

Caltech CDS@20: Education, depth, breadth, and futures

Overview: This tutorial workshop will be organized and presented by John Doyle and Richard Murray. The 20th anniversary of Control and Dynamical Systems (CDS) at Caltech is in 2014 and we will focus on lessons learned in both research and education, with a particular focus on implications for the future of our field. The theory foundations will start with the interplay between robust and nonlinear control and recent progress in distributed control for complex networks, and interactions with computer science in the areas of networking, formal methods, optimization, and statistics. A focus will be on the status and prospects for a more unified theory of control, communication, computing, and physics. Familiar CDC technological case studies (e.g. aerospace, robots, Internet, power) will be augmented with applications to systems and synthetic biology, insect flight, medical physiology, particularly heart rate and other control system variability, neuroscience, physics (turbulence, statistical mechanics), and wildfire ecology. There will be a related full day tutorial before the CDS 20th anniversary in August, 2014 at Caltech, and will also draw inspiration from the 3 days of talks there by alumni and friends. The intent is to be broadly accessible to anyone attending CDC.

Bio: John Doyle is the Jean-Lou Chameau Professor of CDS, EE, and BioE at Caltech. BS, MS EE, MIT (1977), PhD, Math, UC Berkeley (1984). Current interests in theoretical foundations for complex networks in engineering and biology, unifying controls, computing, communications, and physics. Paper prizes include IEEE Baker (top in all IEEE publications), IEEE Automatic Control Transactions (twice), and best conference papers in ACM Sigcomm and AACC American Control Conference. Individual awards include AACC Eckman and IEEE Control Systems Field and Centennial Outstanding Young Engineer Awards. He has held national and world records and championships in various sports.

Bio: Richard M. Murray is the Thomas E. and Doris Everhart Professor of CDS and BioE at Caltech. BS EE Caltech (1985), MS (1988) and PhD (1991) in EECS, UC, Berkeley. In 1998-99 sabbatical leave was the Director of Mechatronic Systems at the United Technologies Research Center in Hartford, CT. Then served as the Division Chair (dean) of Engineering and Applied Science at Caltech from 2000-2005, the Director for Information Science and Technology (IST) from 2006-2009, and interim Division Chair from 2008-2009. Murray's research is in the application of feedback and control to networked systems, with applications in biology and autonomy. Current projects include analysis and design biomolecular feedback circuits; specification, design and synthesis of networked control systems; and novel architectures for control using slow computing. Awards include the AACC Eckman and membership in the National Academy of Engineering (2013). His teaching has won the Caltech Feynman Prize (2006) and ASCIT Award (2005). He has co-written three books, *A Mathematical Introduction to Robotic Manipulation* (1993), *Feedback Systems: An Introduction for Scientists and Engineers* (2008, winner of the Triennial IFAC Harold Chestnut Control Engineering Textbook Prize (2011)) and *Biomolecular Feedback Systems* (2014).

Bio: Control and Dynamical Systems (CDS) at Caltech is now 20 years old and has had an impact beyond its size and age. In that time, Murray has had the #1 cited paper in Proceedings IEEE, #2, 7, 11 papers in IEEE TAC, and #1 in Archive for Rational Mechanics and Analysis. Doyle has the #2 and 13 cited papers all-time in IEEE TAC, and #1 in IEE/IET Control Theory and Applications. Of the top 16 (including Caltech) world universities (2014 THE rankings), all 14 with engineering (e.g. Oxford, Stanford, MIT, Harvard, Princeton, Berkeley, Cambridge, Imperial, ETHZ, UCLA, Columbia, Penn, Hopkins) have professors who are CDS "alums," mostly PhDs. CDS has also promoted diversity, with 3 women out of the 4 most recent professors in the "THE top 14," and 7 women of 7 PhD graduates in 2013. CDS was an

innovation in 1994, and we will focus particularly on an ambitious vision for the next 20 years involving control, computing, and mathematics in engineering and science.

Selected recent publications

- [1] R. Murray, K. J. Astrom, S. P. Boyd, R. W. Brockett and G. Stein, Future directions in control in an information-rich world – A summary of the report of the Panel, on Future Directions in Control, Dynamics, and Systems. *IEEE Control Systems Magazine*, 23 (2):20-33, 2003.
- [2] R. Olfati-Saber, J. A. Fax and R. M. Murray, Consensus and cooperation in networked multi-agent systems. *Proceedings of the IEEE*, 95(1):215-233, 2007.
- [3] R. M. Murray, Recent research in cooperative control of multivehicle systems. *Journal of Dynamic Systems Measurement and Control*, 129(5):571-583, 2007.
- [4] Alderson DL, Doyle JC (2010) Contrasting views of complexity and their implications for network-centric infrastructures. *IEEE Trans Systems Man Cybernetics—Part A: Syst Humans* 40:839-852.
- [5] Sandberg H, Delvenne JC, Doyle JC. On Lossless Approximations, the Fluctuation-Dissipation Theorem, and Limitations of Measurements, *IEEE Trans Auto Control*, Feb 2011
- [6] Chandra F, Buzi G, Doyle JC (2011) Glycolytic oscillations and limits on robust efficiency. *Science*, Vol 333, pp 187-192.
- [7] Doyle JC, Csete ME(2011) Architecture, Constraints, and Behavior, *P Natl Acad Sci USA*, vol. 108, Sup 3 15624-15630
- [8] Gayme DF, McKeon BJ, Bamieh B, Papachristodoulou P, Doyle JC (2011) Amplification and Nonlinear Mechanisms in Plane Couette Flow, *Physics of Fluids*, V23, Issue 6, 065108
- [9] Page, M. T., D. Alderson, and J. Doyle (2011), The magnitude distribution of earthquakes near Southern California faults, *J. Geophys. Res.*, 116, B12309, doi:10.1029/2010JB007933.
- [10] Namas R, Zamora R, An, G, Doyle, J et al, (2012) Sepsis: Something old, something new, and a systems view, *Journal Of Critical Care* Volume: 27 Issue: 3
- [11] O. Venturelli, H. El-Samad and R. M. Murray, Synergistic dual positive feedback loops established by molecular sequestration generate robust bimodal response. *P Natl Acad Sci USA*, 2012.
- [12] T. Wongpiromsarn, U. Topcu and R. M. Murray, Receding Horizon Temporal Logic Planning. *IEEE Trans Auto Control*, 57(11):2817-2813, 2012.