Receding Horizon Games for Dynamic Resource Allocation Problems

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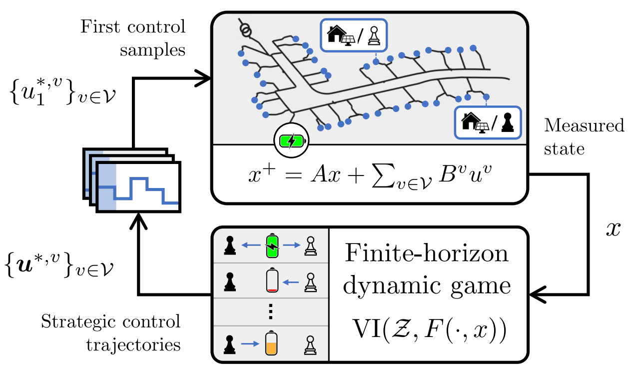

Fig. 1. In RHG, control actions are generated by solving a finite-horizon dynamic game, in a receding-horizon fashion.

Our modern society is underpinned by a multitude of shared infrastructure and resources (e.g., traffic networks, power grids, and fish stocks). These systems and resources need to be carefully managed; if left unchecked, selfish behavior by users can lead to severe societal losses. In addition, in large scale infrastructure problems, decisions need to be made in real-time through control algorithms. Yet, controlling shared infrastructure and allocating resources in real-time is a challenging problem. One of the only systematic and tractable control frameworks for systems with these properties is Economic Model Predictive Control (EMPC) as it allows for general economic objectives and constraints as well as for distributed implementations [1]. However, EMPC implicitly assumes that agents accessing the shared resources are willing to cooperate to achieve a socially-optimal outcome which is an unreasonable assumption. Game-theory comes as a powerful tool for modeling conflict and cooperation between self-interested decision makers but existing works oftentimes solve for open-loop policies which are not robust against disturbances and model mismatch. One approach to introduce feedback is to solve the game in a receding-horizon fashion, measuring the state and recomputing the open-loop trajectory at every sampling time, à la MPC, as shown in Figure 1.

The combination of MPC and game theory, also called Receding Horizon Games (RHG) [2] or Game-Theoretic Planning [3, 4], allows one to handle systems with dynamics, constraints, and self-interested agents. This control paradigm has been successfully employed in various engineering applications, including supply chains [5], robotics [6], autonomous driving [4, 7, 8], electric vehicle charging [9], and smart grids [2, 10].

We will present Receding Horizon Games, focusing on three key aspects: (i) Motivate this novel control paradigm through dynamic resource allocation problems, using applications in energy and groundwater management; (ii) Present the general RHG framework and its solution concept based on variational Generalized Nash Equilibria, which ensure both strategic stability and economic fairness in resource allocation, (iii) Introduce the first formal stability analysis of RHG using dissipativity theory and monotone operator methods, extending beyond potential games, providing numerically verifiable certificates [11].

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