Mechanical Engineering Dissertation Defense

Exploiting Equilibrium Structure for Scalable Solutions to Zero-Sum Differential Games with One-Sided Information

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Abstract

Many real-world adversarial planning problems in security and robotics are best modeled as two-player zero-sum (2p0s) differential games, but they remain difficult to solve in practice because they involve continuous-time dynamics with continuous state and action spaces, strategic interaction, and often information asymmetry and state constraints. In contrast to the current state of the art in imperfect-information game solving --- largely driven by discrete domains (e.g., poker-style solvers) --- these settings demand methods that scale in continuous spaces while preserving the structure induced by asymmetric information. This dissertation develops a unified theory-and-algorithms for two-player zero-sum one-sided incomplete-information differential games (2p0s1) with and without state constraints, where the informed player ``P1'' has full information of the game while the uninformed player ``P2'' only holds partial information along with a public belief, i.e., a probability distribution over the set of possible payoffs/states. Key contributions of this work include the characterization of the value function in 2p0s1 with state constraints, development of scalable plug-and-play algorithms by leveraging the unique equilibrium structure inherent to 2p0s1 and enabling near real-time computation of strategies in 2p0s1 with linear dynamics and quadratic costs via a differentiable tree-Riccati methodology. Together, these contributions bridge rigorous foundations and scalable computation of Nash equilibrium strategies in 2p0s1.

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