2009 American Control Conference -- ACC2009
St. Louis, Missouri, USA
June 10 - 12, 2009

Pre-Conference Workshop Proposal
One full day workshop on

"Applied Fractional Calculus in Controls and Signal Processing"

Web: http://mechatronics.ece.usu.edu/foc/

Organizers' Contacts:

Organizer:
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Co-Organizer:
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1. Why this is important for ACC – Rationale

Why Fractional Calculus? Many real dynamic systems are better characterized using a non-integer order dynamic model based on fractional calculus or, differentiation or integration of non-integer order. Traditional calculus is based on integer order differentiation and integration. The concept of fractional calculus has tremendous potential to change the way we see, model, and control the nature around us. Denying fractional derivatives is like saying that zero, fractional, or irrational numbers do not exist.

In the control side, clearly, for closed-loop control systems, there are four situations. They are 1) IO (integer order) plant with IO controller; 2) IO plant with FO (fractional order) controller; 3) FO plant with IO controller and 4) FO plant with FO controller. From control engineering point of view, doing something better is the major concern. Existing evidences have confirmed that the best fractional order controller outperforms the best integer order controller. It has also been answered in the literature why to consider fractional order control even when integer (high) order control works comparatively well. Fractional order PID controller tuning has reached to a matured state of practical use. Since (integer-order) PID control dominates the industry, we believe FO-PID will gain increasing impact and wide acceptance. Furthermore, we also believe that based on some real world examples, fractional order control is ubiquitous when the dynamic system is of distributed parameter nature.

In the signal processing side, this Workshop will give a brief yet broad overview of some existing fractional order signal processing (FOSP) techniques where the developments in the mathematical communities are introduced; relationship between the fractional operator and long-range

dependence is demonstrated and fundamental properties of each technique and some of its applications are summarized. Specifically, we presented a tutorial on 1) fractional order linear systems; 2) autoregressive fractional integrated moving average (ARFIMA); 3) $1/f$ noise; 4) Hurst parameter estimation; 5) fractional order Fourier transformation (FrFT); 6) fractional order linear transforms (Hartley, Sine, Cosine); 7) fractal; 8) fractional order splines; 9) fractional lower order moments (FLOM) and 10) fractional delay filter. Whenever possible, we indicate the connections between these FOSP techniques.

In the end, we will have a round table discuss on Cyber-Physical Systems (CPS) where sensing, decision, actuation, computation, networking, and physical processes are mixed with high complexity. We will discuss that the complexity in CPS can be better characterized by using tools linked to fractional calculus.

2. Organizers' Credits (selected)

- Previously, Dr. Chen co-organized a one day tutorial at IEEE CDC2002 (Las Vegas) and since then, the workshop notes and CDROM have been widely cited: http://mechatronics.ece.usu.edu/foc/cdc02tw/
- Dr. Xue and Dr. Chen organized a half day tutorial on Fractional Order Control at IEEE Int Conf. on Mechatronics and Automation (ICMA06) in 2006, Luoyang, China. http://mechatronics.ece.usu.edu/foc/ieee-icma06-tutorial/
- Dr. Chen was the plenary lecturer for IFAC Workshop on Fractional Derivatives and Applications (FDA) 2006, Porto, Portugal. His lecture title is "**Ubiquitous Fractional Order Controls?**" slides at http://mechatronics.ece.usu.edu/foc/fda06/01ifac-fda06-plenary-talk%235-chen-utah.ppt
- Dr. Chen will be a plenary lecturer for IFAC Workshop on Fractional Derivatives and Applications (FDA) 2008, Ankara, Turkey. Title: "**Fractional Order Signal Processing: Techniques, Applications and Urgency**" http://www.cankaya.edu.tr/fda08/lecturers.php
- Dr. Xue and Dr. Chen published the first control textbook with a dedicated chapter on Fractional Order Control,
    - Dingyu Xue, YangQuan Chen* and Derek Atherton. "*Linear Feedback Control – Analysis and Design with Matlab*". **SIAM Press**, 2007, ISBN: 978-0-898716-38-2. (348 pages) Chapter-8: Fractional-order Controller - An Introduction.
- Dr. Xue and Dr. Chen has published the first math+Matlab book with a dedicated section on Fractional Calculus introducing systematically how to perform numerical simulation
    - Dingyu Xue* and YangQuan Chen. "*Solving Advanced Applied Mathematical Problems Using Matlab*". **Taylor and Francis CRC Press. 2008** (448 pages in English, ISBN-13: 978-1420082500.)
- More credits can be found from http://fractionalcalculus.googlepages.com/

3. Confirmed Workshop Invited Lecturers/Lecture Titles

YangQuan Chen, Utah State University, Logan, USA
Applied Fractional Calculus in Controls and Signal Processing: A Tutorial Overview

Richard L. Magin, University of Illinois at Chicago, USA.
Fractional calculus for bioengineering signal processing

Dingyu Xue, Northeastern University, Shenyang, China
Fractional Order Control/Filtering: How to simulate in Matlab/Simulink?

Hongsheng Li, Nanjing Institute of Technology, Nanjing, China and YangQuan Chen, Utah State University, Logan, USA
Fractional Order Motion Control: Tuning Rules and Experiments

Yan Li, Math Institute, Shandong University, Jinan, China
Fractional Order LQR (linear quadratic regulator) and Fractional Order UAS (universal adaptive stabilizers)

Ivo Petras, Technical University of Kosice, Kosice, Slovakia
A Note on Stability of Fractional Order Systems

Pierre Melchior, University of Bordeaux – I, Bordeaux, France
CRONE control (Commande Robuste d'Ordre Non Entier) synthesis and applications

4. Tentative Schedule

0800-0830	Welcome and introduction of the workshop (Chen, Xue)
0830-0930	Applied Fractional Calculus in Controls and Signal Processing: A Tutorial Overview (Chen)
0930-1030	Fractional calculus for bioengineering signal processing (Magin)
Break	
1100-1200	Fractional Order Control/Filtering: How to simulate in Matlab/Simulink? (Xue)
Lunch	
1300-1400	Fractional Order Motion Control: Tuning Rules and Experiments (Li, Chen)
1400-1440	Fractional Order LQR (linear quadratic regulator) and Fractional Order UAS (universal adaptive stabilizers) (Yan Li)
1440-1500	A Note on Stability of Fractional Order Systems (Petras)
Break	
1530-1630	CRONE control (Commande Robuste d'Ordre Non Entier) synthèses and applications (Melchoir)
1630-1700	Round table discussions: **"Fractional Calculus and Complexity in Cyber-Physical Systems (CPS)"**

Note:
A workshop CD will distributed to all participants with all presentation slides as well as some survival tutorial papers and Matlab/Simulink codes for beginners.
This workshop CD will also be put online later at http://mechatronics.ece.usu.edu/foc/