COMPLEXITY OF SPEED RESOLUTIONS - CONFLICT DENSITY

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Introduction – Layered Planning

- Total system capacity = \( \sum (\text{Capacity of layer}) \)
- Total system safety = \( \pi (\text{Safety of layer}) \)

IF layers orthogonal

1. J. Varela, 2004, EUROCONTROL Operational Concept Document V2.1, FCO.ET1.ST07.DEL01
3. Anonym, Co-operative Air Traffic Management Concept (CATMAC) - Betriebskonzept für die Durchführung der Flugsicherungsdienste im Bereich der Bundesrepublik Deutschland, Bundesanstalt für Flugsicherung (DFS)
7. H. de Jonge, M. Sourimant, 2004, Gate to Gate Integrated Operational Concept (Consolidated Description) Issue 1.1, Gate to Gate consortium
Instantiations are MSP and Supersector

Traffic Organisation functional layer:
- would provide system safety and capacity
- complexity of this function exceeds human capabilities and is therefore suited for automation

Problem: Investigate Complexity of Speed Resolutions

Result of study The Potential Of Speed Control

- Baseline 1997 traffic = 100%
- Increased to 150, 200, 300% traffic
- Karlsruhe, Reims, Maastricht
- Executive Planning Controller (PC) issues only speed clearances, 15 minutes look-ahead
- PC separates aircraft to 7NM resp. 15NM
- Tactical Controller (TC) gives only speed clearances
- TC separates aircraft to 5NM resp. 10NM

Resolution rates and conflict counts over traffic increase and PC-TC separation minima

11. R. Ehrmanntraut, 2004, The Potential Of Speed Control, in proceedings of the 23rd DASC, Salt Lake City, Utah, USA
Illustration of Conflict Density
<p>| 16. | R. Ehrmanntraut, 2004, Analysis Of Aircraft Conflict Geometries In Europe, in proceedings of the 23rd DASC, Salt Lake City, Utah, USA |</p>
<table>
<thead>
<tr>
<th>No.</th>
<th>Author(s)</th>
<th>Title and Details</th>
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<tbody>
<tr>
<td>22.</td>
<td>Granger, G.</td>
<td>2002, Détection et résolution de conflits aériens : modélisations et analyse, IPT, Toulouse, France</td>
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<td>25.</td>
<td>N. Archambault</td>
<td>2004, Scheduling Heuristics For On-Board Sequential Air Conflict Solving, in proceedings of the 23rd DASC, Salt Lake City, Utah, USA</td>
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## Conflict Density: Definitions

<table>
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<tr>
<th>Formula</th>
<th>Definition</th>
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<td>$C_{SCT}$-DNS</td>
<td>Conflicts-in-Sector Density is the sum of all CPAs in a given sector during a time interval</td>
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<tr>
<td>$C_{RTE}$-DNS</td>
<td>Conflict-on-Route Density is the sum of all CPAs on a route leg during a time interval</td>
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<tr>
<td>$C_{NAV}$-DNS</td>
<td>Conflict-at-Navaid Density is the sum of all CPAs within a radius $R$ from a navigation aid during a time interval</td>
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<tr>
<td>$C_{CPA}$-DNS</td>
<td>CPA Density is the sum of superpositions of protection cylinders at the time of CPA during a time interval in a coordinate system</td>
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<tr>
<td>$C_{VOL}$-DNS</td>
<td>Conflict-Volume Density is the sum of superpositions of Conflict-Volumes during a time interval in a coordinate system</td>
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Illustration: Definition for Conflict Densities
Measured Airspace

[Image of a map showing various airspace sectors and boundaries]
Trajectory Density of Simulations

Density of trajectories for 100, 150 and 200% traffic
Conflicts-in-Sector Density (1)
Conflicts-in-Sector Density (2)
Sector & CPA Density

- OLNO, WESTH, WEST sectors by hour
- Different conflict counting methods
- Reduction of conflicts due to speed resolutions depending on conflict counting method
- 63 - 86% for 200% traffic sample
Sector-on-Route Density

Routes joining NTM and ARCKY (left) and NTM only (bottom)
Resolution Density

- Similar definition as conflict density
- $R_{SCT}$-DNS, $R_{RTE}$-DNS, $R_{NAV}$-DNS, $R_{CPA}$-DNS:
  - Resolution start time instead of CPA-time

Example:
Conflict count and resolution rates for combined OLNO and WESTH sectors
Resolution Density Example

- Unresolved conflict density not meaningful for operations
- Useful for simulations

Resolution density (unresolved, right column) in comparison to CPA density (left column) in 2h slices over Luxembourg area
Discussion

- Visualisation of conflict densities is easy tool to analyse complex situations
- Conflict clusters are static around navaids
- Conflict clusters are static on routes that spread from navaids
- Severity of hotspots seems to be non-linear with the traffic growth, but linear with conflict growth rate

- Speed control:
  - Positive effect on the system - reduces total number of conflicts
  - Direct impact on complexity
Conclusion

- New complexity parameters proposed
  - Conflict density, resolution density
- Powerful tool when visualised
- Gives argument for microscopic airspace modifications around hotspots to reduce conflict densities

- Interpretation:
  - Dynamic air routes organisation during a day to adapt to conflict patterns
- Speed resolutions reduce total number of conflicts by at least 8%
- Positive measure for Traffic Organisation