Evaluation of Advanced Conflict Modelling in the Highly Interactive Problem Solver

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Abstract

The aim of this paper is to describe small scale experiments on advanced conflict modelling support to the planning controller, using the Highly Interactive Problem Solver (HIPS), developed at the Eurocontrol Experimental Centre (Meckiff, 1998; Price and Meckiff, 1997). The HIPS tool was extended through the integration of the probabilistic conflict detection approach of Bakker et al. (2000, 2001). The resulting probabilistic HIPS prototype tool supports conflict detection and resolution and provides a graphic insight into the implications of using collision risk probabilities in air traffic control. Small scale controller supported real-time experiments with the new tool were undertaken using various conflict geometries and collision risk thresholds. For the purposes of comparison, the results of the integration exercise were superimposed on the original HIPS displays that were based on simple geometric conflict detection with fixed separation standards. The results show a clear potential for a probabilistic approach that is based on a collision risk formulation.

1. Introduction

Research into conflict modelling techniques and conflict detection tools has been underway for many years, and in most cases the formulations developed incorporate some notion of 'probability of conflict' to deal with uncertainties e.g. (Warren et al., 1997; Paielli and Erzberger, 1999; Bakker et al., 2000, 2001). For example there might be uncertainty in the predicted along-track position of the aircraft which is characterised by, say, a Gaussian distribution. For a researcher, the notion of a conflict with an associated probability of occurrence is entirely reasonable. Indeed, given the existence of uncertainties in all parts of the system it would seem unreasonable *not* to include probability in the result. Difficulties occur, however, when it is required to present such information to air traffic controllers. In general they wish simply to know whether or not there will be a conflict. Probabilistic conflict modelling/detection alone does not give indication as to how, in practice, the results might be used by controllers.

For this reason an "Advanced Conflict modelling in HIPS" study was initiated. The objective was to integrate the probabilistic conflict detection approach of Bakker et al. (2000, 2001) with the HIPS conflict resolution support tool, and to assess the usefulness of this probabilistic HIPS with support from an air traffic controller. The reason that this particular probabilistic conflict detection approach was selected is that it has shown to be more selective to differences in encounter scenarios.

First, existing NLR software for probabilistic conflict detection was adapted and integrated into the HIPS. Subsequently, small scale real-time experiments using the resulting probabilistic HIPS were performed on NLR's ATM Research Simulator (NARSIM) with support from one Eurocontrol air traffic controller. The goal of these experiments was to perform limited validation and tuning of the probabilistic HIPS, and also to build early confidence in the approach. The aim of this paper is to describe these evaluations.

The paper is organised as follows. Section 2 outlines conflict modelling. Section 3 outlines the HIPS tool and gives references for further information. Section 4 explains the integration into a probabilistic HIPS version. Section 5 details the small scale experiments which were conducted with the probabilistic HIPS. A number of diagrams are included to illustrate the results, and a brief discussion follows each. (Note that these diagrams must be viewed in colour.) The paper concludes with a discussion of the results (Section 6) and draws conclusions (Section 7).

2. Conflict modelling

This review is based on Bakker and Blom (2000).

The objective of conflict modelling approaches is to evaluate a set of planned or predicted trajectories on their conflict potential and to supply other ATM subsytems with the conflict information. Three types of conflict modelling approaches are briefly considered: the classical geometric conflict prediction approach, the conflict probability approach and the collision risk approach.

In the geometric approach, the uncertainty of the predicted trajectory is translated into areas around the predicted trajectory. These are referred to as protection zones. Horizontal and vertical distances between protection zones should be such that it is safe. Two aircraft are said to be in "geometric" conflict when the distance between the protection zones of these aircraft becomes smaller than the minimum allowed distance between them (e.g. defined by ICAO).

Paielli & Erzberger (1999) have developed a method to evaluate conflict probabilities. In their approach a conflict is defined as a situation in which the separation between aircraft falls below a certain separation threshold. Evaluation of conflict potential is done based on the evaluated conflict probabilities. The approach aims to predict the probability that the separation between two aircraft falls below a certain separation threshold (e.g. ICAO separation standards). This probability is called conflict probability. The goal is to keep the conflict probability below some acceptable level. In order to evaluate the conflict probability, Paielli & Erzberger assume that it is realistic to model the deviations of the aircraft from their predicted positions by normally distributed probability density functions. If for the separation threshold a value like the size of an aircraft is used, then the same approach yields the overlap probability, the probability that the aircraft physical volumes overlap.

In the collision risk approach of Bakker et al. (2001), the conflict potential is evaluated through collision risk formulae. The resulting collision risk equals the probability of collision between two aircraft. First, the joint probability density functions of the positions and velocities of individual aircraft are predicted. Then the joint probability density function of the relative position and velocity of an aircraft pair is evaluated, and then the collision risk for the aircraft pair is evaluated using the generalised Reich collision risk formulae. It is important to note that the approach chosen for this study models the probability of collision (metallic contact) between airframes rather than infringement of separation criteria.

For the application of probabilistic conflict prediction in the HIPS, the collision risk approach was identified as the most useful for a number of reasons including:

- It takes account of all aircraft behaviour including speed and period of encounter or potential conflict. This is significant since there is a trade-off between these and other factors (e.g. for some path angles it is safer for a fast aircraft to cross behind a slower aircraft than in front).
- It takes into account equipment fit of individual aircraft. Thus, spacing between two better-equipped aircraft could be less than the spacing between lesser-equipped aircraft.

Next, the background and the concept of the collision risk approach are briefly discussed.

Background of collision risk approach

The probability of collision between aircraft can be evaluated the Reich collision risk equations adopted by ICAO (1998). These equations apply under quite restrictive assumptions only. Therefore, generalised Reich equations have been developed (Bakker & Blom, 1993).

These equations are general enough to evaluate the collision risk for current and future ATM designs and are applied in several safety related studies/projects (e.g. Blom et al., 1998, 2001). Recently these generalised Reich collision risk equations have been applied also to conflict prediction/detection (Bakker et al., 2000, 2001). At any moment in time, the joint probability density functions of the relative positions and velocities of an aircraft pair are needed to evaluate the in-crossing rate between the two aircraft at that time. Predicted aircraft positions and velocities take account of uncertainties such as wind modelling and prediction errors, tracking, navigation and control errors, human errors. In-crossing rates are then evaluated for the whole encounter, or period of potential conflict. The collision risk is evaluated by integrating these in-crossing rates with respect to time. In this way all dynamic aircraft behaviour is incorporated in the probability of collision between the two aircraft for the time period considered.

3. HIPS

Background

The Highly Interactive Problem Solver (HIPS) was developed as a graphical planning tool within the Programme for Harmonised ATC Research in Eurocontrol PHARE, (Maignan 1994). It was designed to enable en route planning controllers to generate conflict-free clearances through sectors in domestic European airspace. The concept is, however, relatively generic, and more recent applications of HIPS have been in areas as diverse as oceanic control (Meckiff, 1998) and experimental Cockpit Display of Traffic Information (Hoffman et al., 2000). This section briefly presents the basic HIPS concept. Details of how they were adapted are given in the following section.

Concept

The HIPS approach to conflict resolution support uses a system of geometrical projections and transformations of trajectories in 4D to show aircraft-free manoeuvre space ***a-priori*** in a static time-independent form. Using this the controller can see where solutions are to be found before trialing a new proposal. The advantages of this approach include: quicker search process; better awareness of solutions which might not otherwise be considered and the possibility to insert more 'optimal' solutions, for example to minimise deviations or leave aircraft at their preferred cruise level for longer. The key point about HIPS is that the resolution process remains firmly in the hands of the controller, the role of the computer being limited essentially to the presentation of graphical information.

No-go zones

As a starting point this technique requires that each aircraft in the system has a predicted 4D trajectory. In PHARE, aircraft were supposed to closely follow a 'contracted' trajectory, so prediction uncertainty was, theoretically at least, well contained. This is not the position of this study, which assumes that uncertainties exist and explicitly handles them.

To get an idea of how HIPS works in plan view consider Figure 1. Here aircraft BA123, is traversing the airspace from west to east, and its trajectory is predicted to be in conflict with that of another aircraft, DH456, which is travelling in a northerly direction. The portion of BA123's trajectory for which there will be a loss of separation is marked with a thicker line. If it is now decided to solve the conflict by changing BA123's course, various options could be tested assuming a fixed point as our start of turn. For each 'trial plan' a conflict check could again be made, with any loss of separation marked on the trial trajectory in bold as before.

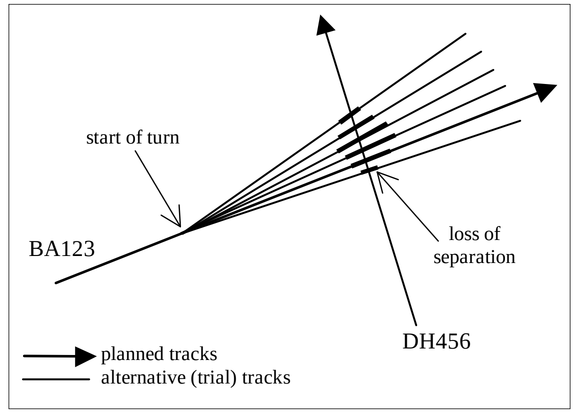

Figure 1: Conflicts on trajectory and trial plans

The essence of the HIPS approach is to eliminate the need for such a time-consuming process. It does this by effectively performing a series of trials automatically, and presenting the results *a-priori* in the form of 'no-go' zones, which correspond to the grouping together of all the bold lines, as shown in Figure 2. This provides a visual device by which the controller can see, in this case, that the conflict can be solved by a relatively small southward, or larger northward deviation to BA123.

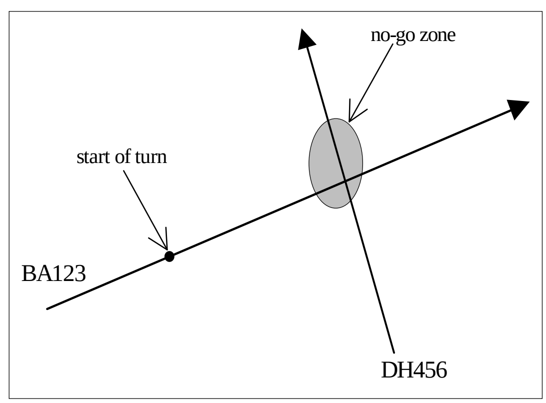

Figure 2: Derived no-go zone

Practical implementation of no-go zones

The technique described above illustrates the principle of no-go zones, but in practice this particular approach is unusable for a number of reasons. Several new techniques were thus developed, and in particular the novel concept of 'manoeuvre surface' was exploited in the PHARE version of the tool. Actual methods for generating the HIPS displays are not discussed in detail here - the reader should consult the references for further information.

Trajectory editing

Once the no-go zones are displayed in an appropriate way, it is a relatively simple matter for the controller to edit the 'subject' trajectory using simple mouse click and/or drag operations. Editing functions normally allow for adding, deleting and moving constraint points, insertion of doglegs etc. The original versions of HIPS allowed changes in horizontal, vertical and/or speed/time dimensions, but this paper only considers horizontal changes.

4. Probabilistic HIPS

The next step was to integrate the probabilistic conflict approach within the HIPS to result in a 'probabilistic' HIPS. Since a version of HIPS was already integrated into NLR's ATC research simulator (NARSIM) for the PHARE Demonstration 3 Continuation Project (Post, 2000), much of the NARSIM/PD3/HIPS environment was used, giving a full function high quality simulation environment. Adaptations to the simulation environment are briefly described below.

Probabilistic collision detection

The most important change to the original HIPS software was obviously the addition of a core probabilistic collision detection routine using existing NLR software. The simple technique illustrated in Figure 1 was adapted to 'mark' the portions of aircraft trajectory for which the *collision risk* was greater than a specified threshold, and this was then extended to build up the no-go zones. In practice this meant that the core probabilistic detection routine was triggered several times for the evaluation of each no-go zone. More specifically, a no-go zone was made up of start and end points of the conflict lines, which were generated for the subject aircraft trajectory and its set of alternative (trial) trajectories, relative to the trajectories of other aircraft. (In contrast to the illustration of Figures 1 and 2, the 'trial' trajectories were in fact a set that ran parallel to the subject trajectory – see Meckiff, 1998 for details.)

HMI changes

To allow easy comparison between geometric and probabilistic results, the HMI was changed to show both sets of no-go zones superimposed. This was done by just showing the borders of each no-go zone (red for geometric and pink for probabilistic). In earlier versions of HIPS the zones were always filled. Note that since this was an experimental HMI, presentation and colours were not optimised.

Calculation performance

Some changes were made in order to achieve "workable" performance for controller evaluation. However, dynamic, real-time behaviour (as in the original HIPS) was not possible due to significantly long calculation times. This meant:

- no calculation of vertical no-go zones
- no dynamic recalculation of no-go zones during dragging of the trajectory - the zones were only calculated after the mouse button was released.

In any real-life application these two concessions would significantly undermine the value of HIPS. However the experimental nature of this work, and regular and substantial increases in computing power render them insignificant for now.

5. Experiments and results

The goal of the experiments was to perform limited validation and tuning of the probabilistic HIPS with the support of an air traffic controller. This was also to be partly a confidence-building exercise. In order to do this, the controller was first familiarised with the NARSIM PD3 system and HIPS in particular, and was shown an initial probabilistic HIPS using a set of default parameter settings for collision detection. The controller's resolution strategy was then examined for a number of basic nominal encounter scenarios for a single aircraft pair. This information was used to tune the parameter settings for each specific encounter such that the resulting no-go zones matched the controller's perception of the traffic situation.

Types of encounter

Each experiment consisted of an aircraft in a typical (nominal) encounter situation with a second aircraft, both flying level and at the same altitude. Four encounter types were considered: crossing (approximately 90 degrees difference in course), head-on, in-trail and overtaking.

Parameter settings

For both conflict modelling approaches (geometric and probabilistic), several parameters can be set. For the geometric approach this includes separation standards and uncertainties in trajectory prediction. In our experiments, the geometric settings from the PD3 experiments were used unchanged i.e. a 5NM separation standard was used. For the probabilistic approach four 'tuneable' parameters were considered in the experiments. The first three were the uncertainties in the predicted aircraft trajectories (standard deviations along track, across track and height). The fourth parameter is the risk threshold. Note again that the risk used here is the predicted risk of *collision* between two aircraft, not risk of loss of separation, which means that values are of the order of 10^{-4} to 10^{-8} (risk of loss of separation would, of course, be substantially higher).

For each of the four encounter types, three experiments were executed with collision risk thresholds set at 10^{-4}, 10^{-6} and 10^{-8} respectively. The results are shown using screendumps of the Plan View Display (PVD), in which the subject aircraft is indicated by the filled pink label, and its trajectory is in green (in general the *subject* aircraft is the one selected for replanning/rerouting by the controller). The no-go zones are generated in each case for a single conflicting aircraft. To allow comparison of the geometric and probabilistic approaches, the two zones are superimposed – with just the border of each zone being shown. In each case the red line shows the border of geometric no-go zones and the pink line shows the border of probabilistic no-go zones.

5.1 Crossing conflicts

The first experiment involved a crossing conflict between two aircraft in level flight at the same level. The aircraft with callsign MSK231B (filled label) is selected as the subject aircraft, DLH6352 is the conflicting aircraft. Thresholds for the collision risk are 10^{-4} (Figure 3), 10^{-6} (Figure 4), and 10^{-8} (Figure 5).

As expected, the probabilistic no-go zone becomes larger with a decreasing risk threshold. The size of the zones is worth noting: despite the complexity of the probabilistic model, the order of magnitude of the result in each case appeared intuitively 'correct'. In particular it is interesting to note that when the risk threshold is 10^{-6}, the probabilistic no-go zone is almost identical to the geometric one: it has the same size and the same shape (in fact the pink zone is almost invisible since covered by the red). The controller made a subjective assessment of the displays from the perspective of a 'planning' (not executive) role, and felt most comfortable with the zone generated for risk threshold 10^{-6}, possibly because it corresponds well to his 'mental picture' of a 5NM separation.

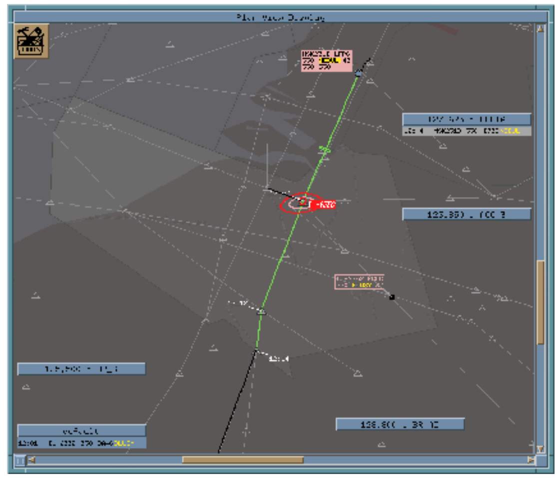

Figure 3: Crossing conflict, risk threshold 10^{-4} (red=geometric, pink=probabilistic)

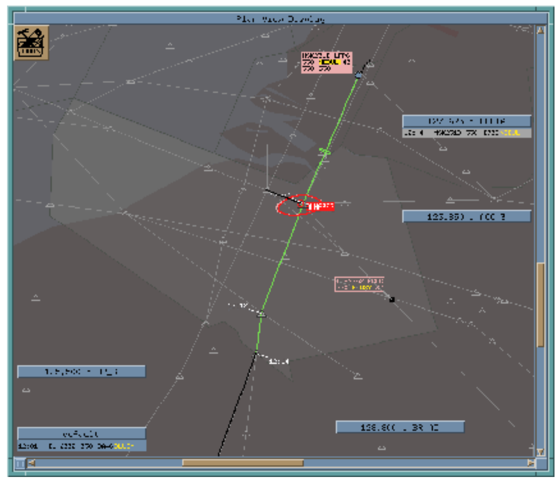

Figure 4: Crossing conflict, risk threshold 10^{-6} (red=geometric, pink=probabilistic)

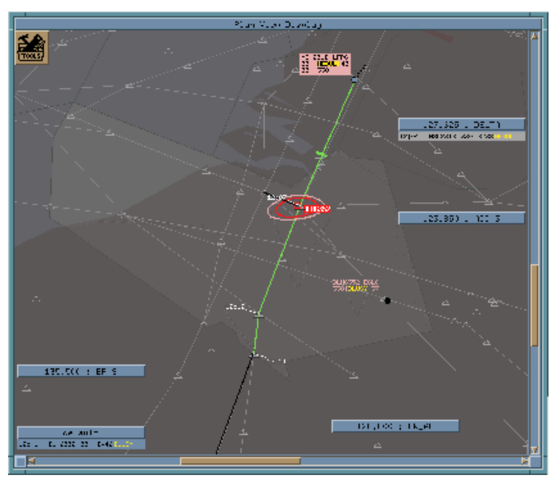

Figure 5: Crossing conflict, risk threshold 10^{-8} (red=geometric, pink=probabilistic)

5.2 Head-on conflicts

The second experiment is a head-on conflict between two aircraft at the same flight level. The aircraft with callsign MSK231A (filled label) is selected as the subject aircraft, MSK231B is the conflicting aircraft. The thresholds for the collision risk are 10^{-4} (Figure 6), 10^{-6} (not shown) and 10^{-8} (Figure 7).

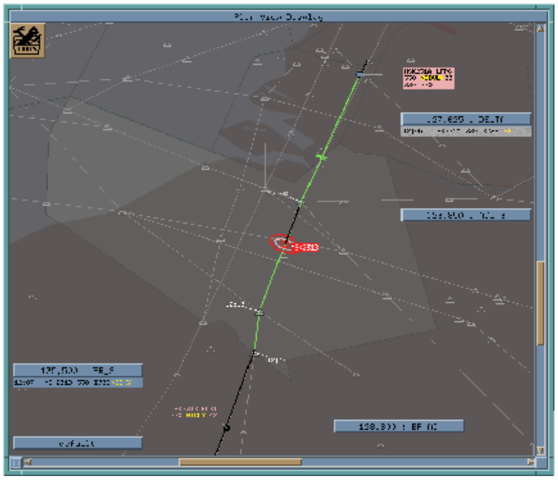

Figure 6: Head-on conflict, risk threshold 10^{-4} (red=geometric, pink=probabilistic)

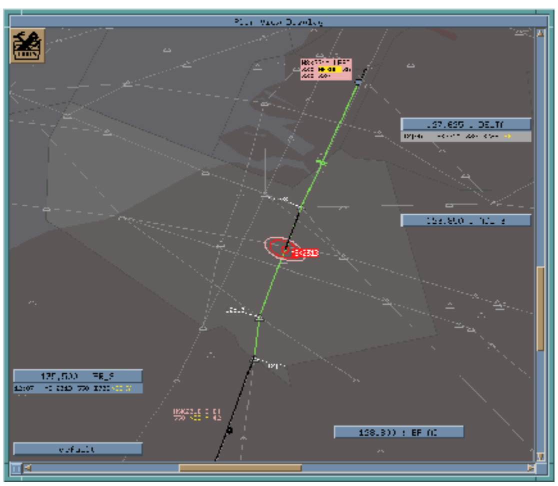

Figure 7: Head-on conflict, risk threshold 10^{-8} (red=geometric, pink=probabilistic)

Only the two extremes are shown here - again the no-go zones for both the geometric and the probabilistic approach are similar in the case of a risk threshold of 10^{-6}. Decreasing the risk threshold to 10^{-8} results in a larger probabilistic no-go zone as expected. However it increases more across the trajectory than along the trajectory. Increasing the threshold to 10^{-4} results in a smaller probabilistic no-go zone. In all cases it is clear that there is a conflict, but at a threshold of 10^{-4} the zone becomes very small.

Due to the high rate of closing between the conflicting aircraft, the air traffic controller naturally perceives this type of conflict as very serious. He would normally solve it as early as possible often by changing both aircraft trajectories to provide safe separation. From the figures, it can be seen that the no-go zone approach does not easily support this type of solution at all, and the controller did not find the HIPS planning tool very suitable for this type of conflict. Much more useful would be a no-go zone more in appearance like that of the 'trailing aircraft' experiment (see below) i.e. relatively long along the aircraft trajectory in order to prompt early resolution.

So in this case the controller was not very satisfied either with the geometric no-go zone nor with any of the probabilistic no-go zones as in Figures 6 and 7. However it was agreed that with the probabilistic approach it might be possible to tune the shape of the no-go zone, and in particular to take into account rate of closing of the aircraft pair. Time did not permit this during the study, but this possibility is further discussed below.

5.3 In-trail and overtaking

An in-trail conflict is one that occurs between two aircraft flying at the same speed, same flight level and track. Here the aircraft with callsign MSK231B (filled label) is selected as the subject aircraft, MSK231A is the conflicting aircraft. The same three thresholds as before were used for collision risk, but only the two extremes are shown here: 10^{-4} (Figure 9) and 10^{-8} (Figure 10).

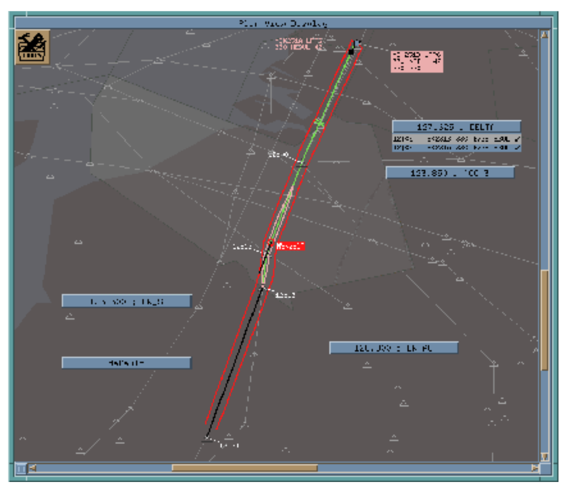

Figure 9: Trailing conflict, risk threshold 10^{-4} (red=geometric, pink=probabilistic)

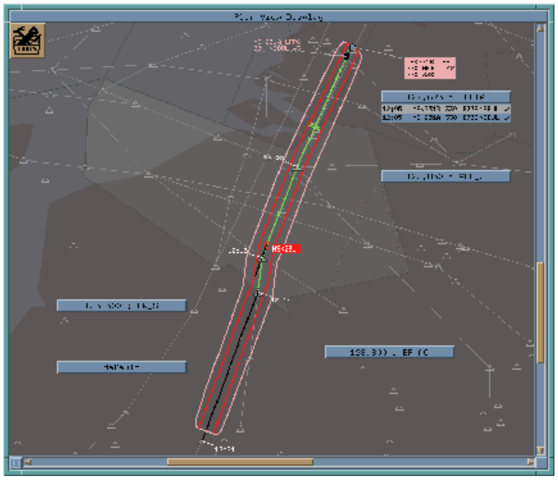

Figure 10: Trailing conflict, risk threshold 10^{-8} (red=geometric, pink=probabilistic)

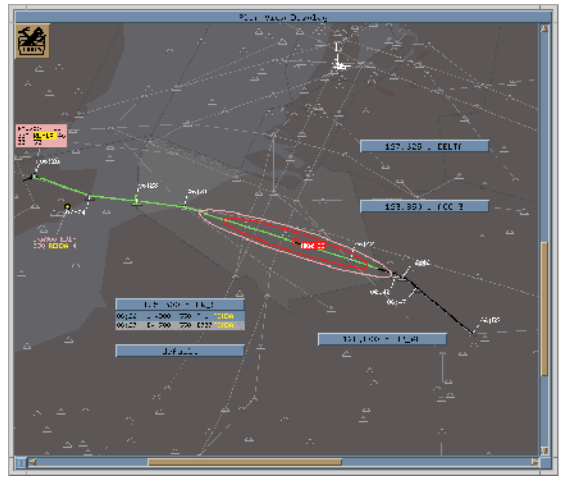

Figure 12: Overtaking conflict, risk threshold 10^{-8} (red=geometric, pink=probabilistic)

A similar pair of results is given for overtaking conflicts, where two aircraft are flying at the same level, similar (but not the same) tracks, with one behind and travelling faster than the other. In this case the aircraft behind, with callsign BAW700 (filled label) is selected as the subject aircraft, UKA900 is the conflicting/target aircraft. The thresholds for the collision risk are 10^{-4} (Figure 11) and 10^{-8} (Figure 12).

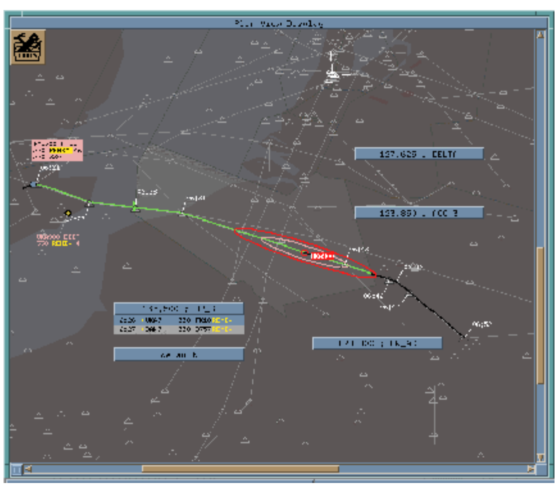

Figure 11: Overtaking conflict, risk threshold 10^{-4} (red=geometric, pink=probabilistic)

These types of conflict tend to result in rather long no-go zones for the geometric approach (red), covering a large part of the display. Evidently this gives problems in practice, since in realistic situations with a number of aircraft following similar routes, a number of large overlapping zones could be generated. The situation is much improved by using probabilistic zones. Intuitively the risk of actual collision is small when aircraft are flying at similar speeds on similar routes. This is particularly evident from Figure 9, where the collision risk threshold is set to 10^{-4}, resulting in almost complete disappearance of the no-go zone. Similar (but not such extreme) results are visible in the case of the overtaking aircraft, although here the zones are slightly larger since potential lateral deviations in trajectories could be more troublesome.

As noted above in the comments on the head-on conflict, rate of closing of an aircraft pair becomes a significant issue for the controller's perception of the severity of a conflict and for his resolution strategy. A low rate of closing leaves more time to solve the conflict, so the situation is perceived as less severe than, for example, a head-on conflict, for which the rate of closing is much higher. In cases where there is low rate of closing, the controller does not need to solve the conflict with the urgency that might be suggested by the geometric no-go zones. Much better results are obtained with probabilistic approach, using a high collision risk threshold (e.g. 10^{-4} instead of 10^{-6} or 10^{-8}). This aligns well with the subjective opinion of the controller.

6. Discussion

Geometric versions of HIPS have previously been included in a number of simulations. Difficulties were observed where no-go zones, although geometrically 'correct', sometimes didn't well represent the controllers' perception of the nature and severity of the problems. Another frequent problem was the presentation of too much information, especially with dense traffic generating too many large no-go zones, rendering the result unusable in practice.

The results presented above indicate that it is possible to rework the shape and size of no-go zones while still remaining on a sound theoretical basis. It would, of course, always be possible to define no-go zone characteristics entirely on the basis of heuristics or subjective controller perception, but that is not the approach of this paper.

The experiments have shown that for crossing conflicts, there is a close correlation between geometric results, probabilistic results, and the controllers' perception of the nature of a conflict. Moreover, a collision risk of 10^{-6} programmed into the probabilistic algorithms resulted in zones almost identical to those generated for a 5NM geometric separation.

For head-on conflicts it seems clear that HIPS in its present form is not an appropriate tool for supporting the display and resolution of conflicts. Some significant re-engineering of the zones is required here.

Finally, for in-trail and overtaking conflicts the probabilistic approach is shown capable of generating zones which are significantly more useful to the controller than the geometric approach.

The probabilistic approach can offer new options while remaining on a sound basis in at least two ways:

- By setting the level of safety according to the desired risk threshold (see below).
- By explicitly accounting for the accuracy (or uncertainty) of the aircraft trajectory. In a real application this will be based on empirical or calculated data, could vary from aircraft to aircraft, and could be time-dependent.

Controller perception of risk

This study also opens up a number of questions with regard to how controllers perceive risk (or safety) associated with a particular conflict situation. Apparently the 'cognitive processing' of the controller will accept the existence of some situations which the theory shows are relatively high risk. For example, in the case of in-trail or overtaking conflict, the controller in this study felt comfortable with a display that depicted zones calculated with probability of collision of 10^{-4}. In these cases the acceptability was clearly modulated by the fact that should the situation become more serious, then there was more time to act to resolve the problem. In the case of head-on conflicts the situation was the inverse.

It is clear that when a human is in the loop, the 'mathematics' does not always correspond directly to human perception. The more general discussion of whether the theoretical output is more appropriate than human judgement will not be pursued here, however these observations could have implications for the design of tools based on probabilistic methods, in ways which are both negative and positive. Negative, since tools might be developed which generate output that is counter-intuitive to controllers, and therefore unacceptable. Positive, since it gives an opportunity to intelligently tune decision support tools for maximum efficiency by, for example, incorporating factors such as closing speed into the formulations (this might be more difficult if output were based purely on geometric criteria).

Tuning for safety

A key single issue for air traffic control is safety. Since HIPS was foreseen as a tool for a *planning* controller, it can be said to be non-safety critical. On the other hand, the planning controller is one 'filter' in a process which might include, flow management, a tactical controller, STCA alerts, TCAS, pilots' visual awareness etc.

The collision risk based approach could support the "conflict filtering process" by setting the risk threshold according to a desired level of safety for the function. A small collision risk corresponds to a high level of safety and yields a large no-go zone, while a high risk threshold yields a small no-go zone. This key feature is significant in that it shows the potential conflict area only if it is probable, with a known level of safety judged appropriate for the planning function. Whether this could be a helpful support to the controller is not yet clear, nevertheless by integrating the probabilistic approach it could be possible to intelligently distribute safety by control layer (e.g. between the planning controller, tactical controller, STCA and TCAS).

7. Conclusion

This paper has described the results of a study designed to investigate the potential of probabilistic conflict detection within the context of planning controller support. To support this investigation, two known techniques were integrated into a prototype tool. The first is probabilistic conflict detection based on the generalised Reich collision risk equations (Bakker & Blom, 1993). The second is the Highly Interactive Problem Solver (HIPS) developed by the Eurocontrol Experimental Centre. A set of small-scale real-time experiments was carried out with the resulting prototype tool.

A fundamental issue for any support tool is controller acceptability. Small-scale experiments with the first version of the probabilistic HIPS were therefore performed with support from one controller. During these experiments, feedback was gathered on the perception of severity of conflicts, and resulting control strategy. In particular, comparison with the geometric approach, and representational issues of the conflict zones were considered. In general there was a clear preference for the probabilistic approach over the geometric approach.

With respect to safety, it is perhaps most interesting to quote from the air traffic controller who supported the experiments:

> *"Finding conflict areas by determining the probability of the conflict occurring and thus setting limits to the probable area could be achieved by adjusting parameter settings ... In ATC it is normal to always ask for a high level of safety, but filtering out potential conflicts at an early stage could in my opinion give a filter designed to catch, say, 95% of the foreseen predictable conflicts. The tactical controller is then left to solve almost all of the remaining problems, with STCA and TCAS as safety nets in case something slips through*."

and

> *"All this is supported by the probabilistic approach and suggests that this method could be used as a general technique, giving the possibility to incorporate the level of exactness in all calculations and assist in the setting of safety standards."*

Further work

This has been an exploratory study, which shows that HIPS can be improved by using a probabilistic approach for its conflict detection algorithms, rather than a geometric one. There is much potential for further research, and to make progress towards any operational implementation further study would include:

- Extended experiment scenarios. Four simple nominal scenarios between two aircraft were evaluated. These scenarios must be extended to incorporate multiple aircraft, vertical (climbing /descending) conflict situations and non-nominal situations (e.g. missed manoeuvres).
- Integration of a full probabilistic trajectory predictor which includes uncertainties in meteo information, aircraft behaviour/capabilities/ equipment, manoeuvre uncertainties, airline specific procedures, controller strategy and equipment, etc.
- Distribution of safety by control layer, in particular by taking a closer look at the roles of planning and tactical controllers given that the planner would have a means of solving a high proportion of conflicts with a known level of safety.
- A closer look at the implications of explicitly introducing probabilities into the control process.
- A closer look at the benefits and techniques for integrating rate of closing and risk threshold setting. It became clear that the rate of closing between two conflicting aircraft plays an important role in the controller's perception of the severity of a conflict and his resolution strategy.

Acknowledgement

Thanks are due to Leif Lundqvist for his constructive support during the experiments.

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