

AI-Based Adaptive Drone Flight Path Optimization in Urban Environments

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Technical progress on the development of suitable air vehicles flying in urban environment is fast and potential applications are manifold. Though the acceptance of such systems could be a major obstacle to its operations. Resistance could come from affected people who do not directly benefit from the application of such systems. Increasing acceptance by minimizing the environmental impact such as pollution and noise as well as reducing risk and improving performance to increase the economic benefit should be a valid approach.

The integration of AI-driven techniques for optimizing drone flight paths in urban environments offers significant benefits, particularly in enhancing performance and minimizing environmental impact. This is especially relevant for applications such as delivery and security operations, where safety and public acceptance are critical and urban air systems are a game changer providing the biggest advantage as compared to existing transport systems.

The models considered in the study can take dynamically into account for urban environment regulations from authorities, traffic situation, temporary inaccessible areas, critical infrastructure, the noise situation and other parameters.

In this study, we present two complementary optimization approaches. The first employs regression trees to quantitatively assess and compare segmented flight paths, enabling data-driven route selection. The second approach utilizes artificial potential fields to define a parameterized flight space based on mission objectives and operator preferences, allowing for gradient-based path optimization.

These methods support dynamic adaptation by enabling the tuning of parameters such as time-to-target, energy consumption, noise emission, avoidance of sensitive zones (e.g., hospitals, power plants, military areas) and reducing risk based on flight physics parameters. Crucially, the framework supports both offline mission planning and real-time adjustments, ensuring robust operations in rapidly changing environments.

The decision tree method uses the assumption that the drone follows predefined flight path sections which all have their known beneficial and detrimental parameter values characterizing their section. The optimized flight path is found by integrating over the different sections from start to target and identifying the one with minimum impact. Impact criteria can be prescribed by the user and can be obtained – time dependent – from digital databases.

The artificial potential method calculates a multidimensional grid of values for each point in the urban space based on the user provided criteria – similar as the decision tree model. Here at every point of the potential flight path the next point along the path is determined by a local gradient search. No predefined path sections exist in this case. Based on the drone type the urban environment and the weather conditions flight physics parameters can be included in both methods for the path generation, the lift off and the landing situation. This is especially useful for emergency scenarios, where rapidly changing and crucial conditions can endanger the system.

Using a case study centered around a hospital in Munich, we demonstrate how optimized noise corridors can be identified—either adaptively for individual missions or as standardized offline routing parameters.

Our results highlight the potential of AI-based path planning to improve the efficiency, safety, and societal integration of urban drone operations.

Biography

Michael Gruenewald



Dr. Michael Gruenewald, a physicist from the University of Karlsruhe and UCLA, has extensive experience in aerospace and technology management. He led simulation and method development at Daimler and Airbus. As a VP at Airbus, he significantly impacted the company's research strategy. He co-founded SRITec and also lectures at Munich's Technical University.