Guest Editorial for Special Issue on Fractional Order Systems and Controls

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I. INTRODUCTION

FRACTIONAL calculus has been applied in all MAD (modeling, analysis and design) aspects of control systems engineering since Shunji Manabe's pioneering work in early 1960s.

The 2016 International Conference on Fractional Differentiation and Its Applications (ICFDA) was held in Novi Sad, Serbia, July 18-20. Quoting from the website http://www.icfda16.com/ "*Fractional Calculus (FC for short) is a modern and expanding domain of mathematical analysis. The notion of fractional differentiation, or more appropriately the differentiation of arbitrary real order, means an operation analogous to standard differentiation which will take into account, memory effects if the independent variable is time, or nonlocal effects in the case of spatial independent variables. The order of the derivative may also be variable, distributed or complex. Basically, FC includes more information in the model than offered by the classical integer order calculus. Besides an essential mathematical interest, its overall goal is general improvement of the physical world models for the purpose of computer simulation, analysis, design and control in practical applications ...*", one has a clear impression that "fractional calculus" is "*application oriented*". The conference had two interesting plenary roundtable panel discussions:

1) Fractional Calculus: D'où venons-nous? Que sommes-nous? Où allons-nous? (Where do We Come From? What are We? Where are We Going?)
2) How to Improve Image and Impact of Fractional Calculus Research Community

The consensus of the community is to move forward with impacts in mind while seeking new frontiers. The Steering Committee chaired by one of the Guest Editors (Y. Q. Chen) decided to have 2018 ICFDA in Jordan and 2020 in Poland.

The aim of this special issue is to show the control engineering research community the usefulness of the fractional order tools from signals to systems to controls. It is our sincere hope that you can find something fractionally delicious in this fractional special issue.

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II. SCANNING THE ISSUE

A fractional number of papers was published in the previous issue (vol. 3, no. 3) which already covered two parts (Fractional Order Modeling and Fractional Order Control) within which another fractional number of published papers was selected to produce video abstracts for a better dissemination.

This issue is still a fractional amount of accepted papers grouped in two parts. Other accepted papers will be published in the upcoming issues.

A. Fractional Order Control Analysis

Control systems engineering goes in the cycles of modeling, analysis and design (MAD). This section included 4 papers. Sathiyaraj and Balasubramaniam studied the controllability properties of fractional order stochastic differential inclusions with fractional Brownian motion in finite dimensional space. It is in an abstract setting but the topic is important because controllability is the first issue to be investigated in control analysis. Fractional order stochastic differential inclusions appear to be an emerging topic in advanced fractional order systems. Alagoz presented a note on robust stability analysis of fractional order interval systems by minimum argument vertex and edge polynomials. The presented results are more advanced and sharpened compared to the existing results. It is interesting to note that the stability checking of interval fractional order LTI systems was included in Chapter 53, in V. D. Blondel and A. Megretski (Editors). "*Unsolved problems in the mathematics of systems and control*" Princeton University Press in July 2004. The 3rd paper is single-authored by M. S. Tavazoei entitled "Criteria for Response Monotonicity Preserving in Approximation of Fractional Order Systems." It offered a new angle and perhaps a new needed constraint when performing finite dimensional FOS (fractional order systems) approximation. It is interesting to note this contribution over the previous two criteria: frequency-domain response fitting as well as time domain impulse response fitting. H. Chen and Y. Q. Chen's paper entitled "Fractional-order Generalized Principle of Self-support (FOG PSS) in Control Systems Design" is perhaps among the few that contains cartoons. The idea is quite interesting and useful. The PSS by late Z. Novakovic in 1992 was almost neglected or forgotten in the control community although he presented convincing amount of experimental results in his book to illustrate his control systems design framework. The key message is: The control signal contains the real dynamics of the system under control.

FOG PSS brings fractional order error dynamic model into PSS which opens a chance to achieve a better performance that the best achievable using the original PSS.

These four papers were included in this fractional issue to showcase the diverse ideas of beneficial use of fractional calculus in control systems analysis.

B. Fractional Order Control Design

Being able to analyze is only the beginning. Being able to design or synthesize based on available information on model, performance and constraints, is a step closer to real applications. Thus "control design" is as interesting as, if not more interesting than, "control analysis". This section includes 5 papers related to "Fractional Order Control Design".

Cheng, Wang, Wei, Liang and Wang presented a very nice tutorial review type of work entitled "Study on Four Disturbance Observers for FO-LTI Systems" with the authors' own developments on new schemes and comparisons. Disturbance observer (DOB) based control has been a very active research topic due to its effectiveness in many real world applications. It is interesting to note that there is a dedicated WeChat group on "Anti-disturbance Control and Applications" with over 100 members mostly in Chinese. Padula and Visioli suggested a set-point filter design for a two-degree-of-freedom fractional control system. Set-point filter can be considered as command filter to condition the final closed-loop transfer function. For fractional order systems, this 2DOF design is original and practically useful. Nie, Wang, Liu and Lan's paper is titled "Identification and PID Control for a Class of Delay Fractional-order Systems" that gives the readers the tool for control engineering practice when starting from a reaction curve test. The final two papers are on nonlinear fractional order systems. Hua, Zhang, Li and Guan's paper is on robust output feedback control for fractional order nonlinear systems with time-varying delays while Zhao, Wang, and Li's paper is about state feedback control for a class of fractional order nonlinear systems.

III. ACKNOWLEDGEMENTS

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YangQuan Chen (M'95–SM'98) earned his Ph.D. degree in advanced control and instrumentation from Nanyang Technological University, Singapore, in 1998. Dr. Chen was on the faculty of Electrical and Computer Engineering at Utah State University before he joined the School of Engineering, University of California, Merced in 2012 where he teaches "Mechatronics" and "Unmanned Aerial Systems" for undergraduates and "Fractional Order Mechanics" and "Nonlinear Control" for graduates. His current research interests include mechatronics for sustainability, cognitive process control and hybrid lighting control, multi-UAV based cooperative multi-spectral "personal remote sensing" and applications, applied fractional calculus in controls, signal processing and energy informatics; distributed measurement and distributed control of distributed parameter systems using mobile actuator and sensor networks.

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Antonio Visioli was born in Parma, Italy, in 1970. He received the Laurea degree in Electronic Engineering from the University of Parma in 1995 and the Ph.D. degree in Applied Mechanics from the University of Brescia in 1999. Currently he holds a professor position in Automatic Control at the Department of Mechanical and Industrial Engineering of the University of Brescia. He is a senior member of IEEE and a member of the TC on Education of IFAC, of the IEEE Control Systems Society TC on Control Education and of the IEEE Industrial Electronics Society TC on Factory Automation Subcommittees on Event-Based Control & Signal and on Industrial Automated Systems and Control, and of the national board of Anipla (Italian Association for Automation). His research interests include industrial robot control and trajectory planning, dynamic inversion based control, industrial control, and fractional control. He is the author or co-author or editor of four international books, one textbook and of more than 200 papers in international journals and conference proceedings.