Cooperative Containment-Formation Control of Non-Holonomic Robots Using Distance-Based Feedback

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***Abstract*—This paper explores the cooperative containment-formation problem involving two non-holonomic robots, with a primary focus on angular velocity control for trajectory regulation. In this study, the robots are assigned the task of maintaining a predetermined circular path around a stationary target, while preserving a specified inter-robot distance and angular velocity. Notably, the robots do not have access to global positioning data and are unable to directly localize the target. Instead, they depend exclusively on real-time, distance-based sensor data related to nearby objects to guide their movement. By employing a leader-follower coordination strategy, we propose an innovative control algorithm that uses distance-based feedback to generate bounded control inputs for the robots. Additionally, the conditions governing the control parameters and initial state configurations are rigorously derived. We provide a comprehensive analysis to demonstrate that, under these conditions, the proposed control strategy successfully achieves the desired cooperative containment-formation behavior. Extensive simulations and experimental validations are conducted to support the theoretical findings and emphasize the robustness of the proposed approach.**

***Index Terms*—Cooperative containment-formation, Non-holonomic robots, Distance-based feedback, LeaderCfollower coordination strategy.**

I. Introduction

The cooperative control of multi-robot systems has emerged as a vital area of research, particularly in applications involving non-holonomic robots such as autonomous vehicles and mobile robots. One of the significant challenges in this domain is the cooperative containment-formation problem, where multiple robots must collaboratively maintain a desired formation while encircling a stationary target. This problem becomes particularly complex when the robots lack access to global positioning data and must rely solely on local, distance-based sensor information to regulate their trajectories.

In this paper, we focus on a specific scenario involving two non-holonomic robots tasked with maintaining a circular path around a stationary target. The robots must preserve a predetermined inter-robot distance and control their angular velocities to achieve the desired containment-formation behavior. Unlike conventional approaches that often assume the availability of global positioning systems (GPS) or other forms of absolute localization, our study considers a more realistic scenario where the robots cannot directly localize the target and must depend entirely on real-time, distance-based measurements from nearby objects.

To address this challenge, we adopt a leader-follower coordination strategy and propose a novel control algorithm that uses distance-based feedback to generate bounded control inputs for the robots. The primary objective of this research is to design a control strategy that ensures the robots maintain the desired circular formation while achieving stable and precise trajectory regulation, despite the absence of global positioning data.

II. Contributions

The main contributions of this paper are summarized as follows:

1) **Novel Control Algorithm:** We propose an innovative control algorithm for the cooperative containment-formation problem of two non-holonomic robots. This algorithm is based on distance-based feedback and generates bounded control inputs, enabling the robots to maintain the desired circular formation around a stationary target.
2) **Leader-Follower Coordination Strategy:** A leader-follower coordination strategy is employed, where one robot acts as the leader and the other as the follower. This strategy is crucial in achieving the cooperative containment-formation behavior without requiring global positioning data.
3) **Rigorous Derivation of Control Conditions:** We rigorously derive the conditions governing the control parameters and the initial state configurations that are necessary for the successful implementation of the proposed control strategy. These conditions ensure that the robots achieve and maintain the desired formation while adhering to the constraints imposed by their non-holonomic nature.

III. Conclusion

In conclusion, this paper presents a comprehensive study on the cooperative containment-formation problem involving two non-holonomic robots, with a focus on angular velocity control for trajectory regulation. We address the challenges posed by the lack of global positioning data by proposing a novel control algorithm that relies exclusively on distance-based feedback. Through the implementation of a leader-follower coordination strategy, we demonstrate that the proposed control strategy effectively achieves the desired containment-formation behavior, ensuring that the robots maintain a stable and precise circular formation around a stationary target. The rigorous derivation of control conditions, coupled with extensive simulations and experimental validations, underscores the robustness and practicality of the proposed approach. Future research may extend this work to more complex multi-robot systems and explore the integration of additional sensory data to enhance the control strategy's adaptability and performance.

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