Integrating Extended Reality in Air Traffic Control: innovative interfaces for drone monitoring at airports

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As unmanned aerial systems (UASs) continue undertaking a growing array of activities, the risk of encountering these vehicles is also rising. This poses potential threats to operational safety, including collisions with other aircraft or structures and unauthorised entry into restricted areas like airports. Furthermore, the expanding scope of UAS operations necessitates increased investment and research into monitoring and managing drone activity technologies, including future “air taxis” [1]. A key challenge is the identification of potential hazards posed by drones operating close to sensitive areas. This study focuses on the concern of drones intruding into restricted airport zones, requiring airport safety and security units and control tower operators to monitor and manage such airspace intrusions. In particular, this study endeavours to harness digital innovations to create and validate an XR-based Human Machine Interface tailored for Air Traffic Controllers (ATCOs) tasked with monitoring UAS traffic near airports.

This interface aims to facilitate a more intuitive and efficient interaction within the control tower, enhancing both performance and situational awareness for ATCOs who must navigate the integration of autonomous drones. The interface design draws inspiration from previous research on airport control towers [2-3], incorporating established concepts such as tracking labels, air gestures interaction, visual and aural cues for external elements, and safety net-based alert systems [4].

The presented concept [5] proposes including an on-demand semi-transparent augmented interface that live-streams the area surrounding the UAS ground infrastructure (vertiport) in the aerodrome area. To avoid the constant presence of an additional interface in the control tower, the ATCOs equipped with a see-through head-mounted display can visualise the HMI only when needed. The logic flow of the drone monitoring system is presented in Figure 1.

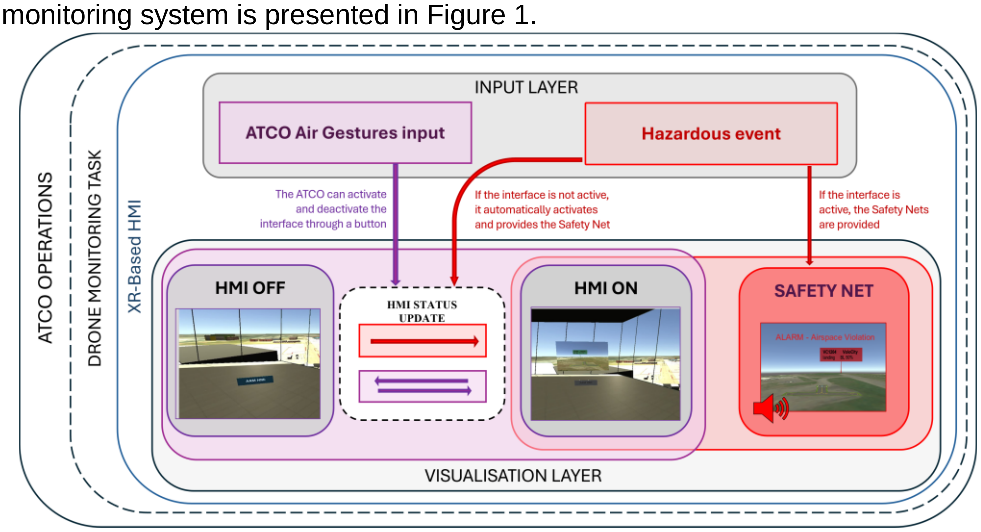

Figure 1: Logic flow of the drone monitoring XR-based HMI. During regular operations, the HMI can be activated and deactivated using air gestures. The closed interface allows for an unobstructed view of the airfield. When the interface is open, it displays drones’ identification and tracking labels, providing real-time information for monitoring UAS traffic. When a hazardous event involving AAM traffic occurs, the safety net system is triggered. If the interface is closed, it automatically opens to ensure immediate situational awareness. The tracking label of the involved drone switches to red, a text clarifies the type of situation, and a directional acoustic cue drives the ATCO’s attention toward the affected area.

A case study was carried out to assess the proposed concept, with the interface developed and integrated into a control tower simulation platform. A human-in-the-loop real time validation exercise was conducted within the simulated environment of Toulouse Airport to validate the developed technical solution and evaluate the human performance of air traffic controllers.
The ATCOs were tasked with integrating drone monitoring duties into their ground control responsibilities, ensuring situational awareness and safe coexistence between conventional air traffic and drone operations. Additionally, they faced unexpected and potentially hazardous events, requiring them to quickly assess and respond to emerging situations to maintain safety and operational efficiency.
The campaign assessed the technical solution: see-through head-mounted smart glasses designed to display the XR-based HMI within the real-world environment. This system provided the controllers with crucial information on drone traffic near the aerodrome, and its performance was evaluated against baseline equipment (Figure 2).

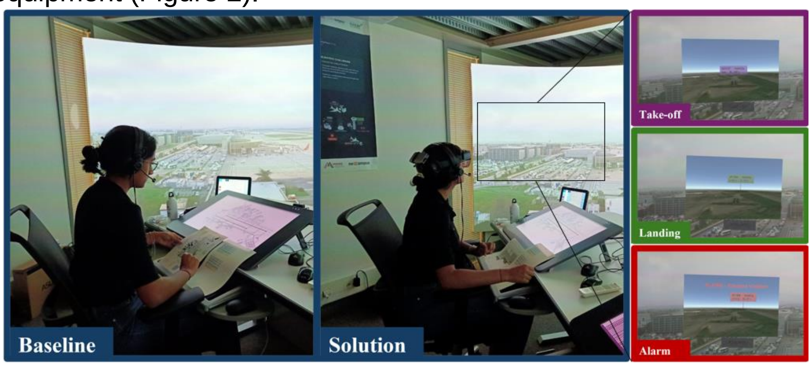

Figure 2: Baseline and Solution scenario equipment. The personal view of the controller in the solution scenario during the take-off and landing of the air taxi, and the emergency (safety net), is depicted in the 3 images on the right.

The validation campaign involved experienced, and student ATCOs and Aviation Engineering students with previous experience in ATC operations simulations. The assessment focused on objective and subjective measures, data were collected through performance metrics, physiological measurements, and questionnaires to assess the workload, and situational awareness of the controllers and the system's usability. The results confirm that the proposed concept is technically and operationally viable, demonstrating its potential to support ATCOs in performing their tasks, reducing the workload while improving performance. The XR-based HMI proved to be an innovative tool, offering ATCOs an intuitive way to monitor UAS traffic, while the interface demonstrated significant potential to enhance safety and efficiency, certain limitations and opportunities for further optimisation have been identified, ensuring continued development towards an efficient and ergonomic ATC support system.
Future work should focus on developing an additional application that would enable a fully integrated air traffic management system capable of handling manned and unmanned traffic cohesively. A first step in this direction has already been taken by developing a proof of concept integrated into a real-time Augmented Reality (AR) interface for tracking airport traffic in the Bologna Airport Control Tower.

Figure 3:Integration of XR-based HMIs in the Bologna Airport scenario: Real-world implementation combining simulated ground infrastructure and unmanned traffic with a real-time AR interface for airport traffic monitoring, as viewed through a Microsoft HoloLens2.

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Biography

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Marzia Corsi is a Researcher in the UAS Department at the DLR Institute of Flight Guidance. With a background in HMI and ATC operations, her current research focuses on the integration of UAS into controlled and uncontrolled airspace. She is investigating concepts and technologies enabling IAM, including air taxis, vertiports, and U-space.