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AN INTERFACE FOR INBOUND TRAFFIC ROUTE PLANNING

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It is expected that, with increasing automation, the emphasis in the air traffic controllers’ work will shift from tactical control towards supervision and planning of aircraft trajectories. To support this work, a planning interface for area controllers has been developed. The interface uses a normal Plan View Display (PVD) supplemented with a Time-Space Diagram (TSD), that visualizes the travel of the incoming aircraft across their planned track. With the constraints on speed and timing as given in the TSD, the interface permits direct manipulation of the arrival time within these constraints. Using a simulation of air traffic, the interface was tested in an experiment. The results indicate that the interface can be used to manage traffic efficiently, but that maintaining a coherent mental picture using both the TSD and the PVD is still difficult.

Air traffic control (ATC) is a complex task, today still performed by human beings with relatively little support from automation. Current required competences for ATC personnel are for example summarized by the ATC Performance Model, developed at ATC the Netherlands (LVNL) (Oprins, Burggraaff, & Van Weerdenburg, 2006; Oprins & Schuver, 2003). With increasing traffic, and without changes to the current system, demands on ATC personnel can only become higher.

An important trend in research programs for future ATC systems (Anon., 2007; Dlugi et al., 2007) is the shift from the current tactical, sector-based air traffic control to strategic, trajectory-based Air Traffic Management (ATM). As an example of this shift, a possible scenario for future ATM in Area Control Center (ACC) sectors is considered. It is expected that, with the application of more fixed routing in the Terminal Maneuvering Area (TMA), the transfer of approaching aircraft to the TMA will have to adhere to stricter timing requirements. Also, in order to increase flight efficiency, holding patterns should be avoided, and aircraft timing will have to be adjusted with speed instructions. A concept is developed in which the ACC controller creates a 4D arrival trajectory for approaching aircraft, and implements this trajectory, optionally using speed requests to an adjacent sector. An interface to support Air Traffic Controllers (ATCo’s) in this task has been designed.

Display Design

Inbound Traffic Management

For this study, a hypothesized future situation regarding inbound traffic management by Area Control will be described, taking planned procedures around Amsterdam Airport Schiphol (AAS) as a starting point. This scenario uses 3D fixed routes in the TMA with merging of traffic in the ACC. Aircraft must arrive at one of the Initial Approach Fixes (IAF) on the border of the TMA at co-ordinated times, and only limited modifications to the arrival time are applied in the TMA (Figure 1).

Since the ACC airspace, especially for the case of AAS, is limited, much could be gained from cooperation with adjacent sectors to change the timing of arriving aircraft. To make such adjustments feasible, the new display will display arriving aircraft as soon as they are available in the system. Using the presentation on the display, an ATCo can determine whether a request to an adjacent center is useful and feasible.

Time-Space Diagram

In order to control the arrival planning of inbound aircraft, ATCo’s need a tool to consider the traffic in four dimensions; the spatial path and the temporal dimension. The main display currently used, the Plan View Display (PVD), offers only support for prediction over a limited time span, sufficient for an experienced ATCo to merge aircraft into a separated stream over the entry point to the TMA, but not sufficient for creating an arrival plan and
issuing speed or heading vectors at or outside the ACC boundary to create a planning for entry into the TMA or solve upcoming conflicts when merging close to the TMA boundary.

As a starting point of the new interface, therefore, a Time-Space Diagram will be used. This kind of diagram has been tested in Eurocontrol’s PHARE-project (Jorna, Pavet, Van Blanken, & Pichancourt, 1999) and by Delft University of Technology for assisting the ATCO in planning and monitoring Continuous Descent Approaches in the TMA (Tielrooij, in ’t Veld, Mulder, & van Paassen, 2008). The principle of the time-space diagram is shown in Figure 2, for an aircraft which is on its way to the IAF. The horizontal axis shows the distance to go before the IAF is reached, the IAF can be imagined to be at the right side of this axis. The vertical axis is a time line. This makes the horizontal axis ‘now’, everything above it ‘the future’ and everything below it ‘the past’. The time-space line moves downward in time, making the intersection with the horizontal axis move to the right: the aircraft flies in the direction of the IAF.

**Aircraft Constraints.** At AAS, aircraft generally enter the ACC at a high altitude, descending from upper airspace controlled by Eurocontrol or horizontally from adjacent centers. When a straight path to the IAF is planned, control of the aircraft speed is the only option to modify the arrival time. Speed control is of course constrained by the aircraft properties, resulting in upper limits on Mach number and lower and upper boundaries on Calibrated Airspeed (CAS). Since the maximum altitude in the AAS ACC sectors is limited to FL 245, the Mach limit does not need to be taken into control. When the ATCo selects a particular aircraft in the interface, the CAS limits for this aircraft are added to the TSD. For aircraft still in the adjacent sector, a double prediction is presented; one assuming that instructions are given by the ATCo in the adjacent sector, and one assuming that instructions are issued after the aircraft enters the own sector. In this way the ATCo can determine whether a request to an adjacent sector is feasible and useful.

For the implementation of the deceleration and descent behavior of the aircraft, the performance envelopes of the three aircraft implemented in the simulation were compared. It was determined that a descent flight path angle of 2 degrees was an acceptable value for all considered aircraft.

**Separation Constraints.** In principle, aircraft paths will be planned straight to the IAF. For aircraft that cross such a path, or converge on these paths, it is possible to calculate “forbidden zones” in the TSD. These zones are specific to the path of a considered aircraft, and indicate time and path combinations that will result in a conflict with another aircraft. Figure 3 shows how an aircraft crossing the path of another aircraft results in a forbidden zone.

Creating or solving a conflict by changing a speed is visualized by bending a time-space line in or out of the conflict zone. For example, when moving the right part of the time-space line of aircraft 1 in Figure 4 up, it will at
some point enter the forbidden zone above it. This implies, that by delaying the aircraft (slowing it down), the aircraft behind it starts overtaking it and a conflict will occur. This indicates a major advantage of the direct manipulation principle: it becomes immediately clear if a forbidden zone is crossed, when dragging the label. In this way, the constraints of the work domain are mapped on the interface. Since meaningful behavior (adjusting the time dimension) is also visible on the interface, direct manipulation is possible.

Inbound Planning Interface. While the time-distance lines in the TSD show the possible speed profile, and on the time axis, the possible arrival times of the aircraft, the planning interface needs to also show the constraints of the total planning process. Aircraft could be guided to the IAF’s with appropriate separation, but their different speeds could result in them running into each other in the TMA. Furthermore, Figure 1 shows that the merging of two streams of traffic takes place in the TMA as well. Both aspects need to be taken into account by ACC when planning at which time the different aircraft should cross an IAF. The designed interface supports this process.

If aircraft performance, route and weather are known, an estimate can be made of the time between reaching the IAF and lining up with the runway. Assume that this is equal to ten minutes for a certain aircraft under certain conditions. On the right side of the TSD, the time at which this point is reached, could then be marked ‘ten minutes above the arrival time at the IAF’. There, the time required before the next aircraft may arrive, can be expressed by a vertical bar. This time, i.e. the height of the bar, depends on the speed of both aircraft, as well as their wake vortex categories. This is shown in Figure 5, in which all bars have been shifted down the time line by the minimum travel time in the TMA for clarity. The bars that are not aligned with the arrival time at the fix indicated in the TSD represent aircraft that arrive, in this case, at the southernmost fix, and have a longer travel time in the TMA.

Path manipulation. In addition to manipulation with the arrival time, and thereby changing the speed of the aircraft, the ATCo is also given the opportunity to change the aircraft path in the plan view interface. Changes are applied to the basic (straight-in) path by adding a waypoint to a path. The changes applied to the lateral path are presented in the TSD as well. See Figure 6 for an example.
an aircraft on almost the same path (behind)
zone caused by a crossing aircraft in an adjacent sector

own sector starts here

Figure 4: The TSD including 'forbidden zones' and margins in time

Figure 5: The time line on the right side of the TSD, indicating arrival times at the final merge point and required separation at this point

Experiment

An evaluation of the display and operational concept was carried out. The main purpose of the experiment was to investigate whether the interface would allow a safe and efficient planning of the inbound traffic, and to identify problem areas and possible improvements.

Experiment Set-Up

Equipment and subjects. The experiment was programmed on a laptop computer. The TSD was shown on the laptop screen, and the PVD was shown on an additional display connected to the laptop. Figure 7 shows a screen shot of the two displays. Ten subjects participated in the experiment, five of whom were active air traffic controllers, with experience ranging from 4 to 26 years. The other five subjects were research staff and students.

Scenarios. Four scenarios were created, with aircraft coming from the North, East and South and entering through one of the two IAF’s (see Figure 7). Aircraft were kept at initial altitude before descent to the IAF with a 2° flight path. A mix of three aircraft types (Boeing 737-800, Boeing 777-200 and Airbus 320-212) was used, the simulation was based on BADA data (Nuc, 2004). Aircraft had to be delivered to one of the IAF’s with time intervals of 1.7 min. Scenarios 1 and 2 were for familiarization, with low traffic rates, scenarios 3 and 4 had a high traffic rate (15 aircraft in 21 minutes), with scenario 4 being the most difficult.

Procedure An experiment session began with a 15-minute briefing. Using scenario 1, the working of the interface was explained, and after explanation subjects could practice with scenario 1. After subjects indicated they felt comfortable with the task, the other scenarios were presented. If at some points subjects had problems with the task, hints were offered by the experimenter. When all aircraft in the scenario had been provided with a plan, the simulation was run in fast-forward to show the results. Total time per subject was approximately one hour. After the runs, subjects completed a questionnaire, scoring statements on a four-point scale (agree, partly agree, partly disagree, disagree) and answering a number of open questions.

Results

This test of the interface should be considered as a first evaluation of a work in progress. The scenarios were fairly short, and in particular scenario 4 started in a state that was not representative of the traffic situation at, for example, a hand-over.
click mouse here → new route and TSD calculated

Forbidden zone caused by AC 2

Figure 6: Re-routing aircraft 1 with a mouse click leads to immediate recalculation of the TSD

Figure 7: The TSD and PVD with the NWA183 selected
Safety and efficiency. The subjective impression of safety was tested by means of the statement “I can handle traffic safely”. All subjects agreed or partly agreed, with the exception of two ATCo’s who disagreed. These felt they were lacking the “mental picture” of the traffic situation. Complaints were mainly about the problem of integrating information from the two displays. All subjects agreed or partly agreed that they could handle traffic efficiently.

Interface use. Most subjects indicated that the TSD became their primary tool for the planning. Creating a plan was started on the TSD, and completed on the PVD when the need arose. Two of the ATCo indicated that it was difficult to interpret the conflict zones on the TSD, and that a better link to the PVD would be needed. The majority of the ATCo’s indicated the need to also use the vertical path of the aircraft for separation. The possibility to request a speed change in the adjacent sector was very much valued.

Conclusions

The objective of the present work was to investigate the creation of a path planning tool air traffic control. The display combination of the extended TSD and PVD enable a human controller to create an efficient arrival planning. The main problem is still the integration of the information from the PVD and TSD to create a single mental picture of the traffic situation. The presentation on the TSD of the constraints of the work domain facilitate direct manipulation of the flight parameters in the search for a solution. A focal point for the future work is the increased (visual) integration of the information on the two displays, and the visualization of the constraints on the PVD, making path manipulations in the PVD as easy as the speed manipulations in the TSD.

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