Maximizing Availability in Operations and Maintenance Planning; An Exact Heuristic

Javad Seif

Advisor: Dr. Andrew J. Yu

THE UNIVERSITY OF TENNESSEE
KNOXVILLE
Space Institute

Introduction

- **Generalization of:**
  - Exact Heuristic for Flight and Maintenance Planning (**FMP**) by Gavranis and Kozanidis (2015)
- **Operations and maintenance planning (OMP)**
- **When** and for **how long** a machine should be in **operation** and **when** its operation should be ceased for **maintenance**?

FMP: Numerical Example

Aircraft (**n**)	**1**	**2**	**3**	**4**	**5**	**6**
Residual Flight Time (availability)	5	38	186	213	257	0
Residual Maintenance Time	0	0	0	0	0	70
Availability Status	1	1	1	1	1	0

Planning Horizon (**t**)	**1**	**2**	**3**	**4**	**5**	**6**
Flight Schedule (hrs.)	97	115	99	121	121	113
Available Hrs. of Maint. Crew	129	148	154	144	126	135

Maintenance station capacity: **3**
Maintenance Interval: **300 hours**

Max. of flight time: **50 hrs.**
Maintenance Duration: **320 hours**

OMP: Generalization

Aircraft (**n**)	**1**	**2**	**3**	**4**	**5**	**6**
Residual Flight Times	(5,105,250)					
Residual Maintenance Times						(70,150,320)
Availability Status	1	1	1	1	1	0

Planning Horizon (**t**)	**1**	**2**	**3**	**4**	**5**	**6**
Operations Schedule (hrs.)	(97,105,45)					
Available Hrs. of Maint. Crew	129	148	154	144	126	135

Maintenance Stations capacity: **3,2**
Maintenance Interval: **300,500,750**
Capabilities Matrix

Max. of operation time: **50 hrs.**
Maintenance Duration: **320,400,500 hours**
Maintenance Duration Varies Based on Class

What was generalized?

	Original Problem	This Problem
1	Limited to aircraft	Any type of processor/machine
2	Only one type of aircraft	Different classes for machines
3	One operation (flying)	• Multiple operations • Machines are linked to these via classes
4	One maintenance station	Different stations for different classes
5	One generic type of maintenance	• Different types of maintenance
6	--	Overlapping PMs

How to model/solve OMP?

- Model (MILP):
  - Increase the dimension of the decision variables
  - Introduce new variables
  - Change the architecture
- Solution Methodology:
  - Same concept
  - New Implementation

OMP Formulation

Maximize Availability

Subject to:

- Maintenance Requirements
- Operation Requirements
- Rotation of the machines into and out of maintenance stations
- Workforce Capacity
- Stations capacity

OMP Formulation

Maximize residual operation time (all machines, all time periods)

Subject to:

- Use up workforce hours for maintenance
- Make sure operations requirements are met
- Rotation of the machines into and out of maintenance stations should make sense!
- Workforce crew has limited time
- Make sure maintenance is performed on time
- Maintenance stations have limited capacity

OMP Formulation

N Set of all machines

P Set of preventive maintenance (PM) activity types

O Set of operations

M Set of machine types/groups, (a superset)

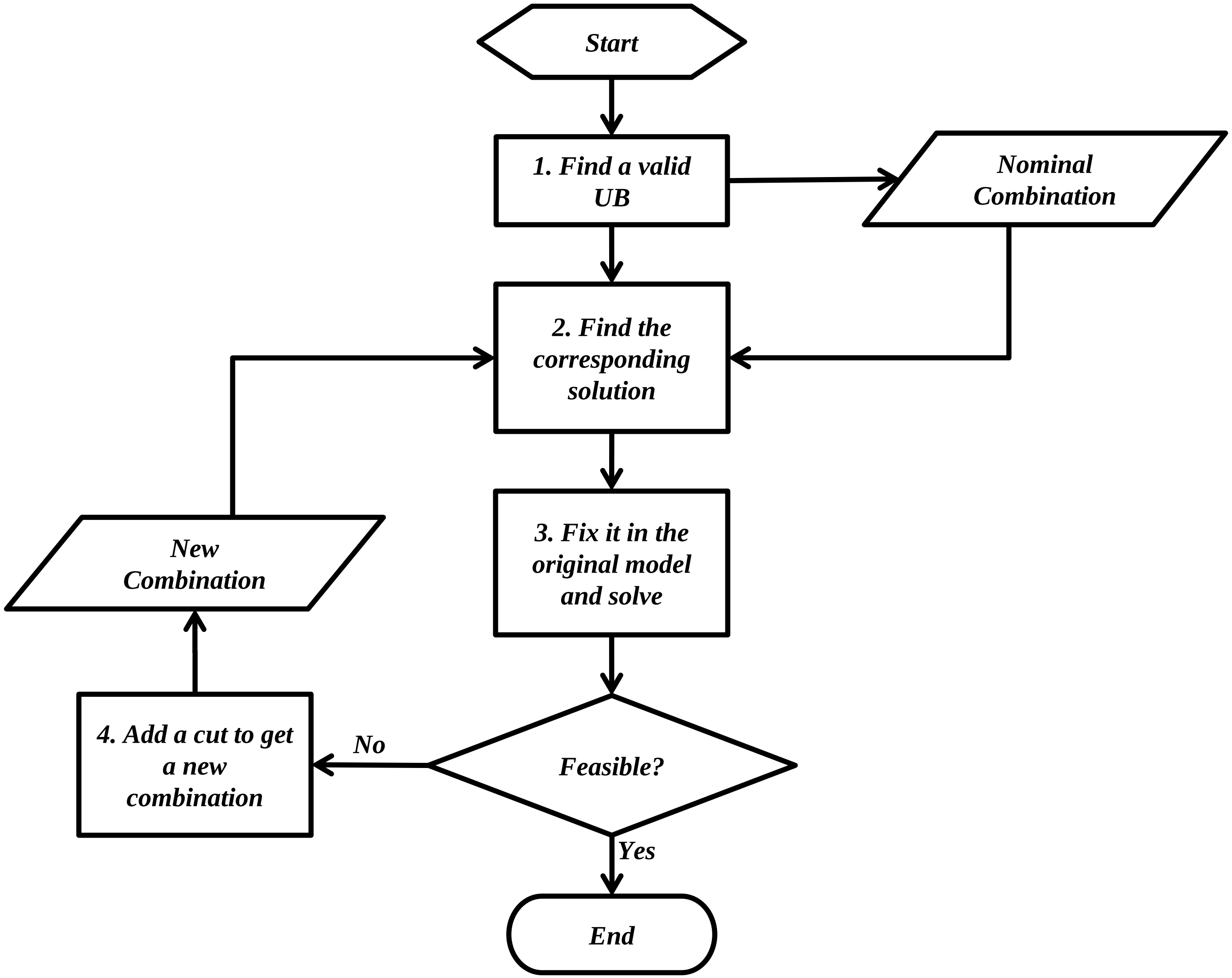
OMP Formulation

$$Max\ COA = \sum_{n \in N} \sum_{t=2}^{T+1} Z_{n,t} \qquad \textit{Subject to:}$$

$$Z_{n,t} \leq y_{n,p,t}, \qquad n \in N, p \in P, t = 1, \ldots, T+1$$

40 Constraint Sets

Solution Methodology



Finding a Valid Upper Bound

Proposition 1. Maximization of COA is equivalent to maximizing

$$cx_t = \sum_{m \in M} \sum_{k=2}^{t} ex_{m,k}$$

Proof.

COA: $$\sum_{n \in N} Z_{n,1} - \sum_{o \in O} \sum_{k=1}^{t-1} R_{o,t} + \sum_{m \in M} \sum_{k=2}^{t} Y_{p'} ex_{m,k}$$

↓ Non-Constant Part

$$cx_t = \sum_{m \in M} \sum_{k=2}^{t} ex_{m,k}$$ → Increase the Flow!

Finding a Valid Upper Bound

Algorithm 1: Finding an upper bound for the weighted cumulative operations availability (COA) problem

order $maintenanceLine$ by whether all their maintenance needs can be fulfilled in the current time period (so they can exit the maintenance station); break the ties by reordering the machines in a tie in non-decreasing order of the machines' total residual maintenance times

order $operationLine$ in non-decreasing order of AROTs (min. of machines' residual operation time)

If there is enough operation to be assigned to this machine so the minimum of its PROTs is fully used, use this machine!

Feasibility Check

fixing the values of decision variables that represent a combination in the original problem, and then, trying to solve the original problem to see if there exists a solution that realizes that combination.

Adding Cuts

After a given combination is found infeasible, the question is whether another combination exists that yields the current bound for the objective function (COA).

Formulate a new MIP that keeps the same value for OF and finds new combination

Adding Cuts

$$\sum_{m \in M} \left(\sum_{t=2}^{T+1} \left| en_{m,t}^{cur} - en_{m,t}^{new} \right| + \sum_{t=2}^{T+1} \left| ex_{m,t}^{cur} - ex_{m,t}^{new} \right| \right) \geq 1$$

Implementation and Results

- ✓ Model implemented in CPLEX and Gurobi
- ✓ Same results after solving test problems of the original paper (FMP)
- ✓ UB algorithm developed in MATLAB and Python
- ✓ Higher Speed of the Algorithm
- ✓ Heuristic and Model give the same results (as is proved!)

Future Research

- Stochastic operations requirements
- Stochastic repair and maintenance
- Maintenance Workforce Planning

Thank You!

Contact:

JSEIF [AT] UTSI.EDU

AJYU [AT] UTSI.EDU

THE UNIVERSITY OF TENNESSEE KNOXVILLE