Home assignment number 2, 2014, in SF2863 Systems Engineering.

Instructor: Per Enqvist, *penqvist@math.kth.se.*

This home assignment should be done in groups of four persons each. If your group is smaller, find more persons using the doodle on the homepage. Limited cooperation with other groups is also allowed, but should be refered to in the report.

One report per group is to be handed in, and you should describe in your own words how the problem was solved. Make the description rich enough so that it is totally clear how you define your states and modelled the problem and describe how you implemented the algorithms. It is not allowed to copy parts of another groups report or computer code! The answers to the questions in the assignment should be given in the main report. (Not in your computer printouts.) Relevant print-outs and plots should be included in the report. Computer code should be held available on request.

State your name, personal number and email adress on the front of the report.

A written report (printed out on paper) should be handed in to the instructor before 13.15, Tuesday, December 16. Note that this deadline is sharp. (Note that the assignment is completely voluntary, but that a correct report that is handed in in time will grant you bonus points at the final exam.) A correct solution and clear report will grant four bonus points on the exam.

The purpose of this home assignment is to stimulate the understanding of how the spare parts optimization theory can be applied to a small test-example.

Problem statement

We consider the case where aircrafts are equipped with 7 different "line replaceable units", $LRU_1, \cdots, LRU_7$ representing wheels, brakes, hydraulics, electric actuators, fuel systems, landing gears and engines.

First just consider one basis to which there is a (random) arrival of airplanes with an LRU_j unit in need of repair. A malfunctioning LRU_j unit arrives with intensity λ_j, where

$$\lambda_1 = \frac{76}{1000}, \lambda_2 = \frac{33}{1000}, \lambda_3 = \frac{66}{1000}, \lambda_4 = \frac{80}{1000}, \lambda_5 = \frac{23}{1000}, \lambda_6 = \frac{55}{1000}, \lambda_7 = \frac{41}{1000}.$$

When a malfunctioning LRU_j unit arrives to a base it is replaced immediately with a functioning LRU_j unit from the local inventory, as long as it is not empty. If there is no functioning LRU_j unit in the local inventory to replace the malfunctioning LRU_j unit with, then there will be a local inventory queue, a backorder is issued and the aircraft is grounded and has to wait for a functioning LRU_j unit to arrive from the repair shop.

The malfunctioning LRU_j unit is directly sent to the local repair shop. The repair time for a malfunctioning LRU_j unit is assumed, on average, to be T_j hours, where

$$T_1 = 2, T_2 = 4, T_3 = 10, T_4 = 3, T_5 = 12, T_6 = 9, T_7 = 25.$$

The cost per unit for LRU_j is c_j where

$$c_1 = 10, c_2 = 8, c_3 = 12, c_4 = 7, c_5 = 6, c_6 = 44, c_7 = 100.$$

Today there are no spare LRU units, and as a consequence it happens regularly that planes are grounded. This is now going to change, and you should implement the process.

Assignments

1. Use the marginal allocation algorithm to determine all the efficient points of the multiobjective optimization problem to minimize the EBO and total cost for spares when the total budget is bounded by $C_{\text{budget}} = 500$. Start with no spares and determine how the expected number of grounded airplanes decrease when adding each new spare LRU unit. Plot the efficient curve and determine in a table the efficient solutions, the corresponding objective function values and the marginal increase in expected downtime for each new unit of cost spent on the LRU spare units.

2. Now assume that we want to determine the best spare parts setup for a certain specified budget, *i.e.*, we want to solve the problem

$$
\left[
\begin{array}{ll}
\min\limits_{s} & \text{EBO}(s) \\[2mm]
s.t. & C(s) \leq C_{\text{budget}}
\end{array}
\right]
$$

where $C_{\text{budget}} = 500$.

This is an integer programming problem, but with some nice properties. Use dynamic programming to solve the problem for the specified budget, by determining the solutions to all problems of the same type but with a smaller budget.

Explain your notation and your solution algorithm with great care. We will not decode your matlab implementation.

You will get a solution for each upper bound on the budget. Because there are so many solutions you do NOT have to put all of them in a table. Instead, compare the solutions from this problem to the efficient solutions determined in the first part of the assignment by plotting them in the same graph. Is the result reasonable?

Please note that the Dynamic programming approach has to be applied, solutions based on total enumeration of all possible combinations will not be rewarded with any bonus points.

Good luck!