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Distributed Observation-based Control Architecture for Multi-agent Aquatic Drones: Application to Environmental Monitoring

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The recent Conseil Économique, Social et Environnemental Régional (CESER) Hauts-de-France report highlights two key priorities in regional water management: preserving water quantity and restoring quality. Devastating floods in the region have underscored the urgent need for resilient infrastructure and decision-making tools as well as enhanced strategies for environmental monitoring particularly in aquatic environments [1]. Current monitoring of aquatic environments which is vital for informed decision-making mostly depends on manually deployed equipment or single-agent systems (SAS) with limited capabilities. In contrast, Multi-Agent Systems (MAS) are gaining attention for their ability to provide autonomous, scalable, and resilient monitoring solutions. Beyond environmental applications, MAS have shown promise in fields such as aerospace, transportation, and defense due to their capabiliity to perform complex cooperative tasks. Effective aquatic environment monitoring with MAS requires drones capable of seamless navigation and coverage of relevant areas [2]. Despite their potential, the deployment of MAS in aquatic drones is hindered by theoretical and practical challenges, particularly the limitations of centralized control systems. Such systems are not very scalable with very large number of agents and are vulnerable to single points of failure. A shift toward distributed and decentralized control is crucial for enabling reliable and sustainable operations. However, aquatic drone networks often suffer from communication uncertainties and unstable topologies, necessitating robust and intelligent control frameworks [3], [4].

Our work addresses the challenge of formation tracking for multi-agent aquatic drones operating in highly unpredictable environments where communication is both asynchronous and aperiodic. Due to communication and physical limitations, each agent can only transmit its position data at discrete time intervals. To address these constraints, a continuous-discrete-time observer in tandem with formation tracking controller is used to drive agents toward a desired formation, enabling the fleet equiped with sensors to monitor the environment while maintaining a given topology. The proposed control framework contributes to the development of intelligent and decentralized strategies for autonomous aquatic drones and aims to improve the effectiveness and robustness of environmental monitoring systems operating in dynamic and uncertain aquatic environments.

References:

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