CARESS1
Commercial Airliner Emergency Safety System

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Abstract: This paper presents the project CARESS1, which is a connectionist system, using an MLP as network structure and GeneRec as learning algorithm, with the purpose to comprehend unforeseen situations in civil aviation and treat them in order to avoid air disasters. The importance of a new safety approach is discussed, related work is given and a system overview is presented. Shortly the first results (in a simulation environment) shall be obtained. The approach is a new and promising means to automatic problem treatment and might lead the way up to the final aim of a fully automatic aircraft.

1 INTRODUCTION

The issue of airplane safety is of high financial and emotional importance. Modern passenger jets cost frequently around 100 Million US-Dollars (see Reuters, 2007) and thus their financial loss is of great impact, even if insurance is involved.

Nowadays the only plausible way from one continent to the other appears to be by airplane. In times of globalization, it should be deemed probable that there will be even more airlines and passengers transported every upcoming year.

Meanwhile a feeling of lack of safety is present to many people inside airplanes (according to Brown, 1996, only 6% feel comfortable). This is indirectly documented by the series of publications, which seek to overcome this uncomfortable feeling such as Brown (2006), Hartman and Huffaker (1995) or Krefting and Bayaz (2000), by the great press attention given to any of the events and by several horror/suspense films, which include aircraft (see the long list presented by Daniel Webster College, 2007).

Whereas the attention given to rare fatal accidents is large and immediate (in such a way to not even wait for confirmation as with Air France flight 358 to Toronto on October 2nd, 2005 commented in Toronto Star, 2005), the attention given to constantly present fears is minimal.

Yet, the well-known statistical result of an airplane being safer than any other way of transportation is actually not a universal truth. Weir (1999) raises a lot of critics concerning the way statistics are conduced and set and he identifies them as a way to blind the ordinary passenger by manipulating the parameters in a way to provide the desired result.

It becomes clear that safety is one of the most important issues on a jet plane and that every effort should be taken to achieve it, so that this form of transport can not only be considered statistically more safe, but actually a reliable means of transport - also emotionally speaking.

2 JUSTIFICATION

The following fatal characteristics may be found in many airliner accidents (found in a series of crashes as seen in Transportation Safety Board of Canada (1998), Folha Online (2008) or Terra Notícias (2005)):

- System malfunction (wrong path, unsuccessful detection of the approach of danger);

- Need for rapid pilot decision (reprogramming or evasion manoeuvres);

- High physical and emotional stress (reprogramming in a hurry, G-forces after the collision);

- A possibility to avoid the accident or its major consequences, if conducted differently;

- Different behavior of the pilot is at least difficult to impossible in the present situation, whereas a mechanical intelligent approach could be fast enough or accurate enough.

Out of the following reasons an automated approach is probable to produce better results:

- It is not subject to emotional stress and stays analytical and focused even in extreme situations;

- It is less subject to physical "stress" (movement, G-forces), if mounted properly;

- It may be much faster than a pilot;

- It is not subject to negligence inside its scope, it has no corporal needs (as sleep on long distance flights).

The aim of the present approach is to develop CARESS1, a project, which shall lead the way to a safety system, intended for commercial passenger aircraft. CARESS1 shall present the following high-level technical benefits:

- Automatic reaction on imminent extreme dangers, overriding the pilot's controls, if applicable;

- Alert of dangerous situations (mechanical failure, weather, wrong decisions etc.);

- Enhancement of automated navigation and treatment of turbulences.

Thus the following non-technical benefits are sought:

- Development of a feeling of high safety and reliability;

- Help in the treatment of the fear of flying.

3 RELATED WORK

Current approaches might be divided into common approaches (which may already be partially or fully implemented) and novel approaches, which still need research to reach the level of implementation.

The following shall give a short overview of some examples.

Several collision avoidance systems were developed and enhanced, as shown in Williams (2004). As he stresses, trace goes back to a 1956 crash over the Grand Canyon and systems have been improved ever since, including versions for ground or air collisions, sounding alerts and radars. There is yet no integrated approach in production, which could automatically evade this type of crashes.

Waterman (2002) gives the interesting idea to be able to override the controls of the cockpit from outside the plane (i.e. from the tower or a mobile station) and thus be able to lock the plane on its course in case o hijacking. This might also be used in case of an imminent disaster when the pilot is unable to solve a problem alone. It, however, does not address the issue of the speed of reaction.

The following approaches may be considered novel and more in the scope of CARESS1. They are currently under development, organized by the NASA (listed in National Aeronautics and Space Administration, 2008) and elaborated with the help of university and industry researchers:

The Integrated Intelligent Flight Deck (IIFD) shall offer an optimized access to controls to the pilot as well as establish good awareness of the aircraft condition. It shall sense internal and external hazards and offer key information for the solution of the problem.

The IRAC (Integrated Resilient Aircraft Control) project is an implementation of on board systems which shall guarantee manoeuvrability and stability margins in case of the presence of sudden adverse conditions (such as structural damage, control surface failure, icing, aerodynamic problems). It relies on integrated multidisciplinary aircraft design tools. Math models are used to model the interactions between control inputs, trajectory planning and guidance and the aircraft structure and propulsion systems.

The project Integrated Vehicle Health Management Project (IVHM) has its focus on automated detection, diagnosis and prognosis which enable mitigation of adverse events during flight. It is different from IRAC in the sense of focusing more on the hardware and software situation of the aircraft. Special importance is given to a proper software analysis, for which the methodology has yet to be developed. One of the main outputs shall be the remaining useful life (RUL) of equipment. Data shall be shared and mined in order to allow a broader analysis and prevention.

CARESS1 differs from these approaches in two

main points:

CARESS1 is a connectionist approach and as such a learning system, which is not fully pre-modelled. It is to learn over time from its own experiences and share them to others.

CARESS1 as a project follows a "from inside out" approach, i.e., firstly a core is modelled with few typical sensors and actuators (and without any demand of completeness). Afterwards the system is "broadened" to attend a list of the above needs.

Final objective of CARESS1 is the fully automated aircraft.

4 OVERVIEW

The purpose of CARESS1 is to treat incidents, which typically pose extreme difficulty on airplane pilots and cannot either be treated by automated means at the present point of development.

The main problems associated are:

- Air traffic: May be at crash course with the plane and – depending on the angle or the day light – may not be naturally seen by the pilot. In this case, malfunctioning or deactivated collision detection systems are an extreme danger.
- Weather conditions: Bad weather can render the jet uncontrollable or cause structural damage with the respective consequences. Pilots may not be able to cope with the weather nor the consequences after.
- Own health status: A system of the aircraft may suddenly fail, an engine might be lost, there may be cracks in the structure etc. etc. A system must be aware of such failures and promptly provide the solution.
- Control info: Ground control may pass important data, which is not correctly registered by the pilot. A system must have a means to receive information and report constantly to the ground.
- Ground in different altitudes: A crash may be caused even at altitude in case of an upcoming mountain peak. This has to be fully treated and seen by a system, at least to the point of evading the obstacle in due time.

In its first version, CARESS1 is presented in the form of a simulation, implemented in Java. It may be obvious to say that the way to a commercial version, used on board a commercial jet liner, is non-trivial, but appears feasible. In the beginning of this project, the focus remains on the implementation of the core

system, which shall provide a basis to judge the feasibility of the proposed core architecture for the tasks involved.

This means that the following elements are currently being implemented: A measuring module for typical aircraft sensors, a translation module for the serialization of information to the Multilayer Perceptron input layer, a core module with a Recurrent Multilayer Perceptron architecture and the use of the GeneRec learning algorithm, a translation module for the de-serialization of information from the MLP output layer to typical aircraft actuators and finally an action module, which controls the immediate action to be taken in the event.

After the definition of the core module and the respective initial universe of sensors and actuators, several tests in simulation shall be executed to guarantee good function, defining sequences for normal operation, small issues and potential hazards. Learning shall be verified. Completing this phase, basically sensors and actuators shall be extended whereas the main algorithm of the system should remain stable with only few changes.

Importantly, it shall be observed that – whereas the actuators currently in use in an aircraft should be almost unchanged – a series of new sensors should also be physically implemented over time to ensure self-awareness of the airplane. This is oriented at the nervous structure of the human body, laying sensors all over the plane, its fuselage (skin) and its equipments (organs). In order to keep the wiring low, it is suggested to establish a data-bus via fiber optics and lead all the data to the main instance, the server with the system (brain).

Concerning the network core architecture the following might be said:

The Multilayer Perceptron is a standard and easily implemented Artificial Neural Network with Boolean inputs, at least one hidden layer of neurons and a layer of real type outputs, which provide values between 0 and 1 (see Haykin, 2008). A recurrent structure (i.e., output values and next input values are transformed into the definitive input values) is necessary in order to work sequences and not mere pairs of input and output.

Learning is done via GeneRec, which is a supervised learning algorithm, considered to be more biologically plausible. Its good function was shown in practice in Schneider and Rosa (2009). The algorithm generates two signals for learning: the expectation of the network, called "minus" and the training signal, called "plus". Propagating these two signals the error related to every point of the network is found in order to have it adjusted. For

more details, refer to O'Reilly (1996).

Network topology and learning algorithm were chosen in order to guarantee a fast and solid approach, which may adjust more easily to future advances in the field of Artificial Neural Networks.

5 PROJECT STATUS AND NEXT STEPS

The project is currently in its implementation phase. Shortly, results concerning the first project phase may be given. Expectations are good as architecturally similar problems have already been solved using an MLP with GeneRec (see Schneider and Rosa, 2009).

Next step shall be extensive testing of the given approach in the simulation environment, bringing up diverse and surprising situations and evaluating the networks adjustment.

Having completed successfully, the project shall be brought to the knowledge of the industry with the aim to plan implementation in commercial aircraft.

6 CONCLUSIONS

This paper presented the objectives, importance and overview of the project CARESS1, a novel connectionist safety system for aircraft.

There are high expectations connected with the research. It has the potential to help make civil aviation much safer, to the extent to be truly considered a safe way of transport.

As a final consequence, a fully automated and secure aircraft may be developed, which may revolutionize the international aviation sector.

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