Can We Monitor Crew Situational Awareness During Flight?

Exploring the use of behavioural markers

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Abstract— Is it possible to automatically and non-intrusively observe flight crew behaviour in the cockpit in order to monitor their Situational Awareness during flight? This work in progress investigates the possibility to automatically monitor flight crew Situational Awareness (SA). The monitoring tool is to automatically analyse the Situational Awareness of both pilots on the basis of their visual scanning, their interaction with cockpit systems and their speech. Visual scanning is an indicator for the first level of Situational Awareness (perception), which is a necessary basis for higher levels of Situational Awareness (comprehension and projection). The timing of pilot interactions with cockpit systems as well as speech could be indicators of these higher levels of Situational Awareness. The question we would like to answer in our work is: can we establish a common behavioural pattern within a flight crew that indicates optimal SA and can we use this as a reference to identify reduced SA? And, if this proves to be impossible, is an individual reference pattern possible and is that a suitable alternative?

Keywords- crew monitoring; Situational Awareness; modelling.

I. INTRODUCTION

Continuous combined efforts by the aviation community have resulted in the achievement of a safety record in air transport that is unequalled by other modes of transport. In recent years, although these efforts continue unabated, the accident rate seems to have reached a stable rate of about 2 accidents per ten million flights [1]. With air transport foreseen to grow in the coming decades (4.7% to 5.0% per year), this accident rate, while very low, will translate to several major incidents and accidents per week.

A fundamental pillar in aviation safety is the requirement that no single failure should result in a catastrophic accident, i.e., the write-off of an aircraft and multiple fatalities. During aircraft type certification the manufacturer must prove to the aviation authorities that the probability of a system failure is below a threshold that is inversely related to the severity of the consequences. For example, potentially catastrophic failures must have a probability of less than one occurrence in every 100.000.000 flight hours.

Aircraft systems have become so reliable, that human error has become more prominent in statistical analyses of factors contributing to accidents. Thus, a large percentage of recent accidents can be linked somehow to a human factors issue, such as poor perception of the environment, inadequate crew coordination, excessive workload, misunderstanding of an evolving situation and inappropriate training.

Even in case of two well-trained pilots, complex and high workload conditions are not uncommon today. Especially in these conditions, optimum crew action depends on an adequate understanding of the situation at hand and the corrective actions that are needed. Monitoring crew status in flight is therefore considered one of the enablers for enhancing overall safety. When suboptimal crew status is indicated, the crew could be assisted. In this work, we particularly look at crew Situational Awareness (SA).

The overall objective of the work is to automatically monitor the pilots' state in a non-intrusive way. This includes constructs such as flight crew's presence in their seats, physical state, drowsiness, workload, distraction, etc. Situational Awareness is one of these constructs. So far, it is not possible to directly measure Situational Awareness in a non-intrusive way. Thus, Situational Awareness is usually assessed using ratings by an observer or using self-ratings and questionnaires, such as Situation Awareness Rating Technique (SART) and Crew Awareness Rating Scale (CARS). These measurements are neither automatic nor non-intrusive and not suitable for day to day use in an airline cockpit. In this operational environment, Situational Awareness should be inferred from automatic behavioural analysis of non-intrusive measurements.

This paper describes the work in progress. The sections included describe: the concept of SA (2), the operational context (3), the potential observables for SA (4), the implementation of the tool in the operational context (5), the method used (6) and the last section the status at the time of writing.

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II. Situational Awareness

One of the most widely accepted definitions of Situational Awareness is that of Endsley [2]: *"the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future"*.

This definition includes three levels of SA:

- *Level 1, Perception* – This is the basic information that is required for Situational Awareness, being able to notice events, people, objects in the external environment. This level simply represents the collection of basic data.
- *Level 2, Comprehension* – Once an event, or object, has been perceived, it is necessary to understand the meaning of that object in the situation. This represents the interpretation of the basic data that is collected through perception.
- *Level 3, Projection* – The third level of Situational Awareness represents the ability to project the interpretation of the current situation into the future. This level of Situational Awareness is required to be able to predict the effect of the information that is currently available onto the future situation.

Situational Awareness of pilots has been assessed during many flight simulation experiments, but monitoring it automatically and non-intrusively in an operational environment is the challenge of this work in progress.

III. The Procedural Character of Flying

The tasks of a pilot consist of actions necessary to fly the aircraft, to navigate, to communicate and to manage systems. Crew behaviour in the cockpit is largely driven by procedures. These procedures are dependent on the flight phase and are influenced by the environment (e.g., weather, terrain), external events (e.g., ATC commands) and the aircraft state (e.g., speed, fuel, systems status).

Crew behaviour is also driven by crew resource management. One pilot is responsible for flying the aircraft and the other for other tasks such as the communication (with the cabin and outside world), and managing systems. The pilots in their roles have complementary tasks, but both need to assure themselves that primary flight parameters are within the acceptable range. Together they are responsible for a safe flight execution.

Descents, approaches and landings are the more busy flight phases, which consist of a relatively predictable number of actions and the use of checklists. Depending on the type of technology available on the airport and other conditions such as visibility, the type of landing, the level of automation is selected. The different landings may require different procedures but it is expected that roughly the visual information acquisition behaviour is similar.

IV. Observables

Much of the information that is available in the cockpit is of the visual modality. Hence, the crew's scanning pattern and visual focus points are an important method of observing the crew's attention. The crew's scanning pattern can be recorded with an eye-tracker. The crew's interaction with cockpit systems and speech can also be recorded directly. How suitable are these three types of behavioural measurements for automatic recording and interpretation on the flightdeck in actual flight?

A. *Eye gaze*

Eye gaze is highly selective in the sense that it provides direct insight in the information that is being used by pilots [3][4] for performing their tasks. Eye gaze is also highly generalizable, i.e., all pilots must visually scan cockpit instruments and the outside world in order to retrieve most of the required information. Eye gaze is highly responsive too: a single eye fixation related to information intake can be in the order of 70 ms. Finally, with state-of-the-art algorithms, eye gaze data can be reliably filtered and interpreted. Note that some displays in the cockpit can present different pages with information. Consequently, the active page should be taken into account when interpreting the data.

B. *Interaction*

Interaction with cockpit systems is highly selective in the sense that it provides direct insight in the tasks pilots are performing. Besides, every crew has to perform the same interactions to obtain the same results, so measures of interactions are also high generalizable. They are highly responsive too: every interaction is directly and instantly related to a pilot task. For this reason, complex filtering is not needed and automatic interpretation is straightforward. Note however, that in less busy flight phases the crew has some freedom in the order of performing their tasks.

C. *Speech*

Speech recognition can provide insight in the topics the pilots are discussing; however, it is more difficult to reliably infer the precise meaning of the vocalizations in relation to task performance. Note that this may change in the near future since speech recognition technology is developing rapidly (consider the "digital assistants" on smartphones, that rely heavily on understanding natural speech). Also note that interpretation of intonation can also give clues regarding crew state and this has been shown to work. However, it provides little concrete information regarding task occupation.

All in all, recordings of eye gaze and interaction with cockpit systems are currently the most suitable behavioural measures for our purpose. Finally, note that these measures primarily relate to SA Level 1 and 2.

V. METHOD

As a first step in our work, the SA assessment module is scoped around one flight phase, for which the required behaviour is particularly procedural and therefore relatively predictable: the full descent under nominal conditions.

The input for the SA module will be the visual acquisition on the basis of eye-tracker information, the altitude in relation to the runway, the information that is displayed on the cockpit systems and the communication with Air Traffic Control.

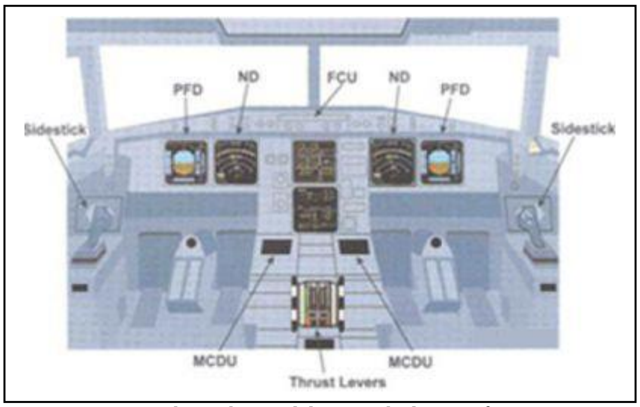

Figure 1 The cockpit and distinguished areas of interest

The methodology consists of two phases: a development phase to create the reference model and a validation [4][5] phase to validate the SA module that compares actual behaviour to the reference behaviour in real time.

A. Development phase

For the development of the reference model, pilots made descents in NLR's Airbus A320 lookalike cockpit mock-up using an eye-tracker system to register their information acquisition.

Scenarios were prepared with full descents to Schiphol airport, Amsterdam. The scenarios started a few minutes before top of descent to allow the pilots to prepare the descent and to build their SA as they would in a normal operation. Approach and landing checklists were part of the procedure. Each pilot, after a familiarisation session, flew three scenarios. One scenario concerned nominal conditions including heading instructions around a weather cell. In the other two scenarios the conditions were less optimal. In one scenario, the fuel on board was low and the landing condition as proposed by Air Traffic Control was less optimal. In the third scenarios a flap malfunction forced the pilot to divert to a different destination airport. It was observed if the pilot perceived the condition, if he understood it and took appropriate action timely.

Participants' behaviour was observed and after each scenario the pilots were interviewed to assess how they experienced the scenario and how they rated their SA in the course of the run. These observations and ratings are used in the development phase to tune the system.

The eye-tracker system delivers visual information acquisition in terms of dwells: the uninterrupted amount of time spent on an Area of Interest. The relevant Areas of interest are visualized in Figure 1. The data was analysed post experiment, in relation to the altitude above the landing runway and compared to the SA ratings and observations. The analysis allowed defining a reference model that represents adequate SA and thresholds for degraded SA. This common reference model was then integrated into the SA module to real-time monitor SA.

B. Validation phase

A group of pilots will participate to a validation exercise. In this exercise the SA module will provide indications of the pilot's SA in real time. This will also take place in a simulator that resembles an A320 cockpit.

VI. CONCLUSION AND FUTURE WORK

In attempts to further increase flight safety, tools are being developed to monitor pilots' status in flight. This work-in-progress aims to develop a module that can monitor the pilots' Situational Awareness in a non-intrusive way. For this, the pilots' visual acquisition and communication with Air Traffic Control are the observables used. A model was developed of minimal desired division of attention on sub-tasks: Aviate, Navigate, Communicate and Manage Systems during descent and landing. The model was incorporated into a module able to monitor the pilots' division of attention, and indicating degraded SA.

At the time of finalising this work-in-progress paper, the module is being evaluated in a validation exercise. This will allow further improvement of the model.

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REFERENCES

[1] Airbus S.A.S., Quality and Safety First, Commercial Aviation Accidents, A Statistical Analysis, May 2015. http://www.airbus.com/company/aircraft-manufacture/quality-and-safety-first/ Last retrieved September 2015.

[2] M. Endsley, "Toward a theory of Situational Awareness in dynamic systems", Human Factors 37, pp. 32–64. 1995.

[3] H. van Dijk, G. K. van de Merwe, and G. D. R. Zon, Situational Awareness Assessment in Flight Simulator Experiment. Proceedings ISAP 2009.

[4] G. D. R. Zon, H. van Dijk, A Selection of Human Factors Tools: Measuring HCI Aspects of Flight Deck Technologies. Proceedings HCI International 2009.

[5] G. D. R. Zon, and M. I. Roerdink, HCI Testing in Flight Simulator: Set Up and Crew Briefing Procedures - Unique Design and Test Cycle. Proceedings HCI International 2007