Identification of Spatiotemporal Interdependencies and Complexity Evolution in a Multiple Aircraft Environment

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Outline

1. Introduction
2. Problem definition
3. STI identification
4. CRT generation
5. Simulation results
6. Conclusions and follow-up research
Introduction (I)

Increased traffic demand: 50% increase in flights by 2035 comparing to 2012

Continuous pressure on ACC for SM provision

CA usually produces inefficient trajectory resolutions: higher vertical rate

Missed provision due to increased ATC workload & insufficient time for reaction: CA activation
Introduction (II)

- Goal: SESAR and NextGen toward future harmonization of air traffic operations through development of airborne and ground-based DMTs
- Response: project AGENT seeks for smooth and coherent transition between safety nets

**Trajectory Management** -> **Separation Management** -> **Collision Avoidance**

- Centrally controlled ATC interventions (agent-centered approach)
- More efficient conflict avoidance operations (multi-agent approach)
Introduction (III)

- AGENT claims for the collaborative and proactive SM system considering a socio-technological approach: multi-agent system (MAS)
- Driven by the certain SESAR KPIs
- ER-TRL 1: no ATC position fully considered
Introduction (IV)

- State-based CD function at strategic level and MAS-based CR algorithm at tactical level
- Assumptions:
  1. Lookahead time (LAT): 5’-to-CPA
  2. No uncertainty at TM level: a linearity of the trajectory segments within LAT
Problem definition (I)

- Designed for operations in traffic densities of 0.3 ac/NM²
- Excellent performances for pair-wise encounters
- Logic drawbacks due to induced collisions in complex traffic scenarios
- System-variant for closure rate changes towards CPA

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Problem definition (II)

Scenario evolution towards Ecosystem Deadlock Event (TW1 --- TW2 --- TW3)
Problem definition (III)

Rate of change in number of resolutions: amending capacity over ecosystem time
STI identification (I)

- **DEF:** set of aircraft inside computed airspace volume, with the trajectory-amendment, decision-making capability, causally involved in safety event

- **STI parameters:**
  1. $m_0$: RBT follow-up
  2. $m_1$: left HDG-C with DA of +30°
  3. $m_2$: right HDG-C with DA of −30°
  4. $m_3$: climb at VR of +1000 ft/min and FPA of +2°
  5. $m_4$: descent at VR of −1000 ft/min and FPA of −2°
STI identification (II)

→ Identification of two ST aircraft: A/C3 through HDG-C and A/C4 through VR

→ CI for a single RBT applying a DA of +30°
CRT generation

- Complexity of ecosystem evolution based on decreasing/perishable rate in number of CRTs over time
- CRT generation: set of TWPs + RWP to RBT
- CRTs evaluated one against another by computation of intrinsic complexity (complexity value larger than the values analogous to the TCAS TAs: proposal rejected

→ Locus of tactical waypoints for introducing delay to resolution
Simulation results (I)

- Historical traffic dated on 24/08/2017: DDR2_M1.so6 data format (flight plans)
- Traffic extraction in the selected period: 08:00 – 09:00
- Operational environment: ECAC en-route airspace above FL300
- Ecosystem test case: nominal structure (4 members)
Simulation results (II)

Evolution of acceptable and candidate RTs and complexity of the minimal complexity solution

Resolutions scenario I: Timestamp 0, lower complexity level
Simulation results (III)

Resolutions scenario II: Timestamp 100-seconds, medium complexity level (A/C1 and A/C2)

Resolutions scenario III: Timestamp 160-seconds, maximum complexity level (A/C1, A/C2 and A/C3)
Conclusions & follow-up research (I)

- Ecosystems creation to support automation at tactical level in the monitored airspace volume

- Analysis of the complexity levels coming from different traffic scenarios to increase the system robustness

- Smooth transition from the ecosystem membership identification to the acceptable candidate resolutions generation provides very valuable insight of the STI structure and a complexity level at a certain moment in a time evolution

- Number of the available RTs drops over time, for a fixed returning point of the intended trajectory; an exponential complexity trend due to chosen metric in evaluation

- Solutions can be compared on basis of the heading changes and delay propagation, followed by the minimal complexity value; prevention of the separation infringements in the horizontal plane, and provision of the compatible aircraft states with TCAS function in which the TAs would not be triggered
Conclusions & follow-up research (II)

- Analysis of the multi-thread conflicts with respect to time to the CPA
- Reduction of the computational time and an incorporation of the fine trajectory predictions for the ecosystem detection and resolution algorithms
- Extension of the parametric values for more robust STI testing
- Development of the agents’ negotiation process and a deterministic prediction of the EDE
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Thank you for your attention!

Questions?