Guest Editorial for Special Issue on Fractional Order Systems and Controls

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I. Introduction

FRACTIONAL calculus is about differentiation and integration of non-integer orders. Using integer-order models and controllers for complex natural or man-made systems is simply for our *own* convenience while the nature runs in a fractional order dynamical way. Using integer order traditional tools for modelling and control of dynamic systems may result in suboptimum performance, that is, using fractional order calculus tools, we could be "*more* optimal" as already documented in the literature. An interesting remark is that, using integer order traditional tools, more and more "anomalous" phenomena are being reported or perhaps complained but in applied fractional calculus community, it is now more widely accepted that "*Anomalous is normal*" in nature. We believe, beneficial uses of fractional calculus from an engineering point of view are possible and important. We also hope that fractional calculus might become an enabler for new science discoveries. Bruce J. West just finished a new book entitled "*The Fractional Dynamic View of Complexity - Tomorrow's Science*" (CRC Press, 2015). We resonate that, with this special issue, "Fractional Order Systems and Controls" will one day enable "tomorrow's sciences".

Since 2012, several special issues were published in some leading journals which showcase the active interference of fractional calculus to control engineering. Clearly, there is a strong need to have a special issue in an emerging leading control journal such as *IEEE/CAA Journal of Automatica Sinica (JAS)*. This focused special issue on control theory and applications is yet another effort to bring forward the latest updates from the applied fractional calculus community. For that we feel very excited and we hope the readers will feel the same.

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 this special issue will become a milestone of a significant trend in the future development of classical and modern control theory. The contributions may stimulate future industrial applications of the fractional order control leading to simpler, more economical, more energy efficient, more reliable and versatile systems with increasing complexities.

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II. Scanning The Issue

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

A. Fractional Order Modeling

Complexity calls for fractional order modeling. The paper by West and Turalska is on the fractional Landau model. The extension is not mathematically but physically motivated by recent experiments showing a dependence of the decay of fluctuations on memory where in the model the exponential is replaced by an inverse power law. This transition is explained herein as being due to critical slowing down. The fractional calculus is used to model this memory and to relate the index of the inverse power law decay to that of the fractional derivative in time. This sets an important example of extension of integer order model to fractional order model that should be physics based.

The next paper by Cao, Chen, and Stuart is on a fractional micro-macro model for crowds of pedestrians based on fractional mean field games. Obviously, the considered system involving human is complex that calls for fractional order models. The same is true for the paper by Huang, Chen, Li, and Shi on fractional order modeling of human operator behavior with second order controlled plant and experiment research.

Ma, Zhou, Li, and Chen presented an interesting study on fractional modeling and state-of-charge (SOC) estimation of Lithium-ion battery. Chen, Li, Wilson, Huang discussed fractional modeling for the coupled MR damper and its damping system analysis based on fractional calculus. In common, we can observe that the human individual in crowds, the individual ion in Li-ion battery, the individual magnetic particle in MR fluid, collectively form complex systems with complex behaviors due to complex interactions of individuals and complex environments. Thus fractional order modeling is called to better service.

In the paper by Zhou, Zhang, Gao, Wang, and Ma, parameter estimation and topology identification of uncertain general fractional-order complex dynamical networks with time delay is developed to get a fractional model.

These papers were included in this issue to showcase the usefulness of the idea of fractional calculus in complex systems modeling.

B. Fractional Order Control

Using fractional order controller has been an intensely studied topic in recent years. We selected five papers to include in this special issue due to page budget limit.

The paper by Wang, Li, and Chen is about H_∞ output feedback control of linear time-invariant fractional-order systems over finite frequency range. It is the first result in fractional order control considering finite frequency range in H_∞ setting. The paper by Chen, Lu, and Li presented a rigorous study of the ellipsoidal invariant set of fractional order systems subject to actuator saturation when the uncertainties are in the convex combination form.

Naderi Soorki and Tavazoei showed how to achieve constrained swarm stabilization of fractional order linear time invariant swarm systems, while the paper by Aguila-Camacho and Duarte-Mermoud focused on how to improving the control energy in model reference adaptive controllers using fractional adaptive laws. This issue ends with a paper by Rojas-Moreno on an approach to design MIMO fractional order controllers for unstable nonlinear plants.

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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" for juniors and "Fractional Order Mechanics" 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 book, one textbook and of more than 200 papers in international journals and conference proceedings.