Weather Technology in the Cockpit (WTIC) Research

US Helicopter Safety Team (USHST) Infrastructure Summit

April 6, 2022
WTIC Rotary Wing
Related Research
Agenda

• WTIC Rotary Wing Gap Analyses Results Overview
• Gap Analysis Findings to Research Project Correlations
• Overview of selected WTIC current and future (FY22/FY23 plans) projects
• Long Term Plan – Convergence of Research Projects
Operator Interviews Approach and Results

- **Approach:**
  - Qualtrics web-based survey
    - Demographics (piloting experience, age, rating, ...)
    - Flight environment (terrain, equipment, ...)
    - Safety of operations (adverse weather encounter types and factors)
  - Distributed to helicopter professionals through professional newsletters and websites
  - Filtered responses to keep only US professional pilots (90% of answers)
    - 69% of pilots had experience in Helicopter Air Ambulance (HAA) operations
      - HAA only accounts for 16% of helicopter flight hours between 2008 and 2018 (FAA GA and part 135 survey)

- **Results:**
  - Weather sources: pilots reported using multiple sources of weather information, more sources for preflight phase than in-flight
  - Opinion on weather products: 71% are satisfied, among dissatisfied pilots, sparsity of information is the most common complaint, 38% answered that information latency could be an issue
  - Training: almost all pilots reported recent IIMC training (less than a year), HAA pilots reported IFR rating and currency at higher rates than non-HAA pilots
Safety Themes

• Five primary safety themes were extracted from the operator interviews

1. Sparsity of weather sensing/reporting or lack of weather information
2. Reliance on local or experiential weather knowledge
3. Impact of current technology on safety
4. External pressures on weather-related decision-making
5. Distrust of weather information
Sparsity of Information

• **Sparsity of information:**
  - Many of the aviation weather sources that are available to pilots are tailored to fixed-wing operations
  - Weather information is sparse when flying to or from a location which is not near an airport/airfield

• **Current Projects Addressing Gap – New Observation Info**
  - Hybrid Solution – Sector and Site Visibility, Sky
  - Helios (Machine Learning Analytics and Wind Socks) – Surface Winds
  - Fire Protection Cameras – Skyreps (Cloud Tops and Bases)
  - Artificial Intelligence Software - Cloud Type Identification
**Experiential Knowledge**

**Experiential knowledge:**
- When weather sources or weather information are sparse, missing, or incorrect, pilots revert to visual scanning and knowledge of weather trends.
- Weather information for their local area can be “reliably inaccurate”
- There are negative implications of pilots discounting certain sources of weather information.

**Current and Future Projects Addressing Gap - Training**
- Augmented and Virtual Reality – Wx Models, App, Mini Courses
- Experiential Training – Three Courses, Development Method
- Weather Information Latency Demonstrator – Latency Training
- Effectiveness of Self Briefings versus Specialist Provided Briefing
- Decision-Making Models – Recognition Primed Decision (RPD) Model
- Flight Safety International (FSI) model – Pilot Reaction Assessment Training
Technological Factors & External Pressures

• **Technological factors and External Pressures:**
  - Weather events that occurred many years ago or in older aircraft may not have been a problem with modern technology
  - Most of the pilots mentioned that they were aware of latency with weather tools
  - Each industry and operator are subjected to unique external pressures
  - Various policies attempt to mitigate the effects of these pressures

• **Current and Future Projects Addressing Gap - Technology**
  - Weather information latency trainer (WILD) – Latency Training
  - Nulling NEXRAD latency (useful for notifications)
  - MITRE Digital Co-pilot with WX – Automating Cockpit Wx Support
  - Weather Representativeness Toolbox – Big Data and Machine Learning
  - Decision-Making Models – Recognition Primed Decision (RPD) Model
  - Flight Safety International (FSI) model – Pilot Reaction Assessment Training
Distrust of Information

• Distrust of Information:
  • Weather information can be misleading or insufficient
    • Requires cognitive effort to decipher disparity among sources
    • Requires recognition of misleading or inaccurate weather sources
    • Technologies may have limitations or specific deficiencies

• Current and Future Projects Addressing Gap - Distrust
  • Building Pilot Confidence in Automated Cockpit Weather Systems
  • MITRE Digital Co-pilot with WX – Automating Cockpit WX Support
  • Weather Representativeness Toolbox – Climate Zones, Big Data, Artificial Intelligence, and Machine Learning
  • Weather Data Quality/Confidence Rating – Crowd Source Dissimilar Sources and Use Strengths of Each
Weather Events Seasonality

• More events in summer (more flights)
• In proportion, more weather events in Fall and Winter
• Higher proportion of wind events in Spring and Summer
• Higher proportion of visibility events in Fall and Winter
Current Project Results Highlights
Weather Representativeness
Motivation

• Calabasas crash (HOWI Sentinel Case Analysis)
  – Data density of close mesonet Wx stations indicates high humidity reports
  – Follow up variables considered – temperature vis-a-vis humidity.

• The closest site may not be the most representative, especially with differences in terrain, lakes or rivers, urban buildings, variable winds and other wx phenomena as well as seasonality.

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Mesonet site monthly relative humidity correlation vs. KVNY ASOS. Location (microclimates) & seasonality influences.
Wx Flight Rules Spatial Representativeness

- Flight Rules Category Decorrelation vs. Distance from KVNY (Van Nuys)
- General decrease with distance, but with significant variation
- Seasonal changes significant
  - KONT in June at over 45 nautical miles away is better correlated than KBUR in December at just over 5 nautical miles away.
KLAX
June
WX Flight
Rules
Correlation
KLAX
December WX Flight Rules Correlation
What percent of stations are best correlated with the closest neighbor?

- 67 “5-minute” ASOS stations in California
- Metric: correlation between ASOS stations based on weather flight rules categories

- Seasonal variation in %
  - One peak in Apr
  - Secondary peak in Oct/Nov

- “Correlation” between sites
  - Not a constant
  - Seasonably variant
Weather Representativeness and Climate Zones

Are climate zones helpful for grouping ASOS stations with similar weather?

While all stations within a given climate zone may not agree with each other, weather events can track differently by climate zone showing that these collectives are meaningful.

The example on the right shows rates of IFR conditions varying between the Central Valley and South Coast climate zones of California.
Automated Cloud Classification

• Motivation for Research
  • Ground-based cameras for aviation weather information and need for machine learning

• Research methods
  • TensorFlow image classifier
    • Classifier training constraints and procedures
  • Case study: Distinguishing between cumulus and towering cumulus
Motivation for research

Provide utility to aviators while minimizing workload for weather-related information processing

Give pilots access to small bits of weather information that:
• Are nearly real time
• Reflect changing weather conditions
• Can be quickly referenced and overlaid with other information

Supplement gaps in current observations

Increasing availability of ground-based camera networks
• Can machine learning be used to autonomously draw cloud type information from this imagery?
Methodology

- Apply an off-the-shelf machine learning algorithm to distinguish between different cloud types in webcam imagery
  - Google’s TensorFlow
- Ultimately: Identify cloud types associated aviation weather hazards (e.g., turbulence, icing)

**Stage 1:** Is it feasible to use a machine learning framework like TensorFlow to identify clouds? **Answer: Yes**

**Stage 2:** Can TensorFlow be used to distinguish between two similar types of clouds under ideal constraints? *Single camera site, similar time of day, similar foreground (seasonal)*

**Currently**

**Stage 3:** Can a TensorFlow machine learning scheme be developed that accurately classifies a variety of clouds? *Single camera site, similar time of day, similar foreground*

**Stage 4:** Can a TensorFlow machine learning scheme be developed that accurately classifies a variety of clouds for many camera sites of interest? *Varying time of day & field of view*
Skyrep Prototype Overview

• A Skyrep is a PIREP-like sky condition report
• Use imagery from the ALERTWildfire camera network in real-time; focus on coastal Southern California stratus/fog events
• Post-analysis of the imagery provided estimates of cloud base and height by assessing the vertical continuity of obscurations (SKYREP)
• Comparison to available pilot reports (PIREPs) indicated this prototype has potential to validate PIREP cloud base-top reports
• May provide independent PIREP-like observations of clouds or other obscurations where camera observations are of sufficient density
• SKYREPs could provide cloud base/top information for day and night operations, including regions where few PIREPs are available
Methodology

• Acquired imagery from Alert Wildfire network for clear and obscured sky conditions for over 100+ cameras in the LA, Orange, and Ventura County Region.

• Evaluated image statistics using RBG, HSV, LAB color space
  • Settled on HSV- and LAB-based histograms as basis for a first algorithm

• Optimized the algorithm threshold to best distinguish between clear vs. obscured images

• Tested the optimized algorithm with an independent dataset
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July 22, 2020 “June Gloom” Fog/Stratus Event
Visibility in Disagreement with ASOS

ASOS Visibility: 10.0 (VFR)
ASOS Ceiling: 400 (LIFR)
Crowd Visibility (Average): 1.25 (IFR)

VEIA Visibility: 4.0 (MVFR)

Chip ID: 10243-1636421110
(Crowd Visibility: 1.0 - IFR)

Chip ID: 10244-1636420882
(Crowd Visibility: 2.0 - IFR)

Chip ID: 10245-1636420930
(Crowd Visibility: 1.0 - IFR)

Chip ID: 10246-1636420825
(Crowd Visibility: 1.0 - IFR)
Visibility in Disagreement with ASOS

ASOS Visibility: 10.0 (VFR)
ASOS Ceiling: N/A

Crowd Visibility(Average): 0.25 (LIFR)
VEIA Visibility: 0.75 (LIFR)

Chip ID: 10017-1635270128
(Crowd Visibility: 0.25 - LIFR)

Chip ID: 10018-1635270431
(Crowd Visibility: 0.25 - LIFR)

Chip ID: 10019-1635270378
(Crowd Visibility: 0.25 - LIFR)

Chip ID: 10020-1635270135
(Crowd Visibility: 0.25 - LIFR)
Convergence of Projects – Long Term Plan
Using New and Existing Observations

• Cockpit Automation (future) - General Overview
  • Use dissimilar observations for a quality/confidence rating
    • Duplex/Triplex methodology
  • Use crowd sourcing algorithms for observation source quality rating to enable overall observation quality/confidence rating
  • Use strengths of each observation source for cross checking to enhance confidence/quality of output from approved Wx sources
  • Use historical data to identify trends, such as decorrelation and representativeness to support notification issuance
  • Notifications primarily to identify atypical Wx conditions and rapidly changing Wx
  • Start with MITRE Digital Copilot and add weather decision support (Alexa-like voice)
  • Identify weather questions frequently asked to Flight Services and Dispatch for inclusion in Digital Copilot Wx
  • Initially automation to provide cross check to pilot assessments, and then progress to decision support by presenting suggestions for pilot to accept/reject
  • Include design elements to aide in building pilot confidence – understand automation, monitor quality of input data
  • Output formats for different users (aircraft types, flight services, dispatch, etc)
Training

Future Weather Training Projects

• Recognition Primed Decision (RPD) Model
  • Assess the effectiveness of virtual reality (VR) scenarios focused on weather hazards to test the hypothesis that a RPD model will lead to adaptive behavior by pilots.

• Flight Safety International’s (FSI) Flight Smart Software
  • Evaluate inadvertent flight into IMC
    • PEGASAS partnership with FSI to use their Flight Smart software (Mixed Reality (MR) simulation with artificial intelligence).
    • FSI has MR for both fixed-wing and rotor-wing aircraft
    • Setup can be as simple as a laptop and basic spring-centering controls and employ a VR headset
    • Use by USAF has had promising results
    • Training goal to enhance safety during inadvertent IMC encounter
    • Artificial intelligence assess pilot decisions and reactions