Three-dimensional laser scanning in aircraft surfaces

Universidad de los Andes

Who are we?

Daniel Páez - Luis Miranda
Environmental

Green roof allocation analysis

Technology

Laser scanner

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Technology

UAV Applications

Terrain - Survey studies

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Three-dimensional laser scanning test in aircraft surfaces

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Introduction

Summary graph, participants-inspection specimens A & B (Erchart, Ostrom, & Wilhelmsen, 2004)

SUMMARY OF FALSE POSITIVE (ERCHART, OSTROM, & WILHELMSEN, 2004)

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Background

- **State-of-the-art of non-destructive inspection (NDI) methods**
  - Visual inspection parameters affecting visual inspection
  - Parameters relevant to visual inspection for aircraft study are:
    - Inspection personnel qualifications and training
    - Inspection area access
    - Lighting
    - Pre-cleaning
    - Color.
    - Working environment factors

(Habermehl, Lamarre, & Roach, 2009)
Background

- **State-of-the-art of non-destructive inspection (NDI) methods**

<table>
<thead>
<tr>
<th>Line scanning thermography</th>
<th>Lamb waves</th>
<th>Lidar</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Dynamic thermal imaging technique</td>
<td>• Are elastic waves that are generated in a solid plate with free boundaries</td>
<td>• Light detecting and raging</td>
</tr>
<tr>
<td>• Presence of sub-surface features are revealed as thermal gradients on the surface</td>
<td>• Can be generated using piezoelectric transducers, etc.</td>
<td>• Proved that damage can be detected by a LIDAR scan and identified by human</td>
</tr>
</tbody>
</table>

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Background

- **Damage metrics**

<table>
<thead>
<tr>
<th>Category 1</th>
<th>Category 2</th>
<th>Category 3</th>
<th>Category 4</th>
<th>Category 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Undetected by direct field inspection</td>
<td>• Detected by direct field inspection</td>
<td>• Obvious damage detected within a few flights</td>
<td>• Discrete source damage immediately known by pilot</td>
<td>• Severe damage created by anomalous ground or flight events</td>
</tr>
<tr>
<td>• Allowable manufacturing defects</td>
<td>• Exterior skin damage</td>
<td>• Accidental damage to lower fuselage</td>
<td>• Rotor disk cut through fuselage</td>
<td>• Events that are outside of design considerations</td>
</tr>
<tr>
<td>• Damage below Allowable Damage Limit</td>
<td>• Interior stringer blade damage</td>
<td>• Lost bonded repair patch</td>
<td>• Severe rudder lightning damage</td>
<td>• Special directed inspections are needed</td>
</tr>
<tr>
<td>• Barely visible impact damage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Baaran, 2009)

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Terrestrial Laser Scanner

<table>
<thead>
<tr>
<th>Range error</th>
<th>Focus range</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>±2mm @10m</td>
<td>0.6m a 120m</td>
<td>to 70 Mpix</td>
</tr>
</tbody>
</table>

Speed of measure: 122000-976000 pts/seg, 30°/360°

General characteristics, Faro laser scanner (FARO, 2013)

Challenges
- Surface finish
- Material type
- Surface color
- Speckle pattern

(Drus, Harding, & Eric, 2011)

Case of study

Dent on A320 Leading Edge
- Laboratory situation
- Identified dent
- To measure the dent

A320 Nose Radome
- Laboratory situation
- To identify scratch
- To measure scratch

Aircraft wing to be tested
- Simulated practical situation
- To identify potentially harmful dents

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Methodology development

- Measurement planning
  - High efficiency, good accuracy and relatively low density
  - Avoid the challenges and noise mentioned on the Terrestrial laser scanner section

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Methodology development

- Measurement planning
  - High efficiency, good accuracy and relatively low density
  - Avoid the challenges and noise mentioned on the Terrestrial laser scanner section

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Methodology development

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  - High efficiency, good accuracy and relatively low density
  - Avoid the challenges and noise mentioned on the Terrestrial laser scanner section

Methodology development

- Identification techniques
  - By light intensity

Data pipeline and processing framework (Chen, Du, Jia, & Song, 2010)
Methodology development

- Identification technics
  - Surface shading based on an imaginary light adjacent to the surface

- Mensuration technics
  - By datum and maximum distance

Data pipeline and processing framework (Chen, Du, Jia, & Song, 2010)

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Methodology development

- Mensuration technics
  - Series of cubic splines by slices

Methodology development

- Mensuration technics
  - Series of cubic splines by slices

Data pipeline and processing framework (Chen, Du, Jia, & Song, 2010)

Results and discussion

- Measurement of the leading edge
  - By datum and maximum distance

<table>
<thead>
<tr>
<th>Measure</th>
<th>Distance [m]</th>
<th>Separation of scan lines [mm]</th>
<th>Separation scan point in line [mm]</th>
<th>Density scan mesh [pts/cm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leading Edge (tilt 1)</td>
<td>1</td>
<td>Not measurable</td>
<td>Not measurable</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>1.407</td>
<td>1.2</td>
<td>59</td>
</tr>
<tr>
<td>Leading Edge (tilt 2)</td>
<td>1</td>
<td>Not measurable</td>
<td>Not measurable</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.09</td>
<td>0.754</td>
<td>122</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>2.3</td>
<td>1.27</td>
<td>34</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measure</th>
<th>Extension [m]</th>
<th>Height [mm]</th>
<th>Depth [mm]</th>
<th>Measured [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flap (tilt 1)</td>
<td>53.72</td>
<td>71.8</td>
<td>9.899</td>
<td>3.94</td>
</tr>
<tr>
<td>Flap (tilt 2)</td>
<td>52.814</td>
<td>72.674</td>
<td>7.4</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>53.9</td>
<td>71.8</td>
<td>10.372</td>
<td>2.5</td>
</tr>
</tbody>
</table>

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FIG Working Week 2015  11
Results and discussion

• Measurement of the leading edge
  – Series of cubic splines by slices

![Diagram of leading edge measurement](image)

Difference between profile and dented profile

Results and discussion

• Identification on the nose radome
  – By light intensity

![Image of radome identification](image)
Results and discussion

• Identification on the aircraft wing

Conclusions

• The light intensity technic for identification of damages in an aircraft surface appears as a powerful tool.
• We found that TLS for aircraft surface inspection is not recommendable to measure at high incidence angles and at distances between 2 and 5 meters.
• The most reliable solution for the shiny surfaces challenge is to coat the surface. This might not be a viable solution for aircraft inspection because of cost and extra time required.
• With the mensuration technics analyzed, the best way was found to be a mean or approximate datum of the dispersion of the data and the range error.
• The described analysis of the laser scanner data does not describe a proved more reliable inspection than a technical human visual inspection.
## Questions?

<table>
<thead>
<tr>
<th>Name</th>
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<th>Address</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
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