Title: Control System Design: From Concepts to Practice, a Historical, Humanistic, Practical, and Rational Account

Chair: Zhiqiang Gao, Cleveland State University, U.S.A

Abstract: This is an abbreviated short course on history, concepts and practice of controls for students, professionals, and practicing engineers who aspire to become a creative problem solver through better understanding of the historical and human side of this profession as it evolved from 1780s. Fundamental concepts and problem solving skills are grasped through the lens of history, as we witness how the ingenious minds rose to the occasion and made the arts and crafts of controls effective, intelligible, and maybe even reproducible. Today, just as two hundred years ago, great solutions for the complex problems in the real world are not to be found in a few rules of thumb or a few textbook formulas, but through human ingenuity and free thinking. This course is designed to inspire, to unlock the minds, to question what has always been done, and to see in history what it takes to be a truly innovative engineering problem solver, operating within a given framework and beyond.

Description of Workshop:

Lecture: Prof. Zhiqiang Gao, Cleveland State University, USA

- I: The Concepts of Control: A Two Hundred Year Evolution
  - What concepts, where did they come from, what questions did they answer?
  - Feedback: consistent performance in a system made of inconsistent parts
  - Feedforward? – the art of anticipation and active control
  - Feedback and Feedforward: the twin evolution from 1788 to present
  - The story of active disturbance rejection and the story of an enduring idea: from Jean-Victor Poncelet, to Grigoriy Shipanov, and to Jingqing Han.

- II: The Three Paradigms In Control System Design
  - A control problem is a disturbance rejection problem
  - Three paradigms: industrial, academic and disturbance rejection
  - The inherent uncertainty in physical process and its centrality in control design
  - What we need to know about a physical process in order to control it: effective action without perfect information
  - Dealing with uncertainties
    - PID tuning
    - Modeling and Robust Control
    - Estimating/mitigating
  - Anticipatory vs. reactive control

- III. Why the Basic Concepts and Skills Matter
  - The language of our understanding: diff. equation, transfer function, state space
  - Vocabulary of engineers: PID, feedforward, bandwidth, error budget …
  - What we want: performance-stability and aggressiveness-energy trade-offs
  - Design choices: finding the right tool for a given problem
Analysis: stability is not “yes or no” question, but one of “how much”.
Robust control: how much uncertainties are out there, how much can we handle?

IV: Active vs. Passive Disturbance Rejection
- The concept of total disturbance, including internal dynamics and external forces
- The 2nd degree of freedom: the disturbance rejection inner loop
- Real time disturbance estimation
- Feedback Design: linear and discrete time optimal solutions
- Parameterization and one parameter tuning
- Digital implementation and algorithm
- Applications

V: Advanced Problem Solving in Control Practice
- What makes it so interesting?
- Bridging the theory-practice gap: problem solving strategy and process
  - Spotting a control problem/issue
  - Formulating it: characterizing the uncertainty, internal and external
  - Evaluating design choices: how to deal with the uncertainty
  - Design and simulation validation
  - Analysis: characteristics of the solution such as stability margins
  - Implementation and tuning
  - Communicating your ideas to others
- Case studies
- Toward the future of control theory and practice: continuous skill development

Biography of Chair:

Zhiqiang Gao, received his Ph.D. in Electrical Engineering from the University of Notre Dame in 1990. Since then, he and his research group at CSU have collaborated extensively with NASA and industry and conducted multi-million dollar research and development projects. Employing an experimental science philosophy to research and a humanistic touch to teaching, Dr. Gao and his team of researchers bring creative solutions to real world problems and vitality of thinking to young minds. Working with Prof. Jingqing Han since 1995, Dr. Gao helped nurturing active disturbance rejection control (ADRC) from its conceptual stage to a maturing and emerging industrial control technology. Recently, the CSU spinoff company, LineStream Technologies, of which Dr. Gao is a founder, successfully implemented the ADRC technology across ten production lines at Parker Hannifin, a Fortune 100 company, with a third party quantification of energy saving well above 50%, along with significant quality improvement in product qualities. Furthermore, Texas Instrument, an industry giant, announced in July 2011 that it has signed a long term, global licensing agreement to embed ADRC algorithms in its chips.

Throughout his career, Dr. Gao has been giving lectures on basic and advanced control
concepts to students and practicing engineers across boundaries of academia and industry, at various universities, research labs, and companies such as NASA, Rockwell Automation, Energizer, Intel, Texas Instrument, Honeywell, Procter & Gamble, Kimberly Clark, Allied Signal. He was also invited to give a talk in July 2010 at the Institute of Control Science, Russian Academy of Sciences, to which the origin of the ADRC conception is traced. This workshop is based on a short course on advanced control he recently taught at the Polytechnic University of Turin, Tsinghua University, Chinese Academy of Sciences, and Tianjin University.

Contact Information:

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