Safe Optimal Control of Autonomous Vehicles with Control Barrier Functions

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We address the problem of optimizing the performance of a dynamic system consisting of multiple interacting autonomous vehicles while satisfying hard safety constraints at all times. Implementing an optimal control solution incurs a high computational cost, which limits it to simple linear dynamics, simple objective functions, and ignoring noise. Control Barrier Functions (CBFs) may be used for safety-critical control at the expense of sub-optimal performance. We will review the basic theory of CBFs and present a real-time control framework that combines vehicle trajectories generated through optimal control with the computationally efficient CBF method providing safety guarantees. A tractable optimal solution is first obtained for a linear or linearized system, then we optimally track this solution while using CBFs to guarantee the satisfaction of all state and control constraints. This Optimal Control and CBF (OCBF) framework can be adapted to allow complex objective functions, noise, and nonlinear dynamics (possibly unknown). We will show how OCBF controllers can be applied to autonomous vehicles in transportation systems where the objective is to jointly minimize the travel time and energy consumption of each vehicle subject to speed, acceleration, and speed-dependent safety constraints. We will also discuss how to overcome the problem of unknown vehicle dynamics using event-driven controllers.

Bio: Christos G. Cassandras (Life Fellow, IEEE) received the B.S. degree in engineering and applied science from Yale University, New Haven, CT, USA, the M.S.E.E. degree from Stanford University, Stanford, CA, USA, and the S.B. and Ph.D. degrees in applied mathematics from Harvard University, Cambridge, MA, USA.,From 1982 to 1984, he was with ITP Boston Inc. From 1984 to 1996, he was a Faculty Member with the Department of Electrical and Computer Engineering, University of Massachusetts/Amherst. He is currently a Distinguished Professor of engineering with Boston University, Brookline, MA, USA, the Head of the Division of Systems Engineering, and a Professor of electrical and computer engineering. He has authored or coauthored six books and 500 refereed papers in the areas of discrete event and hybrid systems, cooperative control, stochastic optimization, and computer simulation, with applications to computer and sensor networks, manufacturing systems, and transportation systems. He was the 2012 President of the IEEE Control Systems Society (CSS). He has been a plenary/keynote speaker at numerous international conferences and has also been an IEEE Distinguished Lecturer. He is a member of the Phi Beta Kappa and the Tau Beta Pi. He is a fellow of the IFAC. He was a recipient of several awards, including the 2011 IEEE Control Systems Technology Award, the Distinguished Member Award of the IEEE Control Systems Society in 2006, and the 1999 Harold Chestnut Prize (IFAC Best Control Engineering Textbook). He serves on several journal editorial boards. He was the Editor-in-Chief of the IEEE Transactions on Automatic Control from 1998 to 2009.