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Extended Reality as an enabling technology to Advanced Air Mobility

Project experiences of the Virtual Reality and Simulation Laboratory at the University of Bologna

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Abstract.
In Human-Centred design methodologies the human figure is the key element for the deployment of transversal effective solutions able to meet real world demands. Extended Reality Technologies aid in conveying such design solutions in a immersive and intuitive way. This paper presents an overview of using Extended Reality Technologies in the aerospace field, emphasizing the contributions given from the Virtual Reality and Simulation Laboratory (VLAB), at the University of Bologna. Moreover, it discusses the potential of incorporating immersive media and Human-Centred Design approach for the deployment of groundbreaking transport solutions such as Advanced Air Mobility and Urban Air Mobility.

Key words. Extended Reality (XR) Technologies, Urban Air Mobility (UAM), Advanced Air Mobility (AAM)

1. Introduction

Human-Centered Design methods are known for providing tailored-to-use solutions and products addressing real world concerns. Most methodologies start with understanding the user and the design problem followed by proposing conceptual solutions, prototyping the most accepted ones and collecting users' feedback for an interactive human-centred process.

When delivering solutions, traditional design mock ups tend to be limited, offering mostly two-dimensional visualization of the proposed idea and little to no interaction, making it harder to communicate the desired information. In addition, the long feedback loops inherent in the human-centred approach and manual interaction result in an increase in production time. Digital prototypes, on the other hand, offer significant advantages over physical ones: they allow for faster implementation and interaction, enhanced collaboration and simulation, and are, eventually, more sustainable. One way of proposing digital prototyping is via digital interfaces such as Extended Reality Technologies (XR).

XR is an umbrella term encompassing immersive media such as Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) and are among the fastest growing advanced Human Machine Interfaces (HMIs). With a market that is expected to grow over 30% by 2030 (Future 2024) such cutting-edge technologies are known to enhance design validation, improve communication and collaboration and reduce training costs of systems and products (Santhosh et al. 2022; Bagassi et al. 2020; Pratticò & Lamberti 2021). One of the key attributes of these technologies is not only the ability to blend the real and virtual worlds but also how it conveys and delivers information in a democratic and inclusive way, given that the same application can be experienced by people with different ages and backgrounds in a seamless and intuitive manner.

In a VR application, for instance, the user is completely immersed in a fully virtual environment, with no knowledge of the real world. On the other hand, when experiencing an AR application, the real world is augmented by means of digital content that is over-imposed to the user's environment. In MR contexts interaction is possible between the digital and real worlds.

In the following sections, it is presented how such digital technologies have been employed to enhance the user experience and thus the interaction between humans and machines in the aerospace sector. Moreover, it is explained the benefits of applying Human-Centred design methods for innovative air mobility such as Advanced Air Mobility and Urban Air Mobility.

2. Extended Reality Technologies in aerospace applications

XR-based HMIs are present throughout the entire aircraft life-cycle and aerospace domain as various types of interfaces such as AR, MR and VR have been extensively used. Different scenarios for aerospace applications can be identified and classified as each XR app is designed blending a real world component and a digital world component and experienced by the user according to the extend of the world that is being displayed (Araujo et al. 2024).

AR interfaces for instance, have been employed as effective solutions in the realm of Air Traffic Control aiming at decreasing workload and increasing situational awareness of Air Traffic Controllers during low visibility conditions. Moreover, due to the nature of the information that is provided to Air Traffic Controllers - via screens and out-of-the-tower view- workers are constantly switching their view from head-up position to head-down position, increasing workload. Thus, a synthetic view by means of an AR application implemented the possibility of conveying all necessary information to the controllers' head-up view through digital overlays superimposed over the out-of-the-tower view and correctly registered to the real environment. Such solution can effectively decrease controllers workload and increase their situational awareness and safety, leading to overcome most current limitations affecting low visibility procedures. Fig 1 shows and illustration of VR tests conducted aiming at testing such AR application in the context of Air Traffic Control. Therefore, it was proven that Augmented Reality can improve the resilience of airports (Bagassi et al. 2018).

Stakeholders such as airspace manufacturers and airlines can also enjoy typical benefits of XR interfaces such as immersiveness and interaction with digital mock-ups, as it is illustrated in Fig. 2. Aircraft manufacturers,in fact, are pushed to continuously improve their level of cabin comfort and noise levels in order to remain competitive in the global market. To that aim, a multi-sensory virtual cabin environment in order to "auralize" aircraft cabin noise levels has been proposed to develop a tool to evaluate passenger comfort and well-being before real prototypes are manufactured (Santhosh et al. (2023)). For the auralization process,acoustic pressure-based numerical results were imported to the virtual model increasing the sense of realism to the user.

Fig. 1. Virtual Reality simulation of Airport Control Tower operations in the realm of RETINA Project conducted in the premises of the University of Bologna, Forlì campus. A digital model of Bologna's airport is displayed on the CAVE (Cave Automatic Virtual Environment) for an immersive simulation for the Air Traffic Operator. Courtesy: Virtual Reality and Simulation Laboratory (VLAB).

Fig. 2. User interacting with an airplane overhead bin in a virtual environment, simulation conducted in the framework of CASTLE Project. The user is immersed in a digital model of an airplane and its experience is being displayed on the CAVE (Cave Automatic Virtual Environment). Courtesy: Virtual Reality and Simulation Laboratory (VLAB).

3. User-Centred Design for Advanced Air Mobility and Urban Air Mobility

As society transitions to a more sustainable and human-centred industrial approach anchored on the realm of 5.0 industry and fostered by climate neutral and sustainable mobility policies proposed by the European Union, the aviation sector is moving towards zero emissions and carbon neutral systems (Commission & for Climate Action (2019)). In this framework, Advanced Air Mobility (AAM) has risen as an alternative and more sustainable transport modality. According to the definition proposed by Ente Nazionale Aviazione Civile,

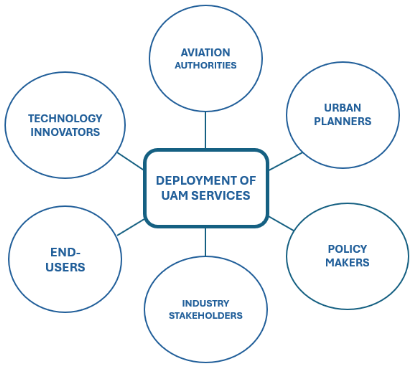

Fig. 3. Urban Air Mobility Stakeholders.

AAM refers to the set of innovative transport services carried out in an intermodal perspective with electrically-powered aircraft systems mainly with vertical take-off and landing (VTOL), with or without an onboard pilot (UAS-Unmanned Aerial System, including so-called drones) or autonomous - together with the related infrastructures - capable of improving the accessibility and mobility of cities, metropolitan areas and territories, the quality of the environment, life and safety of citizens (ENAC (2021)). Such transport operations when conducted inside urban environments are called Urban Air Mobility (UAM). There are various expected VTOL operations and among them are logistics in first and last-mile delivery of parcels, passenger transport services such as air taxi, medical transport and delivery, rescue and surveillance operations. However, since these innovative systems are not yet operative as a service, to successfully integrate the state-of-the-art of UAM systems some challenges and requirements still need to be addressed. Hence, a collaborative approach between policy makers, urban planners, technological innovations, industry stakeholders and citizens is fundamental to the deployment of UAM (see Fig. 3).

Cutting-edge technologies such as XR Technologies are of key importance in view of their benefits of seamlessly communicating information in an immersive and interactive manner. In this context, an XR multi sensory simulator for UAM applications is a powerful

Fig. 4. Virtual Reality renderization of an Urban Air Mobility mission virtually conducted in the premises of the University of Bologna, Forlì campus. Courtesy: Virtual Reality and Simulation Laboratory (VLAB).

tool as it allow us to envision and explore how Urban Air Mobility as a service will be even if it is currently at a preliminary design stages, as an example shown in Fig. 4. Such simulator has two fundamental roles: first is to provide a realistic, collaborative and interactive user experience to demonstrate how future urban contexts will look like once UAM services are deployed and second to be part of UAM systems itself. Within this framework, initial steps of such XR simulation platform have been addressed aiming at the virtualization of a drone mission: a drone operation that was scheduled to happen in an urban context but due to current airspace regulations was conducted in airspace different than the initially planned, is now being realized by means of a VR application. A digital twin of the urban area was proposed containing a virtual prototype of the urban environment and the drone trajectory was implemented following the original telemetry data. Such digital twin model used in the simulation is illustrated in Fig. 5. Such application provides comprehensive tools to explore UAM operations and assess different spheres of public engagement and risk assessment of concept of operations.

Moreover, an XR-based platform enables innovative human-machine interfaces for integrating Urban Air Mobility operations and systems into current airspace. AR applications have been investigated for enhanced monitoring and control of UAS traffic in the context

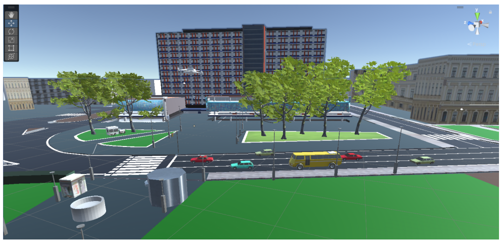

Fig. 5. Three-dimensional model of urban environment implemented in the XR-based simulation platform for Urban Air Mobility applications. Courtesy: Virtual Reality and Simulation Laboratory (VLAB).

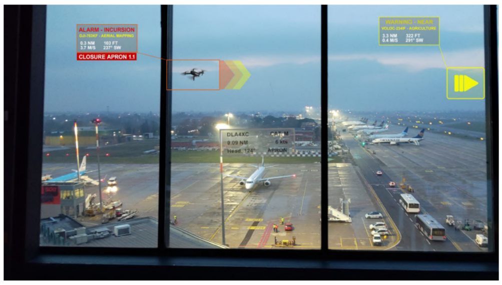

Fig. 6. Proposed Augmented Reality interface design in the case of an airport scenario, reproducing a user view of an airport control tower and highliting the additional information provided by the AR interface with respect to UAM traffic. (Bagassi et al. (2024))

of airport tower control and remote piloting,as depicted in Fig. 6. Such proposed AR interface displays important information to controllers with respect to UAM flight in order to improve their overall situational awareness. Preliminary assessments with simulated unmanned traffic has shown improvements in overall operator efficiency and situational awareness (Bagassi et al. (2024)).

By leveraging the advantages of Extended-Reality-based Human Machine Interfaces we can better exploit and enhance user acceptance and proof of operations of Advanced Air Mobility and Urban Air Mobility services.

4. Conclusions

Extended Reality interfaces as present throughout the entire life cycle of aviation industry, ranging from interfaces to support operators' performance to the design phases. The current state of the art of research in aerospace applications aims at providing sustainable and innovative transport solutions, such as Advanced Air Mobility and Urban Air Mobility. In this framework, an XR-based simulation platform stands out as enabling instrument to Advanced Air Mobility as it provides comprehensive tools to either demonstrate what urban air mobility is likely to look like and also to allow operators, citizens, and local decision-makers to familiarize themselves with what these concepts look and feel like and test the concept of operations.

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