Development of a Hi-Speed Near Real-Time 720i Image Processing Application for Flight Test

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• Test Point
• Goal: Altitude and Airspeed
• Reference Points
Introduction

• Images frames are used as information source to clearly pinpoint the aircraft behaviour at the FTC.

• Air Data System (ADS) Calibration FTC using the **tower-fly-by method** requires the knowledge of the exact aircraft reference altitude.

• The IPEV uses an off-line video processing application that computes the aircraft altitude from a snap-shot picture.
  
  — **Main disadvantage**: measurement accuracy is jeopardized.

• **Solution**: application to process 720i video frames at up to 400 fps to be used for ADS calibration FTC
Imaging Processing

Brightness +143% and Contrast + 79%
Imaging Processing

- Many applications areas

Fingerprint recognition

Digital mammography

Tempel-1 Comet

Electronic Circuit
ADS FTC Overview

• Essential to Flight Safety
• Derived from Dynamic and Static Pressures
• Computation requires Calibration in Laboratory and FTC
ADS Calibration

- Consists n TP: 1.2 Stall Speed to VH

- Requirements for Valid Test Point:
  - $Z_{pb}$ and $V_b$ should be stabilized
  - $\bar{V}_{bi} \leq V_{ti} \pm 5kts$
  - $\Delta Z_{pb_i} \leq \pm 20 \text{ ft}$
  - $\Delta V_{bi} \leq \pm 2kts$

- Where:
  - $\Delta V_{bi}$ maximum deviation of basic speed at the $i^{th}$ (kts);
  - $\Delta Z_{pb_i}$ maximum deviation of the aircraft altitude at the $i^{th}$ (ft);
  - $\bar{V}_{bi}$ mean basic speed at the $i^{th}$ test point (kts)
  - $V_{ti}$ scheduled basic speed for the $i^{th}$ test point (kts);
ADS Calibration

- Requirements are considered within the valid area (ARV)
- Reference Points in the lower corners
ADS Calibration

- Test Site ADS
- Maintain Trajectory
- Camera and RP are static and known position
Challenges

Automatic detection

$1m \pm 0.04m \ @ 1\sigma$

6 x 6 pixels
Challenges

Weather Conditions
Tool Development

- User makes application setup
- Video frames transmitted
- Extraction of target coordinates
- Correction to minimize errors lens distortion
- Computes TSPI
- Results
Tool Development

• Algorithms:
  – Reference point detection;
  – Tarmac centreline detection;
  – Aircraft detection;
  – TSPI Computing; and
  – Test Point Validation
Aircraft Detection

- Segmentation
- First Frame TP is Reference Background Image

\[ I_{rt_{x_{i}y_{j}}} = I_{t_{x_{i}y_{j}}} - I_{B_{x_{i}y_{j}}} \]

, must have aircraft and pepper noises
Aircraft Detection

- Next steps:
  - Detect edges
  - Perform CCL
  - Remove pepper noises
  - Sort ascending size order (CCL)
  - Biggest CCL contains aircraft
  - Perimeter Pixels
TSPI Computing

• Now, requirement is find a fixed reference point on the aircraft (RPA) for measure altitude and airspeed
  – Centroid, Front, Rear and Bottom Edge detection
• After several tests, the Rear is the better
• Found PRA, computes altitude and airspeed

\[ V_t = \frac{k \Delta S}{\Delta t} \quad (\text{m/s}) \]
Tool Evaluation

- MatLab® environment
- Intel® Pentium IV Core™ 2 Duo CPU T5800 2.00 GHz notebook, 4 Gb RAM and Microsoft Windows 7 Professional.
- Camera: best configuration was to generate images in grayscale, 400 fps and 720i resolution.
Tool Evaluation

Runs at 48 fps ± 2 fps @1σ

Single frame of a valid TP
Tool Evaluation

True Reference and Computed Altitude
Tool Evaluation

Altitude Uncertainty = ±0.1331 m @1σ
Summary

• The development and evaluation of a Hi-Speed near Real-Time 720i Image Processing Application for Flight Test was successfully executed.

• This application integrates several simple yet efficient vision tools, which are easy to implement.

• The system can be customized for several aircrafts. As a result the system is very flexible and reliable and it can be used in wide range applications.
Summary

• The next steps are:
  – Evaluate the tool with other aircrafts;
  – Improve system performance using:
    • Parallel processing techniques; and
    • Graphics Processor Unit (GPU) cards;
  – Retrieve images directly from the buffer of high-speed camera; and
  – Develop a tool to integrate this application with GPS and GTS.
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