A Rescheduling Framework for Airline Scheduling

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Abstract: Airline scheduling is a sophisticated area. If a disruption occurs many tasks have to be taken into account. In order to structure the rescheduling process a framework is useful. The existing framework for rescheduling will extend with further information tasks to use various repair methods. The framework is cuts into two parts. The first part includes the precondition of the domain. The second parts described the tasks of the rescheduling process. The use of this framework allows to implement more than one rescheduling method.

1 INTRODUCTION

Airline scheduling is a sophisticated area. Several schedules from different departments are intermeshed, start with the flight schedule, followed by the maintenance schedule, we have the crew schedule and of course the human resource schedules. The interaction between the schedules depends on the business processes of each airline therefore the used time lines in this paper could differ from other airlines.

Disruptions could appear at every time. The influence is more or less serious. This depends on the connection to the other schedules and the time when the disruption happens and therefore on the time left to solve the problem. In (Love et al., 2002) the authors discuss the separate schedules between aircraft fleeting, routing and the crew schedule. Several solutions were discussed for planning and disruption management. Disruption events have different sources. The European Organization for the Safety of Air Navigation (EUROCONTROL) publishes a delay analysis monthly including the significant events. In February 2011 43,89% of the delays were reactions of the primary delays (Central Office for Delay Analysis / EUROCONTROL, 2011). In this paper an overview of the reactive process will be given and expand the process by an disruption analyze step. The process is not only used for solving the disruption by a system but also to get an overview how to process and manage disruptions.

2 RESCHEDULING FRAMEWORK

(Herrmann, 2006) defines rescheduling as "...the process of updating an existing production schedule in response to disruption or other changes" (p.137). The reactive process will perform, if the schedule is already invalidated by a disruption. Three goals have to be solved by the solution: 1) fast reaction against the disruption, 2) the quality of the schedule shall not worsen and 3) minimal changes to the original schedule (Sauer, 2004). A solution of the process is mainly domain dependent. Several researchers investigate different domains. (Pinedo, 2005) defines two domain areas. One area includes the manufacturing trade, the other one represents the supply of services. Of course domain-independent solutions are very welcome but the solutions rely on abstract and more general models (Ghallab et al., 2004). A framework for the rescheduling process for a manufacturing system is introduced by (Vieira et al., 2003) and (Herrmann, 2006). The intension behind the framework was to understand the rescheduling research and the definition of some terms but it was also used as a control strategy. The framework includes the following areas: rescheduling environment, methods and strategies.

The environment describes the type of the schedule whether it is static or if it is a dynamic environment. The authors specify three reschedule methods. The right shift rescheduling delays each remaining job on the involved machine with the

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amount of time in order to get a valid schedule. The partial rescheduling reuse parts of the schedule and only alter the jobs that were affected directly and indirectly. The last method which is mentioned in the framework refers to the complete regeneration. Every job which is not processed before the rescheduling point is included in the rescheduling process. A further repair method which is not mentioned, changes the original schedule by adding or removing activities. This will not only influence the jobs or rather activities, but also the constraints (van der Krogt and de Weerdt, 2005). The third part of the framework is the rescheduling strategy. The authors distinguish between dynamic and predictive-reactive scheduling. Dynamic scheduling is not using a production schedule. The frequency of starting the rescheduling method is defined in three categories: an event-driven, a periodic procedure and a hybrid one. The presented framework is based on (Jones et al., 1998) and (Herrmann et al., 2003). The process is divided into two phases. The precondition defines the tasks which shall be processed only once. The second phase is defined as the rescheduling process, including tasks which are used during each trigger. The precondition describes the schedule based upon the scheme published in (Jones et al., 1998):

Precondition:

– *Requirement generation* is the classification of the schedule
– *Processing complexity* refers to the processing steps
– *Scheduling criteria* matches the performance criteria
– *Parameter variability* defines the degree of uncertainty of the schedule parameter
– *Schedule environment* defines if it is a static or dynamic schedule
– *Rescheduling strategy* defines the policy of the trigger

The rescheduling process is capsuled from the precondition while the precondition is more like describing the domain. This is the reason why the rescheduling strategy is moved from the rescheduling process into the precondition phase.

The rescheduling process is an periodic process used for every disruption which has an influence to the schedule.

Rescheduling Process:

– *Analyze* the disruption and the schedule for possible solution
– *Select* a repair method and algorithm
– *Review* the solution

3 PRECONDITION

The precondition describes the domain and the behavior. The characteristics will help to find a feasible reactive scheduling process. The first three conditions: requirement generation, processing complexity and scheduling criteria are described in (Graves, 1981). The requirement generation differs between open shop and closed shop.

The processing complexity displays the property of the facility. These criteria differ between stages and available facilities:

– One stage – One facility
– One stage – Multi facilities
– Multi stage – Flow shop
– Multi stage – Job shop

The scheduling criteria are grouped into schedule cost and performance. These shall also be described as one of the goals of the rescheduling process in order to verify the solution.

The parameter variability defines the uncertainty of the parameters of the schedule problem. The authors divide the schedule problem into two groups: deterministic and stochastic. The scheduling environment is integrated into the presented frameworks and defines the problem as static or dynamic. The last precondition entry defines one part of the rescheduling solution. Most of the schedules need a reschedule process while the schedule is invalid due to a disruption. Therefore the process is defined previously. The strategies divide into a dynamic and a predictive-reactive one. A periodic, event-driven and hybrid policy is available. A periodic policy checks the schedule after a configured time interval. For real time reactions an event-driven policy is implemented. A hybrid policy starts the rescheduling process periodically and only if a special event takes place an event-driven policy is chosen.

4 RESCHEDULING PROCESS

The iterative rescheduling process is divided into three parts:

– The analyzing of the invalid schedule
– The selection of the repair method
– The review of the solution

This process is triggered by the rescheduling strategies and will run through by each disruption.
The following chapters describe the tree parts in detail.

4.1 Analysis

The analysis is a new part in the rescheduling framework. The goal of this step is to analyze the invalid schedule and provide information for the repair method. This approach implies several questions:

- What kind of disruption takes place?
- Which part of the schedule is involved?
- How much time is available for solving the problem?
- What kind of influence has the disruption to the schedule?
- What kind of precondition items and constraints are affected?

These questions can be clustered into disruption, timing and precondition scopes. (de Snoo, 2011) arranges the questions into two part after a disruption has occurred: 1) the time area includes the time which is necessary to solve the problem and the time which is available and 2) the consequence triggers by the disruption and the solution. The cause of the disruption is divided into extern and intern. The reason behind the split is the different handling, communication and cost aspects. The scope is the main item that influences the rescheduling strategy and the repair method. The available time defines the strategy which includes also the knowledge of the interruption from a running repair method process. The consequence depends on the information process and the actions of the rescheduling process. Each disruption can have different consequences. The information of the analysis will store into a journal. The journal includes also the resources and jobs which are involved in the rescheduling method. This detailed information is needed for the interruption of the rescheduling process if a new disruption takes place. The journal can answer the question whether the rescheduling process is interruptible. If the analysis has done the tasks and logged the information into the journal the repair of the schedule starts.

4.2 Repair Methods

The repair methods are the background for the implemented algorithms in an IT system. Five possibilities exist to solve the problem of an invalid schedule:

- Right-Shift method
- Repair method
- Plan Reuse
- Reschedule from scratch
- Hybrid

The advantage of the right-shift method is, the schedule gets a solution very fast. The disadvantage depends on the cost which is caused by the delays. Some restrictions have to be set using this method:

- How much delay is acceptable for each flight?
- How many flights can be affected till the right-shift shall stop?
- How much cost of this solution is allowed?

The second method works with additions and cancellations. The cancellation does not only refer to jobs, but also to the schedule constraints. The idea behind this repair method is the use of two phases. The first phase removes the constraints. The second phase is the planning phase which includes the extension to satisfy the goal. The advantage is the use of an independent planer because of the split into two phases where the first phase is more domain depended than the second phase. The problem is to find the best possible additions and cancellations of jobs and constraints. Planning from the first principle is called rescheduling from scratch. The second principle describes the plan reuse (Koehler, 1996). The plan reuse method reuses valid parts of the initial schedule. The goal is to leave as many jobs as possible unchanged in order to reduce the modification into the new valid plan. The plan stability is the advantage of this method because minimal changes will be conducted. Generate a plan from scratch is also called replanning. The planner constructs a new plan including every job which is not processed yet. The plan stability is not considered in this case. (Fox et al., 2006) and (Koehler, 1996) declare that the speed of plan production, plan quality, plan stability and the cost is much better when using the plan reuse method instead of planning from scratch. The hybrid combines two or more presented methods in one repair method (Lim et al., 2005). A time duration shifting and the insertion and exchange is developed in the neighborhood search procedure. A hybrid is useful to get the advantages of each method in order to solve the flexibility in an invalid schedule.
The result of the execution of the selected repair method will verify in the last step of the rescheduling process.

4.3 Review

The review serves the auditing of results. The audit includes (Sauer, 2004) (Fox et al., 2006):

- Quality

– Stability
– Robustness

The quality of a schedule depends on the purpose by the different groups. (Kempf et al., 2000) discuss the measurement of quality. The authors differ between:

– individual schedules vs. group of schedules
– absolute measurement vs. relative comparison
– tradeoffs between multiple metrics
– static vs. dynamic measurement

Plan stability defines the deviation between the original schedule and the new schedule. More stable schedules create less stress on execution components and avoids nervousness. The influence of further disruptions is reduced if the repair method generates a robust schedule. That implies less rescheduling in the future. The review step finishes the introduced rescheduling framework.

5 CONCLUSIONS

This paper describes the rescheduling framework phases and steps. The intension of this kind of research is the understanding of rescheduling and setup definition and control strategies .The introduced framework is divided into two phases. The preconditions define the domain and give further information to the second phase. The rescheduling process is an iterative process including the new step of analyzing the disruption, the selection of the repair method and the review of the new schedule.

The next step of the research will be an evaluation of the rescheduling process using a case study from an airline company.

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