

Evaluating the Multi-Conflict Display

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ABSTRACT

The growing demand for air travel in recent years has seen the development of new tools to help air traffic controllers manage their workload and continue to meet safety and performance standards [1]. However, studies have shown that these new tools do not always function as intended, and often result in poor performance outcomes [2]. To design better tools, designers must take greater consideration of the psychological processes involved in air traffic control [3, 4]. The Multi-Conflict Display [MCD; 5] was designed to help controllers by accounting for spatial-temporal processing involved in conflict detection. This paper accompanies a demonstration of the MCD and describes an intended evaluation to assess its effectiveness.

Keywords

Conflict detection, display tools, spatial-temporal process

INTRODUCTION

The radar display is frequently used to help Air Traffic Controllers (ATCOs) detect conflicts between pairs of aircraft. However, despite its popularity [6], the radar display requires ATCOs to employ considerable cognitive effort to detect conflicts [5]. This becomes problematic when one considers the likely future growth in air traffic. Studies have shown that current systems and displays, including the radar, will not be able to help ATCOs meet the forecasted increase in workload due to the unreasonable cognitive effort that will be required to use them [4].

In response to this, the aviation industry has sought new systems to automate some of the cognitive functions involved in conflict detection, and thereby reduce mental workload [2]. However, studies investigating the effectiveness of automation tools have also shown adverse effects for the ATCO. These include reduced situation awareness, cognitive skill loss and unbalanced mental workload [1, 7].

These results suggest that the design process for such tools is less than optimal because it is often difficult to predict the impact of the tool on the user. To design more effective tools, human factors specialists suggest that the design process must take into account the psychological processes involved in conflict detection [4, 7]. Tools can then be designed to target processing constraints and improve performance where it is most needed.

The psychological processes involved in conflict detection

A controller may use several strategies to detect conflicts [8]. The Constant Bearing method involves monitoring the bearing of one aircraft to another over time. If the aircraft are at the same altitude, and their bearings remain constant while

the distance between them decreases, the pair is likely to cross paths and may conflict. The Distance to Velocity strategy involves making a comparison of the arrival times of the aircraft at the crossing point. If two aircraft will arrive at the crossing point at the same time, then this indicates a conflict. Alternatively, Cognitive Motion Extrapolation involves developing a cognitive representation of the aircraft's motion based on its current motion, and then using this to extrapolate the position of the aircraft at a future time and its time to conflict.

Despite differences in strategies, it appears that no matter what strategy is chosen, the controller must somehow make sense of, and integrate, spatial and temporal information when making conflict detection judgments. Although all strategies are consistent on this point, the number of unsuccessful design attempts for automation tools suggests it is yet not clear how to best translate this information to ATCOs in the form of display tools.

Designing tools to support processing: A framework

The Spatial-Temporal framework [9] has been proposed as a method of understanding how spatial-temporal information is dealt with in Air Traffic Control (ATC) and how information may best be represented to help controllers perform their task. This framework suggests that it is not aircraft and information about the aircraft which are important, but the relationships and interactions between aircraft and their constraints that govern a controller's decisions. Therefore, this framework suggests that display tools should not only show the information about aircraft, but also information about the changing relationship between pairs of aircraft over time.

A new tool for conflict detection

Based on these suggestions, the MCD was designed to convey relationships between pairs of aircraft as objects in the display [5]. This work originated in the 3-year '3D-in-2D Planar Displays for ATC' project funded through the EUROCONTROL CARE INO 3 innovation research program. Its goal was to investigate information visualizations that combined 3-D information and spaces within a 2-D display space in such a way that would increase air traffic controllers' ability to manage increased air traffic levels. The challenge was to devise disruptive innovations that had the potential for creating new forms of work that would increase control capacity in 20 years time [10].

The relationship between each pair of aircraft in the MCD is represented by a single point symbol; individual aircraft are not represented. The location of each point symbol represents the relative displacement of one aircraft of the pair from the other. A red circle in the centre of the

display indicates the 'conflict zone'. Pairs which are inside this zone are in conflict (i.e. they are within 5 nm of each other laterally and within 1000 feet of each other vertically). Pairs outside the red circle are not in conflict. Pairs moving towards the central circle are on course to become a conflict; pairs that are not moving towards the central circle are not on a conflicting course. To help controllers view this movement, the point symbols have a history trace. If the history trace shows a movement toward the red circle, this indicates that the pair has had a loss of separation over time.

The underlying logic behind the MCD is the Relative Position Vector (RPV). The RPV describes the distance and direction between two points in space. However, because the units of horizontal and vertical separation are different (nautical miles and vertical feet), they must somehow be equated so that separation can be meaningfully represented. Thus, both horizontal and vertical separation have been transformed into 'safety units'. Both five nautical miles and 1000 vertical feet equal one safety unit. The total length of the RPV between two aircraft reflects the total number of safety units. Therefore, if an aircraft is 5 miles north, 5 miles east, and 1000 feet above another, its RPV would equal 1.73 safety units.

To represent the RPV on a 2-D display, the RPV is rotated about the origin so that it falls onto the horizontal plane. By transforming the horizontal and vertical separation into 'safety units', and rotating the RPV onto the horizontal plane, the three-dimensional separation between aircraft is represented in a 2-D display. To avoid clutter, RPVs have been colour coded according to vertical separation. Pairs of aircraft that are safely vertically separated have green RPVs with history traces dimmed. Pairs that are, or may become, separated by less than 1000 vertical feet have white RPVs.

In summary, the MCD displays relationships between pairs of aircraft as single objects in a display. The display of pairs, instead of individual aircraft, means that controllers can view many pairs simultaneously. Further, the display of the changing relationships over time means that controllers can identify possible conflicts by using direct perception instead of having to calculate conflicts from the radar display.

Evaluating the MCD

In a forthcoming evaluation, we will compare conflict detection performance under normal radar display to performance under radar and MCD display. We will assess performance under several tasks. Tasks 1, 2a and 2b are screenshot tasks. In Task 1, controllers must detect as many conflicts as possible from a single screenshot, within a given timeframe. In Task 2a, one aircraft is highlighted in the radar display, and all of its relationships with other aircraft are highlighted in the MCD. Controllers must identify how many potential conflicts the selected aircraft will be involved in. In Task 2b, one relationship is highlighted in the MCD, and the corresponding pair is highlighted in the radar display. Controllers must indicate whether the selected pair of aircraft is going to be in conflict. In Task 3, controllers will be able to interact with a dynamic simulation to detect conflicts.

Conclusion

The evaluation of the MCD will take place during 2010. It is expected that performance with the radar plus MCD display will be better than performance with the radar display alone. The success of the MCD tool may provide us with a way forward in supporting controllers as they make conflict detection decisions and manage the increasing workload of the future.

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Visual material to be presented as part of Demo

We will show a live demonstration of MCD tool in use. Some screenshots from the tool are included here:

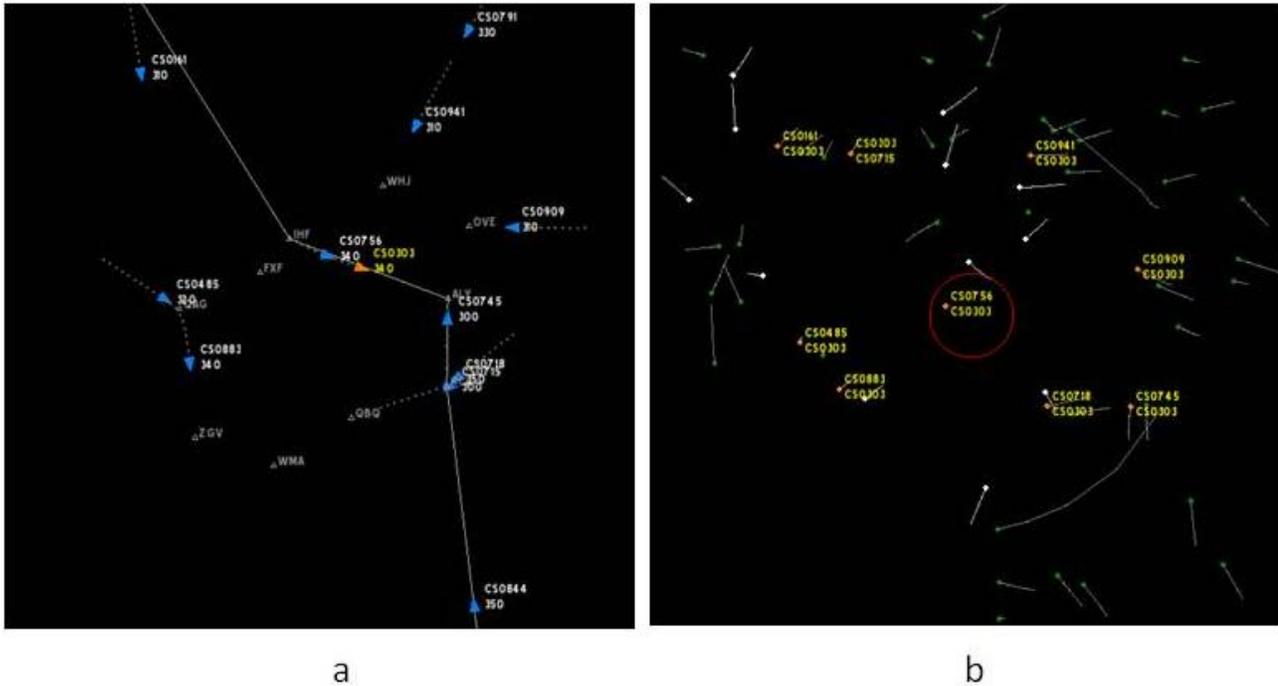


Figure 1. Example screenshot of radar and MCD display. (a) Left hand side of screen shows standard radar plan-view. (b) Right hand side of screen shows MCD display.

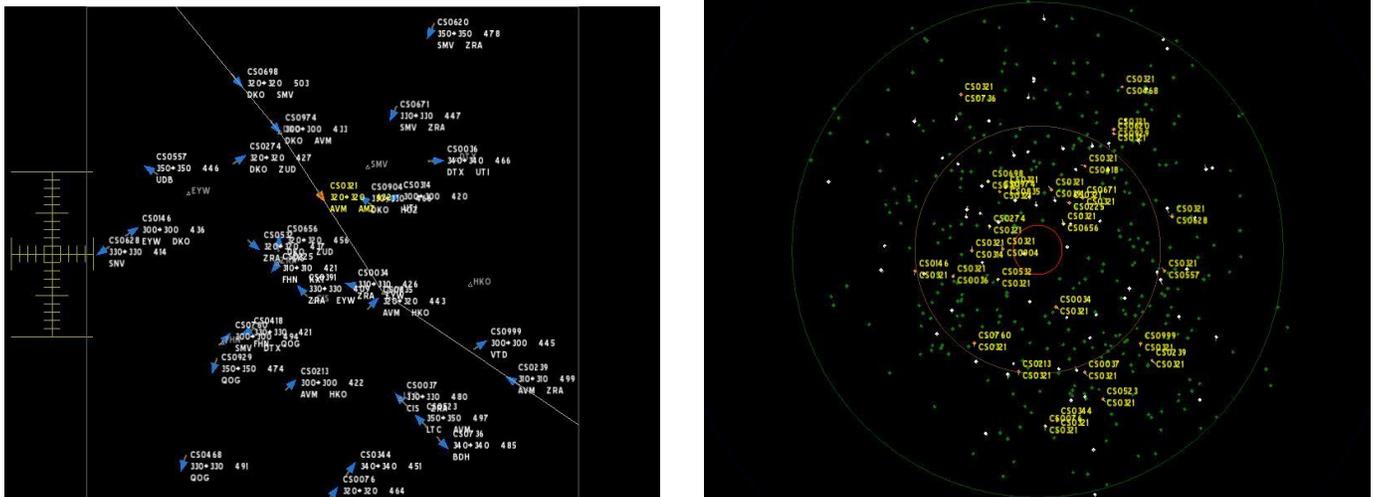


Figure 2. Demonstration of interaction with MCD tool. Selecting an aircraft on the radar display (left) highlights all affected relationships on the MCD display (right).

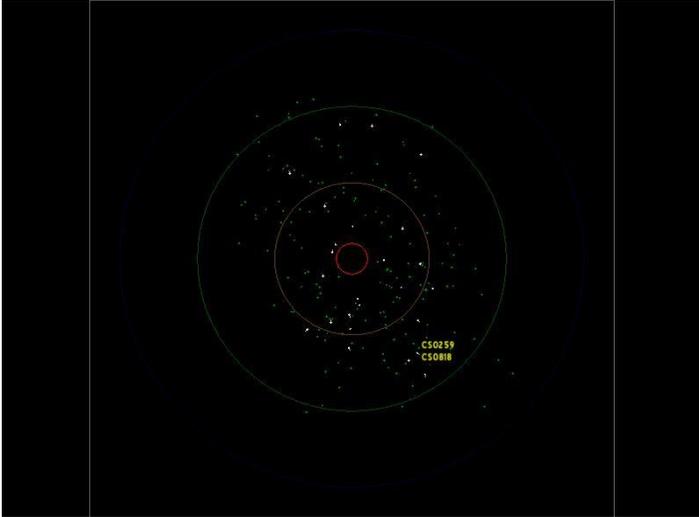
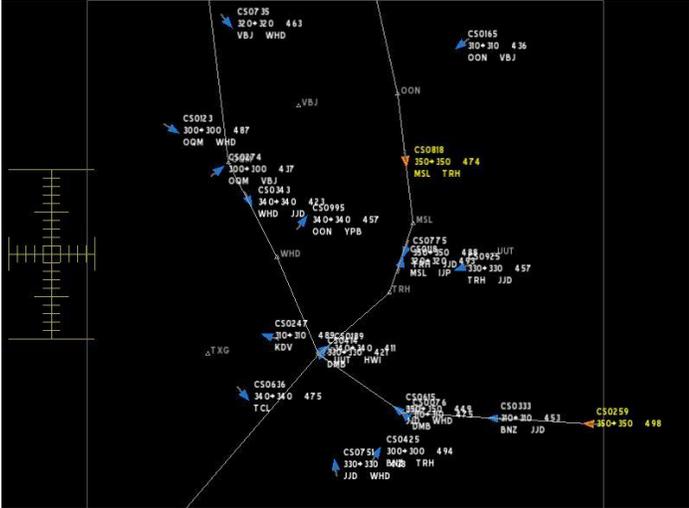


Figure 3. Selecting a pair of aircraft on the radar display (left) highlights the given pair's relationships on the MCD display (right).