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Innovative ideas for the use of augmented reality devices in aerodrome control towers

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Abstract. In recent years Augmented Reality (AR) has become one of the major focus points of user interface development. With the rapidly increasing computing power and developments in software and hardware applications during the last two decades, it has moved from theoretical approaches towards industry-wide application and mass production. The Royal Netherlands Aerospace Centre, NLR, tested several devices in the past, but only recent developments made it possible to effectively use them in an Air Traffic Control (ATC) working environment for Aerodrome Control Towers. In 2021 NLR carried out innovative technology experiments on their high-fidelity real-time air traffic control simulation and validation platform, NARSIM. These experiments were part of the SESAR 2020 project Digital Technologies for Tower (DTT) and focused on advanced HMI interaction modes for aerodrome tower controllers. A proposed Attention Capturing and Guidance concept with an AR device was evaluated inside an aerodrome control tower environment for Amsterdam Airport Schiphol. This paper reflects on the technology development activities that took place at NLR during the last decade and describes the different steps taken to apply the technology in a conventional control tower environment. It is shown that the recent technology developments must be seen as a big step forward in practical application of AR devices for ATC. Furthermore, an outlook into the expected future use of AR devices in conventional control tower environments will be given that goes beyond abovementioned concept elements. This outlook considers additional developments for standardization of digitized airport information and communication between different stakeholders and general performance improvements for AR devices.

Introduction

The technology used for AR combines virtual objects or information generated by a computer with the real world. These computer-generated overlays enhance user perception of the physical environment and, with added sensory input technology, lead to an interactive and immersive user experience. The history of AR devices already dates back several decades, with the technology evolving and advancing over time in the areas of power supplies, display and sound elements, and gyros for orientation. Through this, a major step from a simple display of data towards the inclusion of 3D-images in the real-world view could be achieved [1].

Royal NLR has been actively exploring applications for the use of HMD devices in the aerodrome tower ATC environment for over a decade. Initial research began in 2010 when NLR tested the nVisor ST™ HMD from NVIS in the NARSIM Tower environment, the in-house developed platform for highly realistic real-time simulations of ATC tower operations. The HMD device served as a demonstrator, displaying basic flight strip information that could either be static or change depending on the controller's line of sight.

In 2016, NLR integrated a Google Glass™ device (now known as Glass™) into the NARSIM environment to showcase additional capabilities with improved comfort to a selected group of air

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traffic controllers from ATC The Netherlands (LVNL). The device streamed video feeds from remote cameras. These feeds were then displayed on Google Glass and switched automatically based on the user's direction of view, which was continuously tracked. This demonstration aimed to illustrate how tower controllers could gain visibility into apron areas by looking beyond physical obstructions in the line of sight, such as buildings.

In late 2019, with the arrival of the Microsoft HoloLens 2™ in the AR device market, NLR acquired two of these units. Although NLR had previously used HoloLens devices between 2016 and 2019 for various purposes like aircraft maintenance training, simulation debriefings, and projecting simulation results onto aircraft components, the potential of AR devices in the context of air traffic management and control had not yet been explored [2].

Evaluation of an AR Device for Attention Capturing and Guidance

With abovementioned development steps in mind, NLR continued the goal of investigating the possibilities of AR devices for enhancing the effectiveness and efficiency of tower ATC operations. In 2020 NLR joined a consortium for carrying out a project that focused on advanced HMI interaction modes for aerodrome tower controllers. That project was part of SESAR 2020, the second Single European Sky Advanced Research Programme, and was called Digital Technologies for Tower, DTT [3].

While the display of weather-adaptive static information (buildings and outlines) and flight phase-adaptive traffic labels as well as air gestures to interact with the labels and the system was carried out by other partners of the consortium, NLR focused this activity on the evaluation of an Attention Capturing & Guidance (AC&G) concept [4].

The AC&G concept was demonstrated in 2021 based on visual and auditory cues displayed in the AR device to alert and guide controllers in case of critical events. In order to find relevant events that would trigger that process, two existing Schiphol runway controller alerting systems were considered, the Runway Incursion Alerting System (RIAS) and the Go-around Detection System (GARDS). Both systems were previously prototyped on NARSIM and thus available in the simulation environment.

Different cues for each type of event were designed within the HoloLens application with different types of symbols for information display and user guidance. Various shapes and colours were tested, but also different information content. Aircraft labels available from the NARSIM A-SMGCS servers were also visualized inside the HoloLens and were used as attention getters and guidance elements, increasing the SA of the tower controller.

The test programme consisted of different events and combinations of events that happened while two experienced tower controllers carried out routine work in the NARSIM environment for Schiphol airport. Pseudo-pilots were in control of aircraft movements and communicated with the tower controllers. Similar traffic scenarios were used to compare working with and without the HoloLens. Results were gathered in different ways, using questionnaires after each test run and performing debriefings and interviews [5].

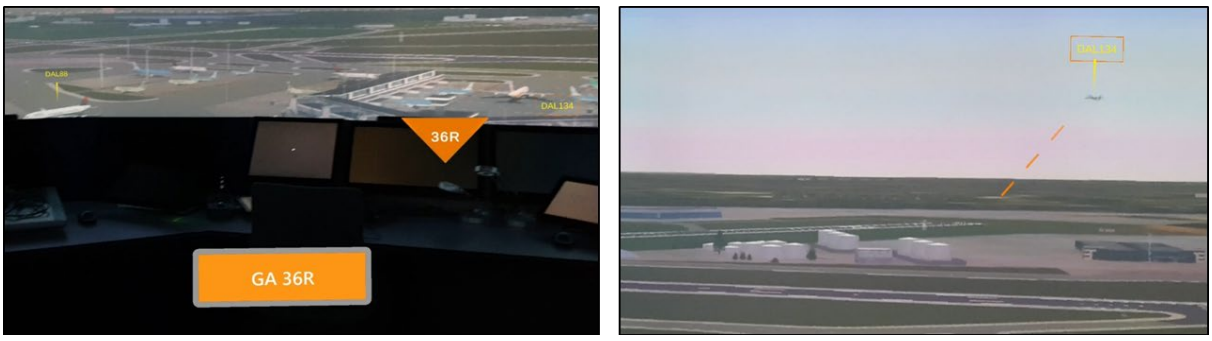

Fig. 1: Go-around Detection Alert as Seen through the AR Device

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Based on the described evaluation experiment, it was determined that the AC&G operational concept for aerodrome tower controllers using an AR device is feasible and has potential. Although the experiment had a limited operational scope, and feedback was provided for improving certain aspects of the concept, the general outcome was positive. The feedback primarily focused on enhancing the symbology and timing of attention guidance cues. Overall, this result provided us with a solid foundation to further advance and refine the concept moving forward.

Additional Ideas about the Future Use of AR Devices in the Aerodrome Tower

Through discussions with the simulation participants, additional ideas emerged regarding potential future development steps and a vision for tower controller work with AR devices was developed. In the conventional context of improving existing visual operations within tower buildings, the inclusion of AR technology holds significant promise. AR presents the opportunity to enhance the outside view for controllers without the need to add further equipment to the working position and without forcing controllers to look down at the working position to acquire vital operational information. The latter means that head-up time is increased.

The augmentation of relevant information in the outside view including integrated 3D aural cues allows for several attention capturing and guidance capabilities that more effectively improve operations than non-AR technology. Intelligent virtual augmentation could include aspects, such as highlighted stop bars and their statuses, enhanced runway- and taxiway edges, indicated cleared routes for taxi operations, building contours and the outlines of other static obstacles or restricted areas. Such augmentation could be adapted automatically to the current visibility condition.

Traffic labels and their appearance and contents could be adapted to visibility conditions, the role of the controller, or the currently known flight status as well [6]. Taking it one step further, it could be investigated whether adaptation of what is shown or highlighted to support a controller could also take place in terms of the amount of traffic controlled or any signs of stress or high workload situations. This would mean that attention guidance would not only occur in case of a safety-relevant event already taking place, as in the case of safety net alerts being triggered, but much earlier in order to prevent such safety-critical situations in the first place.

Other technology additions may be considered as well, such as air gestures or automatic speech recognition. Air gestures generally would help in terms of system interaction, such as pulling up menus to change various settings, or system input operations, such as the selection of a route or a clearance limit as label information. Speech recognition, while generally meant to improve system input by itself, could be used together with AR to also highlight the labels of pilots calling in or, vice versa, callsigns being addressed by the controller, thus increasing SA and reducing workload once again.

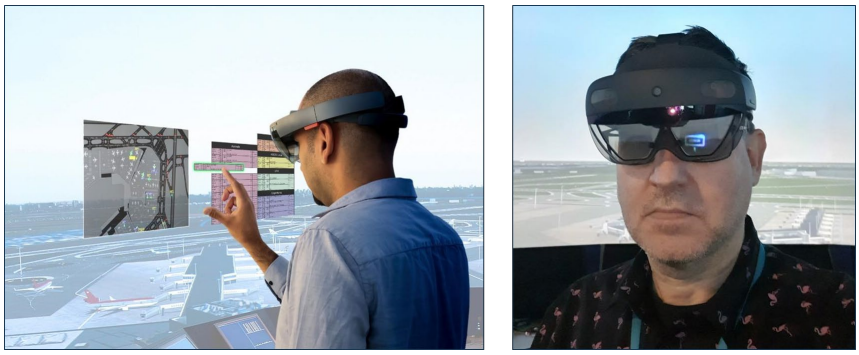

Fig. 2: Innovative Use of AR Devices in the Aerodrome Tower (e.g. EFS, Adaptive Labelling)

Additionally, AR has the potential to redefine the roles and responsibilities of controllers, with the AR system being informed of the sequence of operations and actions required by each individual in the tower and guiding human actions in accordance with the expected procedures.

Naturally, such innovative arrangements would necessitate a high level of automation and a well-defined delegation of authority, particularly during system failures or contingencies. Nonetheless, a potential future milestone could involve a complete redefinition of all existing working arrangements in the pursuit of an optimal operation.

Conclusions

In summary, the potential of using AR devices in the aerodrome tower operational context is very promising but has not fully been investigated yet. Many innovative ideas and functions have not been addressed yet or even been conceived.

For the future, research with an exploratory character should be carried out to show the full potential of the functionalities sketched above, perhaps even from scratch, i.e. without being constrained by current working concepts and organisational structures. The focus of such research should be directed at the main capabilities of AR devices in terms of improvements in safety and operational efficiency, namely to augment controller vision by highlighting operationally relevant elements in an adaptive fashion inserting the most important information directly into the field-of-view. Other functionality exploiting the availability of different sensors (e.g. surveillance and video streams) or adding enhanced prediction capabilities on the basis of Artificial Intelligence [7] could be added to also guide controllers in carrying out operations using different kinds of visual and auditory cues with situation-adaptive information. Last but not least combinations of AR and automated system interaction and input technologies, such as speech recognition with Artificial Intelligence support, should be investigated further [8].

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