The alpha-Potential Game Paradigm: Theory, Algorithms, and Applications

Designing and analyzing non-cooperative multi-agent systems that interact within shared dynamic environments is a central challenge across many established and emerging applications, including autonomous driving, production management, and e-commerce. A key objective in these systems is to identify Nash equilibria, where no agent can benefit by unilaterally deviating from her strategy. However, computing such equilibria is generally intractable unless specific structural properties of the interactions can be leveraged.

In this talk, we present a recently developed paradigm for dynamic N-player games, termed alpha-potential games, in which the change in a player's objective when she deviates from her strategy equals the change in an alpha-potential function, up to an error alpha. This framework reduces the analysis of alpha-Nash equilibria to a stochastic control problem for the alpha-potential function. The study of alpha also reveals critical game characteristics, such as the intensity of interactions and the level of heterogeneity among players. These theoretical insights are complemented by numerical experiments based on policy gradient algorithms, which demonstrate the computational advantages of the alpha-potential game framework for efficiently computing Nash equilibria in dynamic multi-agent environments.