Federal Aviation Administration

Advanced Flight Control Automation

Presented to: 11 th EASA Rotorcraft Symposium

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Outline

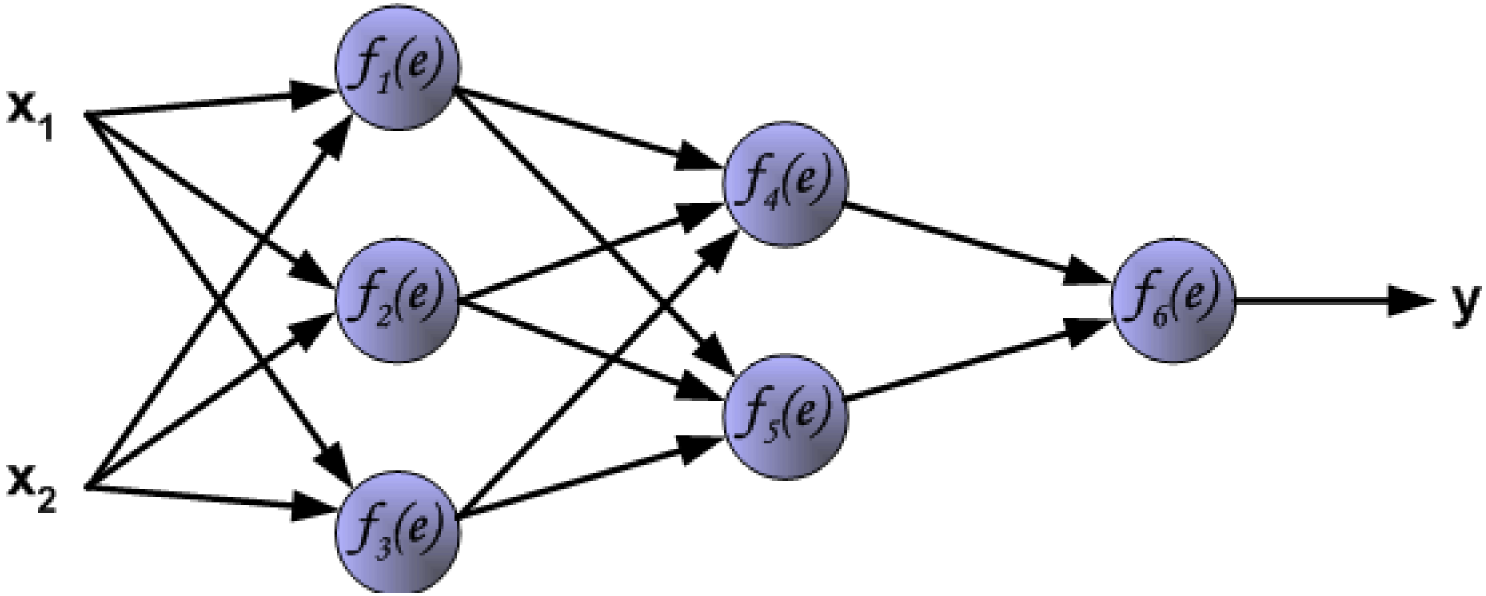
- Terminology
- Certification Challenges
- Development Assurance Considerations
- Approaches to gain trust
- Research
- Other related activities

Terminology

- **Machine Learning (ML) – is an algorithm that give computers the ability to learn without being explicitly programmed**
- **Deep Learning – is machine learning method that uses neural networks with multiple layers between the input and output layer**

Terminology (cont)

- **Neural Network -**



- **Deterministic behavior – given a specific input and state the output is repeatable.**

Level	Name	Definition	Aviate, Navigate, Communicate	Monitors automated flying mode performance	Fallback to performance of flying task which was automated	System Capability (flying modes)
0	No Automation	Human has full time performance of all dynamic aspects of flying tasks	Human pilot	n/a	n/a	n/a
1	Pilot Assistance	Assist with some flying mode	Human pilot and system	Human pilot	Human pilot	Flying mode assistance
2	Partial Automation	Some flying modes executed by the automation	Human pilot or system	Human pilot	Human pilot	Some flying modes
3	Conditional automation	Automation is capable of performance of a dynamic flight control mode with the expectation that the pilot can take over performance of flying tasks when requested	System	System	Human pilot	Some flying modes
4	High Automation	Automation is capable of performance of many flying modes even if the pilot does not respond appropriately to a request to intervene	System	System	System	Many flying modes
5	Full Automation without Pilot Backup	Full-time performance of all all flying modes under all operating conditions the aircraft has been certified for	System	System	System	All flying modes

Background

- Civil rotorcraft already have sophisticated level 2 autopilots including search and rescue functionality
  - **Monitored by the pilot**
  - Developed using a rigorous system, software, and airborne electronic hardware development assurance processes
    - Recognized Means Of Compliance
  - Deterministic behavior
- 27.1309 and 29.1309 states:
  - "the equipment, systems, and installations must be designed and installed to ensure that they perform their intended functions under all foreseeable operating conditions"

Certification Challenges

- Challenge 1: As the level of autonomy is increased how does one show that autonomous flight controls perform their intended function under all foreseeable operating conditions?
  - Weather, operational and emergency contingencies,
  - Rain, fog, snow, dust, lighting, sensor imperfections, sensor sensitivity to temperature changes, etc
- Challenge 2: For Level 3 and above an autonomous function will not be monitored by the pilot unlike today's autopilots
- Challenge 3: Don't have existing guidance for ML
  - May be non-deterministic
  - Can't follow the System V process
  - Can't satisfy all assurance process objectives

Certification Challenge

- Challenge 4: How do we handle autonomous algorithms that continue to learn during operation
  - Should independently verify the output
  - Could diverge from acceptable behavior
  - Could have different behavior for each aircraft
  - Makes analysis of continued airworthiness issues challenging

Machine Learning Development Assurance Considerations

- ML algorithms will make mistakes

  "An ML model typically does not operate perfectly and exhibits some error rate. Thus, correctness of an ML component, even with respect to test data, is seldom achieved and it must be assumed that it will periodically fail."

- ML training set can be incomplete

  –ML models are trained using a subset of possible inputs that could be encountered operationally. Thus, the training set is necessarily incomplete and there is no guarantee that it is even representative of the space of possible inputs.

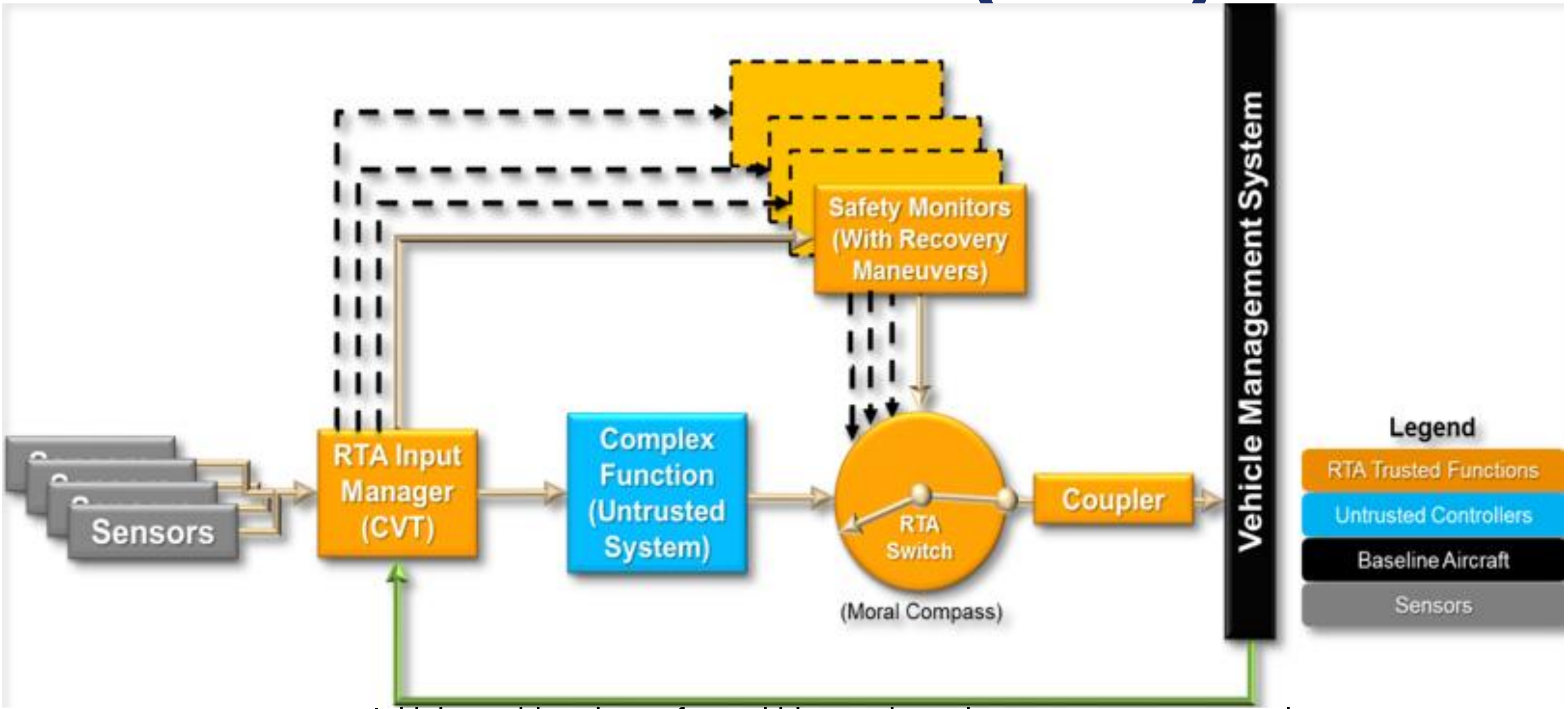
An Analysis of ISO 26262: Using Machine Learning Safely in Automotive Software, Rick Salay, Rodrigo Queiroz, Krzysztof Czarnecki

How can we gain some trust?

–  then 

- Phased implementation
- Safe and methodical reduction in crew workload to the point where automation can be assured to be safe and trustworthy to replace the human in all phases of flight

How can we gain some trust? Run Time Assurance (RTA)



Initial considerations of a multi-layered run time assurance approach to enable unpiloted aircraft

– Bound the behavior and mitigate failure effects through architectural mitigation

How can we gain some trust?

- Extensive Usage
  - Modeling and simulation,
  - Laboratory and **flight tests**,
  - **Operational use**
- Enhanced data recording to allow reconstruction of circumstances that result in anomalous behavior

FAA Sponsored Research

- **“Verification of Adaptive Systems”**
  - Research performers were NASA Langley and Honeywell
    http://www.faa.gov/aircraft/air_cert/design_approvals/air_software/media/TC-16-4.pdf
- **FAA has proposed autonomous systems research**
  - Strategies for adoption and certification of intelligent systems
  - Human factors
- **Aerospace Vehicle Systems Institute is pursuing a Machine Learning Research Project**
  - To start in early CY 2018
  - POC is Dave Redman: dredman@tamu.edu
  - Investigate verification methods for machine learning algorithms.
  - Investigate methods for bounding the behavior of machine learning algorithms so the overall system stays within safety bounds.

Other related activities

- **CARP Rotorcraft Advanced Flight Control Working Sub-Group**
  - Objectives
    - Develop harmonized revisions
      - Advanced flight controls handbook
      - Misc Guidance MG-17 sections of AC 27-1B and AC 29-2C
  - FAA, EASA, TCCA team being formed
  - FAA POC is Ife Ogunleye
    - Ifeolu.Ogunleye@faa.gov
- **Flight Automation Workshop being planned for the summer of 2018 in Washington DC**
  - Wes Ryan is POC
    - Wes.Ryan@faa.gov

Summary

- Significant hurdles to safely introduce machine learning
- Need to craw first
- Research is planned
- Need to leverage the automotive industry
- ML standards development?

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