Towards Reliable Autonomous UAS Landings in Complex Environments

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Innovative Air Mobility (IAM) is expected to enable the autonomous transportation of cargo like medical supplies, urgent parcels or spare parts. Possible destinations include offshore wind parks, ships, harbors, hospitals, or general urban hubs for transportation. However, the realization of this vision depends heavily on the ability of Unmanned Aircraft Systems (UAS) to perform safe and reliable autonomous landings. Challenges in autonomous landings include the detection of occupancy at the landing site as well as the precise navigation of the UAS in order to land safely.
These two subproblems of autonomous landings on vertiports are investigated in two distinct areas of application: The project *VERTIFIED* investigates occupancy detection for landing at vertiports in complex, safety-critical environments such as urban city environments or airports based on information provided by the UAS, vertiport and U-Space Service Provider (USSP). Previous and ongoing projects, such as *Upcoming Drone Windfarms* (UDW) and *Optical Communication and Guidance for Maintenance & Cargo Drones at Offshore Wind Farms*, highlight the challenges of precise relative navigation when landing on ship decks or approaching wind turbines, specifically addressing harsh offshore environmental conditions such as adverse weather.

Vertiports are defined as "area[s] [...] used or intended to be used for the landing and take-off of VTOL-capable aircraft" [p. 6, 1]. An exemplary visualization can be seen in figure 1.

Figure 1:UAV on a vertiport in a simulated urban environment

Depending on their operational environment and use case, they imply different challenges for autonomous landings. Urban vertiports may be occupied by pedestrians, UAVs, vehicles, or unexpected obstacle. The challenge lies in reliably detecting and classifying obstacles on the vertiport under a wide range of environmental conditions, in order to determine the occupancy status of the landing location. These are used as basis for

decisions such as continuing the landing approach or diverting to an alternative vertiport. In addition, communication with the vertiport infrastructure, other airspace users, and the USSP is essential to avoid safety risks in operation like other airspace users occupying the vertiport and also to communicate safety-critical decisions.
The objective is to enable a safe autonomous landing by continuously assessing the occupancy and availability status of a vertiport and making decisions based on sensor data fusion based on the UAS and vertiport. Both cooperative conditions, where communication with the vertiport infrastructure is available, and non-cooperative conditions, where such communication is unavailable or degraded, are investigated. Since safe operations must also be enabled in non-cooperative conditions, detection of occupancy needs to be based on onboard perception capabilities.
Our research uses deep learning-based perception algorithms to classify objects within the vertiport area, distinguishing between humans and other relevant object categories to support occupancy assessment. Furthermore, we assess the risk of UAS operation at vertiports by analyzing how combined design and integration of onboard and ground-based sensing systems can enable safe autonomous landing.

Compared to landings at urban vertiports, ship-based platforms move continuously. The main challenges of a ship deck landing are twofold: first, reliably identifying the landing pad under diverse environmental conditions; and second, computing a relative position to the landing site with centimeter-level precision in real time. This precision is critical due to limited space and relies on minimal ground-based infrastructure. Our work focuses on identifying a suitable sensor suite for landing site detection (Fig. 2) and precise, GNSS-denied relative positioning, specifically utilizing camera-based sensors and computer vision algorithms.

Figure 2: (Left) UAV approaching the DLR ship deck demonstrator. (Right) Example output from the onboard camera-based landing pad detection system

For both, occupancy sensing and relative positioning, we use the same camera-based onboard sensor suite. This system is designed as a modular payload that can be integrated into various UAS platforms. The suite consists of an RGB camera, a thermal camera, and a laser rangefinder. While RGB imaging provides detailed visual information

in favorable conditions, thermal imaging maintains detection capability in low-light, foggy, or otherwise degraded visibility scenarios where RGB perception becomes unreliable. These sensors are networked with a 5G modem and connected to an NVIDIA Jetson, which serves as the main compute platform. This setup offers high flexibility, enabling adaptation for both vertiport occupancy sensing and ship deck landing pad detection.

Upcoming activities include the assembly, setup and integration of the hardware into our UAS platforms. In addition, simulation-based testing helps evaluate the perception algorithms under challenging conditions, such as adverse weather. This addresses the gap in required test data for complex environments like offshore wind parks. The results are intended to provide a practical framework for safe autonomous vertiport landings in future vertiport operations and work towards reliable operations in adverse weather conditions.

[1] EASA, Special Condition for small-category VTOL-capable aircraft – Issue 2, EASA (2024), https://www.easa.europa.eu/en/document-library/product-certification-consultations/special-condition-vtol

Biography

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Sandra Kleinheinz is working for the DLR Institute of Flight Systems, Department of Unmanned Aircraft, Group Unmanned Air Transport. Her background is in safety assessment and certification of UAS and she currently works on the safe operation of UAS within vertiport environments.

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Rebecca Schmidt received her M.Sc. in Electrical Engineering with a focus on Automation Systems from Chemnitz University of Technology in 2023. After that, she joined the German Aerospace Center (DLR), Institute of Flight Systems, as a Research Scientist, where she focuses on developing camera-based perception systems for the automated operation of unmanned aerial vehicles in adverse weather conditions.