From adaptation to estimation: Learned function spaces for safe control

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Abstract: Adaptation at control rates while maintaining safety remains difficult for existing methods, which either adapt a fixed set of model parameters with limited flexibility or rely on learned updates that require retraining and offer few guarantees. We represent system dynamics as a linear combination of neural ODE basis functions, which enables us to reduce adaptation to online coefficient estimation. This formulation converts model adaptation into a Kalman filtering problem, so updates occur via low-dimensional linear estimation rather than retraining, and uncertainty is explicitly characterized in the same coordinate space. We use this structure to enforce safety during adaptation. The coefficient estimate and its covariance define a constrained set of admissible dynamics models. We impose these constraints directly within a robust model predictive control framework, so safety requirements are enforced over all models consistent with the current estimate. Experiments on robotic and aerospace systems show that this formulation supports adaptation at control rates while maintaining constraint satisfaction. Results indicate that concentrating uncertainty in the coefficient space enables faster adaptation and reduces conservatism compared with fixed robust models.

Bio: Ufuk Topcu is a professor in the Department of Aerospace Engineering and Engineering Mechanics at The University of Texas at Austin, where he holds the Judson S. Swearingen Regents Chair in Engineering #1. He is a core faculty member at the Oden Institute for Computational Engineering and Sciences and Texas Robotics and the director of the Autonomous Systems Group. Topcu obtained his Ph.D. from the University of California, Berkeley, in 2008. Before joining UT Austin, he was with the Department of Electrical and Systems Engineering at the University of Pennsylvania. Topcu's research focuses on the theoretical and algorithmic aspects of the design and verification of autonomous systems, typically at the intersection of formal methods, reinforcement learning, and control theory. He takes a relatively broad view on autonomy and tends to tackle abstract problems motivated by challenges cutting across multiple applications of autonomy. Topcu leads several large-scale, multi-institution projects, including an Air Force MURI project, a NASA ULI project, and an NSF CPS Frontier project. His research contributions have been recognized by the NSF CAREER Award, the Air Force Young Investigator Award, the IEEE CSS Antonio Ruberti Young Researcher Prize, and Oden Institute Distinguished Researcher Award. He was a member of the Computing Community Consortium Council.