Enhancing Safety in UAM Corridors: A Self-Separation Scheme Utilizing Estimated Arrival Times at Constraint Waypoints

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We introduce a novel method for assisting in arrival scheduling at Constrained Waypoints (CWPs), focusing on safety. Our approach calculates the minimum Estimated Time of Arrival (ETA) gap at CWPs to ensure safe self-separation among aerial vehicles throughout their flights within the UAM corridor. First, we propose a method for computing the ETA gap based on aerial vehicles' Near-Mid-Air-Collision (NMAC) rules. This approach effectively prevents collisions when vehicles adhere to corridor speed limits, but it may be insufficient if those limits are exceeded. To address this, we also explore an alternative method based on Responsibility-Sensitive Safety (RSS) rules from automated driving, which guarantees collision avoidance even if vehicles exceed speed limits.

Key Words : Urban Air Mobility, Air Traffic Control, Advanced Air Mobility, self-separation

1. Introduction

The surge in Urban Air Mobility (UAM) operations within metropolitan airspace poses a challenge to current air traffic control systems. In response, the Federal Aviation Authority (FAA) has suggested implementing air corridors to establish structured air traffic routes for UAM operations.[1)] Our study proposes a novel air traffic control concept to enhance safety in UAM corridors, focusing on scheduling vehicle arrivals at Constrained Waypoints (CWPs).

2. Air Traffic Control using ETAs at CWPs

We segment the air traffic network into UAM corridors and focus on each single-track UAM corridor with specified minimum and maximum speed limits. Figure 1 depicts the spatio-temporal information regarding the trajectories of vehicles f ("front") and r ("rear") flying in the corridor between CWP0 and CWP1. We also impose limits on vehicle acceleration and braking rates to constrain speed changes. Under these constraints, we propose methods to compute the conditions for ETA gaps at CWP0 and CWP1 to prevent collisions and optimize the traffic flow.

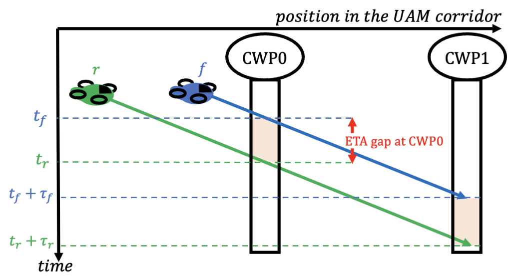

Fig. 1. An illustrative example for ETAs at CWPs in a UAM corridor between CWP0 and CWP1. The horizontal (*resp.* vertical) axis represents the vehicles' positions (*resp.* time). Vehicle f (*resp.* r) is estimated to arrive at CWP0 and enter the corridor at time instances t_f (*resp.* t_r), and spend τ_f (*resp.* τ_r) time duration in the corridor. The ETA gaps at CWP0 and CWP1 are $t_r - t_f$ and $(t_r + \tau_r) - (t_f + \tau_f)$, respectively. The two vehicles collide if their trajectories intersect.

3. Results on ETA Gap Computations

NMAC-based method Our first method follows aerial vehicles' Near Mid-Air-Collision (NMAC) avoidance rules, which require the separation distance between vehicles to be above a specified threshold (e.g., 152.4 meters in[2)]). We compute the minimum ETA gaps to ensure that the separation distance exceeds the threshold. This method guarantees safety if vehicles adhere to the speed limits, but it cannot ensure safety if the vehicles do not follow these limits.

RSS-based method Responsibility-Sensitive Safety (RSS) is a well-known rule-based framework designed to set safety rules for automated driving systems.[3)] Based on this framework, our proposed method calculates the minimum ETA gaps required to prevent collisions throughout vehicle flights within the corridor. Although it may require larger ETA gaps compared to the NMAC-based method, this RSS-based approach provides safety guarantees even when vehicles exceed the speed limits.

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References

1) S. Bradford, "Urban air mobility: Concept of operations v1. 0," *Federal Aviation Administration, Office of NextGen, June*, vol. 26, 2020.

2) S. C. Johnson, A. Petzen, and D. Tokotch, "Exploration of detect-and-avoid and well-clear requirements for small uas maneuvering in an urban environment," in *17th AIAA Aviation Technology, Integration, and Operations Conference*, p. 3074, 2017.

3) S. Shalev-Shwartz, S. Shammah, and A. Shashua, "On a formal model of safe and scalable self-driving cars," *arXiv preprint arXiv:1708.06374*, 2017.