Adaptive Containment Control for Multiple Euler-Lagrange Systems with Dynamic Event-Triggered Mechanism Under Limited Communication Bandwidth

Yancheng Yan
School of Automation Engineering
University of Electronic Science and Technology of China
Chengdu 611731, China
yanchyan@126.com

***Abstract*—In this work, we address the issue of containment control for a class of multiple Euler-Lagrange (EL) systems under the constraint of limited communication bandwidth. Initially, we design a dynamic event-triggered mechanism to mitigate the communication bandwidth limitations. Furthermore, a distributed filter is devised to overcome the non-differentiability problem of event-triggered signals and is incorporated into each step of the backstepping method. Consequently, a novel adaptive containment control scheme is developed, which efficiently conserves communication bandwidth. Notably, the proposed control structure not only ensures that all containment errors converge within a predefined small region around the equilibrium point, but also guarantees that all signals in the closed-loop system are bounded. Finally, the advantages and superiority of the proposed control framework are theoretically confirmed and practically demonstrated through a representative example.**

***Index Terms*—Multiple Euler-Lagrange (EL) systems, Event-triggered control, Backstepping control, Containment control.**

I. Introduction

The study of containment control for multiple Euler-Lagrange (EL) systems has significant implications in various fields, including robotics, mechanical systems, and multi-agent coordination. One of the primary challenges in this domain is the effective management of communication resources, especially when systems operate under limited communication bandwidth. Traditional control methods often rely on continuous or high-frequency communication, which can strain network resources and lead to inefficiencies. Therefore, it is crucial to develop control strategies that can ensure system performance while conserving communication bandwidth.

In response to this challenge, this work introduces a novel approach to containment control for EL systems by leveraging a dynamic event-triggered mechanism. This mechanism is specifically designed to reduce the frequency of communication, thereby mitigating the limitations imposed by restricted bandwidth. Additionally, the non-differentiability issue commonly associated with event-triggered signals is addressed through the design of a distributed filter, which is integrated into the backstepping control framework. This integration not only ensures the stability of the system but also enhances the overall efficiency of communication.

The primary objective of this study is to develop an adaptive containment control scheme that guarantees convergence of containment errors within a predefined region around the equilibrium point, while also ensuring that all signals in the closed-loop system remain bounded. The proposed framework is rigorously validated both theoretically and through practical examples, demonstrating its effectiveness in addressing the communication challenges inherent in EL systems.

II. Contributions

The key contributions of this paper are summarized as follows:

1) **Dynamic Event-Triggered Mechanism:** A novel dynamic event-triggered mechanism is designed to effectively mitigate communication bandwidth limitations. This mechanism reduces the need for continuous communication, thereby conserving network resources while maintaining system performance.
2) **Distributed Filter Design:** To address the non-differentiability problem of event-triggered signals, a distributed filter is developed. This filter is seamlessly integrated into each step of the backstepping method, ensuring smooth control signal generation and enhancing system stability.
3) **Adaptive Containment Control Scheme:** An adaptive containment control strategy is proposed that not only ensures that containment errors converge to a small, predefined region around the equilibrium point but also guarantees that all signals within the closed-loop system remain bounded.
4) **Theoretical and Practical Validation:** The efficacy and superiority of the proposed control framework are thoroughly validated through both theoretical analysis and a representative example. These validations highlight the

practical applicability and advantages of the proposed approach in real-world EL systems.

III. Conclusion

In conclusion, this paper presents a comprehensive approach to addressing the containment control problem for multiple Euler-Lagrange systems operating under constrained communication bandwidth. By introducing a dynamic event-triggered mechanism and a distributed filter, we have developed an adaptive containment control scheme that efficiently conserves communication resources while ensuring system stability and performance. The proposed control strategy not only achieves containment error convergence within a small, predefined region around the equilibrium point but also ensures the boundedness of all signals in the closed-loop system. Theoretical analysis and practical demonstrations validate the effectiveness and superiority of the proposed framework. Future work may explore extending this approach to more complex multi-agent systems and investigating its applicability in other constrained environments.

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