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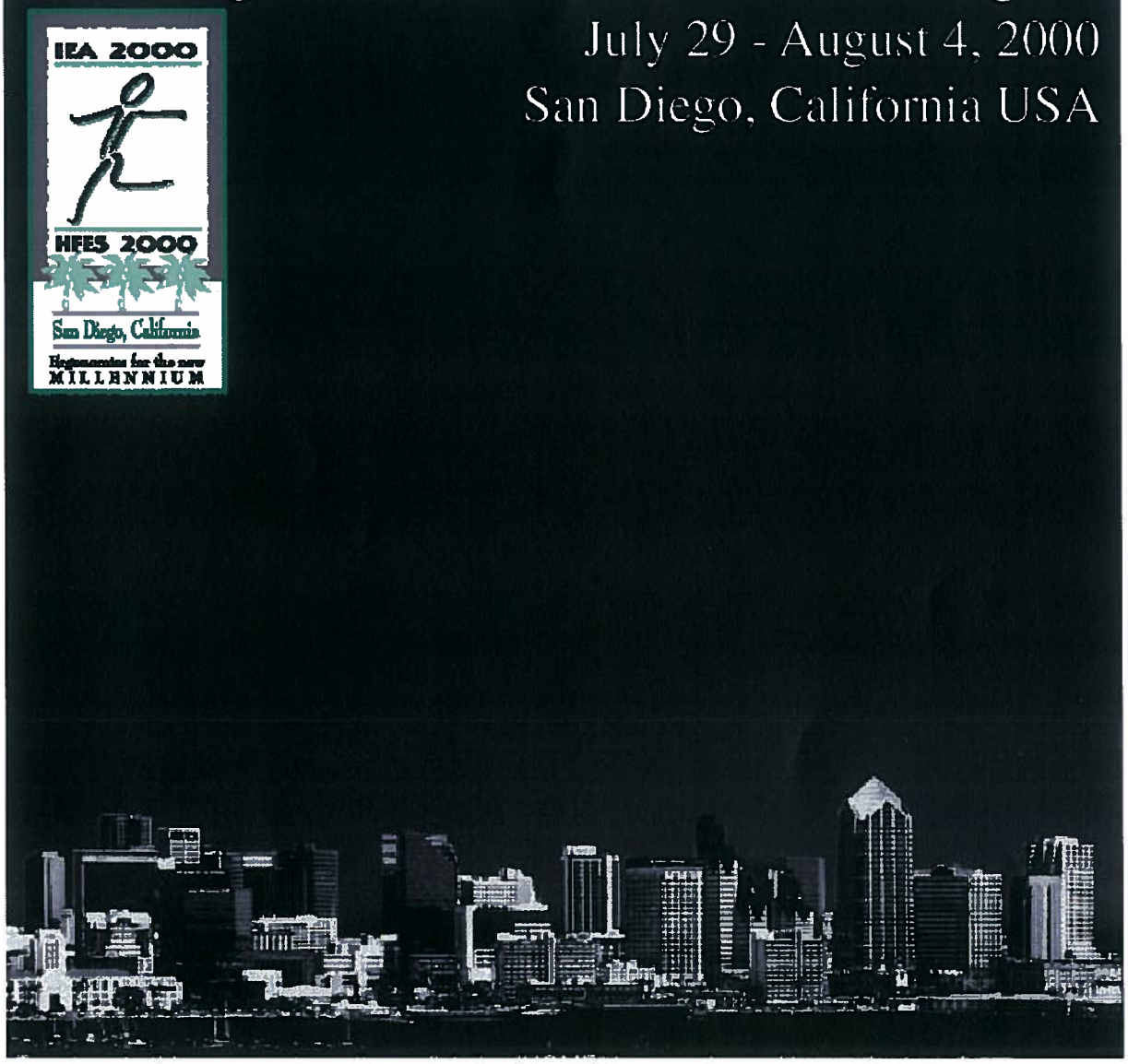

VIRTUAL REALITY IN AIR TRAFFIC CONTROL

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Air traffic control is a highly spatial work. However, there are currently no three-dimensional tools used in the education of air traffic controllers or in the operational work of air traffic control. This paper presents results from some pilot studies aiming to:

- Find new techniques for visualisation and editing of trajectories in air traffic control.
- Investigate how Virtual Reality (VR) can contribute to the air traffic controllers' understanding of the air space and of certain situations. Two VR models have been developed. In one model a procedure called 'holding' is visualised. In the other VR model the different sectors in the air space are shown to make it easier for the air traffic controller to build a mental picture of a sector. In a training package the user can fly around in the sector and see how traffic passes through.

These introductory studies indicate the usefulness of new ways to present the third dimension in a variety of air traffic situations. The tools can be used to visualise a three dimensional situation and help the air traffic controller to build a mental model. The most obvious application area is in training and education of air traffic controllers but other applications such as an explanation and communication tool in the investigation after an incident are of interest.

BACKGROUND

Air traffic control is a highly spatial work. The work puts high demands on the controllers' ability to create a three-dimensional mental model of the current and future situation in the air space (Previc, 1990, Haskell and Wickens, 1993). However, there are currently no three-dimensional tools used in the education of air traffic controllers or in the operational work of air traffic control.

The air traffic controllers work in an environment that is characterised by safety and contains elements like teamwork and interaction with a complex system of technology and people (Endsley and Smolensky, 1997). In order to increase the safety and to handle the current increase of air traffic it is important to find new ways of education and training of controllers. One way to achieve these improvements could be to use three-dimensional visualisation tools.

The department of Design sciences, division of Ergonomics has recently in co-operation with the Air Traffic Control Centre (ATCC) at Malmö Sturup started research in this field and during the last year several students' projects have been successfully carried out. Some results from these projects are presented in this paper.

PILOT STUDIES

Innovative visualisation and editing of trajectories

The purpose of one of the pilot studies was to find new techniques for visualisation and editing of trajectories in air traffic control. The work has been done at the Eurocontrol Experimental Centre, France and includes a review of the use of trajectories in aviation and the development of new, innovative techniques for visualisation and editing of trajectories.

Modern communication technology enables aviation units to exchange large quantities of information. For example the intended route for an aircraft can be broadcast from that aircraft to other aircraft and to air traffic control services. With this information, the controller has more possibilities to plan the traffic flow and avoid conflicts between aircraft's flight paths than was previously feasible.

In this study, techniques for the visualisation of trajectory information have been developed. First, representations of basic features of a trajectory (time, altitude and speed) were searched for along with the development of editing techniques. The basic representations were then put together to form more complete parts of the user interface for en route air traffic control.

VR models in air traffic control

In these studies we wanted to investigate how Virtual Reality (VR) can contribute to the air traffic controllers' understanding of the air space and of certain situations. Two VR models have been developed.

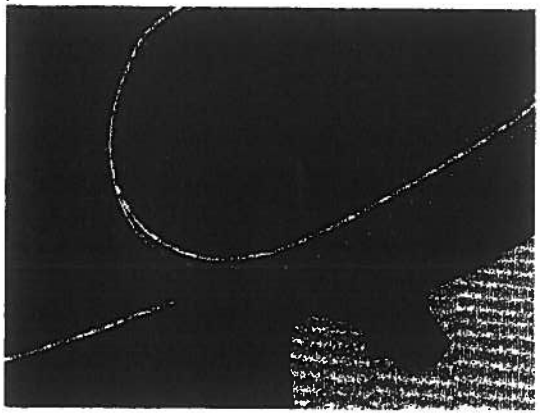
Visualisation of holding. The aim of this VR-model was to investigate the usefulness of VR as a tool for teaching certain work procedures in the air traffic control education. The model is used to visualise a procedure called 'holding' (Figure 1). This is used for example when aircraft have to wait for a landing clearance outside a busy airport. The controller puts

the aircraft in a 'stack' on top of each other, while they are flying a non-circular path. When the bottom aircraft is given a landing clearance, the controller tells all the other aircraft in the stack to enter a new flight level. The aircraft are put one step down. On the radar screen this is a very demanding task, since the picture is strictly two-dimensional (top-view). The area for holding is also quite small, compared to the size of the sector the controller controls and more than 10 aircraft can be involved in the holding procedure at the same time. This makes the radar picture quite messy.

To serve as a tool for the teaching of the holding procedure, the VR model allows the user to see the planned trajectories for the aircraft involved. It is also possible to fly around, rotate and replay the procedure. Several different scenarios can be implemented in the model, though only one scenario was implemented in this study.

This model has been shown to people working in the air traffic control centre and in the air traffic school. The potential of this use of VR in air traffic control, or rather teaching of air traffic control was estimated to be big.

Figure 1. Aeroplanes viewed from above in a holding procedure.



Visualisation of the airspace. The two main tasks in air traffic control are to keep the aircrafts at a safe distance from each other (both horizontal or vertical) and to make the air traffic as efficient as possible. The whole airspace is divided into air sectors, which often have a complicated three-dimensional geometry. An air traffic controller is responsible for all traffic within such a sector and needs to understand the shape of the sector being controlled. This is especially difficult for newly graduated controllers and for controllers who start to work in a new sector. The task of getting familiar with a new sector is very demanding and continuous training is necessary for the maintenance of the familiarity. A controller who does not practice for a month requires several days of training (David, 1997). A VR model may make it easier to build a mental picture of a sector, and will allow the user to fly around in it and see how traffic passes through .

The purpose of this study was to develop and examine the usability of a VR-tool to be used in the education of air traffic controllers when they are learning a new sector. The current way of teaching is based on a two-dimensional representation of sector borders and its altitude denunciations. This way puts heavy demands on the controller's capacity to create a three-dimensional mental model of the sector. Therefore it is very likely that a three-dimensional visualisation tool could speed up and improve the learning of the sector geometry.

As a first step in the study a coarse VR-prototype was developed. The prototype was used to communicate the idea of the tool to the air traffic controllers in order to gather their suggestions of the usage of such tool.

In the next phase of the study, six air traffic controllers and five students at the ATCC Sturup were tested and interviewed. The subjects were asked to think-aloud during the tests. The purpose was to:

- Understand the procedure the air traffic controllers use when learning the geometry of an air sector, they have never experienced before.
- Conclude if they are visualising the sector or the traffic situation in three dimensions and if this is the case to obtain their internal pictures.

During the first part of the test the subjects were shown a common situation in the airspace, where the flight routes into the sector were presented. Beside the radar-picture they were also given information on flight strips. They were then asked to describe how they will manage the situation. Seven subjects declared that they now and then used a three-dimension mental model to understand the traffic situation in the airspace. They mainly use the three-dimensional image when they have enough time to do it or if there was a potential risk in the situation, for example in starting and landing aeroplanes. Their normal three-dimensional view was from above but in some situations they also turned their three-dimensional mental model around and looked from a different angle.

Some of the subjects (four of eleven) thought that they were too familiar with the procedures they learned in school and therefore even if it would be easier to see some of the situations in three dimensions, they didn't prefer to do this, as it may be too confusing. This attitude has to be taken into consideration before making a final conclusion how to use a VR-tool.

In the second part of the test an emergency situation when the radar fails was simulated and the subjects only received information on strips. An interesting result was that in this case all were extremely concentrated on the information they had on the strips and the only picture they had in their mind was an approximated view of the radar screen.

At the last part of the test the subjects were showed the geometry of a quite complicated sector in two-dimensions and they were asked to visualise that sector in three-dimensions

and to make a sketch on a piece of paper. Eight of the subjects did not succeed in fashioning a proper picture within the stipulated time. Afterwards the subject was shown the three-dimensional picture of the sector. The reaction was incredibly positive. Both air controllers and students admitted that they now, much easier could remember the shape of the sector. They also thought that they probably could learn that geometrical shape much faster than before.

The knowledge, experiences and suggestions achieved from the tests and from the following interviews were integrated in a new prototype. The prototype was designed to be interactive and editable and support future changes in the air space. Three different exercises for training of controllers were developed. The user can choose to

- Look at a single sector.
- Compare the sector presented in 2D and 3D.
- Simulate a traffic situation with both radar and stripes and with the VR-modell.

Before the implementation starts the prototype will be evaluated by air traffic controllers for a final design of the functionality of the VR-tool. The prototype will then be implemented using the VR environment "Word Up" and "World Toolkit" together with Visual C++.

DISCUSSION

These introductory studies indicate the usefulness of new ways to present the third dimension in a variety of situations occurring in the air traffic. The tools can be used to visualise a three dimensional situation and help the air traffic controller to get a mental model of the situations. A VR-model also offers possibilities for the users to interact with the Virtual environment and simulate and train new situations.

The most obvious application for a VR-tool is in the education of new air traffic controllers but also for more experienced controllers when they for instance have to learn and understand a new sector. In the future there will probably also be situations identified in the daily work of the air traffic controllers where a VR-model may be an advantage for both safety and the efficiency of the work.

Another use of VR models can be to function as an explanation and communication tool in the investigation after an incident. An incident is a case where two (or more) aircraft are allowed to fly too close to each other. The most common incidents are not safety critical, but the aim is to reduce the number of incidents to zero. The model may be able to explain to the controller what really happened and why it happened. The same information is interesting for the investigators.

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