Adaptive bounded output feedback control for nonlinear multi-agent systems under unreliable communication

Meilin Li
School of Automation Engineering
University of Electronic Science and Technology of China
Chengdu, China
meilinli0126@163.com

***Abstract*—This paper introduces an Adaptive Bounded Output Feedback Control (ABOFC) strategy for nonlinear multi-agent systems operating under unreliable communication conditions. The proposed control scheme addresses the challenge of maintaining system stability and performance in the presence of communication disruptions and data losses. By leveraging bounded output feedback, the control strategy adapts to changes in the system dynamics and communication environment, ensuring robustness and reliability. Theoretical analysis and simulation results demonstrate the effectiveness of the ABOFC approach in achieving desired performance metrics while handling unreliable communication channels. This work contributes to the development of more resilient multi-agent systems capable of operating efficiently in real-world scenarios with communication uncertainties.**

***Index Terms*—Multi-agent systems, bounded output feedback, unreliable communication, adaptive control.**

I. Introduction

In recent years, multi-agent systems (MAS) have garnered significant attention due to their wide range of applications, from autonomous vehicles and robotic swarms to distributed sensing networks and cooperative control. These systems consist of multiple interacting agents that collaborate to achieve common objectives, making them highly effective for complex tasks requiring collective intelligence and distributed problem-solving. However, the performance and reliability of MAS can be severely impacted by communication challenges, particularly when operating in environments with unreliable or intermittent communication channels.

Nonlinear dynamics add another layer of complexity to MAS control, as the system's behavior can exhibit unpredictable and nonlinear characteristics that complicate the design of robust control strategies. Traditional control approaches often struggle to handle such complexities, especially when combined with unreliable communication. To address these challenges, this paper presents an Adaptive Bounded Output Feedback Control (ABOFC) strategy designed to ensure stability and performance in nonlinear multi-agent systems despite the presence of unreliable communication.

This work is supported in part by the National Natural Science Foundation of China under Grants 51939001, 62273072, 62203088, the Natural Science Foundation of Sichuan Province under Grant 2022NSFSC0903.

Problem Formulation The problem of controlling nonlinear multi-agent systems under unreliable communication is multi-faceted. Communication failures can lead to data loss, delayed updates, and inconsistencies in the information exchanged between agents. These issues can disrupt the coordination and stability of the system, making it crucial to develop control strategies that are both adaptive and resilient to such uncertainties.

The key objectives of this research are twofold:

Adaptation to Nonlinear Dynamics: Develop an adaptive control strategy that can effectively handle the nonlinear nature of the multi-agent system, ensuring that the system remains stable and performs well even as the dynamics change. Robustness to Communication Failures: Design a control approach that remains effective despite unreliable communication, addressing challenges such as data loss, delays, and disruptions. Contributions This research makes several significant contributions to the field of multi-agent system control:

Development of ABOFC: The proposed Adaptive Bounded Output Feedback Control strategy integrates bounded output feedback mechanisms with adaptive control principles to handle nonlinear system dynamics and communication uncertainties effectively.

Theoretical Analysis: The paper provides a rigorous theoretical analysis of the ABOFC strategy, including stability proofs and performance guarantees, demonstrating its efficacy in managing nonlinear dynamics and unreliable communication.

Simulation Validation: Through extensive simulations, the effectiveness of the ABOFC approach is validated under various scenarios of communication unreliability, showcasing its ability to maintain system stability and performance in practical applications.

Related Work A comprehensive review of related work reveals several approaches to control nonlinear multi-agent systems and address communication challenges. Existing strategies include centralized and decentralized control methods, robust control designs, and adaptive control techniques. However, many of these approaches either assume reliable communication or are not specifically designed to handle the

complexities introduced by nonlinear dynamics and communication failures. This paper builds on these existing methodologies by incorporating adaptive bounded output feedback mechanisms to address both issues simultaneously.

Structure of the Paper The paper is organized as follows: Section 2 reviews related literature on nonlinear multi-agent systems, bounded output feedback control, and communication reliability. Section 3 presents the theoretical framework and methodology of the ABOFC strategy, including the formulation of the control laws and adaptation mechanisms. Section 4 details the simulation experiments conducted to evaluate the performance of the proposed approach, with results illustrating its robustness under unreliable communication conditions. Section 5 discusses the practical implications, limitations, and potential future research directions, while Section 6 concludes the paper by summarizing the key findings and contributions.

Summary In summary, this introduction highlights the critical need for robust control strategies in nonlinear multi-agent systems operating under unreliable communication. The proposed Adaptive Bounded Output Feedback Control strategy offers a promising solution by addressing both nonlinear dynamics and communication uncertainties, thus advancing the state-of-the-art in multi-agent system control. The subsequent sections provide a detailed exploration of the theoretical and practical aspects of the ABOFC approach, offering insights into its potential applications and impact on the field.