AHPM as a Proposal to Improve Interaction with Air Traffic Controllers

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Abstract. Air Traffic Management (ATM) involves a complex decision-making process that involves several entities as short time to analyze risk situations and many attributes to verify before take an action. So, Decision Support System (DSS) is a great way to air traffic controllers achieve better results in their work. A well implemented DSS must provide a simple Human-Computer Interaction (HCI) to achieve great results. Even a system can provide all functionalities for a specialist, it must achieve his expectations and results by other requirements, i.e., maybe a right answer with delay or hard to find will become a wrong or unnecessary answer. The proposed approach by Air Holding Problem Module (AHPM) has a sub module responsible for forecasting airspace scenarios and another responsible to support decision-making process by an interaction with air traffic controller. Thus, it is possible that air traffic controller interacts with the system and carries out his activities faster and more informed by a simple screen which contains knowledge necessary. The AHPM achieved a great human-computer interaction level because the interaction is very simple and all mandatory information to do great analysis is presented in a same screen by a clean and objective organization.

Keywords: Human-Computer Interaction, Decision Support System, Air Traffic Management, Artificial Intelligence.

1 Introduction

Air Traffic Flow Management (ATFM) is considered a complex decision-making process that involves several entities as: aircraft and human being safety; short time to analyze risk situations; many attributes to verify, analyze and decide about the best group of actions to improve the air traffic flow. There are so many factors related to weather conditions, aircraft operational limitations and human capability to act in a short time interval under high pressure.

Human beings and machines are complementary in several aspects. The power of a taken decision by a human being in areas such as intuition, conceptualization and creativity are the weak points of a working machine. Human weakness, on the other hand, consists in aspects that a computer is accurate to achieve such as speed, parallelism, accuracy and the persistent storage of almost unlimited detailed information. So, a well implemented decision support system could help

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air traffic controllers to take the best actions by a strong Human-Computer Interaction (HCI) that will use the best points of each one.

Moreover, the system must provide a simple interaction to achieve better results. Even a system can provide all functionalities for a specialist, it must achieve his expectations and results by other requirements, i.e., maybe a right answer with delay or hard to find will become a wrong or unnecessary answer. Several factors are essential to reach a great HCI level in ATFM domain, such as key features available by a click, an integrated knowledge base presented in a main screen, alerts graphics for easy perception when status had been changed, interaction with other features without get out of main control screen, and others.

Air Holding Problem Module (AHPM) has four sub modules. Among them, there are sub modules responsible for forecasting scenarios and interaction with specialist. Thus, it is possible that air traffic controller interacts with the system and carries out his activities faster and more informed by a simple screen which contains knowledge necessary.

The Forecast Scenarios Module is responsible for assessing the current scenario, verify possible risk situations and its solutions in accordance with system knowledge. However, as important as the whole process of prediction scenarios is to present clearly and quickly the system knowledge for the air traffic controller detects possible problems and acts quickly. In the ATFM domain is indispensable that actions are taken with great knowledge and in the shortest time possible. In a real-time problem, the best solution for the time T_n probably will not work at a future time T_{n+1}.

This paper presents the decision support system AHPM developed to act on ATFM scenario in Brazil. So, it was modeled considering the reality of the country and its air traffic controllers to achieve more effective results. The paper is organized in the following manner. In section 2, there is brief review of related concepts about Decision Support System and Human-Computer Interaction. Section 3 presents the environment of ATFM, which AHPM acts to support daily tasks by interaction with air traffic controllers. Section 4 presents the decision support system AHPM. Section 5 concludes the paper and proposes the direction of future research.

2 Decision Support System

The decision support systems can be defined as systems that support decision-making process by providing relevant information, suggestions and predictions, which are based on current information to provide a vision of the future, according as some actions are taken in the present.

The business processes that will be automated by a system must be chosen carefully. Specially about control activities; conflict detection and analysis, research and planning execution. Decision Support System (DSS) allows using data and models related to an area of interest to solve problems, semi-structured and unstructured, with which they are confronted to achieve a better system (Beulens et al., 1988; Bayen et al., 2005).

A DSS allows working with problems of a decision-making which the proportion overtakes the normal rational capacity or exceeds temporal and financial means available. The air traffic controller reports his difficulties to take actions with minimum impact in the future, so it can be represented in a system with management and control of existing organization knowledge.

According Agogino et al. (2009), it is essential that systems to support air transportation can be prepared to provide a flexible and automated management to meet requirements inherent in this kind of management. These systems are included in a new generation, which should be prepared to meet this demand.

Among the approaches that are presented in the literature, it is possible to classify a decision support system in four different ways of operation:

1. Without autonomy: the system displays information and the expert must check in several points what is useful, or not, for every situation.
2. Full Autonomy: the system, based on previously acquired knowledge, analyzes each situation and take its decisions.
3. Semiautomatic (more automatic): the system has enough intelligence to assess different situations and as situation decide itself. In other situations, the expert decides what should be done.
4. Semiautomatic (more human): the system has enough intelligence to analyze situations and make suggestions for solutions to the specialist, which will decide what should be done.

The approach of this research follows the fourth way presented. It will always leave the decision-making power with the air traffic controller. However, it will analyze situations and make suggestions to be taken to the specialist. This choice was made because of concern about safety of the airspace. So the air traffic controller will have the information generated by the system but with full autonomy to choose the AHPM suggestion or a new action according to your experience. When specialist decides for new actions, system will learn and suggest these actions for similar scenarios in the future.

Thus, the improvement of human-computer interaction becomes more important because must provide a knowledge base in the best way, so air traffic controller can carry out his activities achieving the best benefits of DSS. The system will be a major provider of knowledge and its interaction with the specialist will make the level of success for ATFM.

2.1 Human-Computer Interaction

The Human-Computer Interaction (HCI) field is responsible to improve how human being interacts with computer systems. There are so many researches to improve HCI covering software engineering, system usability, new approaches to interaction, multimedia technology, knowledge architectures, system design, cognitive computing and others.

Important as the adoption of techniques to improve HCI is continually checking the degree of satisfaction of each user, too. Thus, it will happen a continual improvement process in the interaction in order to achieve a natural interaction between both its. Additionally, the system must be self-adapting as a specialist that use. So, it is possible to make a well experience for all system users in a same level (Leadbetter et al., 2000).

This improvement process should not only check the system, but the business processes which DSS is supporting too. It is possible to remove some complex spots that hinder human-computer interaction and add these points inside of the system, reaching more gains for the air traffic controller such as: time, handled complexity, reduce the impact of actions, take actions more effective and others.

It is necessary to analyze how the process is being automated by DSS and evaluate the negative impact that may be generated, such as semi complete automation generating omission in operation of DSS and make obscure the decision-making process to air traffic controller can decide to accept a suggestion of restrictive measure.

In domains more complex such as ATFM, this may forbid full adherence to the system by the system user because it is unknown what is happening inside the software. The objectives of DSS must walk together to aid air traffic controller instead of hiding everything that is being done, so this approach follows the standard semiautomatic (more human), i.e., making it clear for the air traffic controller to choose his decision (Yoshikawa , 2003; Grudin, 2009).

3 Improving Interaction in ATFM

Air Traffic Flow Management focuses on the supply of information to maintain the traffic flow with safety and reduced impact on airspace scenarios that are necessary to take unexpected measures. The ATFM environment can be organized into three phases: strategic, operational and tactical.

This paper focuses on ATFM tactical level because it is the period which aircraft is in flight. This level consists on tactical decision making covering the period from two hours before the flight until the aircraft arrives at its destination. During this phase increases the problem level because the occurrence of problem and its solution happens on real time. This factor also needs to be focused on HCI to improve the solutions for risk situations in ATFM in real-time environment.

The main problem to be resolved in this work is the Air Holding Problem (AHP), which occurs when aircraft in flight route needs to wait on the air for a particular reason, such as closed airport, hard meteorology conditions, terrorist acts, and others. These situations may impact in other areas of the far Terminal Maneuvering Area (TMA), place where an airport is situated. These impacts can be spread throughout the air traffic flow arriving at one departure airport, and thus preventing an aircraft take off.

The Brazilian airspace covers the entire territory of the country, including part of the Atlantic Ocean. In the airspace of Brazil there are five Flight Information Region (FIR): FIR - Amazon (north); FIR - Recife (northeast); FIR - Brasilia (midwest); FIR - Curitiba (south) and FIR - Atlantic (Atlantic Ocean coast). The FIR's are subdivided into sectors of control, to improve the management activities and obtains better control. Currently, there are 46 control sectors, 14 in FIR - Amazon, 8 in FIR - Recife, 12 in FIR - Braslia, 10 in FIR - FIR in Curitiba and 2 - Atlantic.

These sectors are under supervision of air traffic controllers that are in an Area Control Center (ACC), which is responsible for a specific FIR. In this context, it is possible understand the complexity of management activities and why there are subdivisions to manage so many factors, e.g., the number of aircraft per sector influences directly the management complexity, i.e., the more aircraft flying in the same sector, more security risks involved in the ATM.

Given this context and in order to support ATFM was proposed Air Holding Problem Module (AHPM) as a new approach interaction with air traffic controllers to provide support to decision-making process and improve results on AHP. Currently, air traffic controllers use a control system in standard monochrome and basic screens, i.e., there are basically one screen to the standard radar display which they monitor the traffic flow, detecting possible risk situations and their solutions.

The problem with this model is that system is limited in the presentation of information. All hard work needs to be done by an expert in a short time and basically with a radar screen to survey the necessary information to take his decision. This new approach was shaped for air traffic controller could have more benefits of DSS such as providing knowledge on a screen instead of only some data, add on a screen the current traffic, possible solutions and their impacts, reduce the level of tiredness of their eyes through the visual alerts which reducing the need for high concentration on the screen, and others.

4 AHPM

The Air Holding Problem Module system was developed using two techniques of Artificial Intelligence (AI): Multiagent Systems and Reinforcement Learning. The system consists of four sub modules integrated.

The Information Collection Module is responsible for storing information generated by flight controllers. The Reinforcement Learning Module is responsible for system learning, which will receive information from collection module and transform into knowledge to be used in the future by specialist. The Forecast Scenarios Module is responsible for presenting the airspace scenario in a future instant T_{n+1}, in order to present to air traffic controller what might happen if he choose the action suggested by the system. The Decision Support Module will present the possible actions to be taken and every scenario that will be generated after take a certain action according with a prediction, including the impact on another airspace sector in the future. Figure 1 gives an overview of the architecture of the Decision Support Module and its interaction with the air traffic controller.

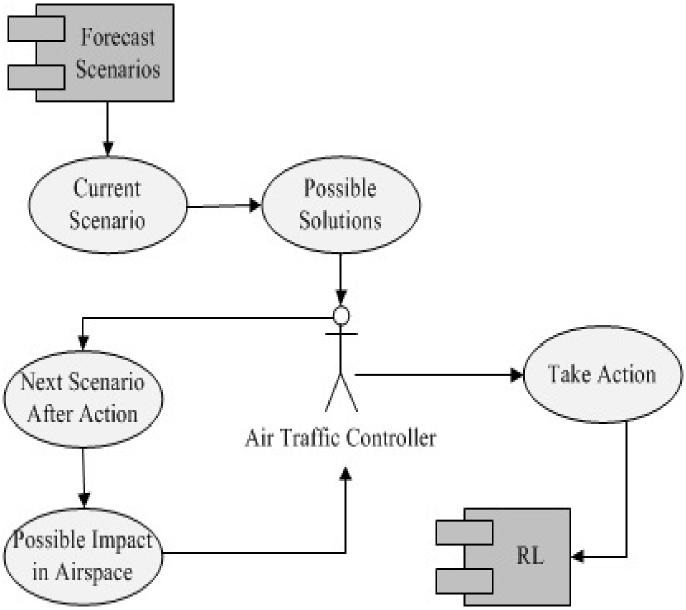

Fig. 1. AHPM architecture

This interaction between air traffic controller and AHPM can be understood as follows:

1. Current Scenario: It is responsible to display current scenario to air traffic controller.
2. Possible Solutions: It is responsible to display, based on Reinforcement Learning, possible scenarios considering taken actions in the past.
3. Next Scenario After Action: It is responsible for presenting the next scenario, if the chosen solution can be taken as restrictive measure.
4. Possible Impact in Airspace: It is responsible to evaluate and display possible impacts as congested or saturated sectors in airspace.
5. Take Action: It is responsible for receiving the action of the air traffic controller and send to the Reinforcement Learning Module for processing and storage. This information will be used for suggestions improvement in the future.

The Decision Support Module is the only module that will display the information and interacts with specialist. After presenting suggestions to air traffic controller the system will wait for his decision. If the chosen decision is accept the suggestions presented by the AHPM, these suggestions will be transformed into knowledge and stored in the database learning. If the specialist chooses an no listed action or only some of the suggested actions, this module will forward in the first case, to the Reinforcement Learning Module and in the second case,

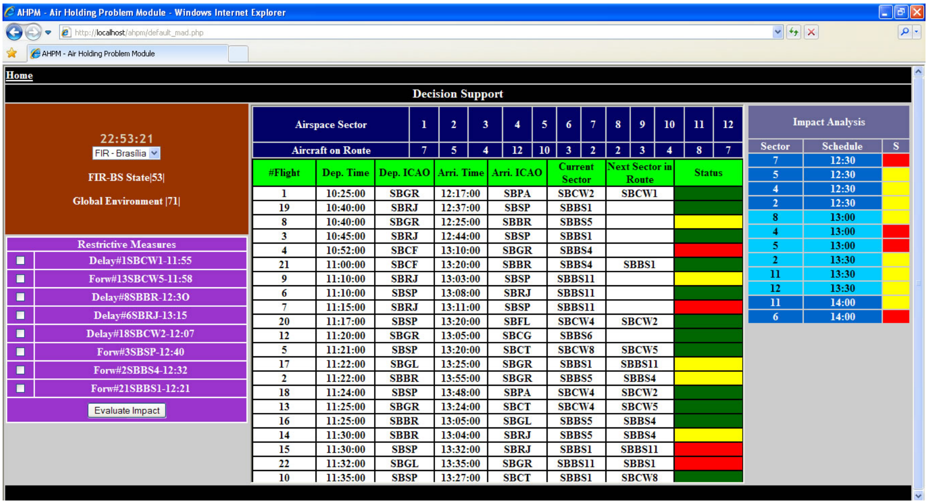

Fig. 2. Human-Computer Interaction with AHPM

for the Forecast Scenarios Module to recalculate states and forward to presenting the expected results for chosen actions to the air traffic controller.

The specialist will choose actions to be taken from possible solutions group. AHPM will try to predict the possible impact in airspace, if those actions are taken. Thus, the air traffic controller will decide about actions to be taken and the results will be storage in AHPM. The human-computer interaction is presented in Figure 2.

In the screen of AHPM is possible verify in a simple and clean manner how the air traffic controller will interact with the system. Initially, the system will verify the date and time which air traffic controller is running its activities. Thus, the screen will load automatically the flights that were planned for that time in an interval of ninety minutes and deviations that are occurring with a tolerance of three minutes. At this moment, the modules begin to act in a integrate way for presenting suggestions.

First of all, it is important to explain the left of screen. On top, it displays what is on FIR and analyzes its state. This is a state of Reinforcement Learning evaluation functions That Indicate an index level of air traffic Which is it defined the FIR state. The more near zero lower traffic congestion in the sectors of FIR on analysis. The global state follows the same principle but considers all sectors FIR's in airspace of Brazil.

On top middle, it displayed how many sectors and aircraft flying exist in analyzed FIR at this moment. There is a capability of aircraft for each airspace sector in one same moment. In Brazil, it is defined as congested sector if there are more than eleven aircraft in each sector and as saturated if more than thirteen aircraft. So, air traffic controller needs to analyze all this information in a short time and decide which are the best actions to airspace. It is presented twelve airspace sectors because this is the amount of sectors in FIR-BS.

On middle, it displayed all flights that are under responsible of a specific air traffic controller. It presents information such as flight number; departure time; ICAO code of departure; arrival time; ICAO code of arrival; current sector which aircraft is flying; if exists, next sector in route and air traffic status in the current airspace sector. The ICAO (International Civil Aviation Organization) code is an international identifier which is used for airports. In case of this status is green, the air traffic is fluent. If yellow, the sector probably will go turn congested and some action about this flight needs to be taken. If red, the sector probably will go turn saturated and needs some restrictive measures in flight with this status.

On bottom left, AHPM presents possible better restrictive measures to be taken at this moment over the flights under his responsibility. According to calculations made by Forecast Scenarios Module are identified some possible actions to be taken. These restrictive measures are classified into two types: delay and forward. One example of restrictive measures is '*Delay#4SBBR2-09:41*', which means delaying the entry of aircraft #4 in sector two of FIR-SBBR to 09:41. Another possible measure could be '*Forw9SBRJ-12:48*', which means forward the landing of aircraft #9 at the airport SBRJ to 12:48.

These restrictive measures are determined by Forecast Scenarios Module and take into consideration, basically all information presented on middle screen. These actions are suggestions for the air traffic controller, which can choose all, some or none. These suggestions consider several factors as system learning. The longer the system is in use, the best suggestions will be based on the scenarios like the current one.

After air traffic controller choose the actions to evaluate the impact, it will presented on top right the impact analysis. This analyze will show possible impacts in airspace sectors for the next three intervals of thirty minutes, for the sectors that will be affected in the FIR which is being analyzed. In case of this status is yellow, the sector probably will be almost congested in a determinate time. If red, the sector probably will be congested. It is possible to analyze the possible evolution by the three intervals, too. Thus, it is easier to verify if some action is so hard for a specific case.

The air traffic controller can analyses as many times as necessary, choosing different actions to be taken. When actions are taken in time, the results will be presented on central and it will be ready for air traffic controller starts the whole process again.

5 Conclusions

In the complex domain of ATFM, there are air traffic controllers who are responsible for some of the most critical activities, because requires a lot of concentration; air traffic experience; high commitment; ability to work under extreme pressure, among other factors that make the daily tiring and stressful. Besides the physical and psychological factors, there is the impact that their actions while working can cause in lives of so many people.

The artificial intelligence proves itself effective in helping the decision-making processes, specifically in the area of aviation. Due to factors such as acting in a real time environment, using large amounts of data, lack of adequate experience to specialist, need to consider several factors in a short time, predict the impact before to take an action, and others. Systems that use one, or several, specific techniques of AI can address these needs and become in an important tool in ATM.

Although good solutions are built using the AI, it is required to be considered how will be held the interaction between system and expert. The DSS must evolve to the next level, which in addition to information for decision support the system must provide an efficient human-computer interaction. Currently, there are large amounts of data that can provide any information to the specialist, but there is so much information available that can limit the progress due to the difficulty of finding what it is important at the time required or by the poor interaction provided in the system.

The AHPM approach was proposed to support air traffic controller in decision-making process by the easy and fast interaction for all needed knowledge. Among some aspects proposed, it was possible to retain the knowledge of more experienced air traffic controllers in the system to help beginners; analyze and predict scenarios, within the time required to take a decision; assess potential impacts before taking a restrictive measure; and others actions to reduce holding traffic on the routes.

The AHPM gets to achieve a great level of human-computer interaction because the interaction is very simple and all the mandatory information to make great analysis is presented in the same screen. The information organization is clean and fast to find a specific data. This is especially important due to short time to detect problems, verify possible situations, analyze better actions to be taken and its possible risks.

For future work, we intend to perform the integration of the strengths of human-computer interaction of AHPM and currently used systems in Brazil to build a more efficient approach for air traffic controllers, such as the inclusion of radar maps with alerts messages to possible risk situations, the possibility of maps to present the 'Impact Analysis' and the inclusion of more information of other airspace control systems.

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