XR-Based Human-Machine Interface for Manned and Unmanned Traffic Control Operations

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 lies in identifying potential hazards posed by nearby drones. 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. Various studies have explored methods for detecting unauthorised UAS activity and assessing the potential benefits of cooperative drone operations in the airport environment [2]. Recognising the need to monitor and regulate UAS traffic, Europe has developed the concept of *U-Space* under its Air Traffic Management research program *SESAR*. U-Space constitutes dedicated airspace for integrating UAS traffic with conventional aircraft, providing essential services for safe operations, and facilitating the identification and tracking of all involved actors. Recent research has led to the publication of the fourth edition of the *U-Space Concept of Operations (ConOps)*, aligning with European regulations [3]. This document outlines requirements for safe drone operations, including identification, tracking, monitoring, geofencing, and segregation. When dealing with Air Traffic Control (ATC) operations, monitoring UAS traffic near airports is expected to add additional workload to the controllers. Supplementary dedicated interfaces intended for UAS traffic information shall be included in airport control towers. To improve ATC operations while reducing controllers' workload, several studies suggest exploiting digital technologies, such as eXtended Reality (XR), to provide users with innovative Human-Machine Interfaces (HMI) presenting surveillance information in a head-up display aligned with the controllers' direct view [4-5]. Leveraging insights from civil aviation traffic management, this work proposes extending XR visualisation techniques to Advanced Air Mobility (AAM) scenarios, drawing upon previous SESAR projects, such as *RETINA - Resilient Synthetic Vision for Advanced Control Tower Air Navigation Service Provision* and *DTT – Digital technologies for tower*. This project aims to develop and validate an innovative, XR-based Human-Machine Interface (HMI) for air traffic control (ATC) that integrates UAS traffic management with traditional Air Traffic Management (ATM). By integrating the latest XR technologies with UAS traffic management systems, this project addresses two critical needs in modern air traffic management: improving situational awareness and reducing ATCO workload. The innovative use of multimodal interaction—combining visual, gesture, and voice-based controls—provides a more intuitive, efficient way for controllers to handle increasingly complex airspace environments. Moreover, the seamless integration of UTM and ATM operations sets the foundation for future air traffic control systems that can adapt to the emerging challenges posed by AAM and autonomous drone operations.

Study Plan

1. Development of a unified HMI that employs XR technologies to display real-time information for manned and unmanned air traffic, tailored to the current operational environment.

2. Test and validation of the proposed solution in simulation environments, focusing on conventional air traffic control scenarios and future AAM operations. A period of activity abroad can be included either to validate the model in a different environment or to implement it with additional technologies employed by the hosting structure.

3. Assessment of the validation results.

4. Reporting activities.

The selected candidate will take part in project meetings and activities and will contribute to the dissemination of results through the submission of journal papers. He or she will also participate in national and international conferences and exhibitions, such as:

- SIDs (SESAR Innovation Days)
- ATM Seminar (Air Traffic Management Seminar)
- ICAS conference (International Council of the Aeronautical Sciences conference)
- AIAA conferences (American Institute of Aeronautics and Astronautics conferences)
- CEAS conference (Council of European Aerospace Societies conference)
- AIDAA conference (Associazione Italiana di Aeronautica e Astronautica conference)

References

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Abstract:

Questo progetto ha l'obiettivo di sviluppare e validare un'interfaccia uomo-macchina, basata sulla realtà estesa (XR), per il controllo del traffico aereo, in grado di integrare la gestione del traffico dei sistemi aerei senza pilota (UAS) con quella tradizionale del traffico aereo (ATM). L'integrazione delle tecnologie più avanzate con i sistemi di gestione del traffico UAS risponde a due esigenze fondamentali della moderna gestione del traffico aereo: il miglioramento della consapevolezza situazionale e la riduzione del carico di lavoro dei controllori di volo. L'approccio innovativo del progetto si fonda sull'uso di interazioni multimodali che combinano controlli visivi, gestuali e vocali, offrendo ai controllori un'esperienza di gestione del traffico aereo più intuitiva, fluida ed efficiente, adatta a spazi aerei sempre più complessi. Grazie all'integrazione armoniosa delle operazioni UTM (Unmanned Traffic Management) con quelle ATM, il progetto getta le basi per lo sviluppo di sistemi futuri di controllo del traffico aereo, capaci di adattarsi alle nuove sfide poste dalla Advanced Air Mobility (AAM) e dalle operazioni autonome dei droni.