A Cloud-Based Vehicle Collision Avoidance Strategy for Unmanned Aircraft System Traffic Management (UTM) In Urban Areas

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Abstract

The study titled "A Cloud-Based Vehicle Collision Avoidance Strategy for Unmanned Aircraft System Traffic Management (UTM) in Urban Areas" presents a new approach for piloting Unmanned Aircraft Systems (UAS) in low-altitude urban airspace. With the increasing usage of drones for delivery, surveillance, and data collection, effective coordination is very important to ensure operational safety. The proposed cloud-based architecture monitors and directs UAS to mitigate the risk of mid-air collisions. This system implements a Priority-Based Distributed Model Predictive Control (MPC) algorithm, which calculates optimal flight trajectories by assigning priority to higher-importance aircraft and dynamically avoiding obstacles and other UAS. Simulation experiments involving three UAS demonstrated successful collision avoidance, thereby supporting the model's effectiveness. These findings show that cloud-integrated traffic management systems can improve the safety and scalability of urban drone operations in future smart city contexts.

Materials & Methods

This study implemented a cloud-based control system comprising three primary components: the Coordinator Manager (CM), Navigation Manager (NM), and the unmanned aerial system (UAS) unit. The CM continuously monitored airspace and assigned unique priority levels to each drone to prevent overlap. In the event of a conflict, the NM of the drone with lower priority recalculated its trajectory. The NM incorporated modules for map management, risk-based path planning, and real-time trajectory prediction.

Simulation experiments were performed in a Robot Operating System (ROS) environment, utilizing both Gazebo and Software-In-The-Loop (SITL) simulation tools. PX4 autopilot software was used to emulate drone flight dynamics. The experimental setup included a fixed altitude, three drones with distinct priority levels, and safety distances defined as $d_1 = 5$ meters (hard constraint) and $d_2 = 10$ meters (soft constraint). Trajectory optimization was conducted using the NLOPT nonlinear optimization library to ensure good accuracy and safety.

Analysis

Simulation results confirmed that the system effectively prevented collisions under varying priority and trajectory scenarios. In tests where three drones followed intersecting routes, the lowest-priority drone altered its path while maintaining the defined safety radii (d_1 and d_2). Higher-priority drones continued along their assigned routes without deviation, as seen in Figure 1 (Stefano Primatesta et al., 2020).

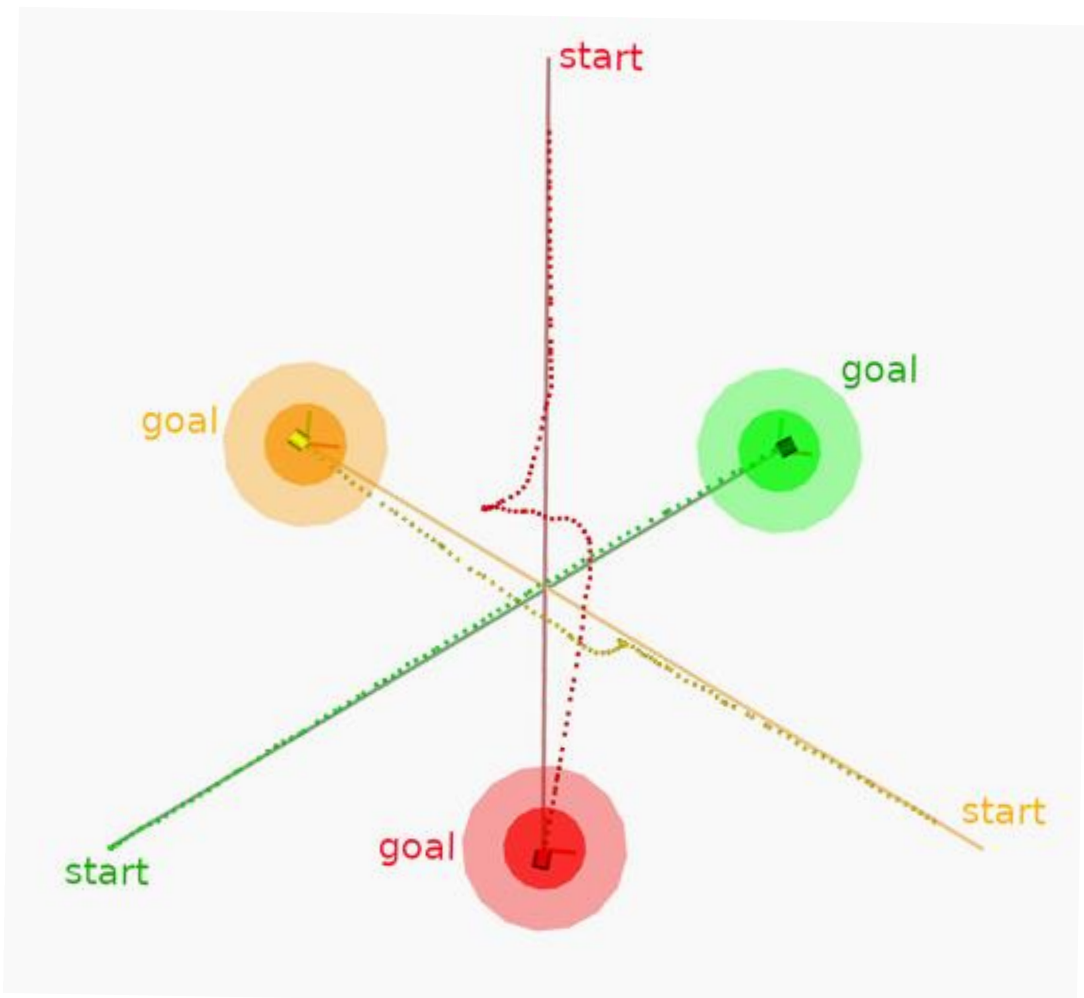

Figure 1: This is a simulation of three UAS. The UAS with the highest priority is in green, the UAS with middle priority is in yellow, and the UAS with the lowest priority is in red. Each UAS

is signified with a square, with the dark circle surrounding it being the hard safety constraint and the lighter circle being the soft safety constraint.

3As the figure depicts, the high priority UAS stayed on its path in a straight line, unaffected by the other two UAS. The medium priority UAS successfully avoided the high priority one, and the low priority UAS successfully avoided all of them. The model predictive control (MPC) algorithm adjusted drone paths at 2 Hz, looking 15 steps ahead to keep routes efficient and avoid collisions. As shown in Figure 2, the distributed control setup lowered computational load compared to centralized systems and made it easier to scale up for larger drone fleets (Stefano Primatesta et al., 2020).

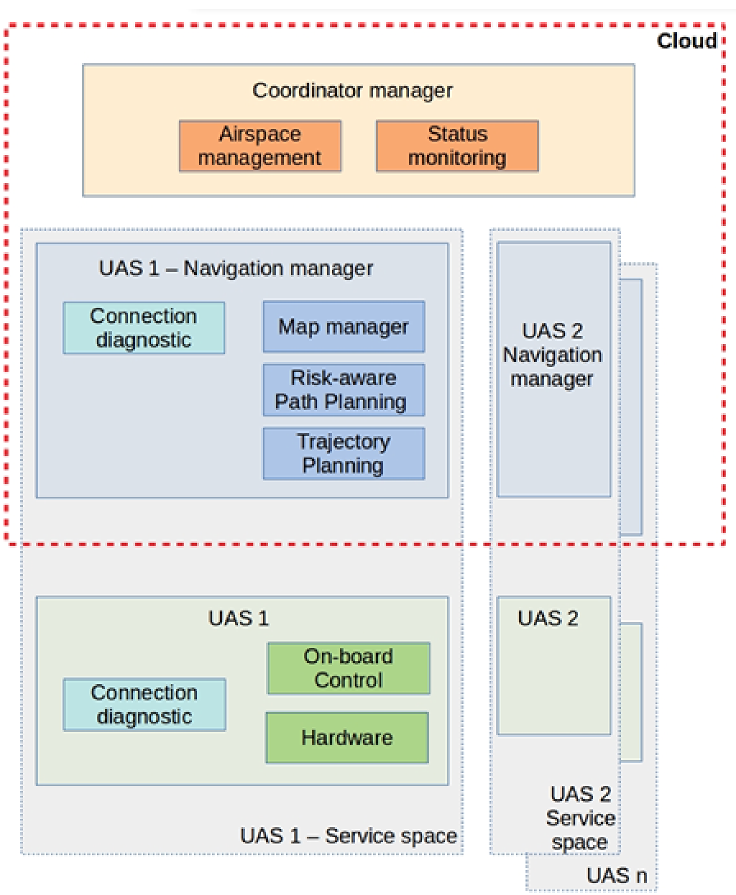

Figure 2: This is the cloud-based architecture for UAS Traffic Management.

These results are relevant to a science project related to an unmanned autonomous vehicle picking up trash in parks, as the same cloud-based collision avoidance strategies can be applied to ground-based robots operating in shared public spaces. In a park environment, multiple autonomous vehicles may navigate simultaneously to collect litter, avoid pedestrians, and adapt to constantly changing obstacles such as animals, bicycles, or children at play. By using a priority-based Model Predictive Control (MPC) system like the one described in the study, each robot could smartly recalculate its route when another higher-priority vehicle or moving object enters its path.

References

Stefano Primatesta, Matteo Scanavino, Lorenzini, A., Polia, F., Stabile, E., Giorgio Guglieri, & Rizzo, A. (2020). A Cloud-based Vehicle Collision Avoidance Strategy for Unmanned Aircraft System Traffic Management (UTM) in Urban Areas. *2022 IEEE 9th International Workshop on Metrology for AeroSpace (MetroAeroSpace)*. https://doi.org/10.1109/metroaerospace48742.2020.9160145