Helicopter Flight Data Monitoring (HFDM) Research

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Feb. 24, 2021
Helicopter Safety

Why does it matter?
FAA Helicopter Flight Data Monitoring
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MITRE
Rowan University

Truth Data
Your Partner in FDM & Analysis

Georgia Institute of Technology

ATAC
Hi-Tec Systems
SEI

PEGASAS
Rotorcraft Mission Segments

- Air Tour
- External Load
- Airborne Law Enforcement
- Aerial Firefighting
- Search and Rescue
- Helicopter Air Ambulance
- Training
- Offshore
- Corporate/VIP Transport
USHST Top 3 Fatal Accident Occurrence Categories

1. Loss of Control
2. Unintended Instrument Meteorological Conditions
3. Low Altitude Operations
Safety Metrics for Rotorcraft Operations

- **Metrics Investigated:**
  - Proximity to Obstacles
  - Proximity to Weather
  - Dynamic Roll-over
  - Autorotation Detection
  - Vortex Ring State Detection
  - Unstabilized Approach (VFR)
  - Mast Bumping

- **In Progress:**
  - Loss of Tail Rotor Effectiveness (LTE)
  - Unstabilized Approach (IFR)
  - Autorotation Phases
  - Vortex Ring State Recovery

- **Future Work:**
  - Retreating Blade Stall
  - Helipad Overrun
Proximity to Obstacles Safety Metric
Proximity to Weather Safety Metric
Example Safety Metric: Approach Stability

- **Stable approach**: approximate constant approach angle glidepath with few fluctuations
- **Unstable approach**: fluctuations in altitude, approach angle, airspeed and/or more:

- **Goals**:
  - Automatically identify approach segments in flight recorder data
  - Use clustering techniques and performance metrics to quantify the stability of each approach
  - Use statistical analysis and machine learning to search for patterns and correlations in the data, and identify precursors to “unstable approaches”
  - FAA has identified unstabilized approaches as a leading cause of helipad overruns and other approach/landing accidents
  → Inform safety decisions, pilot training, standard operating procedures, etc.
Approach Detection Process

1. Approach event detection
   - Visual
   - Instrument

2. Visual approach stability analysis
   - IAP unavailable
   - IAP available

3. Instrument approach stability analysis
   - No close match
   - Close match

4. Classification and plotting

5. Identify nearest airfield to endpoint
   - Import airfield IAP spreadsheet
   - Identify nearest runway/helipad to endpoint

6. Compare IAP waypoints to approach path
   - Select closest IAP to approach path
Published approach plates → Approach spreadsheet format → Read into MATLAB → “Build” approaches

AirNav threshold location info

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IAP Angle

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End
Holds/Procedure Turns

- Algorithm detects procedure turns/holding patterns
- Proper evaluation requires identification of procedure turn pattern or HILO-PT entry

a) Parallel
b) Teardrop
c) Direct
Approach Stability Analysis

- Automated approach detection and categorization from flight data records

- Visual approach detection params:
  - Minimum duration: 20 s
  - Approach start height: 1000 ft AGL
  - Approach end height: 90 – 110 ft AGL
  - Minimum total descent: 100 ft
  - Allowable vertical speed duration: 10 s
  - ROC upper bound: 400 ft/min

- Visualization: 3D flight mapping including local terrain and airports
  - Terrain data imported from GMTED2010 digital elevation map
  - Airport/heliport altitude data imported from FAA database
  - Terrain and heliport altitudes used to estimate height AGL
Approach Stability Metrics

- Added elevation (glideslope) and azimuth (localizer) metrics to track final approach performance
- Only calculated for the region from the FAF to a user-specified endpoint (ex.: 0.5 nm prior to threshold)
Approach Stability Analysis

- Approach stability assessment using user-selectable performance metrics

- “Ideal” approach construction:
  - Straight line from initial to final point
  - Best linear fit of actual flight path
  - User-defined ideal approach angle

- Available performance metrics:
  - Mean, standard deviation, RMS, etc.
  - Altitude and approach angle deviations

- Approach stability classification and analysis with data mining

  - Compare approaches in the user-defined performance metric space
  - k-means and DBSCAN clustering algorithms implemented
    - Allows grouping of approaches with similar stability characteristics
    - All parameters user-configurable
Interest in Loss of Control events

- 30% of all accidents involve Loss of Control (LOC)
- Going after major LOC categories
Loss of Tail-Rotor Effectiveness/Unanticipated Yaw

- Critical low-speed aerodynamic flight characteristic
- Occurs when the angle/speed of the air flow through the tail rotor is altered
- Can result in un-commanded rapid yaw rate and/or loss of aircraft control

Factors influencing LTE (helicopter specifics):
- Wind condition
- Indicated airspeed
- Gross weight
- Density altitude
- Temperature
- Rapid power change
- High power demand situations
- Pilot reaction time

- Low Risk Level
  - IAS < ETL
  - Dangerous wind direction
  - Wind speed < 30 kts
  - 50% < Pedal used < 75%

- High Risk Level
  - IAS < ETL
  - Dangerous wind direction
  - 15 kts < Wind speed < 30 kts

- Loss of Tail Rotor Effectiveness
  - Yaw rate > 20 deg/s
  - Max 100% pedal used

Federal Aviation Administration, "Unanticipated right yaw in Helicopters", Advisory circular 90-95
Current LTE Analysis via Flight Data

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LTE Analysis Process

Previous work:
- LTE event literature review
- Bowtie risk assessment diagram

Current work:
- MATLAB code for LTE event detection
- Flight data analysis

FlightLab LTE modeling & LTE event analysis

Participating Operators
- All Missions
- Flight Training
- Charter
- EMS
- Oil/Gas
- Logging
- Police
- News
- Cargo Lift
...  

Analysis Results:
- Metric event definition
- Evaluation of barriers influences
- More recovery techniques
LTE BowTie Analysis
Development of New LTE Metric – Part 1: Interactional Aerodynamics between MR vortex and TR

- Analyze different models and show how MR and TR interactions give rise to run out of pedal scenarios
- Validation with Padfield results

Bailey Tail Rotor

BET on Tail Rotor

BET on Tail Rotor
Aerodynamic Interference
Metric visualization

Hover scenarios

Pedal Trim %

Density Altitude ft

Weight lbs

Relative wind [kts]

forward

0

90 right

180

150

120

90 right

60

30

0

90 left

180

210

240

300 left

Relative wind [kts]
Vortex Ring State Recovery Techniques Evaluation

- **Objective:** compare different recovery techniques for VRS

- **Experiments:** 2 types of recovery techniques; range of starting altitudes for recovery; 3 directions of recovery: straight, right, and left

- **Method:**
  - Find the VRS boundary based on Johnson’s model:
    - Rotor diameter
    - Local air density
    - Weight of the vehicle
  - Find the VRS recovery time:
    - Using the trajectory plot of vertical speed and horizontal speed, define recovery time as departure from VRS boundary to the point where vertical velocity reaches a positive value
  - Find the altitude drop
    - Altitude difference between entry point of VRS envelope and end point of recovery

- **Metrics to evaluate the techniques:**
  - Recovery time
  - Altitude drop
Vortex Ring State Recovery Techniques – Preliminary Results

- Duration of VRS encounter: 2.1 s
- Recovery time: 7.8 s
- Altitude drop: 155 ft

Relevant variables:

- Altitude (feet)
- Vertical speed (fpm)
- IAS (kts)
- Collective (degree)
- Long-cyclic (degrees)

Trajectory of vertical speed and horizontal speed with corresponding VRS boundary.
Aviation Safety Information Analysis and Sharing (Rotorcraft Update, 2020→2021)

- Rotorcraft Issue Analysis Team (R-IAT) formed.
- ASIAS Executive Board (AEB) incorporation of rotorcraft reps (USHST Co-Chairs).
- Developed ASIAS Procedures & Operations Plan for Rotorcraft Aviation.
- Expanding collaboration and involvement with USHST, helicopter air ambulance operators, air tour operator safety organization, business aviation, other industry organizations.
- R-IAT scoping initial analysis topics.
Questions?