2024 European Control Conference (ECC)
June 25-28, 2024. Stockholm, Sweden

SAFE OPTIMAL CONTROL OF AUTONOMOUS VEHICLES WITH CONTROL BARRIER FUNCTIONS

Christos G. Cassandras and Yingqing Chen

Division of Systems Engineering,
Department of Electrical and Computer Engineering, and
Center for Information and Systems Engineering (CISE)
Boston University
Brookline, MA 02446
cgc@bu.edu, https://christosgcassandras.org

ABSTRACT

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, including mixed traffic conditions where autonomous vehicles share a traffic network with human-driven vehicles.

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