Artificial Intelligence for Air Safety

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Abstract. Safety is a vital aspect of aviation industry, and emphasis has been made by all stakeholders in the industry to ensure aviation safety. Strict safety and regulatory procedures are adapted during all phases of aviation including design and development, manufacturing, operations, maintenance and ground services. Still, accidents and incidents persist in aviation, resulting in loss of human life and huge losses to airlines and aircraft OEMs. Artificial intelligence is an evolving domain, which has gained lot of importance during the last decade, predominantly due the capacity of AI systems to handle and process huge amount of data and implement complex algorithms. This paper is indented to improve the aviation safety with the prudent use of artificial intelligence. The paper focuses on how the effects of the factors like pilot fatigue, adverse weather and false warnings, which affect aviation safety, can be mitigated with the use of artificial intelligence.

Keywords: Artificial intelligence · Machine learning · Smart cockpit assistant · Aviation safety

1 Introduction and Applications of AI in Aviation

Artificial intelligence is a topic, gaining popularity across industries and has a lot of applications in the aviation domain. The concept of AI has originated in 1950s, but the influence of AI has increased recently due to its improved capabilities.

With technologies like Micro Electro Mechanical Systems (MEMS) in sensors and Very Large-Scale Integration (VLSI) in the semiconductors, terabytes of data can be collected and easily stored. Powerful data processing algorithms have evolved for digital signals, image & speech processing that can efficiently process complex data. The advanced control systems are capable of executing complex nonlinear controls at near to real time conditions. The data communication techniques have advanced and now terabytes of data can be shared securely between stakeholders. With all these evolutions & capabilities, AI can influence the aviation industry in an emphatic way. Artificial intelligence has a lot of applications in the aviation industry and can be used in design & development, production, operations, maintenance and customer support [1].

In design, the future of aviation will be unmanned vehicles powered by AI techniques like machine learning and deep learning. The use of AI has already started in

M. Themistocleous et al. (Eds.): EMCIS 2020, LNBIP 402, pp. 577–594, 2020.
https://doi.org/10.1007/978-3-030-63396-7_39

military aviation and unmanned aerial vehicles are performing tasks that are dull, dirty and dangerous with less human involvement. The stringent regulatory requirements of civil aviation have not allowed artificial intelligence into flying activities yet.AI has huge potential in air traffic management, and can reduce the workload of pilots and air traffic controllers [2]. AI algorithms can be used to predict flight delays, trajectory prediction [3] and improving wake separation during landing and enhanced airspace management [4]. AI can be very useful in Customer Relationship Management, where a customer receives better service with AI tools [5]. Airports can use intelligent techniques like face recognition for passenger check-in. With AI, the maintenance concept of aircraft can change from time-based maintenance, where the aircraft goes for maintenance at scheduled intervals, to condition based maintenance, where the aircraft goes for maintenance when a failure is predicted. This paradigm shift, powered by AI tools can improve the availability of aircraft for flying and reduce the downtime.

Application of AI for aviation safety is a very less investigated topic, but with its immense capabilities, AI can definitely improve aviation safety. This paper provides the insights towards the improvement of air safety with the prudent use of artificial intelligence.

2 Research Methodology

Air, safety, which affects all stakeholders in aviation despite advancements in technologies, is a significant concern in aviation. The authentic air accident and incident data, required for the research was collected from sources like National Transportation Safety Board (NTSB). Qualitative studies were carried out to find the practical problems affecting aviation safety, with interviews with pilots and maintenance technicians. Interviews were conducted with test pilots, who fly the experimental prototypes to understand how efficiently they handle an emergency situation compared to commercial pilots. The pilot workload was accessed with the help of standard operating procedures from aircraft manuals and correlated with the flying experience of one of the authors. Scope of artificial intelligence in the problem was worked out by brainstorming and literature surveys. A potential solution for the factors that affect safety was conceptualized be the professional experience of the researchers and concepts of artificial intelligence. The onboard system architecture were conceptualized & validated by professional experience of the authors in design and development of aircraft systems. The research methodology adapted is described in Fig. 1. The core idea of the research was to provide a concept based on Artificial Intelligence that can be further developed by extensive research and retrofitted on the aircrafts to enhance air safety in a cost effective way.

3 Air Safety

Safety is generally considered as a technical parameter, but in reality, is it is a factor affecting every stakeholder of the industry. The International Civil Aviation Organization, (ICAO) the apex body of international air transport, states "one of the key

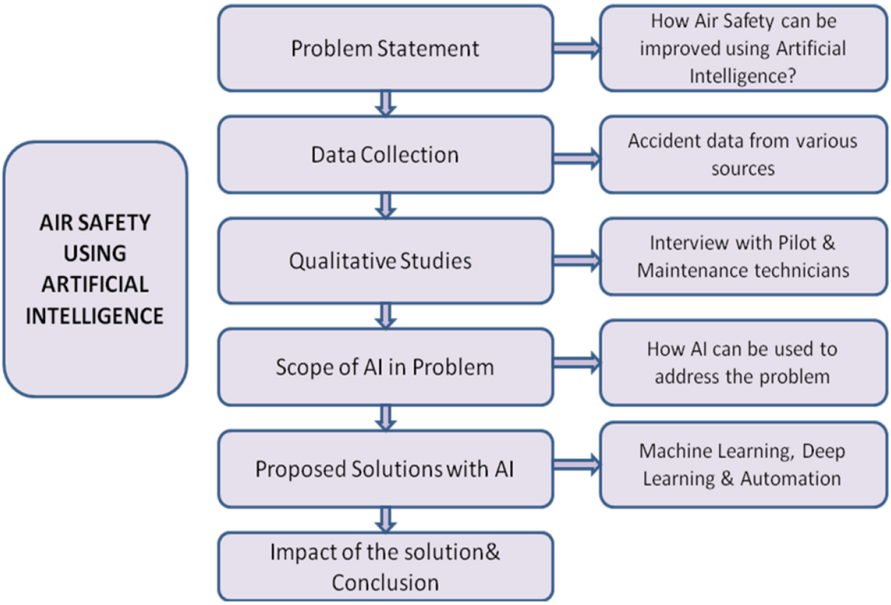

Fig. 1. Research methodology

elements to maintaining the vitality of civil aviation is to ensure safe, secure, efficient and environmentally sustainable operations at the global, regional and national levels." An accident can affect designers, aircraft & equipment manufacturers, regulatory authorities, airlines and ultimately, the passengers. Figure 2 shows the accidents, fatal accidents & fatalities in civil aviation from 2014 to 2018.

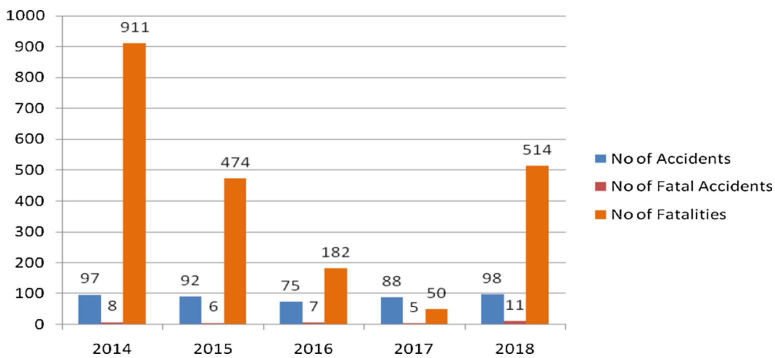

Fig. 2. Number of air accidents, fatal accidents and fatalities

Despite the advances in technology and use of modern aircrafts, 98 accidents occurred in scheduled commercial air transport operations in year 2018. Out of these 11 of the accidents were fatal and has resulted in 514 fatalities in the year 2018 [6].

Air accidents occur in all phases of a flight, and Table 1 shows summary of air accidents during different phases of flight. This indicates accidents occur more during high pilot workload phases of takeoff and landing.

Table 1. Air accidents during flight phases, 2009–2018 [7]

Flight phase	Percentage of fatal accidents	Percentage of fatalities
Taxi/Load/Tow	10	0
Take off & Initial climb	12	6
Cruise	14	31
Initial approach	4	12
Final approach	25	27
Landing	24	10

4 Classification of Air Accidents

Accidents happen due to many reasons and reasons for some crashes like Malaysian Airlines MH 370 still remains mystery. But air accidents have evolved over time. During the initial phases of aviation, the aircrafts consisted of more of mechanical systems with linkages and parts which were prone to failure and less electronics. So, the accidents in the early stages of aviation were mostly machine faults. With the advances in electronics, the aviation has changed drastically and with technologies like fly by wire, there are hardly any mechanical linkages in the aircraft. The modern era aircraft is a complex machine with sensors, microprocessors and data communication systems. The level of sophistication in the aircraft has made the machine safer and reliable, but still the accidents continue. In many cases, the complexity of the machine is more than what an average human brain can adapt and has resulted in accidents. As per analysis carried by Boeing, machine faults resulted in 80% of accidents during the beginning of the century, but with evolution of technology, human errors cause 80% of the accidents [8].

In addition to human faults and machine faults, weather plays an important role in air accidents. The weather at 40,000 feet altitudes is unpredictable with endless air movements. Tornados, ice, thunderstorms, lightning, hail, clear air turbulence, volcanic ashes are a few of the weather hazards that have caused losses in aviation. Aviators still consider weather as a major threat to aviation safety, apart from the human and machine faults. Some of these factors are mitigated with the use of advanced weather radars (Fig. 3).

Figure 4 shows the major weather factors contributing to incidents during different flight phases. Visibility (caused by fog, heavy rain or snowfall) is the most critical factor for accidents during the takeoff, climb and landing phases, where the terrain is much closer to the aircraft. Rain is the second major factor in the take-off, approach and landing phases. Clear Air Turbulence has effect during the cruise phase only.

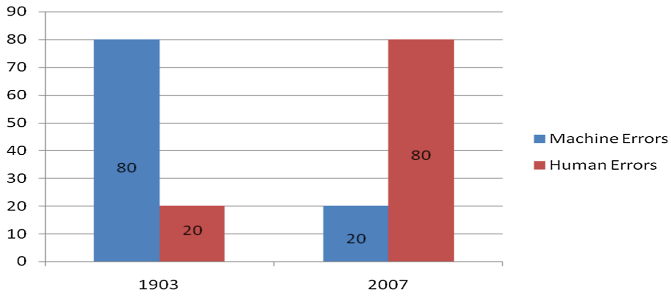

Fig. 3. Evolution of aircraft accidents

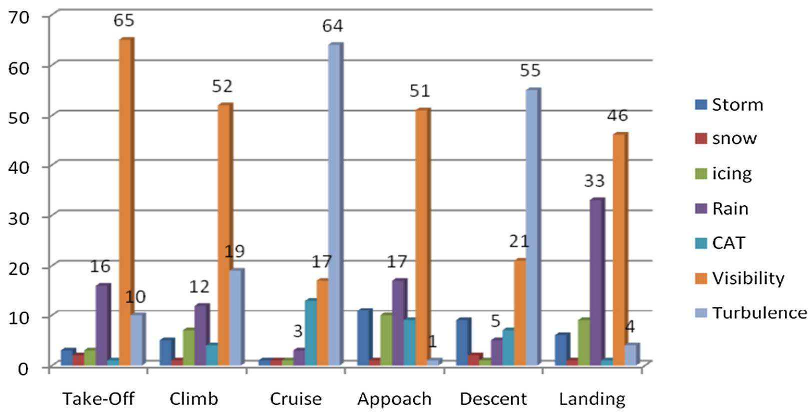

Fig. 4. Contribution of weather factors (in percentage) to air accidents for various flight phases 1967–2010 [9]

5 Analysis of Air Accidents

A detailed analysis of few accidents was carried out using the data from National Transportation Safety Board, and other reports published by accident investigation agencies. A brief of the accidents analyzed is provided in Table 2.

The factors contributing to air accidents can be broadly classified into human causes, machine faults and bad weather.

Human Errors

Human errors leading to accidents can be pilot error or the errors made by the maintenance crew. In many instances, like AirAsia 8501 accident, a wrong maintenance action followed by incorrect pilot responses have lead to accidents. To correlate with the accidents occurring at different phases of flight, the pilot workload in the different phases of flight was analyzed. It can be broadly divided into on ground activities, takeoff activities, in flight activities, landing procedures and ground activities after landing. The maximum workload occurs during the takeoff and landing phases and distraction or emergencies during these phases become critical and lead to accidents.

Table 2. Brief of air accidents analyzed

Accident/Incident	Date	Airline	Reason
Ethiopian Airlines flight, Boeing 737 MAX 8, crashed near Ejere, Ethiopia, shortly after takeoff from Addis Ababa Bole International Airport, Ethiopia killing 157 people	March 10, 2019	Ethiopian airlines flight 302	Accident investigation is still under progress. Preliminary data shows an angle of attack sensor error and incorrect pilot response to it. The left and right airspeed readings were showing different readings. The pilot response to the warnings differed from the assumptions of pilot responses made by Boeing during the functional hazard analysis carried out during the design phase
Lion Air flight 610, Boeing 737 MAX 8, crashed in the Java sea shortly after takeoff from Soekarno- Hatta International Airport, Jakarta, Indonesia killing 189 people	Oct 29, 2018	Lion air flight 610	Accident investigation is still under progress. Angle of attack sensor was showing error between the sensors and there was difference in the left and right airspeed indicators. The same issue had happened during the previous flight with a different crew, and pilots flew the aircraft manually and landed. The pilot response to the sensor warning was different in each case [10]
Air Canada flight 759 (Airbus A 320–211) was cleared to land on runway 28R at San Francisco Airport. Instead, it descended to 100 feet on taxiway C and flew over four airplanes were waiting to take off	July 7, 2017	Air Canada flight 759	Flight crew misidentified taxiway C as the intended landing runway. This was result of the crewmembers' lack of awareness and fatigue. The captain and the first officer were fatigued during the flight, being awake for hours and circadian disruption. The first officer, focused on cockpit tasks, couldn't effectively monitor the approach and recognize that the airplane was not aligned with the intended landing runway [11]
Indonesia AirAsia Flight 8501 (Airbus A 320) operated by AirAsia C, a subsidiary of AirAsia was operating from	28 Dec 2014	Air Asia Flight 8501	A soldered electrical connection in the plane's Rudder Travel Limiter Unit was cracked, likely for a year, resulting in

(*continued*)

Table 2. (*continued*)

Accident/Incident	Date	Airline	Reason
Surabaya, Indonesia, to Singapore. During the flight, the aircraft crashed into the Java Sea, killing all 162 people on board			intermittent cockpit warnings. The data indicated this event happened 23 times during a year. But it was solved by resetting the system, rather than identifying the root cause, the solder crack. On the accident day, the warning appeared four times during flight. First three times it was cleared as per procedures. When the warning appeared for the fourth time, captain was frustrated & decided to reset to the Flight Augmentation Computer circuit breakers. He had seen a ground engineer doing this &believed this could be done in flight also, without knowing its repercussion in-flight. The aircraft stalled, lost control and crashed [12]
An airbus A 330–200, flying from Rio de Janeiro to Paris crashed in Atlantic ocean	1 June 2009	Air France AF 447	Pitot probes were blocked by ice in cruise. The crew become progressively de-structured, by warnings likely never understood that it was faced with a "simple" loss of three sources of airspeed information [13]

Even though only 20% of a flight is spent in landing or take-off phase, most fatal accidents happen in these phases. Summary of analysis of pilot errors that have resulted in accidents are summarized in the Table 3.

The findings from the analysis of the accidents are provided below:

- Multiple alerts and indications in the cockpit increase the pilot's workload and make it difficult to identify the high priority procedure. At times, assistance should be provided to pilots to decide on the highest priority action. This is extremely critical during the critical flight phases of takeoff and landing.
- Many warnings that appear in the cockpit are false alarms and it's only the experience and skill of the pilot in analyzing the situation correctly avoids an accident. This is lacked by many new pilots.

Table 3. Crew factors in air accidents [14]

Si no	Factor	Effect
1	Loss of situational awareness	Situational awareness is ability of humans to combine data into meaningful information (perception), understand the meaning of the information (comprehension) and use it to plan the activity (projection). The loss of situational awareness leads to incorrect response to a situation and lead to accidents
2	Spatial disorientation	Spatial disorientation is the inability of the pilot to maintain awareness of his & aircraft's orientation, position and trajectory relative to the earth. Many accidents were results of spatial disorientation
3	Crew fatigue	The crew fatigue can be result of insufficient rest or the end phase of the flight is affected circadian body clock. This prevents the pilot from taking the correct decisions and slower neuro motor response
4	Crew workload	Full attention of the crew is required during takeoff and landing phases. Diversion of attention due to additional work like an emergency increases the pilot workload
5	Incorrect responses	There are cases where crew does not adhere to emergency procedures as suggested by the flight manual and has taken incorrect actions leading to accidents

- Manufacturers assume that pilots respond in the same way to emergency conditions as accessed by the functional hazard analysis carried out during the design, but the combined effect of alerts and indications are sometimes not evaluated. The combined effects might impact pilots' recognition and lead to accidents as seen in many accidents analyzed.
- The circadian body clock does not adapt fully to altered schedules such as night work and the landing phase of a flight may be during the circadian body low, where the ability of the crew to act promptly becomes compromised.

Maintenance Errors

Errors made by the maintenance crew have also resulted in many accidents. The main points evolved from interview of maintenance crew are:

- It is extremely difficult to identify airframe damages that accumulate over a time due to fatigue. It may show up suddenly.
- Engine problems are plenty in aircraft accidents and monitoring of engine is extremely important to avoid unplanned grounding of aircraft.

The major factors for errors from maintenance crew are provided in Table 4.

Bad Weather

Weather in the upper atmosphere is unpredictable and causes accidents resulting in injury to passengers and crew & damage to the aircraft. The occurrence of tornados,

Table 4. Maintenance factors in air accidents

Si no	Factor	Effect
1	Violations	Maintenance staff sometimes does not follow company policies, processes, and procedures while doing a job, which can ultimately result in an accident
2	Memorizing tasks	Memorizing tasks is a common phenomena observed in maintenance. The practice of using the maintenance manuals are not followed by many aircraft maintenance engineers and technicians
3	Un calibrated equipments	Many people use tools and equipments that are not calibrated to standards
4	Organizational pressure	To avoid events like flight cancellations, maintenance actions are compromised, which leads to accidents

turbulence, icing, hails, lightning are frequent in atmosphere. Aircrafts have to fly through these conditions, avoiding the extremes. Severe conditions of rain or hail has resulted in engine power loss, engine flame out, instability, and forced landings. Certain concentrations of rain and hail can be amplified through the engine core at certain combinations of flight speed and engine power resulting in engine anomalies such as surging, power loss, and engine flameout. Modern aircrafts use weather radars to circumvent the unfavorable weather conditions. But the reflectivity of the weather radar depends on the particle size of the object encountered. The reflectivity of radar signals to particles reduces with size of the particle as shown in Fig. 5.

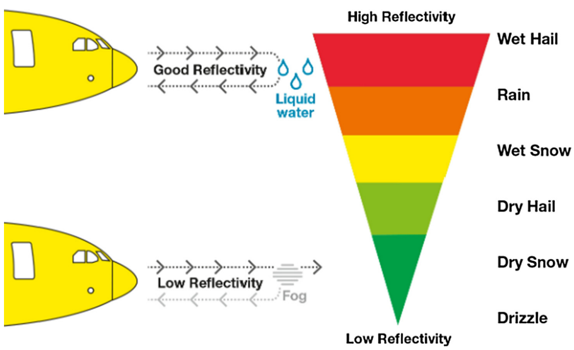

Fig. 5. Aircraft weather radar reflections

The weather radars can inform the pilots about the weather up to 320 nautical miles and provide accurate information up to 40 nautical miles. Weather radars can easily indicate the presence of liquid water. Dry snow, dry hail, drizzles, clear air turbulence and sandstorms are very difficult to identify, which results in accidents or incidents.

6 Potential of Artificial Intelligence in Air Safety

The correlation of the capabilities of AI and its scope in factors causing accidents indicated that AI with its data storage, data analysis and processing algorithms can improve air safety. AI has the capability to predict, remember, make decisions based on data, learn based on the training, analyze data and recognize objects based on training. The capabilities of prediction and recognition can be used to detect pilot fatigue. The analysis capabilities of AI can be very useful in identification of false alarms in the cockpit. The predictive capabilities can be used for predicting the weather, which is not provided by the existing weather radars. The scope is provided briefly in Table 5.

Table 5. Scope of AI in reducing air accidents

Si no	Area	Potential AI tools
1	Pilot fatigue/sleep monitoring	Pilot fatigue and sleep are two factors affecting air safety. Pilot fatigue can be identified by convolution neural networks, trained based on images of the eyes. Machine learning tools can be used to analyze the pilot images, especially of eyes and mouth in real time. The AI module can be trained to identify a potential pilot sleep and provide an alert. Combining images of the pilot with other parameters like circadian body clock, pilot history of sleep incidents as inputs for the model can predict sleep
2	Potential weather impacts on flight	Data can be collected from flights over various conditions like flight over the sea, flight at specific altitudes, flight in icing conditions and flight over volcanic areas. This data can be used to train models, which can predict weather hazards and provide warning to the pilot. Blunt impacts to composite structures from hail are a potential threat and can be avoided by predictions
3	Fault analysis	The experience of a test pilot can be bought in to assist a new un experienced pilot with fault tree analysis. A warning like “The aircraft is flying at 38000 feet above the Atlantic Ocean where chances of ice formation and blockage of Pitot tubes has occurred in the past. A warning of ‘incorrect air speed’ can appear which is temporary” can be very useful. The conditions in which a maintenance fault can result in a cockpit warning can be studied with the help of historical data. The cause for a warning can be an issue like a dry solder. The AI model has to take the maintenance information carried out on the aircraft. A message like “The aircraft reported issue related to angle of attack sensor during the last two flights, the warning could be result of the recent maintenance action. Fly aircraft manually monitoring other parameters” can be very useful to the pilot

7 AI Based Smart Cockpit Assistant

The concept proposed by this paper is named the "AI powered smart cockpit assistant" which can mitigate few of these hazards. The proposed implementation plan of this on Airbus A 320 is covered under this section.

Airbus A 320 has an Electronic Centralized Aircraft Monitor (ECAM) which gets the information from the various aircraft systems and sensors and displays the information to the pilots. In the event of any malfunction, the fault is displayed on the ECAM display, along with the steps for the remedial action. The ECAM system consists of Flight Warning Computer (FWC), System Data Acquisition Concentrators (SDAC), Display Management Computers (DMC) and the pilot interface in the cockpit which helps the pilot to view status of specific systems of the aircrafts. The architecture of the ECAM system is shown in Fig. 6.

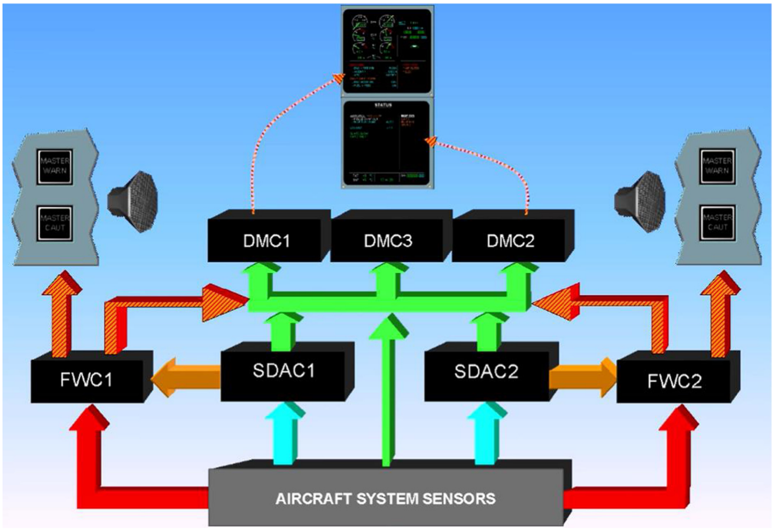

Fig. 6. Airbus electronic centralized aircraft monitor architecture

However, there are few drawbacks for this existing system:

- This is a dumb system which displays the error and provides the steps to rectify the error.
- This system cannot identify the root cause of an error. An interview with a highly experienced test pilot suggested that test pilots can understand the root cause of the error and reason for the warning, with their experience of systems. This experience and knowledge of systems are lacked by new pilots.

The block diagram for proposed smart cockpit assistant which can mitigate the factors associated with air safety is provided in Fig. 7.

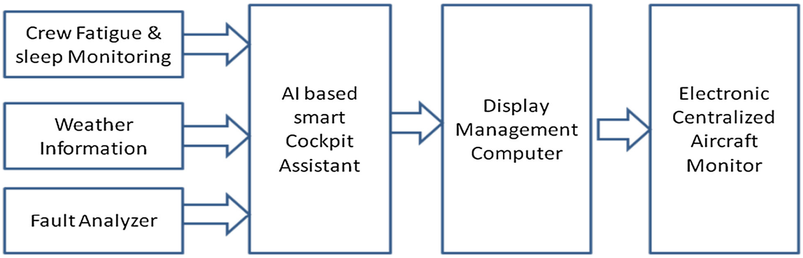

Fig. 7. AI based smart cockpit assistant for airbus A 320

The hardware of the proposed unit will be a graphical processing unit (GPU) and two cockpit cameras that can capture the images of the pilots in the cockpit. The, software, i.e. AI algorithms would be running on this hardware taking inputs from the camera, weather radar and data from aircraft sensors and maintenance information. Modular architecture is proposed for the system to implement functionalities as separate modules, which can be integrated together at a later stage. The detailed architecture for proposed smart cockpit assistant which can mitigate the factors associated with air safety is provided in Fig. 8.

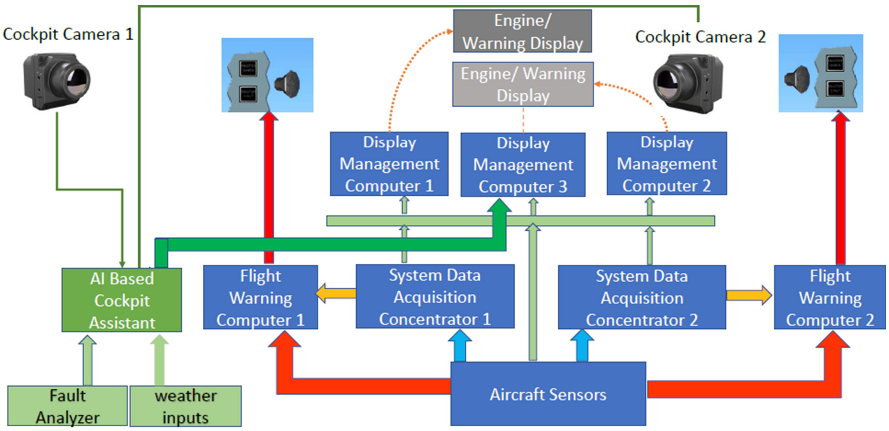

Fig. 8. Detailed architecture of smart cockpit assistant for airbus A 320

There are three AI systems proposed under the scope of smart cockpit assistant.

- The first module would be used for identification of pilot fatigue and sleep. The inputs to the system would be images from the camera installed on the cockpit and variables that can affect crew fatigue like crew age, workload etc.
- The second module would be using the data from the weather radar and with use of historical information, would be providing accurate weather data including hail prediction, turbulence predictions etc.

- The third module would be a fault analyzer that basically can identify a false warning. This system would bring the experience of a test pilot into the cockpit in analyzing the emergency situations and help the pilot to act safely. This would take into cognizance factors like recent maintenance of the component, historical failure of a component etc.

Module to Reduce Pilot Errors Due To Sleep and Fatigue

To reduce accidents related to human faults, the system should be able to detect sleep and fatigue. Sleep can be detected from images of the eye taken from the cockpit camera and combining with factors like crew age, time since awaken, circadian body block etc. using a random forest algorithms. Fatigue can be identified using convolutional neural network which can differentiate a fatigued eye from a normal eye. The input for the sleep monitoring system would be images on the pilot captured from the camera in the cockpit. This module would use reinforced learning, where the module is taught to identify a fatigued or sleepy eye with training data. At the first step the module would be taught to identify closure of the eye. This is based on Eye Aspect Ratio (EAR) shown in Fig. 9. The module uses a detector and a predictor. The detector detects the eye from the camera image and the predictor whether the person is sleepy or not. Closure of the eye alone cannot be identified as sleep and there are other parameters that need evaluation for a crew fatigue warning. Momentary closure of eyes cannot be misunderstood as a sleep. The times for which eye is closed also needs to be checked to correctly identify sleep. In case the eye remains closed for 30 frames (an assumption), it can be classified as a potential sleep and can become a hazard.

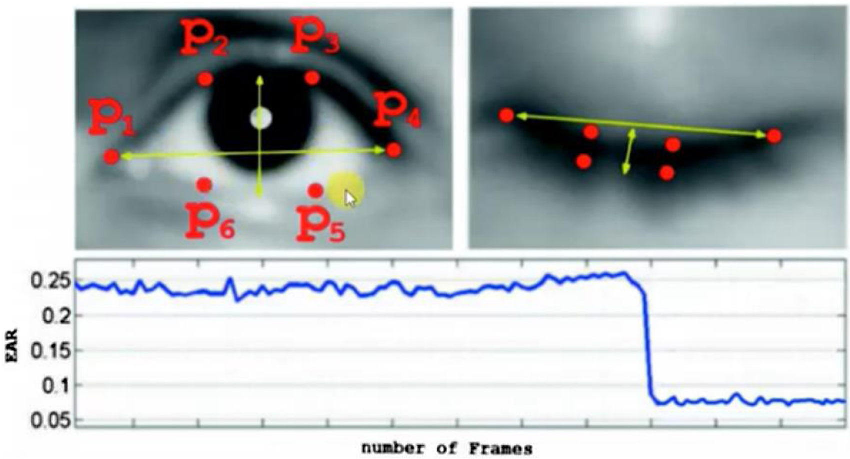

Fig. 9. Identification of eye closure and sleep

$$EAR = \{|P_2 - P_6| + |P_3 - P_5|\}/\{2|P_1 - P_4|\}$$

Additionally, the inputs provided in Table 6 also would be taken by the AI systems to correctly predict the fatigue. These factors will have to be made as a random forest algorithm to predict sleep.

Table 6. Factors for predicting sleep

Si no	Factor	Remarks
1.	Crew age	Sleep becomes more fragmented after about age 50–60 years. Older pilots take longer to fall asleep, gets less sleep overall, and had more fragmented sleep than young pilots
2.	Time since awaken (TSA)	The alertness and performance of crew deteriorates with longer the time they remain awake due to an increasing homeostatic pressure for sleep associated with the longer period of wakefulness
3.	Circadian body clock	The crew flying across time zones experience sudden shifts in the day/night cycle, and end up in landings where the body has the natural tendency to sleep
4.	Direction of flight	Body adapts faster to time zone changes for westward travel (phase delay) than after eastward travel (phase advance) across the same number of time zones
5.	Workload	Workload increases with the number of sectors in a flight duty period. Flying multiple sectors in high density airspace across long duty day increase the workload
6.	Unscheduled duty & early report time	An unscheduled duty or early report time may result in crew member receiving inadequate sleep
7.	Density of Airspace	Flight into high density airspace increase the fatigue for the pilots can result in incorrect responses
8.	Crew fatigue reports	Previous history of crew fatigue reported by the crew himself also would be used for AI system to predict fatigue

Fatigue also can be identified using the images captured by the camera installed in the cockpit. An image is considered as a complex data with multiple layers of abstraction. Neural Networks can be used to train the module and classify images. Neural networks with multiple hidden layers can be used for image processing and detection of pilot fatigue. Each layer can learn features and desired output can be obtained by training one layer at a time. This training can be achieved by training a special type of network known as an auto encoder for each desired hidden layer. First the hidden layers are to be trained individually in an unsupervised fashion using auto encoders. Then a final layer will be trained joining the layers together to form a deep network, which is trained one final time in a supervised fashion (Fig. 10).

Module to Reduce Impacts of Weather

The weather prediction module in the smart cockpit assistant predicts weather more accurately augmenting the existing systems. AI techniques in conjunction with a physical understanding of the environment can improve prediction for multiple types of

Fig. 10. Neural networks for identification of Fatigue

high-impact weather. This approach expands on traditional Model Output Statistics techniques. AI techniques provide a number of advantages, including easily generalizing spatially and temporally, handling large numbers of predictor variables, integrating physical understanding into the models, and discovering additional knowledge from the data. Weather radar data if complemented by knowledge of current atmospheric conditions can predict if the current atmosphere is conducive to hail development. Decision tree-based methods are very useful in predicting hails and turbulences augmenting the weather radar data. A sample decision tree for hail prediction has been provided in Fig. 11.

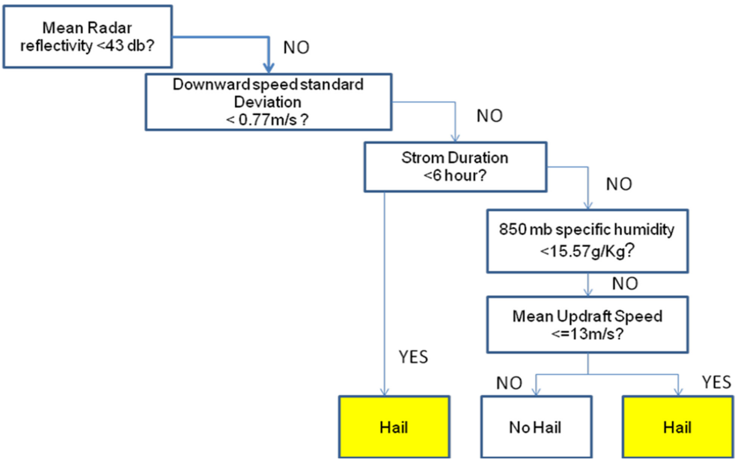

Fig. 11. Decision tree-based method for improved hail prediction

Fault Analyzer Module

The appearance of a warning in the cockpit adds more workload on the pilot. In many accidents analyzed, it was felt that the warnings appear on the cockpit does not correlate with the root cause of the problem. The experienced test pilots are capable on identifying the root cause, but a less experienced pilot finds it difficult to identify the root cause and fail to initiate the correct procedure. A warning has a lot of entropy associated with it, due to lot of reasons. With the use of machine learning, the entropy associated with a warning can be reduced and more information can be gained, which can assist the pilot to take a wiser decision.

The fault analyzer module runs AI algorithms at the back end. It can provide more information to the pilot in addition to the information suggested by the ECAM system. Decision trees can reduce the entropy associated with a warning, which brings the experience of the test pilot and the hazard analysis done by the designer into the system. The decision tree can handle both numerical and categorical data, which assists in decoding the warning accurately. A decision tree for airspeed warning for the case of Air France accident is provided in Fig. 12.

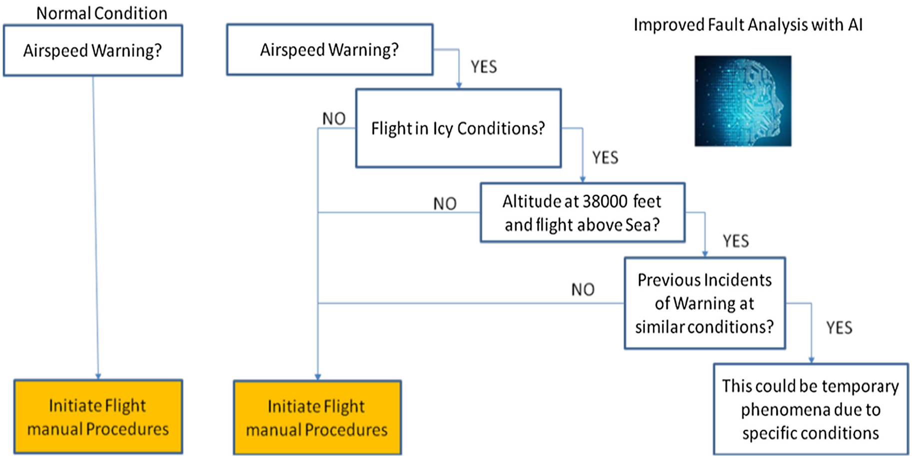

Fig. 12. Improved fault analysis based on decision trees

8 Cost of Accidents

Aviation collision/crash incidents are the second top cause of insured losses globally behind fire and explosion incidents [15]. Air accidents or incidents like hard landing, delays and faulty workmanship cause huge losses for the airlines. There are direct costs involved with accidents which include cost of damaged aircrafts, recovery costs, loss of third-party property, medical care costs for victims, legal costs and cost for accident investigation. Fatal accidents cause a huge of liability to the airlines (Fig. 13).

There are indirect costs arising out of accidents and incidents. The image and reputation of the airlines takes a hit as a result of accident and incidents. Passenger may perceive an airline as unsafe and opt for other airlines, resulting in revenue losses. Additional losses occur if a crew is injured or denied permission to fly after an incident and it affects the operations. Legal actions for compensation are initiated by the families of victims against the airlines. As the safety ratings of an airlines goes low, there

Fig. 13. Costs associated with accidents

are chances that the insurers charge more for providing insurance cover to the airlines. The cost range based on aircraft (type and age) and accident severity will be minimum of 4–211 million €; and maximum of 414–591 million €.

9 Conclusions

Air safety is of critical importance in aviation. A few accidents and incidents in the recent aviation history were analyzed for the purpose of the paper. The major contributing factors for accidents were also analyzed. Interactions were held with stakeholders in the industry including test pilots, commercial pilots and maintenance engineers to gain insight to the real operational scenario. The focus was to propose cost effective solutions with minimal changes to the aircraft. This concept based artificial intelligence can play a crucial role in increasing the air safety to a higher level. The system tries to mitigate three major hazards associated with safe flying, i.e. pilot fatigue/sleep, weather hazards and false warnings.

The concept presented in the paper can be implemented by OEMs who develops electronics systems for the aircraft, after extensive research, testing and validation. Combining the data from the aircraft level and system level hazard analysis carried out by the aircraft manufacturers, the system can be tested, validated and used in different aircrafts. The system proposed can be retrofitted on most of the aircrafts, with very few changes in the existing systems, which would make this a good value proposition for all the stake holders.

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