Abstract

Spreading of an infectious disease or epidemic is shaped by the interplay between biological contagion dynamics and strategic decision-making by a large population of individuals. In this thesis, we leverage tools from game theory and control theory to analyze epidemic evolution when individuals learn to make forward-looking decisions and respond to information that is strategically revealed to them.

The first part of the thesis introduces a dynamic population game formulation for susceptible-infected-susceptible (SIS) epidemics. Individuals are modeled as non-myopic agents who optimize infinite-horizon discounted utilities when they decide whether to adopt costly and imperfect protection measures or remain unprotected. We characterize the stationary Nash equilibrium of this setting, and study the coupled evolution of infection prevalence and protection adoption under evolutionary learning dynamics.

Building on this framework, we consider the susceptible-asymptomatically infected-infected with awareness-recovered-unknowingly recovered (SAIRU) model with forward-looking individuals, who choose their degree of interaction, testing and vaccination. Individuals iteratively update their strategies based on observed population-level outcomes, leading to a feedback loop between game-theoretic learning and disease dynamics. We investigate the impacts of different intervention strategies (such as restrictions on social activity, limited supply of vaccines) and learning rates on infection prevalence.

In the third part of the thesis, we analyze the SIS epidemic setting with asymptomatic infections. When individuals are not aware of their true infection status, a central authority tries to influence their protection adoption behavior through carefully designed signaling policies. We derive optimal static and dynamic signaling schemes that shape individual beliefs and chosen actions to minimize infection prevalence at equilibrium, and along epidemic trajectories, highlighting the power and limitations of information-based interventions.

Finally, we analyze a bi-virus SIS model with two mutant strains. We characterize the disease-free and endemic equilibrium of this setting, and then analyze protection adoption strategies that emerge at a Nash equilibrium.

Overall, this thesis advances the theoretical foundations of behavior-aware epidemic modeling through the development of rigorous frameworks that integrate non-myopic decision-making, evolutionary learning, and information design.

Keywords: Epidemic Modeling, Dynamic Population Games, Evolutionary Learning, Information Design, Epidemic Models with Mutation