Extended Reality possibilities in Air Traffic Management

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***Abstract*— In response to the current challenges of aviation we decided to develop an Air traffic controller decision support system with extended reality presentation at the prototype level for demonstration purposes. We would like to show in our paper the initialization phase of this research. We tested several types of extended reality hardware and software, and found that they could not completely support our research, so we decided to develop a custom software to meet our needs. We created the conceptional diagram of the planned system, and the base for airspace visualization.**

Keywords—virtual reality, augmented reality, mixed reality, air traffic control, air traffic management

I. Introduction

The number of devices participating in air traffic has started to rise dramatically in the recent period and continues to do so at an unbroken pace [1], which poses a challenge to specialists dealing in air traffic management (ATM). In order to obtain a more accurate situational awareness, it may be useful to develop 3D aerial views, which can contribute to the maintenance of safe air traffic. One of the highlighted hypothesis of our research group is that aerial situational images displayed in 3D (aircraft positions, radar images, meteorological data, airspaces, etc.) can help to enhance situational awareness in some cases more effectively than the current 2D visualization. In addition, one of the most dynamically developing areas today is the display of different spatial shapes and events in Extended Realities (xR), such as Virtual Reality (VR), Augmented Reality (AR), or even Mixed Reality (MR). Displaying 3D aerial images on such Extended Reality devices have a potential to offer a new perspective in the field of ATM.

During university education, wich takes place in Department of Air Traffic Control and Aviation [1] we experienced that the concept of different air situations, such as the relative positions of airspaces and aircraft requires serious spatial vision, something various xR technologies can help with. As mentioned in the introduction, the expansion of the aviation sector requires a larger workforce. The labor shortage in air traffic control has already caused serious disruptions [2]. Adressing these needs, the recruitment of new careers, especially young people play a major role. At the same time, the issue of broadening the layer suitable for the performance of tasks is also repeatedly raised. As a result of this, our further highlighted hypothesis is that the use of Extended Reality can facilitate the work of air defense controllers and, more broadly, the work of ATM specialists, possibly certain spatial vision competencies may be omitted in the future or become less important [3].

As members of the Virtual Airport (VR_AD) research group of the Integrated-model airfield Priority Research Area we set out to investigate and demonstrate how different Extended Reality technologies could be implemented in the air traffic management. The Priority Research Area aims to examine how drones can be integrated into airport traffic. An integral part of this initiative is the development of advanced air situation awareness [4] [5].

II. Technical possibilities in the field of xR

In the first step of our research work, we started a thorough market and literature research concerning the area, and we consulted with many specialists. In previous years, the market for various xR technologies began to develop dramatically,

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[1] Ludovika University of Public Service, Faculty of Military Science and Officer Training

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and many forward-looking display devices were launched. As a result of consultations with specialists (various xR developers, IT specialists, and product representatives), delivered extremely diverse results. On the basis of the results we were unable to determine which tool would be optimal for us. Therefore, in this phase, in order to gain empirical experience, the members of our research group tested quite a few xR displays. Such is Microsoft HoloLens2, which is suitable for MR/AR display with holographic technology [6]. Thanks to its independent power supply and the WI-FI wireless communication connection, the user can operate with a high degree of freedom. Gesture- and voice control are another key advantage of the HoloLens2 hence the operator does not rely on any hand-held controllers. This removes one source of malfunction, decreases the operator's physical fatigue. Latter one is critical when it comes to Air Traffic Controllers. Numerous studies have been conducted on this topic, but they are out of the scope of this study [7] [8].

In terms of VR, the HTC Vive [9] and Oculus [10] glasses are widespread. Thanks to its internal storage space, operating system, battery, and Wi-Fi connection, the Oculus Quest 2 VR glasses of the facebook – Meta group are also capable of independent display, which provides a high degree of freedom to the user. At the same time, when connected with a USB cable, it is possible to run programs with a higher computing power using a more powerful computer. The previously mentioned HTC Vive Pro 2 typically requires a wired communication interface. Here, mobility is typically solved with a back mounted computer [11], but at the same time, the list of related additional devices varies widely. During our research period, new HTC devices were released that are lightweight and combine the power and flexibility of a powerful desktop workstation with the freedom offered by their wireless streaming technology. We have not yet had the opportunity to test these and include them in our research, but their advantages make them an optimal choice [12].

In addition to these VR displays, it is also worth mentioning the XTAL-3 glasses from vrgineers [13] and the Varjo glasses [14], which are clearly premium category devices. We also had the opportunity to try the vrgineers portable trainer, on which an F-16 simulator was running [15].

We tested these devices and assessed which one might be the best for us. In the selection, we considered the following aspects: The situation of background support for the devices (available content, development background), display quality, practical and market experience, price/value ratio, and our financial possibilities. Based on this, in terms of VR displays, Oculus is cheaper, widely distributed, and user feedbacks are positive. Regarding the AR/MR display, we decided on the Microsoft HoloLens 2, also because of the positive industrial examples [16] and background support. During the tests, nausea and negative experiences were not typical, with the exception of: images in VR in a static position that cause a sense of movement, i.e. the user was positioned statically (e.g. sitting in a chair), and then the VR glasses played high-motion content (e.g. maneuvers while sitting in a fighter jet). At that time, a dissonance occurred between the seen image and the sensations of the motion receptors, which was accompanied by mild nausea. In fact, a natural reaction appears in this case, as the body detects symptoms of poisoning, as a result of which it wants to empty the contents of the stomach. Three colleagues specifically exposed themselves to this kind of load for experimental purposes in order to push their limits, and in them, more intense sweating was observed with a minimal constant feeling of nausea. In addition, in some immersive situations, spatial conditions (e.g. videos taken from a height) appeared, which aware a natural reaction on the part of the experimental users. Based on the empirical experience, it can be said that our experiences are much more positive than we assumed in advance during the literature research [17] [18]. Several articles [19] [20] discuss the unpleasant sensations caused by xR, which only appeared during our tests in the case of the logical triggers detailed above. For the purposes of this research, it is important to note that the above simulator sickness occurs when the user's visual field (virtual avatar) is moved by the computer. In a stationary situation, where the movement of the visual field is controlled only by the user's natural input (e.g. head movement) and the frame rate of the software is high enough, the incidence of symptoms is almost zero.

III. Software tests

In parallel with testing the xR displays, we also tested the various xR software. We set ourselves the goal of getting to know the possibilities offered by Extended Realities, which we did, and we were able to try out as many different applications as possible. The widely known flight simulators now mostly have a VR/MR module [21], and positive examples can also be observed during the simulator training of ground handling staff or flight attendants [22] [23]. In addition, as a next step, we searched for suitable xR software to verify our research hypotheses.

The Clarity solution of the 360 world company [24], which runs on HoloLens 2 glasses in augmented reality, can be mentioned as a positive example of supporting tower work of the air traffic controllers. The indisputable advantage of the application is the AR aircraft tagging function, during which the air traffic controller can see the device's data (e.g. call sign) on a small label next to the aircraft he sees in reality, thus facilitating the visual identification of the aircraft and the situational awareness. Based on the practical training at our department, as well as the experience of airport air traffic controllers, it can be said that it is quite a serious challenge to mentally track the position of aircraft in the air and develop their own situational awareness. Visual identification of devices of a similar type and same paint (especially in the case of military crafts) is difficult, and in the case of serious traffic, managers often have to rely on their notes. This results in them spending a significant amount of time studying the information on the desks/monitors. With the help of augmented reality-based aircraft tagging, this burden can be reduced. The experience of Hungarocontrol Remote Tower [25] confirms this with this. During a site visit, the local specialist said that during their work, they noticed that the controllers look at the projection wall more often, thanks to the labeling of the devices.

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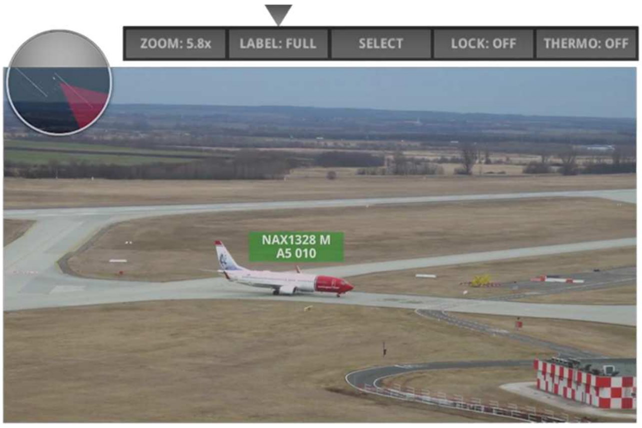

Fig. 1 Augmented reality label in 360 world's Clarity on HoloLens 2 (url: https://360.world/clairity/ downloaded: 16.08.2023.)

The V-Air Traffic Control for Meta Quest simulator [26] is an exciting attempt, where we can experience the work of ATC in virtual reality. This application has more of a perspective in the training of ATC professionals.

Another forward-looking example is the HoloATC mixed reality application for HoloLens 2 glasses, where the traffic of Amsterdam and Atlanta airports can be seen [27]. In its current version one can visualize the 50km terminal airspace of aforementioned airports, having basic flight data by the aerial targets. air traffic controller officers are free to walk within their sector, eliminating the need of mentally visualizing vertical separation. Taking this further, Air Traffic Blitz VR [28] undertakes to simulate approach procedures. Based on our practical experience, it can be said that it was a bit difficult to handle, however, it directed our attention to the importance of creating a Human - VR interface (This is a type of human – machine interface, where is highlighted human – VR content interaction. Based on our practical tests, we determined that these software cannot support our research to 100%, so we decided to develop a unique software designed to serve our own needs.

IV. PRE LIND-A PHASE

LIND-A[2] is an acronym in Hungarian, that means Air traffic controller decision support system with extended reality presentation. The head goal of the planned system is to be able to display 3D airspaces and air situation information in an extended reality at the level of a prototype for demonstration purposes and open up the possibility to later developments such as risk analysis and warning. LIND-A will be a modular framework system - able to integrate services and software/components into its LIND-A API[3], as a single service delivery point. The main module collects, cleanses, integrates and validates data from multiple sources, archives it and sends it to the LIND-A API. The system should be scalable in multiple directions, for example in terms of the number of data sources or the number of aircraft and ground vehicles handled. We started the development using agile methods to make it easy to expand and use in our research as soon as possible. Besides the planned LIND-A API, the most important thing is that we plan to have different display modes, which can be xR or flat 3D, or any other solution that can consume the output of the API. We can take the project further, since due to the modular design, additional projects can be plugged in. We defined, that LIND-A should provide the following planned layers and operation modes. Such as

- Creating an aerial view,
- 3D display of planned airspaces
- Display flight plans and reporting points
- Display of meteorological information
- Display of current air situation
- Airport and approach control module
    - VR/MR module
    - AR airborne equipment tagging
- Area air traffic control module
- Simulations, Incident investigations
- Airport risk analysis, Air protection planning module
- Demo (Recruiting) module

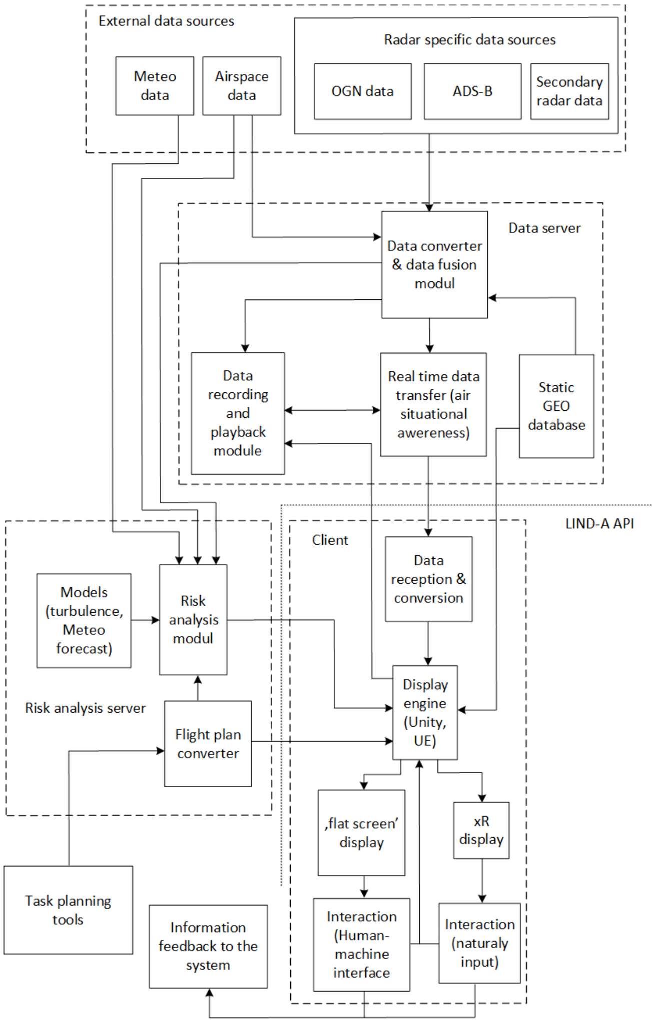

Fig. 2. Conceptional diagram of the planned air traffic controller decision support system with extended reality presentation

As you can see on the second figure, we want to aggregate many radar specific sources to LIND-A, such as secondary

[2] **L**égiforgalmi **Irá**nyítási **D**öntéstámogató Keretrendszer (**A**lternatív valóság megjelenítéssel)

[3] Application Programming Interface

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radar data, ADS-B[4] data, OGN[5] data. Furthermore it will be displayed the airspaces from AIP[6] and other official sources, like daily NOTAMs[7]. You can find on the third figure the VR display of LHRA1 airspace via Infinit Simulation's display method. We created this sample, in order to demonstrate the benefits of this visualization method.

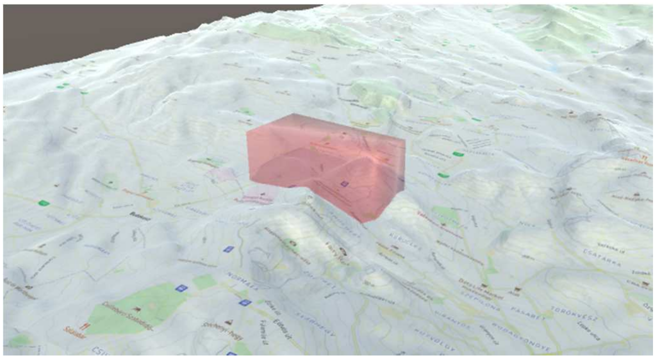

Fig. 3. LHRA1 airscpace VR display via Infinit Simulation's display method (Tamás MARLOK)

Moreover we would like to display meteorological data, such as clouds and thunderstorm activities. The static geographic database covers the areas that must be modeled in advance, topography, artefacts, texture. The display client's working and visualization area is quasi-static so it should be configured on the client in advance, which configuration provides areal filtering information for data converter and fusion module. The output of the conversion and data fusion module is the generation of refined data synthesized from several data sources in a quality and accuracy suitable for display (filters out bad data), so this areal filtering method makes more efficient use of computing capacity. As we recognized, later on in the display client, both Unity and Unreal Engine need some kind of intermediate server application to be able to perform immediate, low-latency, error-free data display from an external source, like the LIND-A API. These software engines are developed and focused for 3D visualization, so inside these the implementation of high-speed data flow and error handling could be difficult. We plan to solve this in a more suitable (programming) environment, leaving as few tasks as possible to the 3D system. Here we consider WebSocket, REST API and message queue data transfer alternatives, but for now we will stick to testing the REST API solution in the hope of a satisfactory result. In the first phase of research we tested the commercial REST API services and established these are not fast and reliable enough here, such as open-sky or ADS-B Exchange [29]. In LIND-A all the incoming data will be recorded per channel and synthesized, and recorded again before sent out to the display client. The user interactions received in the display engine are also captured on a separate channel and stored. The planned risk analysis module which is subject of our later research can apply its ruleset on live and recorded data which will enable our research to apply artifical intelligence models. For this the inputs and outputs of the risk analysis module will also be recorded as a separate channel. Based on the recorded data – which can be considered as big data - a real execution can be replayed for operator evaluation, and the same aerial situation can be loaded again (only for display).

In summary our LIND-A solution collects the ATM relevant data from multiple sources and provides a common API that generates comprehensive, filtered data for any client software for visualization. In our research we have developed and used both a flatscreen client and an xR headset client that have a common codebase, but separated executables due to the different device and interaction options. Both clients are configurable in many ways as discussed earlier in this paper.

Regarding the infrastructure, during the system planning we established the necessity of a high speed and wide bandwidth with minimal delay connection between the servers and clients. This can be ensured within a campus area network via optical fibers and Wi-FI 6 based network solutions, in off-campus areas with 5G/4G mobile communication networks [30] [31].

V. Results of the Pre-LIND-A phase

We have familiarized ourselves with different xR devices, and relevant software for our research. We have mastered the use of xR devices. We designed a backbone of an Air traffic controller decision support system with extended reality presentation. We have experimented with 3D visualization of air traffic using commercial APIs and virtual reality display techniques for airspace visualization. We demonstrate it with LHRA1 airspace and we recognized that, via the LIND-A API any kind of volumetric object can be represented such as meteorological phenomenon or tracks of the aircrafts.

We have tested our partial solution in the LHBP area due to the denser air traffic and airspaces, but this visualization can be configured for any airport or airbase.

For a video demonstration about the results of the Pre LIND-A phase please find the following link: https://youtu.be/VicFfBJGy3o

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