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Maintenance planning on French military aircraft operations

Franco Peschiera[1], Alain Haït[1], Olga Battaïa[1], Nicolas Dupin[1]

ISAE-SUPAERO, Université de Toulouse, France

{franco.peschiera,alain.hait,olga.battaia,nicolas.dupin}@isae-supaero.fr

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1 Introduction

The Military Flight and Maintenance Planning Problem considered here aims to assign missions and maintenance tasks to military aircraft. It is a variant of the Flight and Maintenance Planning problem where flights are not modeled geographically since a round-trip to the base is assumed for each flight. It also includes different objectives and constraints. Although the former has been studied in literature in [1, 2, 3, 4], it has not received as much attention as the latter. In the following, the problem with already scheduled missions is considered. With respect to [2], a new model will be presented.

The problem consists in assigning military aircraft to a given set of missions while scheduling the maintenance operations over a time horizon. In order to generalize the formulation, from now on aircraft will be named "resources" and missions will be named "tasks". A series of $j \in \mathcal{J}$ tasks are planned along a horizon divided into $t \in \mathcal{T}$ periods. Since all tasks are already scheduled, we know time periods $T_j \subset \mathcal{T}$ in which they will be realized. Similarly, all the tasks to be realized in period t are known and defined by set $J_t \subset \mathcal{J}$. Each task requires a certain number r_j of resources $i \in \mathcal{I}$ which it employs for a time duration defined by h_j in each period. Set $a_j \subset \mathcal{I}$ lists the resources that can be assigned to each task and set $O_i \subset \mathcal{J}$ consists of tasks for which resource i can be used. The number of resources in use for each period d_t is also known.

Resources require recurrent preventive maintenance operations since the realization of tasks diminish their remaining usage time. A resource cannot be used for a task j if its remaining usage time is less than usage h_j required by task j. A maintenance operation assigns to the resource exactly H units of remaining usage time. The remaining usage time not used before the maintenance operation is lost. A maintenance operation takes exactly m periods and cannot be interrupted: during this time the resource cannot be assigned to any task. Some resources can be in maintenance at the beginning of the planning horizon, n_t is used for the number of aircraft in such planned maintenance per period t and defined only for the first $m-1$ time periods. In the next section, we present a new mathematical model for this problem.

2 Mathematical model

The decision variables manage the previously defined resources.

A_{jti} = 1 if task $j \in J$ in period $t \in T_j$ is realized with resource $i \in a_j$, 0 otherwise.
M_{it} = 1 if resource $i \in I$ starts maintenance in period $t \in \mathcal{T}$, 0 otherwise.
rut_{it} = remaining usage time (continuous) for resource $i \in I$ at the end of period $t \in \mathcal{T}$.
U_{max} = maximal number (integer) of unavailable resources in any period.
M_{max}= maximal number (integer) of resources in maintenance in any period.

Note that A_{jti} and M_{it} are initially set up to 0 for all resources already in maintenance at the beginning of the planning period for the remaining time periods of maintenance. The remaining usage time for each resource at the beginning of the planning period is used to initialize rut_{i0}.

The objective is to simultaneously minimize the maximum number of maintenances and the maximum number of unavailable aircraft.

$$\text{Min } w \times M_{max} + U_{max} \tag{1}$$

where relative weight w is chosen by the decision maker. The following constraints are used.

$$\sum_{t'=1}^{t} \sum_{i \in \mathcal{I}} M_{it'} + n_t \leq M_{max} \qquad t = 1, 2, ..., m-1 \tag{2}$$

$$\sum_{t'=t-m+1}^{t} \sum_{i \in \mathcal{I}} M_{it'} \leq M_{max} \qquad t = m, ..., |\mathcal{T}| \tag{3}$$

$$\sum_{t'=1}^{t} \sum_{i \in \mathcal{I}} M_{it'} + n_t + d_t \leq U_{max} \qquad t = 1, 2, ..., m-1 \tag{4}$$

$$\sum_{t'=t-m+1}^{t} \sum_{i \in \mathcal{I}} M_{it'} + d_t \leq U_{max} \qquad t = m, ..., |\mathcal{T}| \tag{5}$$

$$\sum_{i \in a_j} A_{jti} = r_j \qquad j \in \mathcal{J}, t \in T_j \tag{6}$$

$$\sum_{t'=\max\{1, t-m+1\}}^{t} M_{it'} + \sum_{j \in J_t \cap O_i} A_{jti} \leq 1 \qquad t \in \mathcal{T}, i \in \mathcal{I} \tag{7}$$

Maintenance capacity is controlled by (2)-(3). The number of unavailable resources is defined by (4)-(5). Tasks' resource requirements are defined by (6). Constraints (7) guarantee that a resource can be used only for one task or maintenance operation at the same period.

$$rut_{it} \leq rut_{it-1} - \sum_{j \in J_t \cap O_i} A_{jti} \times h_j + H \times M_{it} \qquad t \in \mathcal{T}, i \in \mathcal{I} \tag{8}$$

$$rut_{it} \geq H \times M_{it} \qquad i \in \mathcal{I}, t \in \mathcal{T} \tag{9}$$

$$rut_{it} \in [0, H] \qquad i \in \mathcal{I}, t \in \mathcal{T} \tag{10}$$

The remaining usage time is defined by (8) and its limits by (9)-(10).

3 Conclusions and future work

The present work proposes a new model for the Military Flight and Maintenance Problem. This formulation sets an interesting base for further model extensions in order to integrate more complex real constraints.

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