study how uncertainties can affect the classical feedforward control scheme. Afterwards, a robust PI controller is designed by using Quantitative Feedback Theory to account for these uncertainties and to fulfill robust specifications for the regulation control problem. Results based on frequency and time domains are presented.

ThAT5 Le Monde

Optimization in PID Control 1 (Regular Session)

Chair: Barros, Péricles R. Univ. Federal De Campina Grande

Co-Chair: Kaya, Ibrahim Dicle Univ

08:40-09:00 ThAT5.1

Optimized Retuning of PID Controllers for TITO Processses, pp. 268-273

Veronesi, Massimiliano (Yokogawa Italy), Visioli, Antonio (Univ. of Brescia)

In this paper we propose a methodology to evaluate the performance of decentralized PID controllers for two-inputs-two-outputs processes and to retune the parameters. In particular, the model of the process is estimated based on a technique that exploits the final value theorem. Then, an evolutionary algorithm is applied in order to find the Pareto front by considering a multi-objective optimization problem. Finally, the performance obtained with the current tuning is compared with the optimal ones and, in case it is necessary, the PID parameters are retuned accordingly. A procedure to achieve the Nash optimal point is also proposed.

09:00-09:20 ThAT5.2

PID Tuning Method for Integrating Processes Having Time Delay and Inverse Response, pp. 274-279

Ozyetkin, Munevver Mine (Adnan Menderes Univ), Onat, Cem (Inonu Univ), Tan, Nusret (Inonu Univ)

In this paper, a PID tuning method for integrating processes having time delay and inverse response is presented. The method is based on the stability boundary locus method and geometrical center (WGC) approach. The systematic procedure of the method is first to obtain the stability region in the PI controller parameters (proportional gain: kp and integral gain: ki) plane according to derivative gain (kd) using the stability boundary locus method and then to find the weighted geometrical center point of this region. The WGC controllers are obtained by using different values of kd. Simulation examples have demonstrated that PID controller designed by using the proposed

method gives good results.

09:20-09:40 ThAT5.3

Multidisciplinary Optimisation and Controller Tuning: An Analysis with Multi-Objective Techniques, pp. 280-285

Reynoso-Meza, Gilberto (Pontificia Univ. Católica De Paraná), Sánchez, Helem Sabina (Univ. Pol. De Catalunya)

Multidisciplinary design optimisation (MDO) has shown to be a valuable tool for designers when different fields converge in the design phase. Where classical approaches perform a sequential optimisation procedure, it seeks to exploit synergies between interacting subsystems, with the aim of getting a better overall. In this paper, we analyse and compare three different MDO approaches considering the tuning of a Proportional-Integral (PI) controller and plant design simultaneously. As conflicting objectives might appear, we compare such approaches using multi-objective optimisation. With the provided example, advantages and drawbacks are highlighted, in order to provide an insight about the applicability of such approaches.

09:40-10:00 ThAT5.4

Multi-Criteria Optimization of PD Controllers for Plants Including Integral Action, pp. 286-291

Lennartson, Bengt (Chalmers Univ. of Tech)

A simple design method for robust PD controllers is presented for systems including integral action. The design method is based on a multi-criteria optimal control formulation, which is easily solved by a few lines of MATLAB code. Most criteria are based on Hinfsaasaa measures, but since the focus is on reference signal tracking and not load disturbance compensation, the settling time is also included as a relevant performance measure. Since a PD controller is equivalent to a lead filter, the optimal PD controller is compared with ordinary text book design rules for lead filters. More specifically, it is shown that the common recommendation to place the mid frequency of the lead filter at the desired gain crossover frequency often gives bad servo performance. The suggested optimal solution, still including robustness and control activity adjustments, is on the other hand a simple and flexible design method for arbitrary plants including integral action.

ThI1S Lobby

Control Education 2 (Poster/Interactive Session)

Chair: Guzman, Jose Luis Univ. of Almeria

Co-Chair: Berenguel, Manuel Univ. of Almeria

10:00-10:30 ThI1S.1

Closed Form Expressions of Linear Continuous Time System Responses, pp. 292-297

Hauksdottir, Anna Soffia (Univ. of Iceland), Sigurdsson, Sven Th. (Univ. of Iceland)

General closed form expressions of linear continuous time system responses of an arbitrary order are derived, by first relating them to basic responses, i.e., responses corresponding to unity numerator transfer functions. Those are then related to the fundamental solutions of the underlying differential equations. These expressions apply

to all systems without any restrictions on the poles or the zeros, further the systems may be noncausal. We derive responses for all regular types of inputs, impulse, step, ramp, parabola, etc., in addition for all generalized derivatives of the impulse. All the presented results have a direct counterpart in results presented in Sigurdsson et al. (2017) on discrete time systems based on the fundamental solution of the associated difference equation. Efficient evaluations of the fundamental solutions along with their derivatives and integrals can thus be extended to the responses and are readily implemented, e.g., as Matlab functions. Such results may be presented symbolically as functions of time or evaluated numerically at any sequence of times without time stepping.

10:00-10:30 ThI1S.2

Design of Digital PID Controllers Using Particle Swarm Optimization: A Video Based Teaching Experiment, pp. 298-303

Moura Oliveira, Paulo (Univ. De Tras Os Montes E Alto Douro)

The use of videos is a valuable and powerful tool which may significantly contribute to change and improve teaching and learning methods. Lecturers can made their own videos addressing specific topics suitable to fulfill their student's needs. These videos can address control engineering syllabus as well as complementary topics. This paper proposes using video as a tool to introduce the particle swarm optimization algorithm to students within a digital PID control simulation experiment. The experience preliminary results and feedback received from students are quite positive.

10:00-10:30 ThI1S.3

Experimental Study of Nonlinear PID Controllers in an Air Levitation System, pp. 304-309

Chacón, Jesús (Univ. Nacional De Educación a Distancia), Vargas Oyarzun, Hector (Pontificia Univ. Catolica De Valparaiso), Dormido, Sebastián (UNED), Sánchez Moreno, José (UNED)

This paper presents an experimental study of different non linear PI controllers using an academic platform based on an Air Levitation System. The comparison is based on common performance indexes, computed over the data extracted from the experiments. The results verify that, in addition to the PID controller in its classic form, several non-linear modifications can be considered to cope with different control needs, such as optimization on the number of control actions, or go beyond the restrictions that linearity impose on the performance that can be obtained by a PID controller.

10:00-10:30 ThI1S.4

ODYSC: A Responsive Educational Web App for Dynamics and Control, pp. 310-315

Dekemele, Kevin (Ghent Univ), Chevalier, Amélie (Ghent Univ), Loccufier, Mia (Ghent Univ)

The Online Dynamical Systems and Control (ODYSC) web application has been developed for the introductory dynamics and control courses taught to engineers and business engineering of Ghent university, accessible through http://www.odysc.ugent.be/. Generally speaking, the advantage of web apps over conventional software is the compatibility between OS and devices, as only a browser is required. Recently, students bring a mobile phone to lectures. While these are often

used by the students themselves as a distraction, they are actually very powerful computers capable of performing simulations of dynamical systems. Because of this, ODYSC has been designed to be responsive, working equally well on both mobile phone as on a laptop or PC. While ODYSC can serve as a distance learning tool, it can also be employed during classical lectures. While the teacher explains new concepts in dynamics or control, these can immediately be made clear through simulations on the student's phone. Before, the amount of students attending these courses were a practical limitation for organizing computer labs. Even if such infrastructure exists, the software used requires the students to code in a new language, which they are often not motivated enough to do for a single lab, or the software is associated with costly or complicated licensing. ODYSC requires no special infrastructure but a device with a browser which students themselves bring anyway. ODYSC is still in full development and for now can perform open loop and closed loop simulations on LTI systems, and plot bode plots of the system.

10:00-10:30 ThI1S.5

Online Virtual Control Laboratory of Mobile Robots, pp. 316-321

Galan Vicente, Daniel (UNED), Fabregas, Ernesto (Univ. Nacional De Educación a Distancia (UNED)), Garcia, Gonzalo (Univ. of Kansas), Saenz, Jacobo (UNED), Farias, Gonzalo (Pontificia Univ. Catolica De Valparaiso (PUCV)), Dormido Canto, Sebastián (UNED), Dormido, Sebastián (UNED)

In STEM subjects, interactive laboratories are one of the most widely used tools for students to acquire practical knowledge. These laboratories allow them to modify system parameters and analyze the outputs in real time. In control engineering, these laboratories include different predefined controllers with which the student must experiment to study their operation. However, these laboratories usually do not include functions that allow students themselves to create their own controller. This work presents an interactive virtual laboratory to control mobile robots developed in JavaScript. Mobile robots are an attractive platform for students where they can analyze, test and understand fundamental concepts that are difficult to explain from a theoretical point of view. This environment allows the student to generate their own experiments (general statements, controllers, steps to follow over time) and test them with the simulator. For example, they can design their own position controllers and they can compare different PID-type control strategies in real time. Besides, this environment is open and configurable, so the teacher can decide the available features for each experiment depending of the learning goals.

ThBT1 The Globe

Control Education 3 (Regular Session)

Chair: Hagglund, Tore Lund Univ

Co-Chair: Huba, Mikulas Slovak Univ. of Tech

10:30-10:50 ThBT1.1

Evaluation of Student Software Tools for Supporting an Understanding of PID Tuning, pp. 322-327

Rossiter, J. Anthony (Univ. of Sheffield)

There are many software tools available for students to implement PID control laws, but these software tools are not all equally flexible, easy to use, accessible and hence

effective. This paper gives a brief review of three tools: (i) author built tools in MATLAB; (ii) TSC software and (iii) PISIM software. The evaluation considers aspects such as convenience and cost for the academic as well as accessibility and useability for the students. The main results in the paper are written in such a way as to assist staff in deciding in what software its worth investing time and effort developing resources and student activities.

10:50-11:10 ThBT1.2

Teaching PID Control to Computer Engineers: A Step to Fill a Cultural Gap, pp. 328-333

Leva, Alberto (Pol. Di Milano)

Many computer engineers either do not receive any control education, or are led to think that studying control is necessary only for those who want to specialise in embedded systems, real-time, and so forth. This causes a cultural gap that can have highly undesired consequences, since control-based techniques are gaining importance as a means to manage and optimise computing systems. Given the conflicts for time and space that are typical of articulated curricula like computer engineering, however, a full course on the principles of systems and control, tailored to computer engineering, is quite often an infeasible solution. This paper presents an alternative - or maybe better, a workaround - based on a suitably tailored PID-centred activity, where the occasion is taken to introduce and stress selected general ideas.

11:10-11:30 ThBT1.3

The Use of Interactivity in the Controller Design: Loop Shaping versus Closed-Loop Shaping, pp. 334-339

Díaz, Jose Manuel (UNED), Dormido, Sebastián (UNED), Costa-Castelló, Ramon (Univ. Pol. De Catalunya (UPC))

Frequency domain is one of the most popular and powerful framework to design control system. Usually this procedure is done using the open-loop transfer function. In this work, it is explored the possibility to perform the controller design by closed-loop shaping. It is analyzed how graphical representation and interactivity can be used in this framework to help automatic control students during the learning process.

11:30-11:50 ThBT1.4

Design and Implementation of a Real-Time Autonomous Navigation System Applied to Lego Robots, pp. 340-345

Mac Thi, Thoa (Ghent Univ), Copot, Cosmin (Univ. of Antwerp), Ionescu, Clara (Ghent Univ)

Teaching theoretical concepts of a real-time autonomous robot system may be a challenging task without real hardware support. The paper discusses the application of the Lego Robot for teaching multi interdisciplinary subjects to Mechatronics students. A real-time mobile robot system with perception using sensors, path planning algorithm, PID controller is used as the case to demonstrate the teaching methodology. The novelties are introduced compared to classical robotic classes: (i) the adoption of a project-based learning approach as teaching methodology; (ii) an effective real-time autonomous navigation approach for the mobile robot. However, the extendibility and applicability of the presented approach are not limited to only the educational purpose.

ThBT2 El Pais

PID Control of Mechatronic Systems 3 (Regular Session)

Chair: Simoni, Luca Univ. of Brescia

Co-Chair: Goubej, Martin Univ. of West Bohemia

10:30-10:50 ThBT2.1

All Stabilizing State Feedback Controller for Inverted Pendulum Mechanism, pp. 346-351

Bitirgen, Rahman (Istanbul Tech. Univ), Hancer, Muhsin (Necmettin Erbakan Univ), Bayezit, Ismail (Istanbul Tech. Univ)

In the literature, finding all stabilizing controllers are widely studied. In this paper, a case study of inverted pendulum is considered to test the methods for finding stabilizing state feedback controller. First, good set of state feedback gain matrix is calculated, two of feedback parameters are fixed to reduce the computational cost. The other two of feedback parameters that make the system stable are then calculated by gridding. The boundary of the stability region is calculated with the frequency method. In order to have fast response, the eigenvalue region of the closed loop system is defined as the left hand side of the $-1+jomega$ line and the stability region for feedback gains are calculated for this scenario.

10:50-11:10 ThBT2.2

Robust High-Gain Generalization of PID Controllers with Anti-Windup Compensation, pp. 352-357

Borisov, Oleg (ITMO Univ), Tomashevich, Stanislav (IPME RAS; ITMO Univ), Gromov, Vladislav (ITMO Univ), Kakanov, Mikhail (ITMO Univ), Pyrkin, Anton (ITMO Univ), Bobtsov, Alexey (ITMO Univ)

Generalization of PID controllers depending on the plant relative degree is addressed in the paper. The consecutive compensator approach is redesigned in the state-space representation and augmented with the integral loop and anti-windup scheme. The stability of the closed-loop system is proved. Efficiency of the proposed approach is illustrated by the experiments carried out using the 2-DOF indoor quadcopter testbed.

11:10-11:30 ThBT2.3

PSO Based PID Controller for Quadrotor with Virtual Sensor, pp. 358-363

Nazaruddin, Yul Yunazwin (Inst. Teknologi Bandung (ITB)), Andrini, Angela Dian (Inst. Teknologi Bandung), Anditio, Boby (Inst. Teknologi Bandung)

Recent development and implementation on intelligent control system has lead to the development of virtual sensing system technology. Virtual sensing system allows immeasureable state variables to be accurately predicted, which is very beneficial to reduce the amount of sensors required to monitor and control a system, especially for the case of controlling a quadrator. This paper proposes a novel technique to design a PID control using virtual sensing system, consisting of Diagonal Recurrent Neural Network (DRNN) and Extended Kalman Filter (EKF), which predicts the immeasureable states of the quadrator system based on the current states and control inputs. A bio-inspired optimization technique, Particle Swarm Optimization (PSO), is proposed to be applied in DRNN to avoid any possibilities from local extreme condition. Further, a PSO based PID position controller is also developed to be integrated with

the designed virtual sensing system to control a quadrator.

11:30-11:50 ThBT2.4

Reference Tracking of a Nonholonomic Mobile Robot Using Sensor Fusion Techniques and Linear Control, pp. 364-369

Nascimento Forte, Marcus Davi (Univ. Federal Do Ceará), Correia, Wilkley (Univ. Federal Do Ceará), Nogueira, Fabrício Gonzalez (Univ. Federal Do Ceará), Torrico, Bismark Claure (Federal Univ. of Ceara)

This paper presents the control design of a nonholonomic mobile robot with differential drive using control strategies on a linearized space state error model. In this case, a diagonal multi-variable model is obtained for which a decentralized PI controller may be designed. In this paper, PI tuning is performed through a LQR problem whose feedback gains are set as the proportional gain of the PI controller. The use of an Inertial Measuring Unit (IMU) allows for a precise posture feedback by using a Kalman Filter on the output of the sensors. For such purpose, a Sensor Fusion technique is also needed in order to combine multiple sensor output so that physical limitations of each sensor may be compensated.

ThBT3 Fleuri

PID Control of Energy Systems 2 (Regular Session)

Chair: Chacon Vasquez, Mercedes Univ. of Costa Rica

Co-Chair: Gambier, Adrian Fruanhofer IWES, Fraunhofer Inst. for Wind Energy Systems

10:30-10:50 ThBT3.1

Gain-Scheduling Control Solutions for a Strip Winding System with Variable Moment of Inertia, pp. 370-375

Szedlak-Stinean, Alexandra-Iulia (Pol. Univ. of Timisoara), Precup, Radu-Emil (Pol. Univ. of Timisoara), Dragos, Claudia-Adina (Pol. Univ. of Timisoara), Radac, Mircea-Bogdan (Pol. Univ. of Timisoara)

This paper presents four design methods for the speed control of a mechatronics application characterized by variable parameters: variable reference, variable load disturbance and variable moment of inertia. The variations of the operating conditions and also the variations of the process parameters require the development of advanced control solutions. In this context the development of advanced control solutions will be influenced and justified significantly by the knowledge of a detailed mathematical model of the process and its parameters. In order to obtain high performance speed control for the electric drive system, referred to as the strip winding system, four proportional-integral (PI) gainscheduling control solutions are developed and tested: (1) a PI Switching-I Gain-Scheduling version with bump-less switching between three control algorithms (PI-SIGS), (2) a PI Switching-II Gain-Scheduling version with a switching logic based on Euclidean distance metric (PI-SIIGS); (3) a PI Gain-Scheduling version with a switching logic based on a generalization of the monovariable case of the Lagrange interpolating parameter value method (PI-LGS), and (4) a PI Gain-Scheduling version with a switching logic based on a Cauchy kernel distance metric (PI-CGS). The continuous-time speed controllers are tuned by the Modulus Optimum method (MO-m) and are discretized using Tustin's method. The

proposed and developed control solutions were embedded in a conventional control structure (CCS) which involves the switching between different digital control algorithms and are validated by means of simulation results. The strip winding system is discussed in this paper due to its applicability as a controlled plant in the field of mechatronics systems.

10:50-11:10 ThBT3.2

A Multivariable Controller for the Start-Up Procedure of a Solar Membrane Distillation Facility, pp. 376-381

Gil, Juan Diego (Univ. of Almeria), Roca, Lidia (CIEMAT - Plataforma Solar Dealmería), Berenguel, Manuel (Univ. of Almeria), Guzman, Jose Luis (Univ. of Almeria)

This paper presents a multivariable TITO (two inputs two ouputs) controller aimed to improve the start-up procedure of a Solar Membrane Distillation (SMD) facility, located at Plataforma Solar de Almeria (PSA). The control structure includes PID controllers and decouplers, as well as a reference governor based on a real time optimizer. The filtered Smith Predictor (SP) control structure has been used for controlling one of the output variables, whereas a cascade control scheme is employed to control the other one. The proposed approach has been tested in simulation on a nonlinear model of the SMD facility, showing promising results.

11:10-11:30 ThBT3.3

PID Based Particle Swarm Optimization in Offices Light Control, pp. 382-387

Copot, Cosmin (Univ. of Antwerp), Mac Thi, Thoa (Ghent Univ), Ionescu, Clara (Ghent Univ)

In this paper, a particle swarm optimization called multi-objective particle swarm optimization (MOPSO) with an accelerated update methodology is employed to tune Proportional Integral Derivative (PID) controller for a light control system. Nowadays, the demand of energy has exponentially increased and therefore is necessary to use the electric energy efficiently. Here, we tackle the use of light in offices where it is preferable to provide uniform illumination over the entire workplace by combining both natural and artificial lighting. The focus of this research is to regulate the light amount in a room at a constant level, irrespective of the disturbances from outside such as weather conditions. Thus, a control system for closed-loop regulation of the light amount in building rooms is designed. The main benefits would be a higher level of comfort and a continuous saving of energy. The obtained results verify that the MOPSO is able to perform appropriately in complex systems such as light control environment

11:30-11:50 ThBT3.4

PID Control of a Three Phase Photovoltaic Inverter Tied to a Grid Based on a 120-Degree Bus Clamp PWM, pp. 388-393

Mnati, Mohannad Jabbar (Ghent Univ), V. Bozalakov, Dimitar (Ghent Univ), Van den Bossche, Alex (Ghent Univ)

This paper presents a new operating type of a three phase photovoltaic PID current control system connected to the low voltage distribution grid. This operating type introduces a 120-degree bus clamp PWM control method (120° BC-PWM). A 120° BC-PWM is a special switching sequences technique employing bus clamp sequences that

use only one phase under a PWM and PID control state every 60° while the other phases are being clamped. The BC-PWM method was used to generate six PWM signals to control a three phase inverter system every 60° with constant power input and a small dc link film capacitor. The main objective of this paper is to use new PWM techniques with a PID current control method to reduce the switching losses of three phase inverters. The losses were reduced to 1/3th for each transistor by reducing the time operation for each transistor. The simulation results of the BC-PWM method show an improvement in the performance of the three phase inverter system connected to the grid. Simulation setup of the system obtained is built by using a SiC MOSFET, 5 kVA, 400 V line-line and 25 kHz switching frequency. The PID control is not continuously active for each phase but is operational in 60° and saturated at 120° in a half period. Following a proper tuning of the windup, it recovers very easily.

ThBT4 Bouquet

PID Design 2 (Regular Session)

Chair: Vilanova, Ramon — Univ. Autònoma De Barcelona

Co-Chair: Vrancic, Damir — Jozef Stefan Inst

10:30-10:50 ThBT4.1

PI and Adaptive Model Matching Control System That Satisfies the Setting Settling Time, pp. 394-399

Takiyama, Takeshi (Osaka City Univ), Yoshikawa, Tatsuya (Osaka City Univ), Noh, Jinto (Osaka City Univ), Ohta, Yuzo (Kobe Univ)

A new design method that satisfies the setting settling time with small maximum overshoot in a servo controller was developed using a PI controller and an internal feedback system. The internal feedback system consists of the model parameter of the controlled object that was approximated as a second-order lag-time system. Therefore, an adaptive ability that counteracts the changing model parameters was required. In this paper, the variable parameters of the controlled object were obtained by on-line execution of a non-linear least-squares method. Suitable adaptation by the developed method was confirmed in simulation and experimental tests.

10:50-11:10 ThBT4.2

PID Controller Design with an H Infinity Criterion, pp. 400-405

Han, Sangjin (Texas A&M Univ), Keel, Lee H. (Tennessee State Univ), Bhattacharyya, Shankar P. (Texas a & M Univ)

This paper deals with the design of Proportional-Integral (PI) and Proportional-Integral-Derivative (PID) controllers. The main result is a constructive determination of the set S_gamma of stabilizing PI and PID controllers achieving an H_infty norm bound of $gamma$ on the error transfer function. This result utilizes the computation of the complete stabilizing set S recently obtained. We also point out connections between this H_infty design and Gain and Phase Margin designs. Illustrative examples are presented.

11:10-11:30 ThBT4.3

Inverse Pole Placement Method for PI Control in the Tracking Problem, pp. 406-411

Guzman, Jose Luis (Univ. of Almeria), Moreno, Jose Carlos (Univ. of Almeria), Berenguel, Manuel (Univ. of Almeria), Moscoso, Jesús (Univ. of Almeria)

This paper presents the modification of the well-known pole placement method for first-order systems and PI control for the tracking problem. The main drawback of the original method is the presence of a zero in the closed-loop transfer function, which has a negative influence in the desired closed-loop response. Typically, this effect is cancelled by using a reference filter within a two-degree-of-freedom control scheme. However, in this work we present a simple modification of the original method that allows us to consider the zero effect in advance. First, the effect of a zero term in the response of second-order systems is analyzed to see how the time response parameters (overshoot, peak time, rise time and settling time) are affected. Afterwards, this analysis and the resulting equations are combined with the pole placement method to propose the new solution. Finally, simulation results are presented to demonstrate the advantages of the proposed method, where it is shown that faster responses than by using a reference filter are obtained.

11:30-11:50 ThBT4.4

Design of a Data-Oriented PID Controller for a Two Degree of Freedom Control System, pp. 412-415

Kinoshita, Takuya (Hiroshima Univ), Yamamoto, Toru (Hiroshima Univ)

Virtual Reference Feedback Tuning (VRFT) and Fictitious Reference Iterative Tuning (FRIT) are the data-oriented tuning schemes for directly designing feedback controllers. In these schemes, controller parameters are tuned to achieve the desired response without any system identifications. Furthermore, these schemes have been extended to the two-degree of freedom (2DOF) control systems in recent years. The conventional design schemes of 2DOF controllers are a two-step tuning method. The first step is to design a feedback controller to satisfy the desired disturbance response. The second step is to tune the feed-forward controller parameters to achieve the desired reference response. Consider these methods are complicated, this paper provides a one-step tuning scheme for a 2DOF control system based on data-oriented method. According to the proposed scheme, the reference of the complementary sensitivity function is introduced, and the least squares method can be applied to calculate the optimal controller parameters. Finally, the effectiveness of the proposed scheme is verified by using a numerical example.

ThBT5 Le Monde

PID Control Structures 1 (Regular Session)

Chair: Skogestad, Sigurd Norwegian Univ. of Science & Tech

Co-Chair: Veronesi, Massimiliano Yokogawa Italy

10:30-10:50 ThBT5.1

PID Posicast Control for Uncertain Oscillatory Systems: A Practical Experiment, pp. 416-421

Oliveira, Josenalde Barbosa (Agricultural School of Jundiaí), Moura Oliveira, Paulo (Univ. De Tras Os Montes E Alto Douro), Pinho, Tatiana M. (UTAD and INESC TEC), Boaventura Cunha, José (Univ. De Tras-Os-Montes E Alto Douro)

Half-cycle Posicast Control is currently used in a vast range of applications. Although

the proved benefits of this technique, one of its major disadvantages concerns model uncertainties. This has motivated the development and integration of robust methods to overcome this issue. In this paper, a practical experiment for auto-tuning of a two degrees of freedom control configuration using a Half-Cycle Posicast pre-filter (or input-shaping), and a PID controller under parametric variations is presented. The proposed method requires using an oscillatory system model in an auto-tuning control structure. The error derivative among the model and system output is used to trigger both the identifictation and retuning procedure. The proposed method is flexible for choosing identification plus optimization methods. Practical results obtained for electronic filter plants suggest improved performance for the considered cases.

10:50-11:10 ThBT5.2

Study on a Kalman Filter Based PID Controller, pp. 422-425

Wakitani, Shin (Hiroshima Univ), Nakanishi, Hiroki (Hiroshima Univ), Ashida, Yoichiro (Hiroshima Univ), Yamamoto, Toru (Hiroshima Univ)

This study proposes a self-tuning PID controller design method based on a Kalman filter. Recently, data-driven controller tuning methods that can directly tune control parameters by closed-loop data without system models have been received much attention as convenient tuning approaches. On the other hand, in parameter estimation problems, the Kalman filter that can obtain high-precision estimation results has been applied in many research/industrial area. In this paper, a data-driven PID parameters tuning problem that is derived based on a PID control law is resolved as a Kalman filtering problem, and a self-tuning PID controller based on the Kalman filter is proposed. The effectiveness of the proposed method is evaluated by simulation and experimental examples.

11:10-11:30 ThBT5.3

Modified PI Controller for the Stabilization of High-Order Unstable Delayed Systems with Complex Conjugate Poles and a Minimum Phase Zero, pp. 426-431

Hernandez Perez, Miguel Angel (Univ. Veracruzana), del Muro Cuéllar, Basilio (Inst. Pol. Nacional), Novella-Rodriguez, David Fernando (Inst. Tecnológico De Estudios Superiores De Monterrey), Velasco-Villa, Martin (CINVESTAV-IPN), Garrido-Moctezuma, Rubén Alejandro (Centro De Investigacion Y De Estudios Avanzados Del I.P.N)

This work deals with the stabilization problem of a particular class of high-order unstable linear systems with time delay. In particular, systems with one unstable pole, q-1 complex conjugate stable poles and one minimum phase zero. To solve this problem a modified version for the traditional PI controller, called in this work the Proporcional Integral Filtered PIf, is proposed. This new scheme includes a low-pass first order filter and allows improving the existing results on controlling high-order systems with time delay. Necessary and sufficient conditions for the existence of the PIf controller are expressed in terms of the parameters of the system and the maximum allowable time-delay magnitude. The proposed control scheme is illustrated by a numerical example applied to the temperature control of an unstable Continuously Stirred Tank Reactor (CSTR) linear model focused on the production of propylene glycol.

11:30-11:50 ThBT5.4

Observer-PI Scheme for the Stabilization and Control of High Order Delayed Systems with One or Two Unstable Poles, pp. 432-437

Vazquez, Carlos daniel (Inst. Pol. Nacional), Márquez Rubio, Juan Francisco (Inst. Pol. Nacional), del Muro Cuéllar, Basilio (Inst. Pol. Nacional), Novella-Rodriguez, David Fernando (Inst. Tecnológico De Estudios Superiores De Monterrey), Hernandez Perez, Miguel Angel (Univ. Veracruzana), Duchen, Gonzalo (Inst. Pol. Nacional)

This paper considers the problem of stabilization and control of linear time invariant high order systems with one or two unstable real poles, n real stable poles plus time-delay. In order to ensure a stable behavior of the closed loop system, necessary and sufficient conditions for the existence of an observer based controller together with a PI compensator are shown explicitly. Numerical simulation on academic examples are provided to illustrate the effectiveness of the proposed control strategy

ThI2S Lobby

PID Control Applications 3 (Poster/Interactive Session)

Chair: Garrido-Moctezuma, Rubén Alejandro — Centro De Investigacion Y De Estudios Avanzados Del I.P.N

Co-Chair: Zheng, Song — Fuzhou Univ

12:00-13:00 ThI2S.1

Stabilization and Tracking for P/PI Combustion Control Over a Communication Channel, pp. 438-443

Garces, Hugo (Univ. Catolica De La Santisima Concepcion), Rojas, Alejandro J (Univ. Tecnica Federico Santa María), Sbarbaro, Daniel G. (Univ. De Concepcion)

In the present work, motivated by the recent inclusion of optical variables in combustion processes, we consider the control of a reduced Hammerstein plant model over an additive white noise (AWN) channel located at the feedback path. For comparison, assuming uncertainty in the knowledge of the static nonlinearity of the Hammerstein plant model, we first propose in a one degree-of-freedom (DOF) scheme, the design of a proportional controller for robust stability. We then introduce a PI controller, in a 3 DOF scheme, to achieve not only robust stability, but also AWN channel Signal-to-Noise Ratio (SNR) minimization and setpoint first moment tracking.

12:00-13:00 ThI2S.2

Active Disturbance Rejection and PID Control of a One-Stage Refrigeration Cycle, pp. 444-449

Carreño Zagarra, Jose Jorge (Univ. Industrial De Santander), Villamizar Mejía, Rodolfo (Univ. Industrial De Santander), Moreno, Jose Carlos (Univ. of Almeria), Guzman, Jose Luis (Univ. of Almeria)

This document addresses the problem of controlling a one-stage refrigeration cycle by using the opening of the expansion valve and the compressor speed as control variables, while the outlet temperature of evaporator secondary ux and the superheating degree of refrigerant at evaporator outlet are the controlled variables. An uncertain matrix function is obtained in order to represent the full operating range of the nonlinear system. Thus, the control decentralized approach control consists of designing Generalized- Proportional-Integral (GPI) observers for the internal loops of

each controlled variable while PID controllers are tuned based on the Quantitative Feedback Theory for the respective external loops. Simulations results show that the robust controllers reacts quickly reference settings, despite the non-measurement of the disturbance variables and the dynamic coupling of the multi-variable system, compared to decentralised single PIDs proposed with the benchmark.

12:00-13:00 ThI2S.3

PI/PID DO Control in WWTP for Plantwide Nitrogen Removal Efficiency, pp. 450-455

Revollar, Silvana (Univ. De Salamanca), Vilanova, Ramon (Univ. Autònoma De Barcelona), Francisco, Mario (Univ. of Salamanca), Vega, Pastora (Univ. of Salamanca)

In this paper, a PID based hierarchical control structure is proposed to improve the overall WWTP performance. The control problem is focused on the definition of integral efficiency indices for a typical WWTP operation. The efficiency index considered in this work is the ratio between the nitrogen removed in the activated sludge process (Kgr N) and the energy (kWh) required for eliminating that amount of nitrogenated compounds (N/E index). The efficiency index is used as the controlled variable for an upper level PI controller that manipulates the dissolved oxygen (DO) set point to keep the index as close as possible to a desired level. Effect of DO manipulation is analyzed and DO operation is defined in terms of its overall effect instead of local DO dynamics.

12:00-13:00 ThI2S.4

Use of the Benchmark for PID Control in Engineering Studies at the University of Almería, pp. 456-461

Hoyo, Ángeles (Univ. of Almería), Guzman, Jose Luis (Univ. of Almeria), Berenguel, Manuel (Univ. of Almeria)

This paper presents the methodology followed to evaluate students' ability to face the challenge of controlling a refrigeration system based on vapour compression proposed as a benchmark for PID control design in the PID18 Conference. This benchmark has been also proposed as test-bed plant for the design of controllers in the subject “Industrial Control Techniques” at the University of Almería, Spain. The solutions proposed by the students range from simple SISO PID control loops (including anti-windup effect) to MIMO ones, including decoupling, filters and feedforward action to reject disturbances. All these solutions rely on models obtained from the reaction curve method. The selection of adequate specifications is encouraged, although students' creativity has led them to exploit very aggressive specifications taking into account the different system restrictions, and obtaining very good values of the proposed evaluation indexes.

12:00-13:00 ThI2S.5

A Robust PID Autotuning Method for Steam/Water Loop in Large Scale Ships, pp. 462-467

Zhao, Shiquan (Harbin Engineering Univ), Ionescu, Clara (Ghent Univ), De Keyser, Robin M.C. (Ghent Univ), Liu, Sheng (Harbin Engineering Univ)

During the voyage of the ship, disturbances from the sea dynamics are frequently changing, and the ship's operation mode is also varied. Hence, it is necessary to have a good controller for steam/water loop, as the control task is becoming more

challenging in large scale ships. In this paper, a robust proportional-integral-derivative (PID) autotuning method is presented and applied to the steam/water loop based on single sine tests for every sub-loop in the steam/water loop. The controller is obtained during which the user-defined robustness margins are guaranteed. Its performance is compared against other PID autotuners, and results indicate its superiority.

ThI3S Lobby

Nonlinear Systems (Poster/Interactive Session)

Chair: Katebi, Reza Univ. of Strathclyde

Co-Chair: Cajo Diaz, Ricardo Alfredo Ghent Univ

14:00-14:30 ThI3S.1

An Improved Relay-Based Identification Approach Based on Asymmetric Oscillations, pp. 468-473

Sánchez Moreno, José (UNED), Guinaldo, Maria (UNED), Dormido, Sebastián (UNED), Visioli, Antonio (Univ. of Brescia)

A new identification procedure for autotuning of PI controllers has been developed based on the information obtained from the oscillations that a non-linear element as a simple relay introduces in the feedback loop. Features of the method are: (1) the procedure does not demand a priori process information, (b) non-iterative algorithms are needed to derive the process parameters, (c) only one test is needed, and (d) it allows identifying the process at a user-specified phase lag in the third quadrant. The method is presented for estimation of most common transfer functions used for tuning of PI controllers: integrators, first-, second- as well as processes with non-minimum-phase dynamics.

14:00-14:30 ThI3S.2

Lyapunov Function Analysis for System with Stochastic Nonsmooth PI Controller, pp. 474-478

Kumar, Durgesh (IIT (BHU) Varanasi), Kamal, Shyam (Indian Inst. of Tech. Bombay), Tripurari, Kumar, S (Indian Inst. of Tech. Bombay), Ghosh, Sandip (Indian Inst. of Tech. (BHU))

This paper deals with non-smooth feedback stabilisation in presence of stochastic unbounded(normally distributed) noise. The integral term of classical proportional-integral controller is replaced by a discontinuous integrator. The overall control effort is still continuous. The behaviour of the proposed scheme under stochastic perturbations is presented. We have given a sound and non-trivial Lyapunov analysis of the closed loop system controlled by the proposed controller on stochastic dynamics.

14:00-14:30 ThI3S.3

PID-MMAC Using an Approximate H Infinity Loop-Shaping Metric, pp. 479-484

Joshi, Rakesh (Arizona State Univ), Serrano, Victoria (Univ. Tecnologica De Panama), Tsakalis, Kostas (Arizona State Univ)

This paper proposes a PID-multi-model adaptive control (PID-MMAC) algorithm using an approximate H-infinity metric that represents the frequency loop-shaping (FLS) cost objective. Existing MMAC algorithms use L_2 or least squares-based cost functionals on a suitable error signal to perform controller switching, but their strong dependency on

the properties of the excitation makes them sensitive to noise, disturbances and modeling errors. Alternatively, a system-norm-based cost function is advantageous for MMAC as it is less sensitive to the specific signals used for adaptation. In this paper, the H-infinity norm in the FLS cost objective is approximated by frequency decomposition of the real-time signals using filter-banks. An MMAC algorithm using this metric is presented and its application to controller switching is discussed. The buck converter serves as the motivating application where the adaptation seeks to compensate for degradation in its components (inductors and capacitors). A comparative study is conducted of the proposed algorithm and an L_2-based MMAC algorithm under various excitation conditions. The results show that the proposed algorithm is less susceptible to the properties of the excitation signals as compared to the least squares-based MMAC.

14:00-14:30 ThI3S.4

Uncoupled PID Control of Multi-Agent Nonlinear Uncertain Stochastic Systems, pp. 485-490

Yuan, Shuo (Chinese Acad. of Science), Guo, Lei (Chinese Acad. of Sciences)

This paper proposes a PID (proportional-integral-derivative) control design method to solve the regulation problem for a class of coupled multi-agent nonlinear uncertain stochastic systems, where each agent only has access to its own regulation error without communicating with others. A three-dimensional manifold will be constructed based on the information about the Lipschitz constants of both the unknown nonlinear drift and diffusion terms, such that the three parameters of each agent's PID controller can be chosen arbitrarily from this common manifold. It will be shown that such an uncoupled PID design method can globally stabilize the whole nonlinear uncertain stochastic multi-agent system with the regulation error of each agent approaching to zero asymptotically.

14:00-14:30 ThI3S.5

Anti-Windup Scheme for PI Temperature Control of an Open-Loop Unstable Chemical Reactor, pp. 491-496

Franco, Hugo (Univ. Nacional Autónoma De México), Alvarez, Jesus (Univ. Autonoma Metropolitana)

The problem of designing a proportional-integral (PI) temperature control with anti-windup (AW) scheme for an open-loop unstable chemical reactor is addressed. The aim is to improve the systematization of application-oriented designs employed in industrial practice. The combination of nonlinear dynamics and industrial control ideas yields PI control: (i) with back-calculation (BC) AW scheme, (ii) assurance of robust closed-loop operation with criterion to choose control gain and limits, and (iii) outperforms existing AW with BC plus conditional integration (CI) scheme. The proposed approach is illustrated and tested with a representative example through numerical simulations.

Technical Program for Friday May 11, 2018

FrAT1	The Globe
Benchmark System 1 (Regular Session)	
Chair: Costa-Castelló, Ramon	Univ. Pol. De Catalunya (UPC)
Co-Chair: Tsakalis, Kostas	Arizona State Univ

08:30-08:50 FrAT1.1

Benchmark for PID Control of Refrigeration Systems Based on Vapour Compression, pp. 497-502

Bejarano Pellicer, Guillermo (Univ. of Seville), A. Alfaya, José (Univ. of Seville), Rodriguez, David (Univ. of Seville), Morilla, F. (ETSI Informatica, UNED), Ortega, M. G. (Univ. De Sevilla)

The Benchmark proposed for the 3rd IFAC Conference on Advances in Proportional-Integral-Derivative Control (PID'18) held in July 2017 is described. This facilitates researchers to test their recent developments in the design of PID controllers on a challenging control problem. The paper focuses on the control of refrigeration systems: the canonical vapour-compression cycle is first described and then the MIMO control problem selected for the Benchmark PID 2018 is addressed, where the cooling power (through the outlet temperature of the evaporator secondary fluid) is intended to be controlled, as well as the degree of superheating at the evaporator outlet, using the compressor speed and the expansion valve opening as manipulated variables. The control systems described in this paper are ready to test other multivariable control strategies, despite being focused on PID regulators. Full documentation about the Benchmark was linked on the website of PID'18 and it will remain in *http://www.dia.uned.es/~fmorilla/benchmarkPID2018/.*

08:50-09:10 FrAT1.2

Decentralized Active Disturbance Rejection Control for the Benchmark Refrigeration Systems, pp. 503-508

Zhang, Binwen (North China Electric Power Univ), Tan, Wen (North China Electric Power Univ), Li, Jian (North China Electric Power Univ), Zhou, Rong (North China Electric Power Univ)

In this paper, decentralized linear active disturbance rejection control (LADRC) method is applied to the benchmark refrigeration system presented at the 3rd IFAC Conference on Advances in Proportional-Integral-Derivative Control (PID18). Two second-order *LADRCs are tuned by trial and error without the knowledge of the benchmark refrigeration system. To overcome the saturation of the actuators, an anti-windup scheme for LADRC is adopted. Simulation results show that LADRC technique is simple to apply in practice and can achieve good performance compared with the given PID controllers for the benchmark system.

09:10-09:30 FrAT1.3

Coupled Evolutionary Tuning of PID Controllers for the Benchmark on Vapor Compression Refrigeration, pp. 509-514

Hernandez-Riveros, Jesús-Antonio (Univ. Nacional De Colombia - Sede Medellín), Amador Soto, Gerardo José (Univ. Nacional De Colombia), Gómez López, Juan Manuel (Univ. Nacional De Colombia)

In the present work, an evolutionary tuning is used to determine in a coupled manner the controllers of a refrigeration system (VCRS) proposed in the challenge of the 2018 IFAC Conference on Advances in PID Control. The evolutionary strategy finds the parameters of the controllers that best satisfy the problem, fulfilling all the requirements and restrictions imposed by the challenge. The evolutionary strategy is independent of the structure and domain of the model, both the plant and the controllers.

09:30-09:50 FrAT1.4

Application of Multivariable Virtual Reference Feedback Tuning with Anti-Windup to the Benchmark PID 2018, pp. 515-520

Bordignon, Virgínia (Univ. Federal Do Rio Grande Do Sul), Campestrini, Luciola (Univ. of Rio Grande Do Sul)

This work presents an application of the Virtual Reference Feedback Tuning (VRFT) method to a multivariable refrigeration system benchmark. For the Benchmark PID 2018 problem, two approaches are developed: decentralized and centralized multivariable PID controllers are designed using only open-loop collected data. In order to cope with the saturation of the process' input variables, an anti-windup strategy is associated with the PID controllers. Finally, the closed-loop behavior achieved with VRFT is compared with the reference controller originally provided by the problem, where it can be noted that the performance is considerably enhanced by both proposed designs, with obtained combined indexes of 0.4134 and 0.3635 for the decentralized and centralized controller, respectively.

09:50-10:10 FrAT1.5

A Robust PID Autotuning Method Applied to the Benchmark PID18, pp. 521-526

Zhao, Shiquan (Harbin Engineering Univ), Cajo Diaz, Ricardo Alfredo (Ghent Univ), Ionescu, Clara (Ghent Univ), De Keyser, Robin M.C. (Ghent Univ), Liu, Sheng (Harbin Engineering Univ), Plaza Guingla, Douglas Antonio (Escuela Superior Pol. Del Litoral (ESPOL))

In this paper a proportional-integral-derivative (PID) autotuning control strategy is presented and applied to the benchmark system presented at the 3rd IFAC Conference on Advances in Proportional-Integral-Derivative Control (PID18). The automatic tuning of controller gains is based on a single sine test, with user-defined robustness margins guaranteed. Its performance is compared against a model based designed controller with computer-aided design tool based on frequency response (FRtool) and against the benchmark reference controller. The closed loop control simulations, applied on the benchmark, indicate that the method properly performed.

10:10-10:30 FrAT1.6

Model-Free Adaptive Control for a Vapour-Compression Refrigeration Benchmark Process, pp. 527-532

Yu, Xian (Beijing Jiaotong Univ), Hou, Zhongsheng (Beijing Jiaotong Univ), Zhang, Xin (Beijing Jiaotong Univ)

A model-free adaptive control (MFAC) is applied to the Refrigeration Systems based on Vapour Compression of the BENCHMARK PID 2018. A SISO MFAC controller and a MIMO MFAC controller are designed to control the outlet temperature of evaporator secondary flux and the superheating degree of refrigerant at evaporator outlet by

manipulating the expansion valve opening and the compressor speed. The two designed controllers are the pure data driven control methods without using any model information of the refrigeration process in the control implementation by virtue of the dynamic linearization technique, and the PID controllers can be considered as special cases of the two designed controllers. The qualitative and quantitative comparison results between the MFAC schemes and the default PID controllers given in the simulation platform provided by the Benchmark PID 2018 demonstrate the effectiveness of the two designed controllers.

FrAT2 Le Monde

Fractional PID Control 2 (Regular Session)

Chair: Padula, Fabrizio Curtin Univ

Co-Chair: Vinagre, B. M. Univ. De Extremadura

08:30-08:50 FrAT2.1

Structural Vibration Attenuation Using a Fractional Order PD Controller Designed for a Fractional Order Process, pp. 533-538

Birs, Isabela Roxana (Tech. Univ. of Cluj-Napoca), Muresan, Cristina Ioana (Tech. Univ. of Cluj Napoca), Prodan, Ovidiu (Tech. Univ. of Cluj-Napoca), Folea, Silviu (Tech. Univ. of Cluj-Napoca), Ionescu, Clara (Ghent Univ)

Structural vibration is a highly studied topic, especially in civil structures. Unwanted earth vibrations during seismic activity endanger life and often destroy buildings. In this paper, a Fractional Order Proportional Derivative controller is designed with the purpose of vibration mitigation in a three-story building. The experimental setup consists of a third floor building equipped with an active pendulum attached to the last floor. The controller is designed for the fractional order mathematical approximation of the structure by imposing frequency domain constraints such as gain crossover frequency, phase margin and robustness to gain variations. The validity of the controller is analyzed considering the simulated behavior of the compensated building to the El Centro earthquake and experimental disturbance rejection performance.

08:50-09:10 FrAT2.2

A Numerical Study for Plant-Independent Evaluation of Fractional-Order PID Controller Performance, pp. 539-544

Alagoz, Baris Baykant (Inonu Univ), Tepljakov, Aleksei (Tallinn Univ. of Tech), Yeroglu, Celaleddin (Inonu Univ. Engineering Faculty), Gonzalez, Emmanuel (De La Salle Univ. - Manila), HosseinNia, Hassan (Delft Univ. of Tech), Petlenkov, Eduard (Tallinn Univ. of Tech)

A stunning outcome of fractional calculus for control practice are fractional-order PID (FOPID) controllers. Based on their experimental and numerical results, several studies have reported improvements in control performance of closed loop control systems by FOPID controllers compared to classical PID controllers. However, the industry at large is still cautious about adopting FOPID controllers because of the lack of concrete data about the related cost-benefit trade-off. Main concerns arise at the point that there have not been a quantitative evaluation scheme that clearly demonstrates for which concrete cases FOPID controllers can provide considerable improvements in control. Therefore, there is a need for more thorough theoretical and quantitative

demonstrations. To that end, this study presents a plant function independent evaluation methodology to reveal inherent advantages of FOPID control. Impacts of two additional controller coefficients, namely fractional orders of differentiator and integrator, are analyzed in the frequency domain and their contributions to open loop gain maximization, phase margin and Reference to Disturbance Rate (RDR) performance are investigated.

09:10-09:30 FrAT2.3

FLOreS - Fractional Order Loop Shaping MATLAB Toolbox, pp. 545-550

van Duist, Lennart (Duistech), van der Gugten, Gijs (TU Delft), Toten, Daan (TU Delft), Saikumar, Niranjan (TU Delft), HosseinNia, Hassan (Delft Univ. of Tech)

A novel toolbox named FLOreS is presented for intuitive design of fractional order controllers (FOC) using industry standard loop shaping technique. This will allow control engineers to use frequency response data (FRD) of the plant to design FOCs by shaping the open loop to meet the necessary specifications of stability, robustness, tracking, precision and bandwidth. FLOreS provides a graphical approach using closed loop sensitivity functions for overall insight into system performance. The main advantage over existing optimization toolboxes for FOC is that the engineer can use prior knowledge and expertise of plant during design of FOC. Different approximation methods for fractional order filters are also included for greater freedom of final implementation. This combined with the included example plants enables additionally to be used as an educational tool. FLOreS has been used for design and implementation of both integer and fractional order controllers on a precision stage to prove industry readiness.

09:30-09:50 FrAT2.4

Improvement of the Control System Performance Based on Fractional-Order PID Controllers and Models with Robustness Considerations, pp. 551-556

Meneses Navarro, Helber (Univ. De Costa Rica), Guevara Betancourt, Edder (Univ. De Costa Rica), Arrieta, Orlando (Univ. of Costa Rica), Padula, Fabrizio (Curtin Univ), Vilanova, Ramon (Univ. Autònoma De Barcelona), Visioli, Antonio (Univ. of Brescia)

In this paper we assess the performance improvement achievable by using one-degree-of-freedom fractional-order proportional-integral-derivative controllers (FOPI/FOPID) instead of their integer-order counterparts (PI/PID). To this end, we take into account a single-pole fractional-order model, which has the advantage of representing a wide variety of process dynamics, ranging from over-damped (first-order models) to under-damped behaviors, depending on the fractional order $alpha$. In the proposed analysis we consider a combined performance index which deals with the trade-off between servo and regulatory control modes. Moreover, the performance of the closed-loop system is optimized subject to a robustness constraint, expressed as a target maximum sensitivity of either 1.4 or 2.0. The obtained performance assessment results are shown for different values of the fractional order $alpha$ of the model and for different normalized dead times, thus quantitatively evaluating the benefits achievable with fractional controllers on a wide variety of process dynamics.

09:50-10:10 FrAT2.5

Cascade Fractional-Order PI Control of a Linear Positioning System, pp. 557-562

Lino, Paolo (Pol. Di Bari), Maione, Guido (Pol. Di Bari)

This paper proposes a method for designing robust fractional-order proportional-integral (FOPI) controllers to be employed in a cascade control system. The FOPI controllers are employed for controlling two nested loops. The design is based on performance and robustness specifications in the frequency domain. Taking inspiration from well-known tuning rules, the open-loop frequency response in the two nested loops is shaped around the gain crossover frequency to obtain a nearly flat phase diagram, then a nearly constant phase margin. The method is tested to control the speed and position of a linearly sliding motor.

10:10-10:30 FrAT2.6

Web-Based Fractional PID Controller Design: Www.pidlab.com, pp. 563-568

Cech, Martin (Univ. of West Bohemia in Pilsen)

The purpose of this paper is to introduce an advanced virtual tool for fractional PID (FPID) controller design. It implements generic Nyquist plot shaping and/or sensitivity functions shaping capabilities. In this context, one can define e.g. gain and phase margins, sensitivity functions limits or loop bandwidth. The procedure relies on generalized robustness regions method for fractional PID controllers. The technique is best applicable namely for any non-oscillatory or slightly oscillatory linear system even with dead time, both integer and fractional order. The robustness regions can be computed and painted for more system models hence the robust controller design can be done. Here the method is validated on three illustrative examples. The author believes, that the virtual lab will be worthwhile for both researchers and industrial practitioners and will help to boost the employment of fractional order PID controllers.

FrAT3 El Pais

Optimization in PID Control 2 (Regular Session)

Chair: Reynoso-Meza, Gilberto Pontificia Univ. Católica De Paraná

Co-Chair: Arrieta, Orlando Univ. of Costa Rica

08:30-08:50 FrAT3.1

Data-Driven PID Control Tuning for Disturbance Rejection in a Hierarchical Control Architecture, pp. 569-574

Bordignon, Virgínia (Univ. Federal Do Rio Grande Do Sul), Campestrini, Luciola (Univ. of Rio Grande Do Sul)

This work presents some guidelines for tuning PID controllers in order to increase robustness within a hierarchical control structure focused on load disturbance rejection, in which the process' mathematical model is unknown. The proposed structure consists in two control loops: an inner PID control layer tuned using only data collected from the process, whose set point signal is governed by an outer predictive control layer, with the purpose of increasing closed-loop performance and enabling the specification of constraints. Some simulation results are presented, in which it is shown that the appropriate tuning of the PID controller allows the outer loop to correctly predict the inner loop behavior and therefore provide better disturbance rejection than the data-based tuned PID alone.

08:50-09:10 FrAT3.2

I-PD Controller Design for Integrating Time Delay Processes Using Optimum Analytical Formulas, pp. 575-580

Kaya, Ibrahim (Dicle Univ)

In industrial applications, it is possible to encounter processes that have an integrator in its transfer function. The most widely used controllers in the control of these processes are Proportional-Integral-Derivative (PID) controllers. However, it is well known that PID controllers do not perform well in controlling integrating processes. Hence, in this study, the use of I-PD controllers for controlling integrating processes has been given. Optimal and analytical tuning rules have been derived to identify tuning parameters of the I-PD controller. Simulation examples have been provided to show the use of the proposed optimal I-PD tuning formulas. Comparisons with existing PID and I-PD design methods to control integrating processes have been supplied to illustrate the closed loop performance of the proposed optimal I-PD design approach.

09:10-09:30 FrAT3.3

Two-Loop Design for a Dual-Rate Cascade System, pp. 581-585

Ito, Sho (Univ. of Hyogo), Sato, Takao (Univ. of Hyogo), Araki, Nozomu (Univ. of Hyogo), Konishi, Yasuo (Univ. of Hyogo)

A cascade control system consists of inner and outer loops, where the update interval of the inner controller is shorter than that of the outer controller. In the present study, a new data-driven approach is applied for such a dual-rate cascade control system. In the proposed method, the fictitious reference iterative tuning method is used for optimizing the cascade control system. Hence, the control system is designed using only the control data, and the modeling procedure is omitted. In the present study, the controller parameter in the inner loop is optimized firstly, and next that in the outer loop is also optimized. Because the inner loop is updated faster that the outer loop in the dual-rate system, the control performance of the proposed dual-rate design is superior to that of the conventional single-rate systems. The effectiveness of the proposed method is shown through numerical examples.

09:30-09:50 FrAT3.4

PID Controller Tuning for Integrating Processes, pp. 586-591

Vrancic, Damir (Jozef Stefan Inst), Huba, Mikulas (Slovak Univ. of Tech), Moura Oliveira, Paulo (Univ. De Tras Os Montes E Alto Douro)

The proposed tuning method for integrating processes, which is based on Magnitude optimum criterion, has been extended to PID types of controllers. The method requires either the process transfer function (in frequency-domain) or the measurement of process steady-state change (in time-domain). The PID controller parameters are calculated analytically by solving fourth-order polynomial. By changing refer-ence-weighting parameter b, the user can favour tracking (higher b) or control performance (lower b). The proposed method has been tested on several process models (lower-order with delay, higher order with delay, and a phase non-minimum process) and the closed-loop responses were relatively fast and non-oscillatory. The comparison with other tuning method based on process step-response data results in favourable tracking and control performance.

09:50-10:10 FrAT3.5

Loop Shaping for PID Controller Design Based on Time and Frequency

Specifications, pp. 592-597

Bosman Barros, Clarisse Pétua (Univ. Federal De Campina Grande), Barros, Péricles R. (Univ. Federal De Campina Grande), da Rocha Neto, José Sérgio (Univ. Federal De Campina Grande)

In this paper it is described a new method to design PID controllers using a linear programming approach for optimizing performance subject to robustness constraints. It is based on the shaping of a reference loop gain transfer function which forms a convex region on the Nyquist diagram which contains and bounds the designed loop gain Nyquist plot. The convex region is approximated by a set of lines in order to formulate a linear optimization problem. It is also presented an optional performance specification related to the crossover frequency of the designed loop gain. The class of stable linear time-invariant single-input simple-output (SISO) systems is considered and the optimization problem is proposed, solved and analyzed.

10:10-10:30 FrAT3.6

Matlab/Octave Toolbox for Structurable and Robust Output-Feedback LQR Design, pp. 598-603

Ilka, Adrian (Chalmers Univ. of Tech)

In this paper, a structurable robust output-feedback infinite horizon LQR design toolbox for Matlab and Octave is introduced. The aim of the presented toolbox is to fill the gap between available toolboxes for Matlab/Octave by extending the standard infinite horizon LQR design (from Matlab/Control System Toolbox, Octave/Control package) to robust and structurable output-feedback LQR design. The toolbox allows to design a robust infinite horizon output-feedback controller in forms like proportional (P), proportional-integral (PI), realizable proportional-integral-derivative (PID), realizable proportional-derivative (PD), realizable derivative (D), dynamic output-feedback (DOF), dynamic output-feedback with integral part (DOFI), dynamic output-feedback with integral and realizable derivative part (DOFID), and dynamic output-feedback with realizable derivative part (DOFD). In addition, the controller structure for all supported controller types is fully structurable. The toolbox relies on Yalmip (A Matlab/Octave Toolbox for Modeling and Optimization) and on linear matrix inequality solvers like SeDuMi, SDPT3, etc. Notions like "simple", "highly customizable", and "user-friendly" have been used and considered as main terms during the development process.

FrAT4 Bouquet

PID Design for Load Frequency Control (Regular Session)

Chair: Hote, Yogesh Vijay — Associate Professor, Electrical Engineering Department, Indian Inst. of Tech. Roorkee

Co-Chair: Chakrabarty, Sohom — IIT Roorkee

08:30-08:50 FrAT4.1

PID Controller Design for Load Frequency Control: Past, Present and Future Challenges, pp. 604-609

Hote, Yogesh Vijay (Indian Inst. of Tech. Roorkee), Jain, Shivam (Indian Inst. of Tech. Roorkee)

In this paper, a brief literature review for the design of a PID controller for load frequency control (LFC) in power systems is presented. The transfer function models

for various configurations of power systems are developed. For a systematic presentation of the review, the PID tuning schemes are categorised into soft computing techniques, robust control schemes, fractional order based PID design and internal model control (IMC) based PID design approaches. Due diligence has been taken to include all the design schemes. Further, the paper also enlists various future challenges that are still unresolved and can form the basis of future research work.

08:50-09:10 FrAT4.2

Design of Fractional PID for Load Frequency Control Via Internal Model Control and Big Bang Big Crunch Optimization, pp. 610-615

Jain, Shivam (Indian Inst. of Tech. Roorkee), Hote, Yogesh Vijay (Indian Inst. of Tech. Roorkee)

This paper presents a new technique for the design of an optimal fractional order PID controller for Load frequency control (LFC) in power systems. The proposed approach utilizes a unique combination of Big Bang Big Crunch (BB-BC) algorithm which is a recent soft computing technique and internal model control (IMC) scheme for the design of a fractional order PID controller and it also unifies the notion of order diminution with controller design. A detailed mathematical description of the proposed approach is elucidated in the paper. Since BB-BC is a stochastic search technique, hence a thorough statistical analysis of the response specifications is performed. To demonstrate the effectiveness of the proposed approach, an exhaustive comparative analysis in terms of time response specifications and performance indices is also carried out. It is inferred that the proposed approach is highly efficient and outperforms the existing techniques in the literature.

09:10-09:30 FrAT4.3

Robust CDA-PIDA Control Scheme for Load Frequency Control of Interconnected Power Systems, pp. 616-621

Kumar, Mahendra (Indian Inst. of Tech. Roorkee), Hote, Yogesh Vijay (Indian Inst. of Tech. Roorkee)

This paper proposes a robust CDA-PIDA control scheme for load frequency control problem. The proportional integral derivative acceleration (PIDA) controller is a variant of PID and it is used to cope with large overshoot and settling time in higher order systems. The tuning of PIDA controller is based on coefficient diagram algorithm (CDA). The CDA is based on algebraic design approach and it is demonstrated sufficient condition for stability. In this paper, CDA-PIDA control scheme is designed for two area interconnected power system. The overall closed loop system stability is guaranteed in case of two area power system because each area CDA-PIDA controller is designed independently. The robustness of the proposed control scheme is demonstrated in presence of parametric uncertainty, load disturbances and physical constraint. The robustness and eminence of CDA-PIDA control scheme is proved through comparison between the CDA-PIDA and recently published control schemes.

09:30-09:50 FrAT4.4

PI Controller Based Load Frequency Control Approach for Single-Area Power System Having Communication Delay, pp. 622-626

Saxena, Sahaj (Thapar Inst. of Engineering and Tech), Hote, Yogesh Vijay (Indian Inst. of Tech. Roorkee)

The modern power systems are becoming complicated day by day because of the delays introduced by the communication networks. Due to this reason, the traditional load frequency control (LFC) design scheme depicts a destabilizing impact and an unacceptable performance. Therefore, this paper proposes an analytico-graphical approach for designing PI controller for a single-area LFC system having communication delay. The concept is based on extracting stability region in parameter space (kp; ki) with predened gain and phase margins. Further, the values of optimal kp and ki are selected using integral error criterion. The proposed scheme gives faster disturbance rejection response as compared to the recently developed LFC scheme. The controller also works well when the system parameters are perturbed from their nominal values.

09:50-10:10 FrAT4.5

Robust PID Load Frequency Controller Design with Specific Gain and Phase Margin for Multi-Area Power Systems, pp. 627-632

Sharma, Jitendra (Indian Inst. of Tech. Roorkee), Hote, Yogesh Vijay (Indian Inst. of Tech. Roorkee), Prasad, Rajendra (Indian Inst. of Tech. Roorkee)

In interconnected power systems, the load frequency control (LFC) is considered a hugely beneficial ancillary service. The goal of the LFC in an interconnected power system is to limit the frequency of each area within certain bounds and to maintain the tie-line power flows within some pre-specified latitudes by balancing the power outputs of the generators so as to satisfy ever changing load demands. In the classical control theory, PID controller is said to be robust if it provides some specific gain and phase margin. In this paper, a novel methodology is proposed for the robust PID controller design having specific gain and phase margins for LFC in a multi-area power system. The proposed technique is based on stability boundary locus and PID controllers are designed for four-area power system having different types of turbines. The simulations are carried out using MATLAB and effectiveness of the proposed methodology is verified by the comparison with a recently published approach.

10:10-10:30 FrAT4.6

Analysis of Effects Due to Right Half Plane Zeros in PI Controller Based Hydro Turbine, pp. 633-638

Bose, Soumyadeep (Indian Inst. of Tech. Roorkee), Hote, Yogesh Vijay (Indian Inst. of Tech. Roorkee), Hanwate, Sandeep (Indian Inst. of Tech. Roorkee)

In this paper, some detrimental time-domain characteristics (zero-crossings, overshoot(due to zeros) and initial undershoot) are analyzed using the system transfer function model, for identifying the presence of these effects in step response of non-minimum phase linear systems. Moreover, regarding initial undershoot, a theorem for detection using the state-space model, without the need to obtain transfer function, is proposed. In addition to detection, a theorem for estimating the percentage of initial undershoots is also proposed. Applications of these theorems are carried out on load frequency control of hydro-electric power plant which employs hydro-turbine, a non-minimum phase system. Moreover, the effect of a PI controller on initial undershoot is discussed for a general non-minimum phase linear system and illustrated for load frequency control of hydro-electric power plant.

FrI1S Lobby

PID Control Applications 4 (Poster/Interactive Session)

Chair: Campestrini, Luciola Univ. of Rio Grande Do Sul

Co-Chair: Zhou, Jing Univ. of Agder

10:30-11:00 FrI1S.1

Non-Ideal Modelling and IMC Based PID Controller Design of PWM DC-DC Buck Converter, pp. 639-644

Vishwanatha, Siddhartha (Indian Inst. of Tech. Roorkee), Hote, Yogesh Vijay (Indian Inst. of Tech. Roorkee), Saxena, Sahaj (Thapar Inst. of Engineering and Tech)

This paper presents a non-ideal model of DC-DC PWM buck converter considering the parasitic elements (or non-idealities) such as equivalent series resistances (ESRs) of inductors and capacitors, parasitic resistances of semiconductor devices (diode, MOSFET) during conduction and the forward voltage drop of the diode. Incorporating this non-ideal model, a proficient PID control technique is proposed based on the internal model control (IMC) strategy. The salient features of proposed control methodology are: (i) tuning is such that the controller yields the desired bandwidth; (ii) unlike the conventional IMC-PID, the PID parameters are obtained by direct formula without trial and error. The proposed control scheme is simulated in MATLAB/SIMULINK and validated on a hardware setup using DSPACE DS1104 to confirm the superior results under variation of input voltage, reference voltage and load.

10:30-11:00 FrI1S.2

Tensor Product Model Based PID Controller Optimisation for Propofol Administration, pp. 645-650

Kuti, Jozsef (Obuda Univ), Galambos, Péter (Antal Bejczy Center for Intelligent Robotics, Obuda Univ)

This study investigates the computer-regulated propofol administration in anesthesia during medical interventions considering output feedback and robust PID control. The paper applies the Affine Tensor Product Model Transformation to derive the appropriate polytopic quasi-LPV representation of the closed-loop dynamics. This model form enables the use of LMI-based optimisation techniques to evaluate the closed loop performance. Despite the highly non-convex nature of this output feedback problem, the PID gains can be locally tuned through simplex optimisation. The proposed method provides a systematic way of tuning PID-controlled propofol administration for individual patients with theoretically established worst-case performance measures.

10:30-11:00 FrI1S.3

Optimal PID Design for Load Frequency Control Using QRAWCP Approach, pp. 651-656

Hanwate, Sandeep (Indian Inst. of Tech. Roorkee), Hote, Yogesh Vijay (Indian Inst. of Tech. Roorkee)

In this paper, a new approach is proposed to design optimal PID controller for load frequency control (LFC) problem. This scheme is based on Quadratic Regulator

Approach with Compensating Pole (QRAWCP) technique. Application of this control law is done to both single area and multi-area power system based load frequency problem. In addition to the nominal situation, robustness of this controller is also tested on the same systems with respect to parametric uncertainty, external disturbances, and non-linearities like Generation Rate Constraint (GRC) and Governor Dead Band (GDB). The performance evaluation is done using Matlab & Simulink based simulations and the obtained results are compared with the performance achieved using the recent control strategies designed for LFC.

10:30-11:00 FrI1S.4

A Tuning Proposal for Direct Fuzzy PID Controllers Oriented to Industrial Continuous Processes, pp. 657-662

Rodriguez-Castellanos, Jhon Edisson (Univ. Nacional De Colombia), Grisales-Palacio, Victor Hugo (Univ. Nacional De Colombia), Cote-Ballesteros, Jorge Eduardo (Univ. Nacional De Colombia)

Conventional PID controllers have been a practical solution when controlling linear processes but its response is degraded considerably in strongly nonlinear processes. Fuzzy control presents an improvement in the response because its nonlinear nature. However, there is no absolute tuning methodology, with solutions ranging from trial and error to sophisticated computational methods. In this paper, we present a simple but effective systematic approach for the tuning of several direct fuzzy PID controllers, based on the calculation of static gains of linear sub-models and controller scaling factors. The proposed methodology was successfully tested in a nonlinear process model and a CSTR model.

10:30-11:00 FrI1S.5

PID2018 Benchmark Challenge: Learning Feedforward Control with a Conditional Integrator, pp. 663-668

Zhao, Yang (Shandong Univ), Dehghan, Sina (UC Merced MESA Lab), Ates, Abdullah (Inonu Univ), Yuan, Jie (Southeast Univ), Zhou, Fengyu (Shandong Univ), Li, Yan (Shandong Univ), Chen, YangQuan (Univ. of California, Merced)

The design and application of learning feedforward controllers (LFFC) for the one-staged refrigeration cycle model described in the PID2018 Benchmark Challenge is presented, and its effectiveness is evaluated. The control system consists of two components: 1) a preset PID component and 2) a learning feedforward component which is a function approximator that is adapted on the basis of the feedback signal. A B-spline network based LFFC and a low-pass filter based LFFC are designed to track the desired outlet temperature of evaporator secondary flux and the superheating degree of refrigerant at evaporator outlet. Encouraging simulation results are included. Qualitative and quantitative comparison results evaluations show that, with little effort, a high-performance control system can be obtained with this approach. Our initial simple attempt of low-pass filter based LFFC and B-spline network based LFFC give J=0.4902 and J=0.6536 relative to the decentralized PID controller, respectively. Besides, the initial attempt of a combination controller of our optimized PI controller and low-pass filter LFFC gives J=0.6947 relative to the multi-variable PID controller.

FrI2S Lobby

Fractional PID Control 3 (Poster/Interactive Session)

Chair: Konigsmarkova, Jana Univ. of West Bohemia in Pilsen

Co-Chair: Copot, Dana Ghent Univ

12:00-12:30 FrI2S.1

Reduced Order Model Based Optimally Tuned Fractional Order PID Controller for Pressurized Water Nuclear Reactor, pp. 669-674

Murugesan, Santhiya (Kongu Engineering Coll), Abraham, Anuj (Anna Univ), Natarajan, Pappa (Anna Univ), Murugan, Chitra (Dept. of Inst. Engineering, MIT Campus, Anna Univ)

In this paper, the reduced model of the Pressurized Water Nuclear Reactor (PWR) is derived based on the point kinetics equations and thermal equilibrium relations. The power level of the nuclear reactor is controlled by adjusting the insertion reactivity of the rod. Several controllers such as Genetic Algorithm based PID controller (GAPID), Fractional Order PID controller (FOPID) and Genetic Algorithm based Fractional Order PID Controller (GAFOPID) are used to control the power level of the PWR reactor. The simulation results depict that the Genetic Algorithm based Fractional Order PID Controller (GAFOPID) shows the satisfactory response than other control techniques.

12:00-12:30 FrI2S.2

Tuning for Fractional Order PID Controller Based on Probabilistic Robustness, pp. 675-680

Wu, Zhenlong (Tsinghua Unversity), Li, Donghai (Tsinghua Univ), Xue, Yali (Tsinghua Univ), He, Ting (Tsinghua Univ), Zheng, Song (Fuzhou Univ)

To improve the control performance and robustness of fractional order PID (FOPID) controller for the uncertainty model, a tuning method for FOPID controller based on probabilistic robustness is proposed in this paper. Based on the Monte Carlo simulation, a probabilistic robustness index is formulated to represent the controller sensitivity to the uncertainty model. Stability boundaries of FOPID is depicted to provide the search space, in which the optimal group of parameters are selected based on the probabilistic robustness index. The procedure of the proposed method is designed to obtain the optimal controller parameters for the uncertainty model. Numerical examples are performed to verify the efficacy of the proposed method, and simulation results show that the proposed method has better performance, stronger robustness and ability of handling uncertainties.

12:00-12:30 FrI2S.3

An Improved Frequency-Domain Method for the Fractional Order PID Controller Optimal Design, pp. 681-686

Zheng, Weijia (Foshan Univ), Luo, Ying (South China Univ. of Tech. & Utah State Univ), Chen, YangQuan (Univ. of California, Merced), Pi, YouGuo (South China Univ. of Tech), Yu, Wei (Foshan Univ)

An improved frequency-domain design method is proposed to design the fractional order PID controller. Using this improved method, the parameters of the fractional order PID controllers can be obtained immediately according to the model characteristics and design specifications. A proportional relation between the integral gain and derivative

gain is built, while the derivative order is set to be equal to the integral order. The proportional coefficient between integral gain and derivative gain is studied and modeled based on priori knowledge and data fitting, and then the estimation model for the optimal proportional coefficient is built. The proposed tuning method is applied to design a fractional order PID controller for a permanent magnet synchronous motor servo system. Motor speed control simulations are performed to verify the proposed method. Simulation results show that the obtained control system can achieve robustness and the optimized step response performance.

12:00-12:30 FrI2S.4

Performance Assessment of Classical and Fractional Controllers for Transient Operation of Gas Turbine Engines, pp. 687-692

Tsoutsanis, Elias (Sheffield Hallam Univ), Meskin, Nader (Qatar Univ)

The nonlinear behavior of gas turbine engines has motivated the development of advanced controllers for ensuring their safe and reliable operation. In this paper, the problem of controller design for a two-shaft industrial gas turbine is addressed. Specifically, a transient dynamic engine model has been developed in MATLAB/Simulink for assessing the performance behavior of the engine. Observed engine behavior during transient maneuvers has enabled the development of a PI controller capable of ensuring a smooth gas turbine operation. The performance of the gas turbine engine implementing the developed PI controller has been also compared to a fractional PI controller. Results demonstrate and illustrate the remarkable impact that transient engine simulation has in the developement of robust controllers.

12:00-12:30 FrI2S.5

On the Fractional Variable Order Cucker–Smale Type Model, pp. 693-697

Girejko, Ewa (Bialystok Univ. of Tech), Mozyrska, Dorota (Bialystok Univ. of Tech), Wyrwas, Malgorzata (Bialystok Univ. of Tech. (BUT))

In the paper the Cucker-Smale type models with a fractional variable order operator are considered. The asymptotic stability of a class of linear fractional variable order discrete-time systems is used to study a consensus in the nonlinear fractional variable order discrete-time systems. Basing on a linearization method of the considered multi-agent system we give the sufficient conditions that guarantee the consensus. Finally, an example illustrates our results.

FrBT1 The Globe

Benchmark System 2 (Regular Session)

Chair: Normey-Rico, Julio Elias — Federal Univ. of Santa Catarina

Co-Chair: Tan, Wen — North China Electric Power Univ

12:30-12:50 FrBT1.1

Robust and Decoupling Approach to PID Control of Vapour-Compression Refrigeration Systems, pp. 698-703

Rodriguez, David (Univ. of Seville), Bejarano Pellicer, Guillermo (Univ. of Seville), A. Alfaya, José (Univ. of Seville), Ortega, M. G. (Univ. De Sevilla)

This paper presents a combined approach to the design of PID control applied to vapour-compression refrigeration systems. The underlying controller consists of two

decentralised PIDs, aiming to control both the reference on the temperature of the evaporator secondary fluid, imposed by the cooling demand, and the degree of superheating, by manipulating the compressor speed and the expansion valve. A partial decoupling matrix is calculated to reduce the high coupling between the controlled variables, while the PIDs are tuned applying affine parameterisation and considering the condition for robust stability given by the study on the uncertainty sources and the estimation of the uncertainty region around a nominal linear model. The designed controller is applied to the system proposed in the Benchmark process challenge and some comparative simulations are presented and discussed, while the performance indices of the proposed controller with respect to the reference one are analysed.

12:50-13:10 FrBT1.2

Data-Driven Control Design by Prediction Error Identification for a Refrigeration System Based on Vapor Compression, pp. 704-709

Denardi Huff, Daniel (UFRGS), Gonçalves da Silva, Gustavo R. (Federal Univ. of Rio Grande Do Sul), Campestrini, Luciola (Univ. of Rio Grande Do Sul)

This paper deals with data-driven control design in a Model Reference (MR) framework for multivariable systems. Based on a batch of input-output data collected on the process, a fixed structure controller is estimated without using a process model, by embedding the control design problem in the Prediction Error (PE) identification of an optimal controller. A multivariable extension of the OCI (Optimal Controller Identification) method is applied in the design of PID controllers for a refrigeration system based on vapor compression, which is the subject of the benchmark process challenge of the IFAC PID 2018 conference. Simulation results show the obtained controllers perform significantly better than the ones provided by the benchmark challenge.

13:10-13:30 FrBT1.3

Decentralized PID Control with Inverted Decoupling and Superheating Reference Generation for Efficient Operation: Application to the Benchmark PID 2018, pp. 710-715

Garrido, Juan (Univ. De Córdoba), Lara, Manuel (Univ. of Cordoba), Ruz, Mario L. (Univ. De Córdoba), Vazquez, Francisco (Univ. De Córdoba), A. Alfaya, José (Univ. of Seville), Morilla, F. (ETSI Informatica, UNED)

This paper deals with the control problem of a refrigeration vapor compression system proposed as a benchmark for the IFAC Conference on Advances in PID Controllers (PID'18). This refrigeration system is a multivariable nonlinear process that shows interactions and is subjected to input constraints. In this work, a decentralized PID control with inverted decoupling is proposed as control structure. The inverted decoupling is designed from an approximated multivariable linear model. Then, the PID controllers are tuned by genetic algorithms to minimize a performance index. In addition, a superheat reference generation is developed to achieve stationary operation points with maximum coefficient of performance which is a widespread efficiency measurement in these systems. Simulations considered in the benchmark show that the proposed design achieves better performance than the reference case.

13:30-13:50 FrBT1.4

A Kind of Nonlinear PID Controller for Refrigeration Systems Based on

Vapour Compression, pp. 716-721

Lei, Zhengling (Shanghai Ocean Univ), Zhou, Yue (Shanghai Ocean Univ)

There are different ways in making nonlinear PID controllers. In this paper, a kind of nonlinear PID controller designed by special usage of nonlinear function is introduced, which is called Han's nonlinear PID controllers for short according to the name of the original inventor. Typically, a fal function based nonlinear PID controller has been taken as an example for performance verification upon the Benchmark PID 2018 platform. The simulation results prove that, by parameters tuning for the performance of minimal control efforts, the fal function based nonlinear PID controller can achieve the desired cooling goal under more stable operating conditions yet holding nearly the similar quality steady-state performance.

13:50-14:10 FrBT1.5

Control of Refrigeration Systems Based on Vapour Compression Using Multi-Objective Optimization Techniques, pp. 722-727

Reynoso-Meza, Gilberto (Pontificia Univ. Católica De Paraná), Sánchez, Helem Sabina (Univ. Pol. De Catalunya), Alves Ribeiro, Victor Henrique (Pontifícia Univ. Católica Do Paraná)

In this work a tuning procedure by means of multi-objective optimization techniques is used for a refrigeration system based on vapour compression, stated as the benchmark process control challenge organized by the IFAC Conference on Advances in Proportional- Integral-Derivative (PID) Control. The advantage of such a procedure lies in the capacity to perform an analysis on the trade-off among con icting design objectives. The resulting controller fullls the requirements of the contest, and gets and overall performance index of 0.4028 outperforming the base line controller.

14:10-14:30 FrBT1.6

IMC Based PID Control Applied to the Benchmark PID18, pp. 728-732

Cajo Diaz, Ricardo Alfredo (Ghent Univ), Zhao, Shiquan (Harbin Engineering Univ), Ionescu, Clara (Ghent Univ), De Keyser, Robin M.C. (Ghent Univ), Plaza Guingla, Douglas Antonio (Escuela Superior Pol. Del Litoral (ESPOL)), Liu, Sheng (Harbin Engineering Univ)

In this paper an Internal Model Control (IMC) based proportional-integral-derivative (PID) control is presented and evaluated on the benchmark system presented at the 3rd IFAC Conference on Advances in Proportional-Integral-Derivative Control (PID18). The controller is designed based on the model of the benchmark system. Its performance is compared with a computer-aided design tool based on frequency response (FRtool) and against the benchmark reference controller. The results show that the proposed method has a better performance due to the fact that IMC based PID parameters depend totally on the model.

FrBT2 Le Monde

Fractional PID Control 4 (Regular Session)

Chair: HosseinNia, Hassan Delft Univ. of Tech

Co-Chair: Lino, Paolo Pol. Di Bari

12:30-12:50 FrBT2.1

From the Standard PID to the CRONE First Generation Controller: Application to an Anti-Roll System for Electric Vehicles, pp. 733-738

Termous, Hussein (Lebanese Univ. CRSI LAB; Univ. of Bordeaux, IMS LAB), Moreau, Xavier (Univ. of Bordeaux, FRANCE), Francis, Clovis (Lebanese Univ. Faculty of Engineering, Branch 1), Shraim, Hassan (LSIS, Univ. AIX Marseille III)

In this paper, the standard PID controller and the fractional first generation CRONE controller are applied on the anti-roll moment system to improve ride comfort for passengers in the frame of global chassis control of electric vehicles. A comparative study is done showing the performance and the robustness of the two controllers, in frequency and time domain. It is shown that the first generation CRONE control-system is able to provide robust fractional order controller for uncertain perturbed plants.

12:50-13:10 FrBT2.2

On Fractional-Order PID Controllers, pp. 739-744

Edet, Emmanuel (Univ. of Strathclyde), Katebi, Reza (Univ. of Strathclyde)

A new Fractional Order Proportional-Integral (FOPI) controller is proposed in this paper for process control systems. This is achieved by combining Biggest Log-modulus Tuning (BLT) method and Internal Model Control (IMC) method of designing conventional PID controllers to tuning FOPI controllers for multivariable processes. Unlike the conventional PID case, internal model control method is first used to design the FOPI controller and obtain preliminary values of controller parameters. This yields simple formulae for setting controller gains. Thereafter, the FOPI controller gains are adjusted using a single detuning factor (F) until a biggest log modulus of 2n dB is obtained where n is the number of loops. Extended simulation studies show that good compromise between performance and robustness can be achieved for multiloop process control applications with the proposed FOPI controller.

13:10-13:30 FrBT2.3

A New Variable Fractional-Order PI Algorithm, pp. 745-750

Sierociuk, Dominik (Warsaw Univ. of Tech. (ISEP)), Wiraszka, Michał Sławomir (Warsaw Univ. of Tech. (ISEP))

In this paper the authors present a novel control algorithm based on control error sign--dependent variable-fractional-order PI controller. The algorithm is being optimized via ITSE criterion for control error. It is tested both for unconstrained control signal and a more real-case scenario, i.e. +/-2.5 saturation on control signal. The algorithm is tested for A-,B-,D- and E-type variable-order PI controllers and compared to basic PI and fractional-PI (FPI) controllers. Important parameters, including rise and settling time, overshoot and peak time of unit-step response, as well as graphical representation of unit-step response are presented. Conducted numerical simulations show some interesting behaviour of the A-type definition both in non-limited and limited control signal cases, i.e. switching between derivation and integration action. Moreover,

collected unit-step response parameters indicate the A-type definition to be the best behaving in all considered criteria. However, some unwanted minor oscillations in the unit-step response are to be observed, whose origin will be investigated in further research.

13:30-13:50 FrBT2.4

Fractional-Order PI Controller Design for Integrating Processes Based on Gain and Phase Margin Specifications, pp. 751-756

Cokmez, Erdal (Dicle Univ), Atİc, Serdal (Batman Univ), Peker, Fuat (Dicle Univ), Kaya, Ibrahim (Dicle Univ)

Fractional-order PID controllers have been introduced as a general form of conventional PID controllers and gained considerable attention latterly due to the flexibility of two extra parameters (fractional integral order λ and fractional derivative order μ) provided. Designing fractional controllers in the time domain has still difficulties. Moreover, it has been observed that the techniques based on gain and phase margins existing in the literature for integer-order systems are not completely applicable to the fractional-order systems. In this study, stability regions based on specified gain and phase margins for a fractional-order PI controller to control integrating processes with time delay have been obtained and visualized in the plane. Fractional integral order λ is assumed to vary in a range between 0.1 and 1.7. Depending on the values of the order λ, and phase and gain margins, different stability regions have been obtained. To obtain stability regions, two stability boundaries have been used; RRB (Real Root Boundary) and CRB (Complex Root Boundary). Obtained stability regions can be used to design all stabilizing fractional-order PI controllers.

13:50-14:10 FrBT2.5

Tuning and Performance Assessment of Complex Fractional-Order PI Controllers, pp. 757-762

Ghasem Moghadam, Mehdi (Tarbiat Modares Univ), Padula, Fabrizio (Curtin Univ), Ntogramatzidis, Lorenzo (Curtin Univ)

In this paper, we propose an optimization-based tuning methodology for real and complex Fractional-Order Proportional-Integral (FOPI) controllers. The proposed approach hinges on a modified version of the Integral Absolute Error (IAE) sensitivity-constrained optimization problem, which is suitably adapted to the design of fractional controllers. As such, it allows the exploitation of the potentiality of the (possibly complex) fractional integrator. We also propose a method, based on the well-known CRONE approximation, which delivers a band-limited real-rational approximation of the real part of the complex-order integrator. Finally, based on a First-Order-Plus-Dead-Time (FOPDT) model of the process, we use our design and approximation techniques to find an optimal tuning for real, complex fractional-order, and integer PI controllers and we provide a quantitative performance assessment.

14:10-14:30 FrBT2.6

Robust PI/PID Parameter Surfaces for a Class of Fractional-Order Processes, pp. 763-768

Konigsmarkova, Jana (Univ. of West Bohemia in Pilsen), Cech, Martin (Univ. of West Bohemia in Pilsen)

Recently, PID tuning rules based on integer-order model set approach has been

developed. This paper shows how they can be enhanced through extending the set of a priori admissible systems to fractional-order form. Firstly, such set covers wider range of real process plants. Secondly, a new parameter affecting the model set span was introduced. It can help to reach the proper robustness/performance ratio especially in the case when the system has a lower order which is known. The authors believe that the procedure of fully automatic computing of robust PI/PID parameter surfaces will in the future lead to huge dataset that will serve as a base for deriving mature 2DOF PI/PID tuning rules based on various requirements.

FrBT3 El Pais

PID Control Structures 2 (Regular Session)

Chair: Liu, Tao — Dalian Univ. of Tech

Co-Chair: Visioli, Antonio — Univ. of Brescia

12:30-12:50 FrBT3.1

Should We Forget the Smith Predictor?, pp. 769-774

Grimholt, Chriss (Norwegian Univ. of Science and Tech. (NTNU)), Skogestad, Sigurd (Norwegian Univ. of Science & Tech)

The PI/PID controller is the most used controller in industry. However, for processes with large time delays, the common belief is that PI and PID controllers have sluggish performance, and that a Smith Predictor or similar dead-time compensator can give much improved performance. We claim in this paper that this is a myth. For a given robustness level in terms of the peak sensitivity (Ms), we find that the performance improvement with the Smith Predictor is small even for a pure time delay process. For other first-order processes a PID controller is generally better for a given robustness level. In addition, the Smith Predictor is much more sensitive to time delay errors than PI and PID controllers.

12:50-13:10 FrBT3.2

Development of Basic Process Control Structures, pp. 775-780

Hagglund, Tore (Lund Univ), Guzman, Jose Luis (Univ. of Almeria)

This paper treats development and research at the regulatory control layer in process control. It is noticed that very little attention is payed to this subject, with the exception PID controller tuning. The reason for this is discussed. Two examples of recent advances in the field treating feedforward control and ratio control, respectively, are presented. A goal of the paper is to point out the need for further research in the area. One reason for this is the great industrial impact such research may have, since the functions appearing in this layer are used at so many places in so many industries. A second reason is the need for well functioning regulatory control layers to form solid foundations for the advanced process control layers.

13:10-13:30 FrBT3.3

New Robustness Measure for a Kind of Event-Based PID, pp. 781-786

Miguel-Escrig, Oscar (Univ. Jaume I), Romero, Julio Ariel (Univ. Jaume I), Sanchis, Roberto (Univ. Jaume I)

In this paper we present a study of the appearance of limit cycles in event-based PID control systems. Our approach is based on the extension of the Tsypkin method, which

has been widely used to study the relay control systems. A new margin has been obtained to measure the robustness to limit cycles of continuous controllers when applied on event based control loops. The margin has been calculated to characterize some well known PID controllers tuning methods applied to the control of FOPTD systems with SSOD sampling strategy.

13:30-13:50 FrBT3.4

I-PD Controller As an Structural Alternative to Servo/regulation Tradeoff Tuning, pp. 787-792

Vilanova, Ramon (Univ. Autònoma De Barcelona), Arrieta, Orlando (Univ. of Costa Rica), González, Rafael (Petronor), Xabier Gaizka, Garrido Basagoiti (Petronor)

One of the recurrent topics in the PI/PID literature of recent years is the incorporation of the tradeoff between the two possible modes of closed-loop operation: servo and regulation. Tuning rules are usually provided as for servo or regulation. Operator should choose which one to apply depending on the most usual loop operation. As an alternative, the so called tradeoff tunings provide a controller tuning that is not optimal in either of the operation modes but aims to provide a reasonable (in fact, the best) tradeoff among both in such a way that the loss of performance is minimised with respect to the corresponding optimal tunings. In this paper the use of the I-PD controller structure is proposed as an structural solution to the tradeoff tuning. The proposal states that a direct, simple and efficient solution is found if the controller tuning is addressed for the servo mode but using the I-PD controller structure. This is the feedback error just drives the integral mode or, if preferred, a two degrees of freedom controller with the set-point weight to zero.

13:50-14:10 FrBT3.5

Control of Second Order Processes with Dead Time: The Predictive PID Solutions, pp. 793-798

Peterle, Fabio (Univ. Degli Studi Di Padova), Rampazzo, Mirco (Univ. Degli Studi Di Padova), Beghi, Alessandro (Univ. Degli Studi Di Padova)

Dead times affect many industry processes and are mainly caused by the time required to transport mass, energy or information. In process with dead times the performance of classical PID controllers may be significantly decreased, especially when the dead times are large and higher than the dominant time constant of the process. Several solutions have been presented over the years to improve the control in such cases. The paper contributes in this direction by presenting an extension to second order stable processes of the predictive PI controller introduced by Hagglund in 1996 for first order processes. Both real and complex poles cases are considered. The solutions are derived in special forms in which the classical PID controller is maintained and a new linear block, which just requires one additional parameter, is inserted. In this way, the flexibility of the PID is conserved and control performances improve. For the sake of coherence with respect to the Hagglund's controller, the proposed solutions are called Predictive PID controllers (PPID). Simulation examples show the good performance of the PPID controllers.

14:10-14:30 FrBT3.6

An Augmented PID Control Structure to Compensate for Valve Stiction, pp. 799-804

Bacci di Capaci, Riccardo (Univ. of Pisa), Scali, Claudio (Univ. of Pisa)

It is well-known that valve stiction causes sustained oscillations on process variables when a traditional PID controller is implemented in the feed-back loop. In the literature, there is a vast collection of solid techniques to compensate for valve stiction which employ different approaches and require various prior knowledges on process and stiction dynamics. Among others methods, PID retuning or changes to the traditional algorithm and structure of PID can be useful solutions to mitigate or remove negative effects of valve stiction. Appropriate controller retuning can reduce significantly amplitude and frequency of oscillation, but it cannot remove the problem permanently. Modifying traditional PID algorithm or augmenting standard structure of the controller are also robust approaches for the scope. This paper briefly revises some PID-based stiction compensation techniques and illustrates a new version of stiction-aware PID. A standard PI(D) controller is augmented with a two-move compensator and, by monitoring the control error, it is able to remove effect of valve stiction and to guarantee set-point tracking and disturbance rejection. This PID-based structure requires the estimation of controller output associated with the desired valve position at steady-state and the estimate of valve stiction parameters.

FrBT4 Bouquet

PID Control Applications 5 (Regular Session)

Chair: Tan, Nusret Inonu Univ

Co-Chair: Wakitani, Shin Hiroshima Univ

12:30-12:50 FrBT4.1

PID-Based Controls in Computing Systems: A Brief Survey and Some Research Directions, pp. 805-810

Leva, Alberto (Pol. Di Milano)

Applying controls to manage and optimise the behaviour of computers and networks is an important research field. In recent years, controllers have been gaining a role not only as add-ons to improve the efficiency of already functioning systems, but also as core components of those system themselves, and of their design. This paper provides a brief but reasoned review on the matter, evidencing the preminent role of PID-centred control solutions, and outlines some open issues for future research directions.

12:50-13:10 FrBT4.2

New Constrained Predictive PID Controller for Packet Dropouts in Wireless Networked Control Systems, pp. 811-816

Chacon Vasquez, Mercedes (Univ. of Costa Rica), Katebi, Reza (Univ. of Strathclyde)

A new constrained predictive PID controller is presented to achieve stability and performance robustness in Wireless Networked Control Systems (WNCS), where the communication is subject to dropouts in both communication directions: sensor to control and control to actuator transmission. The control strategy is based on a new PID controller with similar properties to Model-Based Predictive Control (MBPC). A Kalman filter used for output prediction and a consecutive dropouts compensator have also been added to the control scheme. The purpose of this approach is to develop an estimation algorithm and a control system that maintain information of the sensor packets and the control actions. Several experiments using the TrueTime network simulator showed that the predictive PID controller performs as good as the MBPC

scheme with the advantage of having a simple structure.

13:10-13:30 FrBT4.3

Composite PID Control with Unknown Dynamics Estimator for Rotomagnet Plant, pp. 817-822

Xing, Yashan (Fac. of Mech. Elec. Eng., Kunming Univ. of Sci. & Tech), Na, Jing (Fac. of Mech. Elec. Eng., Kunming Univ. of Sci. & Tech), Costa-Castelló, Ramon (Univ. Pol. De Catalunya (UPC))

Although PID control has been widely used in practical engineering, its ability to reject external disturbance and to handle severe nonlinearities should be further enhanced. In this paper, we present a simple robust unknown dynamics estimation, which can be easily incorporated into PID control to achieve satisfactory control for a rotor plant subject to period disturbance. The use of this estimator together with PID control leads to a feedforward like composite control framework. Unlike other estimators (e.g. DOB, ESO), only low-pass filter operations on the input and output and simple algebraic operations are needed to construct our estimator, while exponential convergence can be guaranteed. Numerical simulations are given to show the validity of the proposed estimator and composite PID control.

13:30-13:50 FrBT4.4

An Industrial PID Data Repository for Control Loop Performance Monitoring (CPM), pp. 823-828

Bauer, Margret (Univ. of Pretoria), Auret, Lidia (Stellenbosch Univ), Le Roux, Johan Derik (Univ. of Pretoria), Aharonson, Vered (Univ. of the Witwatersrand)

Control loop performance monitoring methods to detect problems in PID loops are developed and tested using industrial data sets. The data is captured from the process, passed on to the researcher who tries out new detection and diagnosis methods. The data is not generally shared with other researchers working on similar problems. The authors therefore have implemented a data repository to categorise and store the data so that it becomes accessible to all researchers. Existing methods can be compared and enhanced using the data sets. This paper describes the context of CPM as well as the data repository. The repository is set up, hosted and maintained by the South African Council for Automation and Control using a professional web developer.

13:50-14:10 FrBT4.5

Model-Free Control of an Artificial Tide Generation Experimental Apparatus, pp. 829-834

Tognin, Davide (Univ. Degli Studi Di Padova), Rampazzo, Mirco (Univ. Degli Studi Di Padova), Pagan, Martina (Univ. Degli Studi Di Padova), Carniello, Luca (Univ. Degli Studi Di Padova), Beghi, Alessandro (Univ. Degli Studi Di Padova)

Small-scale experiments allow to reproduce and understand phenomena and to draw inferences about large-scale processes. In this paper, we consider a peculiar experimental apparatus which is aimed at reproducing a typical lagoonal environment subject to tidal forcings. This apparatus is useful for performing morphometric analyses of synthetic tidal networks. The quality of these kind of experiments strongly depends on the behaviour of the artificial tide that has to exhibit predefined characteristics. To this aim, the height of the artificial water wave is controlled in real-time. Due to the intrinsic complexity of the system, the development of a control algorithm as simple as

possible but able to ensure suitable control performance over a wide range of operative conditions, is a non-trivial task. In this paper, we have developed and tested a model-free control algorithm, that is the intelligent-PI (i-PI). Finally, the performance of the i-PI controller are compared with those of a standard regulator for different type of experiments.

14:10-14:30 FrBT4.6

Improved PI Control for a Surge Tank Satisfying Level Constraints, pp. 835-840

Reyes-Lúa, Adriana (Norwegian Univ. of Science and Tech), Backi, Christoph Josef (Norwegian Univ. of Science and Tech), Skogestad, Sigurd (Norwegian Univ. of Science & Tech)

This paper considers the case of averaging level control, where the main objective is to reduce flow variations by using varying liquid levels. However, to avoid overfilling or emptying the tank, the liquid level needs to satisfy safety-related constraints. In the simplest case, a P-controller can be used, but may not give acceptable averaging of the flow, especially if the surge tank is relatively small. In addition, the P-controller does not allow the level setpoint to be adjusted. We propose a simple scheme with a PI-controller for normal operation and two high-gain P-controllers to avoid the liquid level constraints, which is compared with a benchmark MPC strategy. We demonstrate that the proposed method has similar performance, but with less modeling effort, less computational time and simpler tuning.

FrI3S Lobby

Fractional PID Control 5 (Poster/Interactive Session)

Chair: Wu, Zhenlong Tsinghua Unversity

Co-Chair: Li, Donghai Tsinghua Univ

14:30-15:00 FrI3S.1

Design of PI Controller Using Optimization Method in Fractional Order Control Systems, pp. 841-846

Dogruer, Tufan (Gaziosmanpasa Univ), Tan, Nusret (Inonu Univ)

In control systems, controller preference and design is an important issue for meeting the desired design criteria. In this paper, PI controller design was performed by using optimization method for fractional order systems. First, all the PI controller parameters that make the control system stable are calculated by using the stability boundary locus method. However, each controller parameter selected in the stability region may not be able to optimally control the system. Optimal controller parameters that provide the best control from the PI controller parameters that make the system stable by using the optimization method are obtained. In the optimization process, the optimal PI controller parameters are calculated by using the integral performance criterion based on the error. Simulation studies have been done for closed loop control system including a fractional order transfer function with time delay. It has been shown that the presented method can be successfully applied to fractional order control systems.

14:30-15:00 FrI3S.2

IMC Based Fractional Order Controller Design for Specific Non-Minimum Phase Systems, pp. 847-852

Arya, Pushkar Prakash (Indian Inst. of Tech. Roorkee), Chakrabarty, Sohom (Indian Inst. of Tech. Roorkee)

Internal model control (IMC) structure is derived from classical control by introducing the model of plant in the control loop and thereby having significant advantages over classical control such as dual stability, perfect control and zero-steady state offset. The basic one degree of freedom (ODF) IMC provides good compromise between set-point tracking and disturbance rejection and works well for non-minimum phase (NMP) systems. In this work, an IMC based fractional order (FO) controller is designed for NMP system which satisfy desired phase margin (fm) at a desired gain-crossover frequency(wg). The domain of desired fm and wg is provided from which they can be selected. Simulation studies are done for (i) DC-DC boost converter which is a NMP system with one zero in right half of s-plane and (ii) first order plus time delay (FOPTD) system which is also a NMP system because of the delay. Significance of the proposed methodology is verified by comparing with other well-known techniques in IMC based on the performance measures, such as rise time (Tr), settling time (Ts) and overshoot (%Mp) and performance indices such as integral square error (ISE), integral absolute error (IAE) and integral of the time weighted absolute error (ITAE).

14:30-15:00 FrI3S.3

Numerical Simulations for Fractional Variable-Order Equations, pp. 853-858

Mozyrska, Dorota (Bialystok Univ. of Tech), Oziablo, Piotr (Bialystok Univ. of Tech)

The objective of the paper is to present the method of fitting finding constant lambda coefficient and a parameter of an order function of the processes described by variable-, fractional-order backward difference of the Grunwald-Letnikov-type. As a qualitative criterion of the estimation the Coefficient of Determination (which we mark as R^2) and the Mean Square Error are used. All the numerical experiments were done with MATLAB.

14:30-15:00 FrI3S.4

Tuning of Fractional Order PI D Controllers Using Evolutionary Optimization for PID Tuned Synchronous Generator Excitation System, pp. 859-864

Kumar, Lalitesh (Ajay Kumar Garg Engineering Coll), Kumar, Prawendra (Gdań Sk Univ. of Tech), , Satyajeet (JSS Acad. of Tech. Education), Narang, Deepak (Ajay Kumar Garg Engineering Coll)

This paper has propounded the notion of the design of cascaded integer order (IO) PID - fractional order (FO)PI D controller by evolutionary multi-objective based optimization approach for a synchronous generator excitation system. The three contradicting performance indices have been framed in time domain as well as in frequency domain to minimize error, escalate the robust stability and to minimize the energy consumption. This paper propounded the issue of contradiction in minimizing error, escalation of robust stability and minimization of energy consumption by framing cascaded IO PID - FO PID controllers as multi-objective optimization problem. The optimization problem is solved to generate the design parameter that meets the competitive multi-objective specifications relating to performance, robust stability and to optimal control by making trade-off between them and respective weightage given to each objective function. The solution generates the non-dominated set of Pareto-optimal solutions and allows the designer to select a particular controller configuration with respective weightages. With the application of this proposed design to the excitation system of synchronous generator to a power plant's, the dynamic robust stability enhanced explicitly with

minimum energy consumption.

14:30-15:00 FrI3S.5

Multivariable Fractional Order PI Autotuning Method for Heterogeneous Dynamic Systems, pp. 865-870

Cajo Diaz, Ricardo Alfredo (Ghent Univ), Muresan, Cristina Ioana (Tech. Univ. of Cluj Napoca), Ionescu, Clara (Ghent Univ), De Keyser, Robin M.C. (Ghent Univ), Plaza Guingla, Douglas Antonio (Escuela Superior Pol. Del Litoral (ESPOL))

In this paper the application of robust Fractional Order Proportional-Integral (FO-PI) autotuning control strategy is presented and applied to heterogeneous dynamic systems using decentralized control. The automatic tuning of controller gains is based on a single sine test, with user-defined robustness margins guaranteed. Its performance is compared against two other fractional order controllers based on PI gain-crossover autotuning method and Internal Model Control (IMC). The closed loop control simulations applied on the heterogeneous dynamic systems indicate that the proposed method performs properly.

FrCT1 The Globe

Benchmark System 3 (Regular Session)

Chair: Yamamoto, Toru Hiroshima Univ

Co-Chair: Ortega, M. G. Univ. De Sevilla

15:00-15:20 FrCT1.1

A MIMO Robust Design of a PID for Refrigeration Systems Based on Vapour Compression, pp. 871-876

Tari, Massinissa (Bordeaux INP, IMS CNRS UMR 5218, Univ. of Bordeaux), Lanusse, Patrick (Bordeaux INP - Univ. De Bordeaux)

In this paper, an original method for the design of PID Controller for MIMO application is presented. The proposed method is based on the CRONE MIMO approach which makes easier the design of MIMO robust controllers. The problem treated here is the control of a refrigeration system based on vapour compression in order to achieve high energy efficiency and to satisfy the cooling demand. Simulation results show the good control performance and robust stability for a wide set of operating points.

15:20-15:40 FrCT1.2

PID2018 Benchmark Challenge: Multi-Objective Stochastic Optimization Algorithm, pp. 877-881

Ates, Abdullah (Inonu Univ), Dehghan, Sina (UC Merced MESA Lab), Yuan, Jie (Southeast Univ), Zhao, Yang (Shandong Univ), Yeroglu, Celaleddin (Inonu Univ. Engineering Faculty), Chen, YangQuan (Univ. of California, Merced)

This paper presents a multi-objective stochastic optimization method for tuning of the controller parameters of Refrigeration Systems based on Vapour Compression. Stochastic Multi Parameter Divergence Optimization (SMDO) algorithm is modified for minimization of the Multi Objective function for optimization process. System control performance is improved by tuning of the PI controller parameters according to discrete time model of the refrigeration system with multi objective function by adding conditional integral structure that is preferred to reduce the steady state error of the

system. Simulations are compared with existing results via many graphical and numerical solutions.

15:40-16:00 FrCT1.3

PID2018 Benchmark Challenge: Model Predictive Control with Conditional Integral Control Using a General Purpose Optimal Control Problem Solver -- RIOTS, pp. 882-887

Dehghan, Sina (UC Merced MESA Lab), Zhao, Tiebiao (UC Merced), Zhao, Yang (Shandong Univ), Yuan, Jie (Southeast Univ), Ates, Abdullah (Inonu Univ), Chen, YangQuan (Univ. of California, Merced)

This paper presents a multi-variable Model Predictive Control (MPC) based controller for the one-staged refrigeration cycle model described in the PID2018 Benchmark Challenge. This model represents a two-input, two-output system with strong nonlinearities and high coupling between its variables. A general purpose optimal control problem (OCP) solver Matlab toolbox called RIOTS is used as the OCP solver for the proposed MPC scheme which allows for straightforward implementation of the method and for solving a wide range of constrained linear and nonlinear optimal control problems. A conditional integral (CI) compensator is embedded in the controller to compensate for the small steady state errors. This method shows significant improvements in performance compared to both discrete decentralized control (C1) and multi-variable PID controller (C2) originally given in PID2018 Benchmark Challenge as a baseline. Our solution is introduced in detail in this paper and our final results using the overall relative index, J, are 0.2 over C1 and 0.3 over C2, respectively. In other words, we achieved 80% improvement over C1 and 70% improvement over C2. We expect to achieve further improvements when some optimized searching efforts are used for MPC and CI parameter tuning.

16:00-16:20 FrCT1.4

PID2018 Benchmark Challenge: Model-Based Feedforward Compensator with a Conditional Integrator, pp. 888-893

Yuan, Jie (Southeast Univ), Dehghan, Sina (UC Merced MESA Lab), Ates, Abdullah (Inonu Univ), Zhao, Yang (Shandong Univ), Fei, Shumin (Southeast Univ), Chen, YangQuan (Univ. of California, Merced)

Since proportional-integral-derivative (PID) controllers absolutely dominate the control engineering, numbers of different control structures and theories have been developed to enhance the efficiency of PID controllers. Thus, it is essential and inspiring to operate different PID control strategies to the PID2018 Benchmark Challenge. In this paper, a novel control strategy is designed for this refrigeration system, where a feedforward compensator and a conditional integrator are utilized to compensate the disturbances and remove the steady-state error in the benchmark problem, respectively. The simulation results given in the benchmark problem show the straightforward effectiveness of the proposed control structure compared with the existing control methods.

FrCT2 Le Monde

PID Control of Biosystems 2 (Regular Session)

Chair: van Heusden, Klaske Univ. of British Columbia

Co-Chair: Mendonça, Teresa Faculdade De Ciências Da Univ. Do Porto

15:00-15:20 FrCT2.1

Robust Fixed Point Transformation Based Proportional-Derivative Control of Angiogenic Tumor Growth, pp. 894-899

Kovacs, Levente (Obuda Univ), György, Eigner (Obuda Univ), Tar, Jozsef Kazmer (Óbudai Egyetem), Rudas, Imre (Óbuda Univ)

The usability of advanced control methods of physiological processes have been several times demonstrated. Advanced (i.e. MPC) control approaches cope with practical difficulties of limited measurability of the state variables, model-imprecisions, significant interpatient variability of the available model's parameters and limitations in the sampling frequency of the variables that at least in principle can be directly measured. However, the lack of the necessary information prevents the use of state estimators. Compensation of the effects of the presence of model-imprecisions needs the application of robust control methods or adaptive techniques. The Proportional-Derivative (PD) control completed with Robust Fixed Point Transformation (RFPT)-based adaptive control was invented for tackling such difficulties. The current paper investigates the applicability of this technique in case of angiogenic growth of tumors using different scenarios of tumor volume measurement. Conclusions are drawn on the basis of numerical simulations.

15:20-15:40 FrCT2.2

Optimal PID Based Computed Torque Control of Tumor Growth Models, pp. 900-905

Czako, Bence (Obuda Univ), Kovacs, Levente (Obuda Univ), Sápi, Johanna (Obuda Univ)

In the past few decades cancer research has delivered several new treatment options, of which can be highly expensive thus reducing its applicability in medical practice. However, advances in control engineering can tackle this issue by the use of an appropriate optimal controller. In this paper a Computed Torque Control (CTC) based PID controller was designed for the Hahnfeldt tumor growth model which can provide an optimal administration protocol for every individual patient. The paper contains the system model in conjunction with the detailed design steps of the controller. The control strategy was tested by numerical simulations which can be found at the end of the paper together with the conclusions.

15:40-16:00 FrCT2.3

Fractional Order PID-Type Feedback in Fixed Point Transformation-Based Adaptive Control of the FitzHugh-Nagumo Neuron Model with Time-Delay, pp. 906-911

Tar, Jozsef Kazmer (Óbudai Egyetem), Bito, Janos (Obuda Univ), Kovacs, Levente (Obuda Univ), Faitli, Tamas (Obuda Univ)

The operation of the nervous system, consequently the various dynamic neuron models, show strong nonlinearities. Their control, that may result in the treatment of

various diseases, have to cope with the essential difficulties as the great deviations/uncertainties in the parameters of the available models, and the time-delay related to the observations of the measurable quantities, the computation, and the exertion of the control signal. For tackling model uncertainties a novel, fixed point transformation (FPT)-based adaptive control approach was suggested that generally works by the use of fresh observations on the behavior of the controlled system, therefore its operation may be degraded by time-delay effects. Furthermore, in the practice time-delay effects can be reduced by using model-based extrapolation of the motion of the controlled system for the “dead period” spanned between the observation and the actual appearance of the control action. In the lack of reliable dynamic model such an extrapolation may be questionable. In this research, up to or knowledge, at first time, time-delay effects are studied in the FPT-based adaptive control of the FitzHugh-Nagumo Neuron Model using novel fractional order kinematic feedback terms. This neuron is a relevant paradigm because showing very sharp nonlinearities in its dynamics. It is concluded that the use of an approximation-based extrapolation in a control of this special fractional order PID-type feedback can considerably reduce the consequences of the time-delay problems.

16:00-16:20 FrCT2.4

Novel Optimum Magnitude Based Fractional Order Controller Design Method, pp. 912-917

Dulf, Eva Henrietta (Tech. Univ. of Cluj Napoca), Susca, Mircea (Tech. Univ. of Cluj-Napoca), Kovacs, Levente (Obuda Univ)

Due to adding the extra degree of freedom, the fractional order PID controllers can achieve better control performance than the integer order PID controllers. The present paper proposes a novel fractional order controller design method, inspired by the Kessler's optimum magnitude method. The explicit tuning rules are accessible even to less experienced users in fractional calculus, taking only the advantages of the controller and not the disadvantage of complex mathematical background. The advantages of the method are demonstrated by a case study.

FrCT3 El Pais

PID Design 3 (Regular Session)

Chair: Scali, Claudio Univ. of Pisa

Co-Chair: Bacci di Capaci, Riccardo Univ. of Pisa

15:00-15:20 FrCT3.1

Further Results on Dominant Pole Placement Via Stability Mapping Approach, pp. 918-923

Dincel, Emre (Istanbul Tech. Univ), Mutlu, Ilhan (IAV GmbH), Schrödel, Frank (IAV GmbH), Söylemez, Mehmet Turan (Istanbul Tecnical Univ)

Dominant roots of the closed loop characteristic equation play a crucial role in terms of the performance of Linear Time Invariant (LTI) systems. Within the scope of this study, a dominant pole placement approach which has two main phases is proposed for PI/PID type controllers. In the first phase, characteristic equation is partitioned into its dominant and non-dominant polynomial pairs and dominant poles are placed to predetermined locations. In the second phase, it is required to determine how far the non-dominant poles can be placed. In the current study, this requirement is

transformed into a stability problem and Lyapunov Equation-based stability mapping approach is used. This combined approach creates a more flexible design environment compared to the currently existing approaches in literature. In order to demonstrate this flexibility, two benchmark case studies are included with different definitions of dominant pole placement problem.

15:20-15:40 FrCT3.2

PID Controller Design for Controlling Integrating Processes with Dead Time Using Generalized Stability Boundary Locus, pp. 924-929

Atİc, Serdal (Batman Univ), Cokmez, Erdal (Dicle Univ), Peker, Fuat (Dicle Univ), Kaya, Ibrahim (Dicle Univ)

This paper proposes a method so that all PID controller tuning parameters, which are satisfying stability of any integrating time delay processes, can be calculated by forming the stability boundary loci. Processes having a higher order transfer function must first be modeled by an integrating plus first order plus dead time (IFOPDT) transfer function in order to apply the method. Later, IFOPDT process transfer function and the controller transfer function are converted to normalized forms to obtain the stability boundary locus in , and planes for PID controller design. PID controller parameter values achieving stability of the control system can be determined by the obtained stability boundary loci. The advantage of the method given in this study compared with previous studies in this subject is to remove the need of re-plotting the stability boundary locus as the process transfer function changes. That is, the approach results in somehow generalized stability boundary loci for integrating plus time delay processes under a PID controller. Application of the method has been clarified with examples.

15:40-16:00 FrCT3.3

Robust PID Controller Design for Both Delay-Free and Time-Delay Systems, pp. 930-935

Nobuyama, Eitaku (Kyushu Inst. of Tech), Kami, Yasushi (Akashi National Coll. of Tech)

Robust PID controller design methods are proposed for linear single-input single-output systems. Non-parametric models represented by a finite number of frequency responses are used for them. Sufficient conditions for closed-loop stability are derived based on the Nyquist stability criterion and the sufficient conditions are reduced to convex constraints. Together with the convex constraints and closed-loop model matching problems the robust PID controller design problems are formulated as convex optimization problems. A important feature of the proposed design methods is that they can be applied to delay-free and time-delay systems in the same manner. Moreover, the proposed methods are extended to two-degree-of-freedom PID controller design methods.

16:00-16:20 FrCT3.4

Design of Digital PID Controllers Relying on FPGA-Based Techniques, pp. 936-941

Aguirre, Adriana (Escuela Superior Pol. Del Litoral), Muñoz, Leonardo (Escuela Superior Pol. Del Litoral), Martin, Cesar A. (Escuela Superior Pol. Del Litoral (ESPOL)), Ramírez, María José (Escuela Superior Pol. Del Litoral), Salazar, Carlos Alberto (Escuela Superior Pol. Del Litoral, ESPOL)

A major challenge of higher education institutions is to prepare professionals capable of learning by building effective solutions that are able to integrate different disciplines and knowledge areas. With this in mind, academics and researchers from ESPOL university in Ecuador, have designed laboratory experiments for a digital control class that introduces students to a modular design of embedded feedback controllers using Field Programmable Gate Array (FPGA) technologies. The proposed experiment includes the design of direct discrete time PID controllers, for an existing speed control system with three different sampling times, to test and compare their performance. The obtained controllers are implemented using a prototyping strategy that relies on FPGA development boards. The prototype controller is tested using the experimental plant, and the system performance is contrasted with results from simulations under realistic conditions.

FrCT4	Bouquet
Control Education 4 (Regular Session)	
Chair: Leva, Alberto	Pol. Di Milano
Co-Chair: Moura Oliveira, Paulo	Univ. De Tras Os Montes E Alto Douro

15:00-15:20 FrCT4.1

A Pole Placing PID Type Controller, pp. 942-947

Hauksdottir, Anna Soffia (Univ. of Iceland), Sigurdsson, Sven Th. (Univ. of Iceland)

The problem of designing a pole placing PID type (ppPIDt) controller is considered, motivated by educational considerations. Effectively, the number of controller zeros, integrators and filtering poles can be extended to aid in the response shaping and stabilizing of the closed loop, while simultaneously avoiding spikes in the control signal. In contrast to the state feedback observer-controller, we do not emphasize maintaining the original systems order, rather we utilize the increased order of the closed loop to shape its response by a suitable choice of poles in the closed loop. This is similar to the classical PID which typically increases the order of the original system by two in the closed loop. We also propose a prefilter to cancel stable system zeros and ppPID zeros and replace them by new zeros if desirable. This results in a new overall transfer function of the controlled system, with full pole placement including good input tracking and disturbance rejection properties and guaranteed closed loop stability. The material is presented in a tutorial way suitable for basic undergraduate control courses and has been used successfully by the first author in such a course.

15:20-15:40 FrCT4.2

Analysis of Anti-Windup Techniques in PID Control of Processes with Measurement Noise, pp. 948-953

Silva, Lucian Ribeiro da (Univ. Federal De Santa Catarina), Flesch, Rodolfo C. C. (Federal Univ. of Santa Catarina), Normey-Rico, Julio Elias (Federal Univ. of Santa Catarina)

This work presents an analysis of the effect of measurement noise on the closed-loop performance for three anti-windup strategies, used together with a PID controller. The study is done both analytically and experimentally and considered stable, integrating and unstable processes with dead time subjected to saturation of the actuator. The PID tuning rule, used for all the presented case studies, is based in a low-order approximation of the filtered Smith predictor. The analysis shows that the error

recalculation anti-windup technique gives better reference tracking performance when compared to the incremental algorithm and back-calculation techniques, being able to reduce the effects of noisy measurements on the calculation of the control action, thus resulting in lower control and process variable variability. In addition, it is shown that when the process operating point is near a saturation limit, noise can cause an offset between the process variable and the reference and it is also proven that the error recalculation anti-windup strategy can significantly attenuate this behavior.

15:40-16:00 FrCT4.3

Comparing Filtered PI, PID and PIDD2 Control for the FOTD Plants, pp. 954-959

Huba, Mikulas (Slovak Univ. of Tech), Vrancic, Damir (Jozef Stefan Inst)

The aims of the paper are: (a) to extend the 2DOF PI and PID controller design for the first order time-delayed (FOTD) plant by the multiple real dominant pole method to the 2DOF PIDD^2 control, (b) to modify for this controller augmented by an nth order series binomial filter required for the derivative action implementation and measurement noise attenuation the simple integrated tuning procedures known already for the PI and PID control. (c) to align all the filtered controllers as for the guaranteed stability range in case of unstable plants, and (d) to compare the performance limits expressed in terms of the integral of absolute error (IAE) and (e) to discuss the corresponding closed loop robustness by a simple test based on comparing impacts of ``exact'' and simplified tunings based on the integral + dead time (IPDT) models.

16:00-16:20 FrCT4.4

Performance Measures and the Robust and Optimal Control Design, pp. 960-965

Huba, Mikulas (Slovak Univ. of Tech)

The paper discusses performance measures used dominantly in the robust and optimal control design. By simple examples of the first order time delayed (FOTD) system control it illustrates that the usually prescribed levels of the maximal and complementary sensitivity functions indeed define situations with interesting loop properties, but may not be universally applied to the robust and optimal design of systems with an uncertain feedback variable in a broader range. For this purpose the shape related measures based on deviations from monotonicity yield results matching the technological requirements of practice in a much more appropriate way. It is also shown that in an optimal nominal controller design the monotonicity based performance measures nearly coincide with the multiple real dominant pole (MRDP) method. For the loop optimization using a broader spectrum of different performance measures, the performance portrait method may be recommended. It avoids the problems of convergence to the absolute optimum and, once generated, the performance portrait may repeatedly be used with a limited effort for a broader spectrum of different cost function specifications.

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PID 2018 Keyword Index