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Event-triggered Distributed Model Predictive Control for Scalable Multi-agent Systems

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The cooperative control of multi-agent system (MAS) has wide range of applications such as multi-robot coordination [1], unmanned aerial vehicle(UAV) formations, decentralized motion planning of automated guided vehicles, etc. all of which require robust and effective control strategies. Distributed control allows each agent to update its controller based on local information received from its neighbor which enables MAS to achieve coordination task such as consensus, containment and formulation [2]. Model Predictive control has played a major role in the coordination control of MAS. As an optimization based control technique, it optimizes the system control actions over a finite prediction horizon to minimize a predefined cost function such as tracking error or energy consumption [3]. Compared with the centralized MPC of one single system, the distributed MPC of MAS involves multiple MPC controllers for groups of agents. Each agent has its own controller, which optimizes its actions while considering interactions with other agents [2]. Each local controller solves an MPC problem using local information and may exchange data with other controllers to enhance overall performance. Previously, a number of distributed MPC protocols have been proposed [4,5], which typically rely on periodic communications amongst agents which result in high energy consumption, bandwidth overload and impractical deployment in environments where connectivity is intermittent or constrained. Also, there is the challenge of scalability of MAS with structurally changing networks in the design of MPC algorithms. In varying networks, agents may occasionally join and leave the network which bring extra difficulties into the distributed control design which existing MPC algorithm are not capable of coping with the dynamicity.

This work addresses the challenges of achieving efficient and scalable coordination in multi-agent system by proposing an event-triggered distributed model predictive control (ET-DMPC) framework. To overcome the limitation of periodic communication amongst agent, this approach introduces a communication-efficient mechanism where agents exchange information only when a locally evaluated condition is satisfied. This event-triggering mechanism will reduce communication load without sacrificing system performance [6]. More so, a novel consensus protocol will be designed to ensure convergence under changing network topologies. The consensus objectives, a fundamental requirement for coordinated behavior in MAS, is approached through a discrete-time average consensus protocol where each agents updates its state using information from neighbors. The communication graph representing the inter-agent connection is allowed to vary over time, capturing realistic dynamics such as mobile robots entering or existing a communication range. In order to ensure convergence despite this variability, the connectivity of the graph over uniformly bounded time intervals is maintained. Stability analysis of the proposed control strategy is performed using a set-valued Lyapunov function, which provides a robust measure of collective convergence in the presence of dynamic network topologies. The proposed framework will be applied to scalable autonomous vehicle platooning and robotic swarms, with validation through simulation and real-world scenarios.

This research contributes to the broader goals of scalable resilient control in distributed systems. By merging theoretical developments with practical testing the project aims to bridge gaps between abstract control frameworks and operational realistic of coordination in multi-agent systems

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