Accuracy Comparison of an Operational and Experimental Strategic Conflict Probe

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Overview

- Introduction
- Previous Work
- Conflict Probe (CP) Terminologies
- New CP Model
- Comparison Experiment vs. Operational CP
- Conclude – Questions and Answers

Introduction

- Air traffic controllers (ATCs) monitor assigned aircraft, and separate air traffic to ensure safety and efficiency
- Conflict is loss of the minimum separation standard between aircraft pairs, aircraft and airspaces, or aircraft and weather
- Conflict probe (CP) is an important component of decision support tools (DSTs)
- Alerts ATC of potential conflicts normally up to twenty minutes into the future, i.e.:
  - User Request Evaluation Tool (URET)
  - En Route Automation Modernization (ERAM)

Introduction (cont.)

- ERAM is replacement to the Host Computer System and URET
- NextGen Separation Management: Modern Procedures
  - Improvement to the ERAM DST to mitigate the safety risks of increased traffic growth
  - Introduces new concepts for future separation management functions
  - Computer human interface enhancements
  - Algorithmic enhancements to the CP to increase the usability

- **Goal: Experiment with new CP model to begin the process of identifying prospective areas for improvements to the separation management task.**

Previous Work

- CP model first used to approximate conflicts across the NAS in the U.S.A to characterize conflict properties
  - Knowledge of these geometries relate to complex models estimating the probability that a conflict is detected
  - Relationship of the geometric variables to the uncertainty of conflict predictions
- Conflict properties such as:
  - Encounter angle
  - Conflict duration
  - Vertical phase of flight at conflict start time
  - Number of conflicts per unit time
  - Number of conflicts by altitude levels
- CP Model called Trajectory Conflict Probe (TrajCP)

CP Terminologies (cont.)

	CONFLICT OCCURS	CONFLICT DOES NOT OCCUR
ALERT	CP predicts conflict and it occurs (VA: valid alert)	CP predicts conflict and it does not occur (FA: false alert)
NO ALERT	CP does not predict conflict and it occurs (MA: missed alert)	CP does not predict conflict and it does not occur (NC: correct no-call)
Total Number of Alerts	Total Number of Conflicts	Total Number of Non-Conflicts (Encounters that did not have conflicts)

CP Terminologies (cont.)

Time Metric	Definition
Warning Time	Amount of lead time between the ATC being notified of the predicted conflict and the conflict actually occurring.
Deletion Lag Time	Amount of time it takes a CP to delete the notification of a predicted conflict after the conflict has actually ended.

Conflict Probe Strategies

- Accurate CPs attempt to do the following:
  - Minimize the number of false alerts
  - Minimize the number of missed alerts
  - Maximize the number of valid alerts
  - Maximize the warning time of conflict predictions
  - Minimize the time it takes the system to delete prediction after separation violation no longer occurs

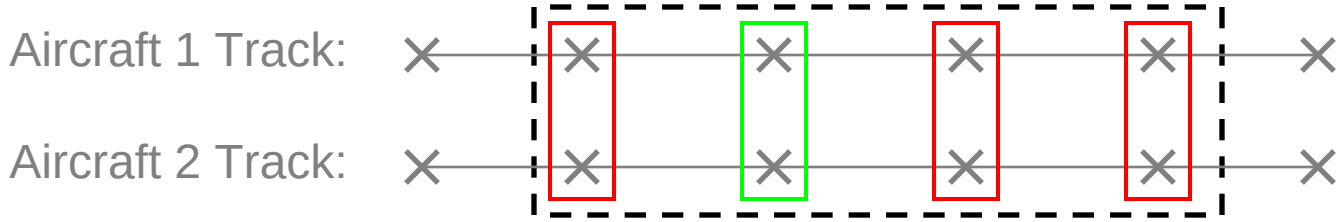
- Performance Trade-offs
  - Reduce missed alerts at the cost of increasing false alerts

Conflict Probe Model

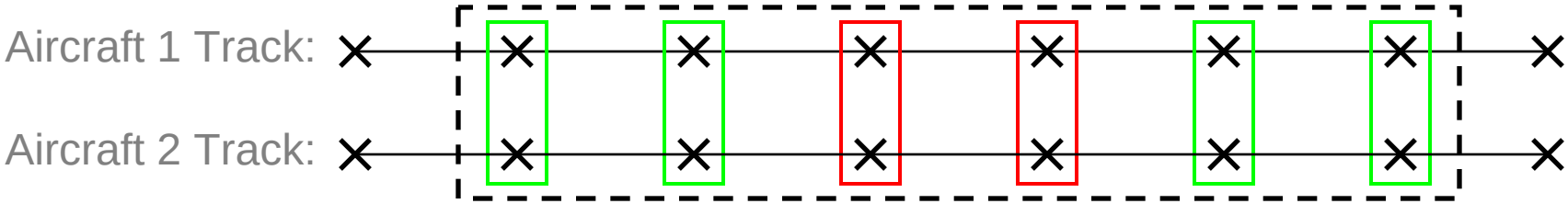
- TrajCP is conflict probe model designed in a unique manner
  - Modular design to plug different trajectory predictor models
  - Probes for potential conflicts for every radar track report
  - Uses I of J logic in the decision making process in the system consideration of addition or deletion of alerts
    - J – number of track reports used conflict prediction consideration window
    - I – the number of track reports where a successful predicted conflict consideration is made

Alert Notification: I of J Example

- Add alert notification
  - I of J = 3 of 4 to add/accept notification of conflict alert



- Delete alert notification
  - I of J = 4 of 6 to delete notification of conflict alert



TrajCP Input Parameters

- I of J setting for the start of conflict prediction alerts
- I of J setting for the end of conflict prediction alerts
- Look ahead time – the amount of time in the future probed for a potential conflict (i.e., 20 minutes)
- Minimum horizontal separation – the horizontal separation value defining a separation violation (i.e., 5 nautical miles)

**** Only inputs studied in this paper ****

Optimizing Input Parameters Experiment

- Factorial experimental design was instituted in the performance optimization of TrajCP
- Responses were as described previous in typical CP strategies (i.e. minimize false alerts)
- Results of the this experiment is presented below

Parameter Setting	TrajCP-Recorded	TrajCP-HybridMerge
Add: I of J	5 of 5	25 of 25
Delete: I of J	10 of 10	20 of 25
Look Ahead Time	25 minutes	25 minutes
Min. Horz. Sep.	9 nmi	9 nmi

Comparison Experiment

- TrajCP was develoepd as a test bench to plug different TPs and configurable CP settings
- TrajCP was tested against an operational CP, URET, under two settings
  - Trajectories generated by in-house simple hybrid algorithm using deck reckoning and flight plan modeling techniques (TrajCP-HybridMerge)
  - Trajectories loaded from archived trajectories from external system (TrajCP-Recorded)
    - For experiment had access to archived trajectories from URET
- Both TrajCP settings were executed on 6-hour ZDC air traffic scenario from March 17, 2005
  - Same used in ERAM Formal Acceptance Test
  - Time-shifted to induce “pseudo-conflicts”
- Conflict prediction accuracies were compared and evaluated in the hope to discover areas for CP enhancements

Accuracy Results

Conflict Prediction Metric	URET	TrajCP-HM	TrajCP-Rec
Valid Alert (VA)	237	233	228
Missed Alert (MA)	5	9	8
False Alert (FA)	98	34	61
Verified Conflicts	242	242	236
Verified Alerts	335	267	289
R(MA)	0.0207	0.0372	0.0339
R(FA)	0.2925	0.1273	0.2111
Avg. Warning Time	00:04:44	00:03:59	00:08:32
Med. Warning Time	00:02:23	00:01:10	00:04:20
Avg. Deletion Lag Time Time	00:02:56	00:07:48	00:05:09

Comparison Metrics

- Algorithm to match cases and compare the performances of two CPs
- Identifies areas where discrepancies between different CPs occurred
  - **VA_MA** – first CP correctly predicted conflict where the second CP did not
  - ***MA_VA*** – vice versa from above
  - ***FA_NC*** – first CP predicted conflict and it did not occur where the second had no-call
  - ***NC_FA*** – vice versa from above

Crowell, Andrew, Confesor Santiago, "An Algorithmic Method for Regression Analysis of Conflict Probe Accuracy," *Proceedings of the American Institute of Aeronautics and Astronautics (AIAA) Guidance, Navigation, and Control Conference,* August 2009.

Comparison Results

Comparison Result	URET vs. TrajCP-HM	URET vs. TrajCP-Rec
VA_MA	9	4
MA_VA	5	1
FA_NC	78	66
NC_FA	8	17
SAME_VA	225	223
SAME_MA	0	4
SAME_FA	19	27

URET vs TrajCP-HybridMerge

- VA_MA (9)
  - Aircraft in the flight pair being given an interim clearance altitude and TrajCP-HM modeled leveling off at it
  - HybridMerge TP having poor along track error
- MA_VA (5):
  - URET unable to build trajectories
  - TrajCP-HM finer interpolation in the modeling of trajectories and processing for probing conflicts
- FA_NC (78):
  - Many times URET had multiple conflict notifications in small amount of time, where TrajCP-HM handles the absorption of multiple notifications to present one alert
  - Many in-trail conflicts
- NC_FA (8):
  - Increase of min. horz. separation to 9nmi introduced more FAs

URET vs TrajCP-Recorded

- VA_MA (4)
  - At times the missed alerts are predicted to come within 1,000 feet of each other; maybe URET includes 1,000 separations as conflicts (greater than or equal discrepancy)
- MA_VA (1):
  - Finer interpolations enabled TrajCP-Recorded to have in the modeling of trajectories and processing for probing conflicts
- FA_NC (66):
  - Similar issue as before in TrajCP, many times two separation alerts generate by URET are only modeled as one
  - Many in-trail conflicts
- NC_FA (17):
  - Same as before with TrajCP using 9nmi

Conclusion

- Presented a new CP model that performs in the ranges of URET
- Better trajectory modeling capability would result in performing closer to URET
  - Implement similar trajectory modeling capable as in URET to handle interim altitudes
  - Decrease along track error (need to include aircraft performance data)
- Probing for conflict every track report with I of J logic help decrease number of false alerts
- CP accuracy is very dependent on the accuracy of the predicted trajectory
  - Fine sensitivities (interpolation, modeling interim and other restrictions)
  - Suggest operational CP developers to investigate this
- These findings help lead research to identify prospective areas for improvements to the Conflict Probe
- In the future, we hope to experiment with other scenarios and improve the trajectory modeling capability TrajCP

Questions?

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