Designing a framework for flight simulator training scenarios. An Evidence Based Training Approach.

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Research in Progress Abstract:

Despite all the technological improvements currently available in aeronautical training, most accidents still have Non – Technical Skills as main contributing factors. Thus, acquisition and learning of Non-Technical competencies by trainee pilots are critical factors for the elevation of Aviation and Aerospace safety. In this line, flight simulators provide a risk free and safe environment for the acquisition, application and practice of necessary flying competencies and personal behaviors. Among the most demanding tasks for the effectiveness of flight simulator training is the customization of the training scenarios (a.k.a flight scripts) to the individual trainee pilot competencies, based on data provided from aviation accident databases, professionals (e.g. flight instructors / senior pilots) as well as previous training sessions and performance assessments. This customization is still mainly the responsibility of a certified flight instructor rendering thus the design and development of personalized flight training scenarios a challenging process in terms of time, effort, knowledge and other resources required.

A promising solution to this challenge lies in the design and development of a software framework that will support a flight instructor in semi-automatically design, publish, re-use and adapt flight training scenarios, according to individual trainee pilot competencies.

The software framework will pre-populate some fundamental components in the flight script and then the flight instructor would be given the “final touch” (i.e. Go / Adapt /Non Go decision) for fine tuning the training session. Information and data for prepopulating the flight script could be provided from Certified Flight Instructors, Aviation Accident Analysis reports, and previously training sessions and performance assessments.

For making this integrated system to work, a shared conceptualization is required between the different entities that will provide data, for our proposed software framework. In this research in progress work we set and present the foundations for our framework and demonstrate a flight training script based on the principles of Evidence Based Training (EBT).

Keywords: Aeronautical Industry, Scenario Based Training, Flight Simulators, Evidence Based Training

1. Setting the Scene

Despite all the regulatory and technological improvements that exist in the air transportation industry, still the majority of incidents and /or accidents are due to fallible human performance, decisions and/or behavior in expected and unexpected flight events. To avoid further escalation, recently, Aviation Authorities and Trade organizations like the European Aviation Safety Agency (EASA), the International Airlines Transport Association (IATA) and the International Civil Aviation Organization (ICAO) are promoting a new training paradigm that aims to integrate all kinds of competencies required for flight crew optimal performance. These competencies both procedural (e.g. Technical) and human performance (e.g. Non-technical), are widely known as Evidence Based Training (EBT). EBT recommends nine basic competencies to be assessed and trained in ab initial and recurrent flight simulation training sessions.

According to the official IATA EBT training manual and paradigm, pilots should be subjected to known and unexpected (i.e. deterministic and non-deterministic) flight events “situations” specifically designed to test and improve their flight skills and competencies in simulated operational contexts. Flight simulators as virtual training and learning environments allow the acquisition, application and transfer of knowledge and flight competencies in a safe and risk free environment, in alignment with Aviation Authorities regulations for ab initial and recurrent flight training sessions and performance assessments.

Among the most challenging tasks for the effectiveness of flight simulator training sessions is the design and customization of the flight training scenarios, also known as “flight scripts” to the individual trainee pilot competencies and flight scenario peculiarities, based on data obtained from Aviation Accident Databases, previous training sessions and individual profile assessments. A typical flight simulation training session exposes trainee cadets to flight conditions and challenges specially designed to elicit, unfold and practice certain behaviors and personality traits. These situations can range from basic Navigation procedures training, to basic and advanced flight maneuvers and even recovery techniques. The level of appearance of these trainee behaviors, reflects the possession or not of the flight skills considered vital for the addressing the flight emergency raised.

Given the innumerable number of potential challenges and events that may emerge in a flight deck (expected and unexpected), and the complex correlation between certain simulated events

and the required flight skills needed to safely resolve these events, mapping, designing, and developing flight training scenarios is not a simplified and straightforward task.

In this line, scenarios development is highly dependent on the experience and ability of a certified flight instructor, for matching individual trainee competencies and simulated flight events for remedial training and further development of trainee competencies. Thus the creation of flight training scenarios becomes a very demanding and challenging task in terms of time, effort, knowledge and other resources required.

2.1. Presenting Related Work – Flight Simulators

From the early days of flight, flight simulators have been advanced into simulation environments and end to end training ecosystems. Aviation safety studies support that both experienced and less experienced flight operators could initially learn in a simulator and then supplement their training with hands-on experience. One of the reasons why simulators are so important is because they simulate a safe and risk free environment in which flight operating personnel can develop and im-prove the skills necessary to operate the aircraft in the safest possible manner at all times.

With current technology, practically any situation (emergency / event) that may arise in flight can be simulated, but the sequence in which these unexpected events may occur must conform to consistency criteria and pay attention to cognitive fidelity. The latter represent the core difficulty of designing flight training scripts and over-coming this difficulty is highly associated with development of flight crew competences. In other words, a carefully designed scenario rich of learning and development outcomes is more important than the technical visual fidelity of the simulator.

2.2. Presenting Related Work – Scenario Based Training

Scenario-Based Training (SBT) is a framework which places trainees to realistic simulations, specifically designed to bring out, train and assess certain actions and behaviors. These actions can be associated to the expected performance level for procedural (i.e. Technical) and Non-technical skills required in the real domain. SBT has been widely used not only in the Air Transportation and Aerospace industries, but also in several critical decision making areas, including but not limited to medical, defense and military as well as oil ring extraction and nuclear applications.

Flight simulator training sessions mainly focus on the representation of a flight script, which contain an operational environment and a set of expected and unexpected flight events (e.g. a system malfunction, a human error, weather conditions, critical air traffic conflicts) distributed throughout the session. A key principal for our re-search is that the design of realistic flight training scripts requires the correct combi-nation of flight events as well as consistency in

representing these events, which directly influences the fidelity of the flight simulator training session.

To the authors best knowledge, there are few professionals from Academia who recognize the need for enhancing the automation (at least partially) of the development process of flight training scenarios and are currently working on it either on empirical or research level. In this line, the need for a standardized and formal vocabulary conceptualization is critical in airline flight crew training. This was recently highlighted by EASA in 2021 which found mismatches in the training vocabularies used even among regional and local aviation authorities. EASA in the same line with other accreditation bodies (ICAO and IATA), highlighted the need to universally harmonize the aviation vocabulary and terminology required for improving the effectiveness and efficiency of flight crew training.

In conclusion, in the field of flight crew training there are literally no effective semantic tools that enable information interoperability and a common domain vocabulary between all the stakeholders involved for the development of the required training scenarios. A specific shared vocabulary and common terminology system becomes instrumental in such an integrated approach for flight simulation training sessions

3.1. Setting the Foundations for a Common Vocabulary for Flight Training Scenarios

This research sets initial foundations for the development of a software framework that will support a flight instructor to semi-automatically create flight training scenarios, customized to the individual trainee cadet needs. For doing this and for supporting the information interoperability requirements between the different aviation entities that will provide data resources for our platform, we propose a unified and shared conceptualization vocabulary for flight training scripts creation namely as “Unified Flight Training Language” (UFTL).

UFTL will formulate a well-structured description language to define and formally represent all flight phases, i.e. Taxing, Take off, Climbing, Cruise Flight, Maneuvering, Descent, Approach, Landing and Emergency scenarios with the aircraft on the ground and/or in the air.

As a starting point for test bed use cases and flight scripts we used the IATA, EBT Implementation Guide as this is described in the revised official guide. Then the domain is formulated following the systematic approach, suggested by Durak et al (2014). The basic idea is to start with a conceptual model for creating the UFTL metamodel and then provide a transformation of this model by incorporating new concepts and relationships as progress is made in a stepwise approach. Following the approach suggested by Fablo et al (2012), for ontologies and metamodels in software creation, we created the initial UFTL metamodel. Future research will include also the Base Object Model (BOM) metamodel, to support the transformation of the UFTL metamodel into executable flight scripts that can be deployed and reused in simulators.

3.2. Evidence Based Training and Modelling Scenarios

At the heart of Evidence Based Training (EBT) lays the correlation of the flight script with the competencies to be learned and assessed for each individual trainee. IATA and ICAO proposes that an Aviator's competency can be conceptualized as a combina-tion of flight skills, knowledge, behavior, personality, and attitudes required to ad-dress a challenging task to the Safety standard. In line with Evidence Based training, nine foundational competencies have been officially proposed by EASA, IATA and ICAO, which are used for assessment and training in ab initial and recur-rent flight simulator training sessions. For the purposes of this research we will use as a base of our discussion the competences highlighted by IATA in their official "Competency Assessment and Evaluation for Pilots, Instructors and Evalua-tors" Guide, revision 2021.

Aviator's Competencies and Observable Behavior according to IATA, ICAO and EASA are used as a discussion base for our research and are defined below:

i. Leadership and Teamwork – Ability to Influence others to contribute to a shared goal and collaborate to accomplish the share goal
ii. Communication – Ability to communicate in an operational environment both for normal and abnormal situations
iii. Application of Procedures and Compliance – Ability to identify and apply proce-dures according to official operating instructions and regulations
iv. Workload Management – Ability to prioritize and distribute workload and available resources
v. Aircraft Flight Path Management, Automation – Ability to manage the aircraft flight path through automation
vi. Application of Knowledge – Ability to understand required information and aircraft operating instructions for flight safety
vii. Aircraft Flight Path Management, Manual Operation – Ability to manage the aircraft flight path through manual intervention and control
viii. Problem Solving and Decision Making – Ability to identify potential problems and make decisions for mitigation actions
ix. Situational Awareness – Ability to understand the operational context and potential effects of actions in the operation

Taking these competencies into consideration, a flight training scenario development process can be described as follows:

A flight script (i.e. flight training scenario) is a rigid and interrelated combination of expected and unexpected (i.e. deterministic and non-deterministic) flight situations. In our description language (UFTL), these situations are identified and categorized as Events and Constraints. Events are identified as deterministic and non-deterministic challenges that arise during the flight (e.g. aircraft technical failures, unexpected weather deterioration, flight crew errors, air traffic congestions). Events are the critical pillars of the flight scripts, but their effectiveness is strongly defined and con-strained by the operational context in which they are materialized. In this line, Constraints are the entities that formulate the context, and are generally more stable and predictable concepts. Examples of constraints can be the flight phase, the aircraft type, the flight path, its payload, etc.

3.3. Unified Flight Training Language Specification Requirements

Specifying the requirements that UFTL should meet was performed with the support of subject matter experts. A series of brainstorming discussions and open meetings were held with experts in Scenario Based Training and Evidence Based Training field. The team was composed from 6 people - (4 flight instructors,1 aeromedical psychologist and 1 aeromedical physician). These brainstorming discussions aimed in collecting use cases for the initial development of flight training scenarios. Additionally, a set of guidelines and limitations (i.e. constraints) were created that would drive all the remaining processes for the development of the UFTL ontology.

A paradigmatic example of such a limitation (i.e. constraint) is the need to trigger an unexpected event in different phases of flight. For example, a critical powerplant failure, does not require the same sequence of activities and flying crew skills for upset recovery if the failure occurs during final approach, as when cruising at a high altitude or even worst during take-off roll, since the decision making time margin and actions to be performed are completely different for supporting flight safety. To this end, these types of limitations (i.e constraints), which add to the consistency and sequence of presenting the flight events and increase the fidelity of the modeled flight script should be made explicit and formally represented.

4. Unified Flight Training Language Metamodel

The following paragraphs highlight the methodology that we followed to formulate the UFTL metamodel. First the ontology classes are defined, and then an overview of the UFTL metamodel is depicted. Table 2. highlights that the initial version of UFTL ontology has nine base classes.

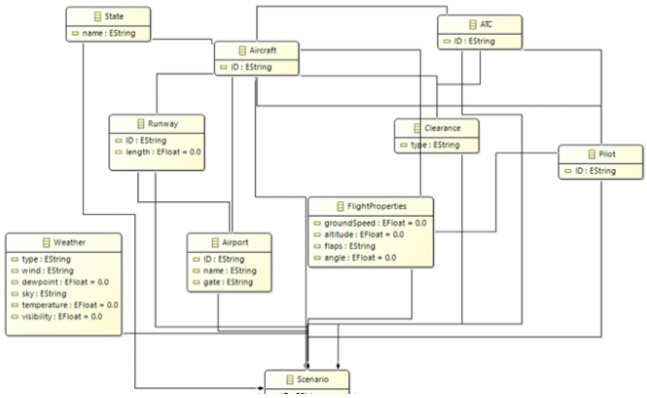
Each of the nine base classes has specific subclasses. For instance, the Aircraft Type class has two sub-classes, describing whether the aircraft is a General Aviation Aircraft or a Commercial Airliner. In another example Weather class has four sub-classes, describing the weather in terms of cloud formation, winds, precipitation, visibility. All remaining UFTL base classes are presented in Table 2.

Table 2. UFTL Base Classes and Sub - Classes

UFTL Base Classes	**UFTL Sub-Classes**
1.Aircraft Type	General Aviation Aircraft (e.g. Cessna 172 SP) | Commercial Airliner (e.g. Airbus A320)
2.Aircraft Characteristics	Payload weight (in Lbs) | Fuel (in Lbs) | Center of Gravity (FWD – AFT)
3.Weather	Cloud formation | Winds (Knts – Direction) | Precipitation | Visibility | Humidity
4.Time	Real World Time (Country / Region) | UTC Time
5.Aircraft Geographic Location	Airport Selection / Area Selection | On ground (Take off Position – On the Ramp) | On Air (Approach – VFR Approach (3nm) – IFR Approach (10nm) | Aircraft Heading, AirSpeed, Altitude
6.Equipment Failures	Aircraft System Failures (e.g. Powerplant, Electrical System, Pneumatic System, Hydraulic System, Avionics, Landing Gear, Fuel System)
7.Unexpected Non Equipment Failures	Pressure from Unruly Passenger, Pressure from Sick Passenger on Board, Blocked Runway at Destination, Amended Air Traffic Clearance at Last Minute
8.Timestamp / Triggering of the Events	Immediately, 3 Minutes after Take Off, 5 Minutes after Take Off, 10 Minutes after Take Off, During Landing
9.Aircraft Attitude	Take off, Climb, Maneuvering, Descent, Approach, Landing

A preliminary version of the UFTL Metamodel is provided in Figure 1. A future UFTL metamodel version will include all base classes and sub classes identified in Table 2. From Figure 1, we can see that the Aircraft Type class is associated to several other categories and define its properties. In our case the Aircraft has a call sign, it is connected to the port of origin and destination, it is connected to the departure and arrival runway and of course any details of the flight plan and enroute weather are also associated with the aircraft class. In addition, the aircraft is associated with a pilot class and the Air Traffic Controller responsible for monitoring the specific aircraft. The pilot is responsible to adjust the aircraft attitude based on the instructions of the air traffic controller. The aircraft is then trimmed based on its Heading, Speed and Altitude. Finally, the weather class associates the enroute weather conditions throughout flight duration.

Figure 1. UFTL Initial metamodel for flight training entities



5.1 Sample Take Off Scenario

A sample take off script is presented below in order to highlight the use of UFTL in defining and formally representing this scenario. For simplicity, only the main entities needed are defined.

"*Aircraft SX-GKNT stands in front of airport stand 06 at XYZ Airport. Pilots request from ATC taxi clearance. ATC provides taxi instructions towards RWY 03R, holding point Alpha 11. Pilots then start taxiing following ATC instructions. Tower then provides information about the Weather, Heading and Altitude R03R/2800FT, HDG/220. Then pilots ask for a Take-Off clearance and ATC grants the clearance*."

Figure 2 presents the flight script attributes for the conceptual flight script. Such as aircraft, pilot, Air Traffic Control, Weather, Human Factor, Equipment failures. Future research will include the Base Object Model metamodel for UFTL in order to transform the sample flight script into executable flight simulator session.

Figure 2. Conceptual flight script attributes for Take-off Procedure

5.2. Subject Matter Experts Feedback

As a critical step before designing the final version of the UFTL metamodel, preliminary versions were discussed in a workshop with subject matter experts from the European aerospace field (pilots, flight instructors, air traffic controllers). In this way, the different specialists, could get an idea of how it will be used for scripting flight training scenarios.

Workshop discussions aimed to identify what main classes and sub classes they would improve or add in the description metamodel. More than 85 % agreed with the statement about clarity and ease when using UFTL as flight training language. But when indicating what information they believed would be appropriate to add, two results were repeated among the responses, one was the pilot's flight hours and the other referred to the psychological profile of the pilots. Finally the also believed that it would be necessary to include information from Air Traffic Control.

6. Concluding Remarks

Despite the criticality of high-fidelity flight scripts for effective flight simulator training sessions, still there is a lack of common understanding and milestones required for their effective formulation. A promising solution to this challenge lies in the formulation of a software framework that will support a flight instructor for semi-automatically develop flight training scripts adapted to the individual trainee cadet needs and learning preferences. This software could intelligently create flight scripts based on real evidence and data integrated from several

data sources (e.g. Flight Instructor Input, Aviation Accident Analysis Reports as well as previous training sessions and individual cadet profile assessment). Such a system, will be of immediate support for flight instructor for assessing in real time the flight competence, behavior and performance of each individual trainee and give them appropriate feedback for remedial training and further competence development.

To make this happen as a first step a shared conceptualization terminology and domain vocabulary is required for enabling information interoperability between the different data sources required for the flight scripts' development process. Our proposed description language, presented in this paper, namely – Unified Flight Training Language (UFTL), takes advantage of expert knowledge and presents a common terminology vocabulary for the flight training domain, as an initial effort for standardizing scenario based flight training.

In this research in progress work we set and present the foundations for our framework and demonstrate a flight training scenario (i.e. flight script) based on the nine core principles of Evidence Based Training (EBT). Once fully developed, our framework will support flight instructors in formally standardize, represent, re-use and adapt flight training scripts according to individual trainee competencies. Although in preliminary phase, UFTL aims to facilitate information interoperability between aviation authorities, flight academies and flight simulator manufacturers with regard to the design of Scenario - Based training scripts.

From an academic perspective, our research in progress contributes to information and data interoperability between aviation authorities, airlines, flight academies and flight simulator manufacturers with regards to standardizing the development and re-usage of flight training scenarios.

As a future research we suggest the development of a Graphical User Interface and an editor that would support the semi-automatic transformation of conceptual scenario models into executable flight training scripts as well as effective sharing of these scripts between different flight training organizations and different flight simulation environments. Finally, we also suggest to explore the role of Artificial Intelligence and Machine Learning in flight simulator training, especially for prepopulating a flight script and accurately matching the script to a trainee pilot profile. Initial findings related to the proposed future research items will be presented in an updated version of this research in progress.

Copyright Statement

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