Emerson Hall

Ramana M. Pidaparti

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Multi-UAV Coordination and Safety Constraints

Introduction

The goal for Week 10 was to add advanced capabilities to the UAV simulation by introducing multiple UAVs into the same environment. The objective was to test whether each UAV could plan and follow its own path while still avoiding collisions with both obstacles and other UAVs. This week focused on multi-UAV coordination, improved safety, and more consistent path planning. The system used the same Frenet-based controller developed in Week 9 but expanded it to support several agents that could operate together under wind disturbances and dynamic conditions. The aim was to show that the UAVs could work independently yet still coordinate within a shared airspace.

Method

The simulation was created by building on the final Week 9 system and extending it to multiple UAVs. Each UAV used its own A* path planner, path smoother, and Frenet-frame follower. The same 20 by 20-meter environment from the previous week was used, containing random static objects such as walls and boxes along with one moving obstacle that oscillated from side to side. A steady background wind and random gusts were also included to test how the UAVs handled external disturbances. Each UAV accounted for the wind by adjusting its air velocity to maintain the desired ground speed and direction toward the goal. The code is shown in GitHub.

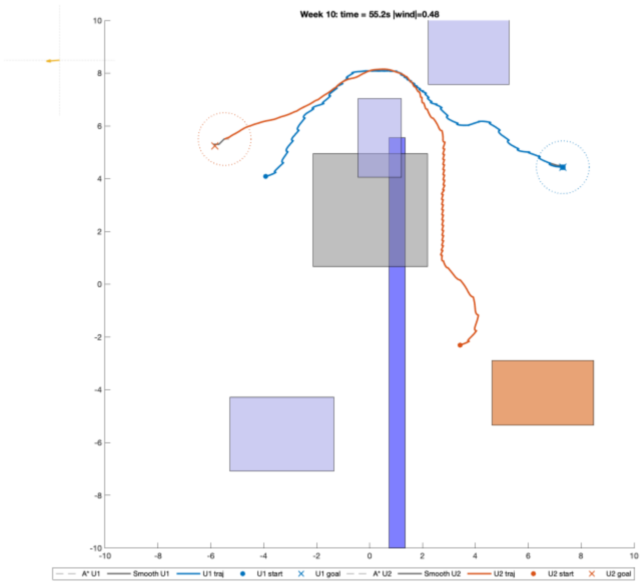

Figure 1: 2 UAVs

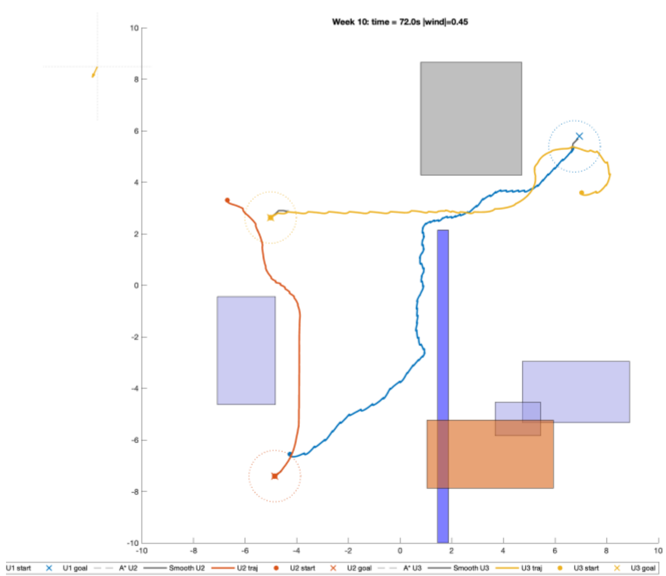

Figure 2: 3 UAVs

To manage multiple UAVs in the same environment, a shared occupancy grid was implemented. Each UAV treated other UAVs as moving obstacles when planning, using a safety mask to prevent paths from overlapping. The A* planner updated regularly to adjust to changes in the environment, and each path was refined through a string-pulling method that removed unnecessary points while checking that the route stayed within safe boundaries. The Frenet-based controller followed these smoothed paths, using lateral correction and soft repulsion to maintain a stable distance from walls and other objects. Additional features such as sub-step collision checking, target projection, and sliding motion along boundaries were included to make the movement more realistic and prevent any UAV from passing through obstacles. The final system also included goal-hold behavior so that UAVs stopped and remained stationary once they reached their destination.

Results

Two main simulations were conducted for testing. The first simulation used two UAVs to confirm that both could plan paths independently and reach their goals without interference. Both UAVs successfully avoided static obstacles and the moving box while navigating through the world. Each vehicle adapted smoothly to changes and stopped at its goal without oscillation. The second simulation introduced a third UAV to make the environment more crowded and test coordination under more difficult conditions. All three UAVs were able to replan when needed and avoided collisions even when their paths intersected. The smooth paths created by the string-pulling algorithm allowed each UAV to follow realistic and efficient routes. The anti-tunneling and sub-step collision checks ensured that none of the UAVs crossed through inflated obstacle zones, even when their trajectories changed suddenly.

The addition of the goal-hold feature allowed UAVs to stop correctly when they reached their targets, improving stability at the end of the flight. The wind model caused small shifts in trajectory, but the controller compensated automatically. Overall, the simulation showed consistent coordination among all UAVs and strong reliability of the control system. The video results displayed smooth motion, obstacle avoidance, and successful cooperation between multiple UAVs operating in the same airspace.

Discussion

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Conclusion

Week 10 successfully implemented advanced multi-UAV coordination and safety features into the simulation. Each UAV was able to plan and follow its own path while adapting to dynamic changes and avoiding collisions. The added features, including shared occupancy awareness, stall recovery, and goal-hold behavior, made the UAVs more stable and realistic. The Frenet controller continued to perform smoothly under wind and random disturbances, showing that it could scale beyond a single vehicle. This week demonstrated that the system could manage multiple autonomous agents in a shared environment, marking another step toward reliable and cooperative UAV trajectory optimization in simulation.