From 2D to 3D in ATC? Can operators be trained?

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Abstract

Currently, ATC operators work with 2D representations of the airspace and air-traffic that they monitor and control. This controlled airspace is visualized on computer screens as a 2D map and textual information in the form of labels or pull down menus is available as supporting information. From this the operators have to build and constantly update a 3D model of the airspace in their head, which they use to validate their control decisions. Most of these decisions have to do with resolving location conflicts in time and space. With the predicted increase in air traffic in 2025 not only the workload of the operators will increase, but simple measures such as more operators simultaneously for smaller segments of airspace will not help. Therefore, new methods and techniques are needed to reduce the operator workload and automate more of the traffic control, while maintaining the same strict safety margins. One direction in which a solution could lie, is to use 3D Virtual Environments as the working space for the ATC operator, assuming that what is essentially a 4-dimensional control problem can be more easily and directly visualized and recognized in 3D (or time-enhanced 3D), thus freeing up cognitive processing capacity for the actual solution finding.

Historical perspective and still unanswered questions

The use of 3D techniques have been investigated before in the ATC domain, but not to the extent of actually using a 3D immersive virtual environment, specially constructed for doing controlled usability experiments and measuring operator performance and to investigate and experiment with the human factors and visualization aspects of a 3D VE based solution. The real question is if the use of a 3D virtual environment will actually help ATC operators to perform better with a more realistic and immersive rendering of their work domain, and in particular if they can be trained to develop a problem solving behavior that matches well with their perception capabilities in such a 3D visualization. And of course we have to find out if it is at all possible and acceptable for experienced operators to switch from their current solutions to such a new and break-through and significantly different solution.

To illustrate the sort of possible scenarios that drive new solutions for air traffic control, consider the following: the current practice in air traffic control is to line up the planes that come in to land in a straight line and down to the landing lane. Doing it that way requires a lot less cognitive resources from an operator to monitor for conflicting situations and solving them, then if planes were allowed to come from all directions and make their final approach with a curved path, coming from multiple directions 'at almost the same time'. But in order to cope with the expected increased traffic density and improve the air side capacity of an airport, the need for more air space will maybe drive a change in approach procedures that actually may give pilots the freedom to fly in from multiple directions for a curved final approach. In this case the work of a human air traffic controller to maintain correct situation awareness and spot and resolve conflicts in time, will become a lot more demanding.

Tools for usability and user performance studies

The 3D virtual environment should be able to support the two main ATC processes: en-route monitoring and control and take-off and landing monitoring and control, using 'life' data from sensor and other sources. The first process is probably less impacted, even under the higher workload conditions expected in future denser air traffic. But for the latter processes 3D is expected to make a significant difference in helping to handle the expected changes in traffic

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load and procedures. Probably the hardest task in designing the right 3D virtual environment set-up will be to determine what and how we need to measure and how to generate and capture all the different data streams that we need to set-up and analyze the experiments, with the many human operators in a repeatable and reliable way. From a cognitive and psycho-physiological perspective we want to measure things such as information overload, problem solving strategies, change blindness, vigilance, fatigue, and many more parameters.

And we want to measure them in relation with the many different events in the many complex scenarios. And we want to do experiments in VR looking at the performance of trained operators under controlled conditions. For this we need to build a dedicated experimental immersive VR environment, focusing on an ATC context, both civil and military. We will use tools and technology from third parties of course, but we will have to set up and validate our own experimental methods and capture and analysis techniques and tools. And not only do we want to measure the behavior of people during training exercises, to get a better understanding on how well they learn and what we can do to improve their learning curve, but we also need to find out how 'stable' their new skills are and how well they will transfer into the real work domain. The latter may sound trivial if the aim is to use a 3D VE technology as the new ATC system solution, but we cannot simply take that for granted.

And because the number of aspects that need to be looked at and understood is too big to handle in any reasonable amount of time by one institute or company, we need to set up partnerships with universities and SMEs to help in the work. Therefore, the 3D VE and the utilized measurement and analysis techniques, but also the scenarios and experimental set-ups need to be standardized, so that they can be build and used in several places and their results can be combined and integrated and become a corpus of re-usable experimental data.

Some early experiences with setting up and using such an immersive environment

With the help of a 3D cave-like technology provider (TechViz, in France), we have constructed a first prototype ATC environment and presented this on the Thales innovation Days and on Eurosatory 2014. These presentation served to familiarize Thales higher management and customers alike about the intended studies, to 'test the water' so to speak. These interactions also helped to generate many concrete questions about for example interfacing and visualization issues. And they generated new ideas about remote collaboration between controllers that could add a whole new dimension to 3D VE based solutions. A selected sample of these preliminary findings will be discussed in this presentation. The next step is to design and construct a 3D Virtual ATC Experimental Platform with a minimum of two and possibly more nodes, to facilitate distributed and remote collaboration between experimental traffic control centers. The Platform will be equipped with cameras, microphones, polygraphs, eye-trackers and other non-invasive and invasive measurement equipment to capture and register multiple simultaneous data streams, necessary to analyze various human factors aspects of air traffic controllers in experiments. Aspects such as workload and cognitive workload, cognitive control, stress factors, situational awareness, vigilance will be monitored with the help of existing and new-to-develop models that link the data to the human factor aspects of interest. Experiments will be designed (and must of course be validated) to test both operator and operational system performance. Special care must be taken to design test scenarios that allow the comparison of performance measures in both the current 2D situation and new 3D proposed ATC solutions. Baseline for the design of these experiments will be a thorough analysis of the current state-of-the-art in 2,5D, 3D visualization studies. See as an example of this literature [1], [2], [3]. Also recent work on navigation and selection of data in 3D scientific and medical data spaces will serve as a starting point for these future ATC directed studies. See as an example of this literature: [4], [5].

And finally, two aspects must be considered above all. The first is that in a safety critical domain such as ATC a new solution that is totally dependent on advanced computer technology, must always have some back-up solution that can be called upon. And the second is that a new solutions is only acceptable if it (provable!) makes air traffic safer than it already is today. This safety and performance behavior of the human-machine solution is of primary importance, but it is still an open question how to measure it and maybe transform it into a norm. What is clear is that the later can only be defined properly in an open discussion between end –users, scientists and industry.

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