LiDAR Performance Requirements and Optimized Sensor Positioning for Point Cloud-based Risk Mitigation at Airport Aprons

A novel field of application for LiDAR-based Surveillance

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Agenda

• Motivation: Risk Situation on the Apron
• Research Approach
  • Methodical Selection of LiDAR
  • Experiences from a Field Test
• Risk Mitigation Concept
  • LiDAR Performance Requirements
  • Optimized Sensor Positioning
• Conclusions and Outlook
The Need for Risk Mitigation

- future aviation and ATM concepts call for improved safety targets (e.g. SESAR, ICAO GANP)
- the risk contribution of airport surface operations (injuries to human health and damage to material) should be considered
- surface operations take place on the movement area
  - maneuvering area

**Diagram:**

- Fatal accidents:
  - Taxi, load, unload, parked, tow: 12%
  - Takeoff: 12%
  - Initial climb: 8%
  - Climb (flaps up): 10%
  - Cruise: 8%
  - Descent: 4%
  - Initial approach: 10%
  - Final approach: 11%
  - Landing: 25%

- Onboard fatalities:
  - 0%
  - 16%
  - 14%
  - 13%
  - 16%
  - 4%
  - 12%
  - 13%
  - 12%

Exposure (Percentage of flight time estimated for a 1.5 hour flight):

- Taxi, load, unload, parked, tow: 1%
- Takeoff: 1%
- Initial climb: 14%
- Climb (flaps up): 57%
- Cruise: 11%
- Descent: 12%
- Initial approach: 3%
- Final approach: 1%
- Landing: 25%

Source: Boeing Statsum
Current (Risk) Situation at the Apron

- **airport apron** is “A defined area [...] intended to accommodate aircraft for purposes of loading or unloading passengers, mail or cargo, fuelling, parking or maintenance” [ICAO Annex 14]
  - manifold processes
  - various responsibilities
  - various environmental conditions
- aprons provide a highly **dynamic, heterogeneous environment**
The Apron – Is there a Safety Problem?

• “safety iceberg”-problem: incomplete/not publicly accessible reporting of safety relevant occurrences on the apron

• available statistics indicate the apron to account for a significant share of the total risk in aviation:
  - probability of apron personnel at US airports to be fatally/severely injured: $0.47 \times 10^{-6}$ per aircraft departure [NTSB]
  - 5 of 41 recorded ground occurrences at Australian airports FOD-related [ATSB]
  - US fatal accident rate during pushback: $2.12 \times 10^{-8}$ [NTSB, AIDS, ATADS]
  - $\approx$ $6.8$ million total costs of material damage resulting from ground handling accidents [Global Aviation Safety Network]

Sources: airdisaster.com, aviationpics.de

**Distribution of Australian Ground occurrences by location (except from the RWY)**

Research Approach

• operating principle on the apron: see-and-avoid

• Risk mitigation approach: improving surveillance capabilities of potential risk mitigators in the apron area by taking advantage of post-processed 3D point clouds

• the selection of LiDAR technology for point cloud generation results from analyses of related domains

• Requirements to allow comparability:
  • automated object detection, classification and tracking
  • deployed in dynamic, heterogeneous surroundings

→ Autonomous driving
Methodical Selection of LiDAR Point Clouds

Valuable LiDAR features

- capability to generate **3D point clouds**
  - major requirement for extracting 3D objects
- **high temporal and spatial resolution**
  - real-time extraction of geometric information from raw data
- **non-cooperative measurement principle**
  - independency from the target object
  - complying with SESAR ATM Target Concept D3
- **reduced dependency from environmental conditions**
  - compared to direct view and video

Source: Velodyne.com
Experiences from a Field Test
Experiences from a Field Test - Accuracy

- **Measurement graph:** varying fuselage height of a Boeing 757 over time during turnaround
- **Accuracy:** Standard deviation $\sigma$ of 3.7mm@43m
Experiences from a Field Test - Object Classification

- **Unique contours** of different aircraft fuselages discernable even for a **small number of measurement points**
Experiences from a Field Test - Object Classification

- Shading due to **line-of-sight** principle reduces number of measurement points
- Increasing distance to target reduces point density
Research Approach

**Apron Management Service, AMS** (local ATC unit/airport operator) as **starting point for risk mitigation**, 
- central authority “to regulate the activities and the movement of aircraft and vehicles on an apron” [ICAO Annex 14]
- can act at short notice
- close contact to all relevant apron stakeholders
- surveillance tasks mainly depends on “see-and-avoid”
Risk Mitigation Concept

• **central measure**: point cloud-based visualization and, if appropriate, automated situation interpretation to support the AMS in de-escalating from hazardous situations by...
  • **Recognizing emerging hazard indicators**
  • **Distribute information about critical situation development, terminate related operations if damage is inevitable**

• **safety-relevant events to be prevented**:
  • Collision/Contact of/between aircraft, vehicle or pedestrians
  • Damage caused by Foreign Object Debris (FOD)
The Risk Mitigation Concept - Visualization
LiDAR Performance Requirements

**Requirements imposed** on the LiDAR sensor/infrastructure (excerpt):

- to fully cover the apron "core zones" → at DRS≥200m range performance
- To recognize significant contours of relevant apron objects in real-time at least within 200m → vertical/horizontal resolution of ≤0.16°/1.3°

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Horizontal Field of View</th>
<th>Vertical Field of View</th>
<th>Range</th>
<th>Vertical Resolution</th>
<th>Horizontal Resolution</th>
<th>Type of Scan Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDL-64 S2</td>
<td>360</td>
<td>26,33</td>
<td>120m</td>
<td>0,4°</td>
<td>0,09°</td>
<td>Overlapping</td>
</tr>
<tr>
<td>OPAL 360HP</td>
<td>360</td>
<td>45</td>
<td>1100m</td>
<td>0,03°</td>
<td>0,0057°</td>
<td>Non-Overlapping</td>
</tr>
</tbody>
</table>

Sources: neptec.com, Velodyne.com
Optimized Sensor Positioning

Theoretical coverage of OPAL 360 series at maximum PRR
Conclusion & Outlook

Today presented:

✓ the need for improving the current safety level of apron operations
✓ risk mitigation approach (enhance situational picture, LiDAR point clouds, AMS as promising risk mitigator)
✓ surveillance concept sketched

In progress/ future steps

• hazard and cause analysis along Eurocontrol SAM
• detailing of risk mitigation measures as input for the surveillance concept
• 2nd field test to identify model parameters for the envisaged simulation-based validation
Questions – opinions – suggestions?

Thank you.

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