LEARNING FROM THE PAST: SUPPORT FOR AUTOMATIC NEGOTIATION ON AIRLINE OPERATIONAL CONTROL CENTERS

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1. Motivation

Airline operational control is an important and difficult task which airlines have to face daily. Even for small airline companies such as TAP Portugal, this is a complex problem. The optimal operational scheduling, which results from the application of optimization techniques, has a high probability of being affected due to the occurrence of unexpected events (disruptions), having unintended consequences, the most common being the flight delay. If nothing is done to manage this disruption, the delay of a flight can be propagated to other flights, increasing the complexity of the its resolution.

The process of planning and scheduling the flights of an airline consists of several steps, some of which are prepared several months in advance. Even though, having a great plan is as important as keeping it, this task can be quite demanding due to unexpected events (disruptions) that can occur close to the operation date. Such problems can lead to delays and/or cancellation of flights, if nothing is done to prevent it [1].

There are several causes that may lead to non-compliance of the scheduled plan. According to [2], the *International Air Transport Association* (IATA) has defined the main causes that can lead to a disruption. The main causes identified are from two types: (i) reactionary, which result from delay propagation; and (ii) technical, resulting from air traffic, passenger or weather problems. Any disruption can cause entropy in the international air traffic system, which makes this task both complex and critical.

To address these anomalies, airlines generally have an Operations Control Center. There are several types of architectures for the Airline Operational Control Center (AOCC), being the most common the Decision Center, the Integrated Center or the Hub Control Center [3]. Regardless the type of organization used, the roles of Supervisor, Aircraft Manager, Crew Manager and Passenger Manager, among others, are common to all architectures' types [4].

The statistics presented in [2] show that these problems, although not planned, are very frequent. Regarding costs, the same authors estimate that every minute of delay costed, in 2011, about seventy-two euros to the air companies, including direct and non-direct costs. It is thus of utmost importance that an airline is able to react in time to these changes, through disruption management, i.e. the process of minimizing the delay and cost of flights [5].

The solution proposed in [5] is a multi-agent system (MAS) called *Multi-Agent System for Disruption Management* (MASDIMA) able to detect problems, analyse which were the affected resources and propose a solution, respecting the constraints of the environment.

2. Goals

This thesis aims to introduce learning from the past on AOCC, supporting the automatic negotiation already implemented on MASDIMA prototype. We intend to study the possibility of obtaining solutions decreasing the average response time of the system to a new disruption problem, increasing its degree of trustworthiness, while maintaining the level of quality of the solutions presented.

A system with a high degree of trustworthiness is a system whose responsible for its supervision feels that it produces solutions to which he agrees. The quality of the solutions will be measured by the utility assigned by each responsible agent (Supervisor, Aircraft Manager, Crew Manager and Passenger Manager).

3. Work Description

In this thesis we implement a software module which introduces learning from the past on MASDIMA prototype. So that the implementation could be done, we developed a methodology called *Case-based Reasoning - for Dynamic Distributed Environments* (CBR-DDE), based on the *Case-based Reasoning* (CBR) methodology.

We begin this thesis by reviewing literature regarding paradigms and methodologies used. We start by addressing key aspects of the CBR methodology, from its origins to the various steps that compose it, and analyse briefly some examples of its application in commercial systems.

Then we explore the MASDIMA prototype, including an analysis of its structure, approaches to problem solving that have already been implemented, and its current limitations, which led to the work of this thesis.

We describe the solution studied and implemented in this work, formalizing the concepts of problem and solution within the MASDIMA system, conceptualising the notion of case in this context. We have defined the similarity function used to determine the degree of similarity between cases, as follows:

$$f(Case_1, Case_2) = \sum_{i=1}^{n} a_i x_i, \quad \text{with}$$
$$\sum_{i=1}^{n} a_i = 1, \quad a_i \in [0,1] \quad \text{and} \quad x_i \in [0,1] \tag{1}$$

where i represents each variable used to compare cases; n the number of variables to compare to; x_i is the comparison value between $Case_1$ and $Case_2$ on variable i; and a_i the weighing of each variable into the similarity function.

Then we present the methodologies to be applied in each step of the CBR cycle. We describe a new methodology, called CBR-DDE, based on CBR, which was built to eliminate some of the barriers of using CBR methodology in distributed systems and dynamic environments.

Finally, we identify the scenario where the experiments are performed and introduced new approaches based on CBR-DDE. We present and discuss the results of experiments performed.

4. Conclusion

In the evaluation of our experiments we found that it is possible to reduce the average response time of the system to a new problem in about 64%, increasing both their degree of trustworthiness and restricting the loss of solution utility measured by the Supervisor agent, including, in some cases, superior solutions to the best ones generated by already existing approaches.

From the work done to allow the verification of the goals, we can draw some scientific contributions of which we highlight the following:

- The creation of a new methodology, called CBR-DDE, based on CBR, which allows reuse and adaptation of solutions when working with dynamic environments. We believe that the methodology was shown to be applicable to the problem of disruption management in AOCC, and it is formalized to a sufficient level of abstraction that allows its instantiation in applications on other research fields;

- The introduction of *Case-based Reasoning* as a technique for problem solving in disruption management on AOCC, which allowed the reduction of the time required to generate a meritorious solution;

- A method of comparing disruptions in the airlines operational plans, which gauge their similarity and may be used in other projects within this scope.

5. Future Work

From the work developed in this thesis we understand that there may be new research interests in this area, particularly in the search for a methodology that incorporates the best of the preexisting MASDIMA and CBR-DDE approaches into a single approach, improving overall system performance. The constant change in the knowledge base, with the expected commissioning of the system will lead to the creation of dynamic sub-clusters. The construction and maintenance of this sub-clusters is also an area that can be explored in future research.

We believe the CBR-DDE methodology, now presented, could be introduced in other areas where the CBR methodology has not been applied by the difficulty of reusing and adapting solutions.

References

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