USC Viterbi School of Engineering
Ming Hsieh Department of Electrical Engineering

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Center for Systems and Control

Multi-agent Cooperative Control and Estimation for Flying Cars and Spacecraft Swarms

Soon-Jo Chung
California Institute of Technology

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Abstract: Recent advances in self-driving car and drone technologies are turning a century-old dream of vertical-take-off-landing personal transportation vehicles into a reality with many existing projects in development. Caltech's Center for Autonomous Systems and Technologies (CAST)'s engineers and scientists have developed a 1/5 working scale model of their Autonomously Flying Ambulance (AFA) with innovative design ideas, including flight by a hybrid of distributed fans and deployable wings, bio-inspired flight and control, and vision-based navigation. The model has been flight-tested successfully in CAST's unique drone arena using an open-air distributed fan-array wind tunnel. CAST's AFA rotorcraft and autonomy technologies can provide solutions for a range of short-distance travel challenges: point-to-point delivery of packages on Earth or scientific samples on Mars. I will review some of the control theoretical results derived for control and coordination of novel aerial robotic platforms. First, I will present distributed, motion planning and multi-point routing algorithms for optimally reconfiguring swarms of vehicles with limited communication and computation capabilities from various pick-up locations to target locations. The real-time guidance algorithm solves both the optimal assignment and collision-free trajectory generation in an integrated manner. Three related approaches have been derived for optimal assignment problem for real-time routing: (1) distributed auction assignment, (2) novel probabilistic swarm guidance that employs time-inhomogeneous Markov chains; and (3) potential games solved by binary log-linear learning. Second, nonlinear tracking control and estimation is utilized to track optimal reconfiguration trajectories with a property of robustness (finite-gain Lp incremental stability). I will also show such nonlinear incremental stability analysis can be extended to a set of Ito stochastic nonlinear systems for synchronization control and nonlinear estimation, including exponential stability of a distributed Bayesian filtering algorithm, robust nonlinear estimation for visual SLAM, and consensus stability of distributed reinforcement learning for flying ambulances or taxis.

Biosketch: Prof. Soon-Jo Chung received the S.M. degree in Aeronautics and Astronautics and the Sc.D. degree in Estimation and Control with a minor in Optics from MIT in 2002 and 2007, respectively. He received the B.S. degree in Aerospace Engineering from KAIST in 1998 (school class rank 1 out of 120). He is currently Associate Professor of Aerospace and Bren Scholar in the Graduate Aerospace Laboratories of the California Institute of Technology (GALCIT). Prof. Chung is also a Research Scientist of the Jet Propulsion Laboratory. For August 2009-August 2016, Prof. Chung was on the faculty of the University of Illinois at Urbana-Champaign. His research areas include nonlinear control and estimation theory and optimal/robust flight controls with application to aerial robotics, distributed spacecraft systems, and computer vision-based navigation. He is the recipient of the UIUC Engineering Dean's Award for Excellence in Research, the Beckman Faculty Fellowship of the U of Illinois Center for Advanced Study, the AFOSR Young Investigator Award, the NSF CAREER Award, and three best conference paper awards (2015 AIAA GNC, 2009 AIAA Infotech, 2008 IEEE EIT). Prof. Chung is an Associate Editor of the IEEE Transactions on Robotics and the AIAA Journal of Guidance, Control, and Dynamics.

Host: Mihailo Jovanovic, mihailo@usc.edu