Intermodal Safety Net for Urban Air Mobility

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In the highly dynamic landscape of Urban Air Mobility (UAM), ensuring safety in dense urban and regional areas is a critical challenge. This study introduces a novel strategy to create a dependable intermodal safety network through dynamic and adaptable ground traffic control. The core inquiry investigates the potential for intersections to be used as emergency landing areas, and whether intersections can be safely used with appropriate ground/city traffic management. This traffic management system could be implemented through centralized coordination of traffic across the city, car-to-car communication, or a network of interconnected traffic junctions with sense and react capabilities.

The study has three primary objectives: first, to identify appropriate intersections and controllable ground areas along proposed flight paths; second, to establish effective communication protocols between air and ground traffic management systems; and third, to develop strategies for managing ground traffic during declared emergency cases of flying platforms. The feasibility of this combined air-ground traffic management approach is examined using OpenStreetMap data to derive a realistic urban area and simulation scenarios for air and ground traffic.

The study measures safety enhancements by minimizing third-party involvement and presenting safety-focused routes that incorporate street and intersection networks as a contingency management system. The innovative research combination of two transportation modes will intensify safety in urban air mobility. Already in its preliminary stages, this research already holds significant potential for enhancing aviation safety. We expect this cooperative air/ground approach to be a mandatory element for future urban air operations and part of a safety standard [1].

In urban air mobility, landing sites are in densely populated urban areas, and air emergencies have a high potential for interaction with the urban infrastructure and traffic structure [2]. Traffic areas such as roads and intersections could be utilized for emergency landings, but these are subject to dynamic use during the day [3]. Modern city traffic management centers could actively support an emergency landing (e.g. by closing intersections to road traffic). At the same time, the landing can also be supported by people on the ground. In this case, simple communication with the drone, e.g. via gesture control, would be a prerequisite [4].

In urban areas, not all open spaces are suitable landing sites as they may not be under the control of operators. It cannot be guaranteed that these areas are free of obstacles and can be safely used for emergency landings. Modern intersections can be managed using traffic lights controlled by central traffic management systems [5]. These systems already enable dynamic prioritization of traffic, such as public transport, by switching traffic lights based on local arrivals. These intersections can be used for air emergencies by preventing ground traffic from entering the intersection. Our approach supports flight plans with a ground-based safety net, and the intended trajectories can/must consider the expected traffic situation and the associated traffic management.

Approach

We model traffic dynamics and facilitate potential emergency landings by creating a simplified road network and aircraft trajectories in Anylogic (Fig. 1, left). The network encompasses nine intersections equipped with traffic lights operating on a 15-second cycle of green and red signals. Cars only enter the road network at the upper-left and left at the lower-right corner. The simulation incorporates a flying platform with a velocity of 90 km/h (Fig. 1, left). Alternative flight trajectories are indicated by dotted lines. Each entering car is initiated at a speed of 30 km/h, capable of reaching a maximum speed of 50 km/h (city traffic rule). To simplify the ground traffic, we assume at each intersection, that cars face a decision point with a 50% probability of proceeding straight or making a right turn onto the subsequent road.

Various traffic scenarios are being examined as follows with the aim of identifying an optimized combination of adjusted flight trajectories and associated ground traffic management to provide an additional safety layer. The average speed of traffic on the road network is used as a target value.

- Once ground traffic is initiated and has been running for 20 minutes, the overflight takes place.
- Along the flight trajectory, a suitable intersection is chosen and temporarily closed to traffic from all directions for a brief period.
- This selection process is based on optimization techniques aimed at minimizing expected ground waiting times (using Mixed Integer Linear Programming).
- A variety of overflight scenarios are being evaluated.

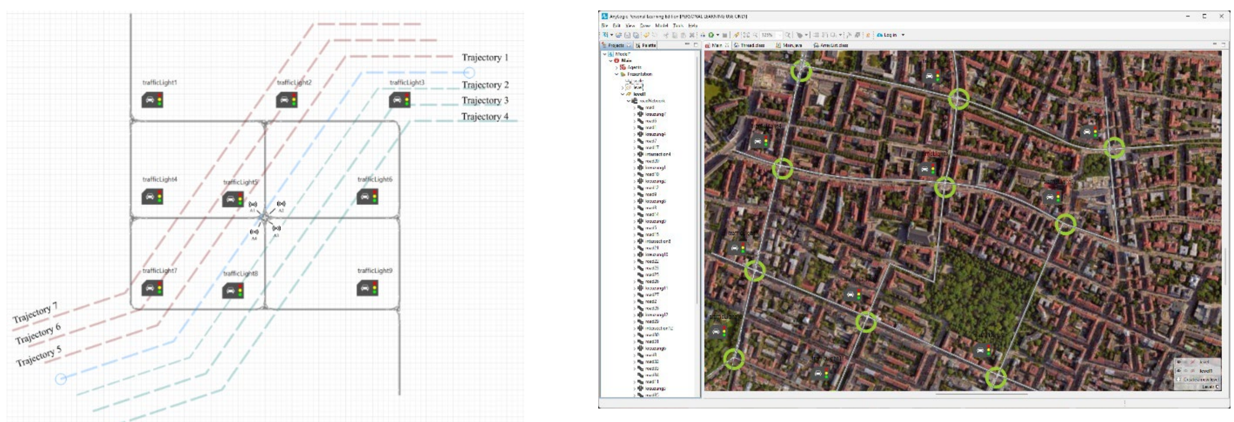

*Figure 1: (**left**) Simplified road network with alternative flight trajectories. (**right**): Case study Munich*

It is to be expected that with increasing air traffic, the negative impact on road traffic will increase and the associated delays will rise. It is important to note that the selected intersections are only blocked for a short time during individual flight segments and are released immediately after a successful flyby. Flight segments are determined and assigned to intersections by continuously monitoring and optimizing the traffic situation both on the ground and in the air. Nevertheless, it is important to achieve a balance between the necessary safety requirements for air traffic and the efficient management of ground.

We have already observed various impacts on ground traffic within the simplified road network and subsequently optimized the selection of traffic lights and their control times. In the next step, we will delve into a case study focusing on the Munich urban area (Fig. 1, right) to explore more realistic effects on the transportation system.

References

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