Aircraft Atypical Approach Detection using Functional Principal Component Analysis

Gabriel JARRY

ENAC - The French Civil Aviation University

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Outline

1. Introduction
2. Atypical Approach Detection
3. Algorithm & Results
4. Conclusions
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Non Stabilized Approaches (NSA)

**Figure** – Stabilized¹ vs Non Stabilized Approach²

2. https://www.youtube.com/watch?v=u0osv1-khBs
Non Compliant Approaches (NCA)

Figure – Compliance Criteria

Operational Context

French Safety State Programme (SSP) :

- NCA identified as undesirable events\(^4\)
- Approach flight path safety management.\(^5\)

Accidents Study - DGAC 2015 :

- 57% NSA with 74% of them in NCA
- While stabilized 84% compliant
- 74% bad weather condition, 15% final approach downwind

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Main Idea and Objectives

- Approach Flight Path Safety Management
- For pilots or ATCs?
- Post-operational atypical behaviour detection algorithm
Available Mode S Radar Data

- Altitude, position
- Ground Speed vs Indicated Air Speed
- No weight information
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Detection

How can we detect atypical approaches?
Geometrical criteria for NCA detection

**Figure** – Lateral and vertical margin for NCA Detection
Non Compliant Approach Distribution

**Figure** – NCA types for operations at CDG Airport between December the 1st and December the 31st 2011

- Compliant - 77.1% (14529)
- Glide Deviation - 11.0% (2063)
- Too High - 9.0% (1700)
- Others - 2.9% (546)

Total NCA types for operations at CDG Airport between December the 1st and December the 31st 2011.
Glide Interception From Above detection tools at CDG Airport

**Figure** – GIFA detection tool using the APW at CDG Airport
Glide Interception From Above detection tools at CDG Airport

Actual detection approach do not use speed or energy information which are critical in approach and landing
Why to use a functional Approach?

**Figure** – Statistical approach
Why to use a functional Approach?

**Figure** – Functional approach
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Our Methodology

- Total Specific Energy:
  \[ E_t = E_c + E_p = \frac{1}{2} \cdot V^2 + g \cdot h \ (\text{J/kg}) \]

- Functional Principal Component Analysis
  \[ \gamma(t) = \sum_{k=0}^{K} \alpha_k \cdot \phi_k(t), \ (\text{K min}) \]

- Sliding Window to analyse portion of trajectories

- Operational criteria on ground speed for results comparison
Algorithm

FPCA

Trajectory Space

Outlier Scoring

Figure – Algorithm
New Ground Speed criteria

**Figure** – Ground Speed criteria from on-glide deceleration studies$^6$

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Case Study Analysis

- Runway 26L - CDG
- A320
- 25NM to runway threshold
Algorithm Results

**Figure** – Algorithm results over the whole trajectories
## Algorithm Results

<table>
<thead>
<tr>
<th>Trajectory Type</th>
<th>Number</th>
<th>Atypical</th>
<th>Nominal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Descent Approach</td>
<td>30</td>
<td>4</td>
<td>26</td>
</tr>
<tr>
<td>Glide Interception From Above</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Ground Speed Warning</td>
<td>12</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Nominal</td>
<td>1270</td>
<td>10</td>
<td>1260</td>
</tr>
</tbody>
</table>

**Table** – Result of our detection algorithm on different types of trajectory
Algorithm Results on Continuous Descent Approach

Figure – Continuous Descent Approach
Algorithm Results on Glide Interception From Above

**Figure** – Glide Interception From Above
Algorithm Results on Ground Speed Warning

Figure – Ground Speed Warning
Algorithm Results on Other Altitude Interception

**Figure** – Other Interception Altitude
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Conclusions

- Efficient atypical behaviours detection Methodology
- Landing approach application with specific total energy
- Encouraging results on case study analysis at CDG Airport
Perspective and Future works

- Operational validation with airlines
- NSA/NCA link study
- Atypical trajectory generation
- Online predictive tool
Questions

Thank you for your attention, any questions?