OPTIMIZATION OF OPERATING TASKS ASSIGNED FOR ENGINE ROOM STAFF

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Abstract

The present work shows the two approaches to the problem according to the situation in which the engineer is made to take certain decisions. In formulation of the two most substantial operating states of a ship like lay time in port and sea voyage, knapsack algorithms and task scheduling algorithms were applied. For both approaches was formulated objective function, decision variables and constrains.

Keywords*: task scheduling, knapsack problem, ship power plant, decision making*

1. Introduction

According to many experts' opinion proper management of engine room presents serious difficulties for decision – making engineers. This is caused by among others:

- increasing number of automated ship's systems,
- many work processes performed simultaneously,
- information shortage which allow fast familiarization with Engine Room systems and work scheduling,
- frequent change of ship staff,
- increasing safety requirements for staff, ship and environment.

Moreover the changes of international maritime law put on the engine room staff many additional works relating new procedures and report them.

That state creates situations, which large number of factors do decision making difficult and the engineer's knowledge and experience can be not enough to make a correct decision. Decision making relating of Engine Room management could be irrelevant or irrational, causing the different kind of loss. For example - the loss of time, what increase the general cost of ship used.

To eliminate that situations engineer could use a computer application, as a tool supporting him at managing of task scheduling in Engine Room.

Nowadays a lot of ships have computer systems supporting a ship engineers in power plant management being installed or functioning. The chief engineer has by himself to analyze all information's and make the proper decision about scheduling the operation tasks.

The objective of such tool would be to solve the following problem:

Knowing a set of tasks to be performed and taking into consideration all accessible resources (technical, human, time) as well as ship operating states, make a choice of such tasks, which make use of resources most effectively.

In other words, the idea is to take rational decisions referring to above-mentioned tasks, what will be the best from operating viewpoint at a certain time, and assigning them to suitable E.R. staff. Such "a tool" can be a computer-aided program of E.R. management supporting a chief engineer in making those decisions.

2. Operating task scheduling

2.1 Problem formulation

The solution of decision – making problem what a chief engineer deals during E.R. managing is a rational schedule of tasks which are important to be performed in a certain operating situation.

Analyzing situations, which a chief engineer is likely, to be made to solve a decision – making problem described above, a few situations depending on operating condition of a ship can be distinguished.

For example, the ship is on a long sea voyage. In this case there are no strict time restrictions in completing either operating process in E.R. or a particular operating task. Therefore the decision – making problem can be formulated as a tasks scheduling with no time limits. So the tasks must be scheduled with optimum application of accessible human and material, also concerning execute moment of a certain task imposed by external factors such as: producer of marine machineries, classification societies, port controls (*Port State Control*), etc.

Another situation is when time limits occur, e.g. during stay in port time. The exact departure time is known and the number of tasks to be completed exceeds considerably E.R. staff capabilities. Situation like this, the chief engineer has to take decision which operating tasks are to be completed in the allowed time and which tasks can be postponed for further term. Making inappropriate decisions at this moment can lead to execute failure tasks. Result of this can be detention of the ship by port control (*PSC, FSC*) or break off of normal operating process of E.R. (e.g. *black out*) in further. Decision – making problem in this situation can be formulated as a choice of the most relevant tasks from viewpoint of E.R. operating and scheduling them so as to make the most of the available time.

There are a lot of other situations in ship operating process, e.g. anchoring, manoeuvres, passing through a channel etc., when an engineer could be made to the decisions on task scheduling. However, these states make a tiny percentage of the overall operating time of a ship, they occur very seldom in her operating process. Otherwise the situation demands immediate decision about the method of acting (e.g. port manoeuvres), computer aided system is unlikely to be used. Therefore the two first specified situations have been taken into account: stay time in port, sea voyage.

In general theory of decision making the decision problem is the situation, when the decision-maker faces before necessity of choice one from at least two possible variants of working. In Engine Room the chief engineer has to decide, what variant with all decision variants (schedule of operation task) will be the best. According with definition of this problem chief engineer must from among all operation tasks, which are to execute, choose and schedule for operators these which are the most important in particular operation situation consider all occurrent condition and constraint.

The decision making process of chief engineer relating the scheduling tasks of the operators in E.R. can distinguish tree of the principle stages:

- accumulation and processing all accessible and necessary information [4],
- selection tasks, which realization be limited by the every operation constraints and conditions in what the decision be making [3],
- assigning of the tasks to the E.R. staff according with his competences (qualifications), so to the schedule was the best [1][2].

2.2. Application of knapsack algorithm

In present work described the last stage, so the allotment of the operation tasks to operators in this situation. The strategy of allotment of these tasks in such situation can go to two aims:

maximization of the schedule value, what is the choice of the most important tasks, or the best use of the available time.

Problem of the tasks scheduling in E.R. in both aims, it similarly how many industrial problems, could be implemented as packing problem (knapsack problem), being a special case of 0-1 linear programming.

Many authors describe several methods and algorithms of scheduling, which concerned of varied special types of problems [5][7]. But these models are general the most comprehensive in relation to reality problems and not account many different practical conditions.

Standard knapsack problem depend on completion the limited knapsack volume, by "packs" which volumes and weight are different, in such way that, the knapsack get maximum worth.

In analogous it is possible to formulate a scheduling problem of chief engineer. Specific situations like e.g. short stay in port or short sea voyage, where the operation tasks are assigned to E.R. staff in such to execute the most important tasks and to use available time maximally also.

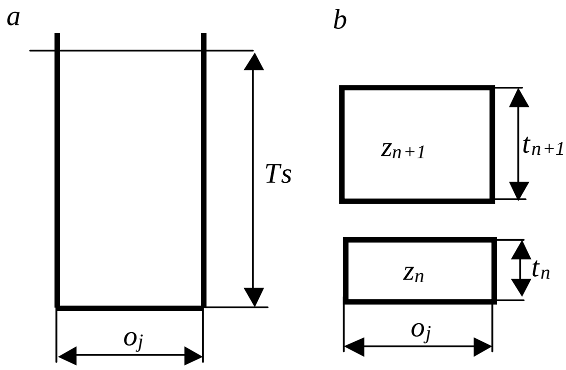

Fig.1. Graphic representation of knapsack problem

2.3. Application of multi-knapsack algorithm in task scheduling in Engine Room

The problem of scheduling operation tasks to all operators in *E. R.*, could be possible to consider as multi-knapsacks problem (*in shortcut: 0-1 MKP*) [6]. The operators o_j (*E. R.* staff) are representing by "knapsacks". Theirs height is available time T_S (e.g.: short stay in port or short sea voyage). The competence (qualification) $k_j=o_j$ what possess the operator is symbolize by width of the knapsack (fig.1a).

The tasks are representing by "packs" (fig.1b), which are placed in knapsacks. Every task possess few parameters:

- competence what need operator to do it, it's a width of pack,
- time t_i necessary to do it, it's a height of pack,
- task weight wg_i, what is the validity of the task, with operation of view point, it's worth of pack.

The solution of that introduced problem will be tasks schedule, what need to realized for every of accessible operators in this situation in Engine Room, with fulfilling all constraints.

2.4. Mathematical model

Fundamental elements of chief engineer decision-making as packing problem are:

- tasks with the parameters (e.g.: task weight wg_i, realization time t_i, etc.),
- operators with possess competence k_i,
- available time T_S.

In presented scheduling operation tasks in E.R. approach was accepted few general foundations and constrains:

- every operator can execute only one task in the same time,
- every task can be executed by one operator only,
- number of execrable tasks in the E.R. is larger then operators can realize,
- every tasks possess few parameters keeping in database or appointing in earlier [1][2],
- assigning of the tasks will be execute accordantly whit the professional qualification.

A big number of operating tasks, which should be used to scheduling, bring many solutions filling all restrictions. In order to point out the optimum task planning from operating viewpoint, determination of importance indicator of each task and determination of quantity indicator *Fj* of each solution (objective function of optimization problem) are necessary.

Objective function

In this problem we admit two optimization's criterions. The first, should be execute the most important tasks fj_1 (eq.1). Such schedule should consist the tasks attached of all operators whit possibly the largest weight coefficient wg_i. Second, the best utilization the available time differently fj_2 (eq.2).

$$fj_1 = wg_1 x_{1j} + wg_2 x_{2j} + ... + wg_n x_{nj} = \sum_{i=1}^{n} wg_i x_{ij} \quad (1)$$

$$fj_2 = x_{1j}\frac{t_1}{T_S} + x_{2j}\frac{t_2}{T_S} + x_{3j}\frac{t_3}{T_S} + ... + x_{nj}\frac{t_n}{T_S} = \frac{\sum_{i=1}^{n} t_i x_{ij}}{T_S} \quad (2)$$

where:

$i = 1, 2, 3, \ldots\ldots, n$ - number of tasks,
$j = 1, 2, 3, \ldots\ldots, o$ - number of operators,
wg_i – weight of task importance,
x_{ij} - *0 or 1*, if task *i* is assigned to operator *j*,
t_i - execute time of task *i*,
T_S – available time for execute of tasks.

According with principles of formulating the objective function [8] in problem like this, was accepted as scalar combination this two criterions. Generally it's definite as valid sum: the coefficients of tasks weight and time, what occupy there execute.

In that case this is two-criterions optimization problem. To equation introduced coefficients of weight's criterions ρ_1 and ρ_2, what gives to user the possibility of choice which criterion is more important. A chief engineer chooses dependence which criterion is the most important in this moment. Coefficients ρ_1 and ρ_2 can admit value from compartment <0,1>, and their sum always has to be equal 1. The most often takes it like $\rho_2=(1-\rho_1)$.

Objective function of this problem is as follows:

$$Fj = \max \sum_{j=1}^{o}\sum_{i=1}^{2} sk \cdot \rho_i \cdot fj_i(o_j) = \sum_{j=1}^{o}\left(sk \cdot \rho_1 \cdot \sum_{i=1}^{n} wg_i x_{ij} + (1-\rho_1)\frac{\sum_{i=1}^{n} t_i x_{ij}}{T_S} \right) \quad (3)$$

where:

ρ_1– weight of criterion,
sk – scale coefficient.

Such form of objective function possesses some imperfection. The schedule folds many low weight tasks (less important) and a short of execute time. It can have larger value of objective function, then schedule which folds high weight tasks (very important) and longer time of execute.

Is proposed modified this form of objective function to eliminate that imperfection. It depends on addition to the first of criterions fj_1 (eq.1), a coefficient of task relative size kw_i (eq.4). This is represented by the product of execute relative time and relative competence. In notation of knapsack problem it's represented by the size of pack (height × width) in relation to knapsack's size where is placed in.

$$kw_i = t_{wzgl} \cdot k_{wzgl} = \frac{t_i}{T_S} \cdot \frac{k_i}{k_o} \qquad (4)$$

where:

kw_i – relative size coefficient,
k_i – necessary competence to execute the task,
k_o – operator competence.

Objective function follows as:

$$Fj = \max \sum_{j=1}^{o} \left(sk \cdot \rho_1 \cdot \sum_{i=1}^{n} wg_i kw_i x_{ij} + (1-\rho_1) \frac{\sum_{i=1}^{n} t_i x_{ij}}{T_S} \right) \qquad (5)$$

Decision variables and constrains

The decision variables in that formulated problem are the facts whether the tasks will go into consider schedule, or not. It is defined by indicator x_{ij}, which can accept one of two values 1 or 0 (eq.6). The decision-maker decides, which of tasks the foundling oneself in created schedule as well as, in what the orders should be realized.

$$x_{ij} = \begin{cases} 1 & \textit{if the task go into the schedule} \\ 0 & \textit{if the task is skip in schedule} \end{cases} \qquad (6)$$

Four of principle constrains appear in such approach:

- the total of execute time for every of operators can not be larger than available time T_S:

$$\sum_{i=1}^{n} t_i x_{ij} \le T_S \qquad \forall i, \forall j : i \in Z_Z, j \in Z_O \qquad (7)$$

where:

Z_Z – tasks collection,
Z_O –operators collection.

- the task attached only once in schedule:

$$\sum_{i=1}^{m} x_{ij} \in H \le 1 \qquad \forall i \in Z_Z \qquad (8)$$

$x_{ij} \in H$ – the task *i* belongs in schedule *H*.

- the way of assign the tasks to individual operator is definite as following:

$$k(o_p) \le k(o_j) \qquad \forall x_{ij} \in H \qquad (9)$$

where:

$k(o_j)$ – competence of operator, who is assigned the task in schedule ***H***,
$k(o_p)$ – competence of operator, who has attached the task in duties.

The task can be assign to operator o_j in schedule who has a competence equal or larger then operator o_p who has it attached in duties.

- every of tasks could be executed by once of operators only,

$$\sum_{i=1}^{m} o_n(x_{ij}) \leq 1 \qquad \forall n \in Z_O \tag{10}$$

2.5. Choice of computational method to solution of problem

To solution of task scheduling in E.R. optimization problem was chosen the indirect review method called also the review with recurrences method. Cause of simplicity, contains basic steps almost all review methods and simultaneously is the one of the quickest among them [6].

The review with recurrences algorithm finds the solution of the problem by systematic searching whole space of acceptable solutions. It uses the representation of the space solutions in the figure of tree. In this every of decision variables are represented by tree level. Every of tree nodes can have two branches only, what accept value 0 or 1 only (fig.2a). The method depends on searching of solutions space through creating first the left branch. When search after left side achieves finish, is created right branch and search moves on this side. Such method of creating tree's nodes is very thrifty and despite of this does not skip any node, which would lead to better solution.

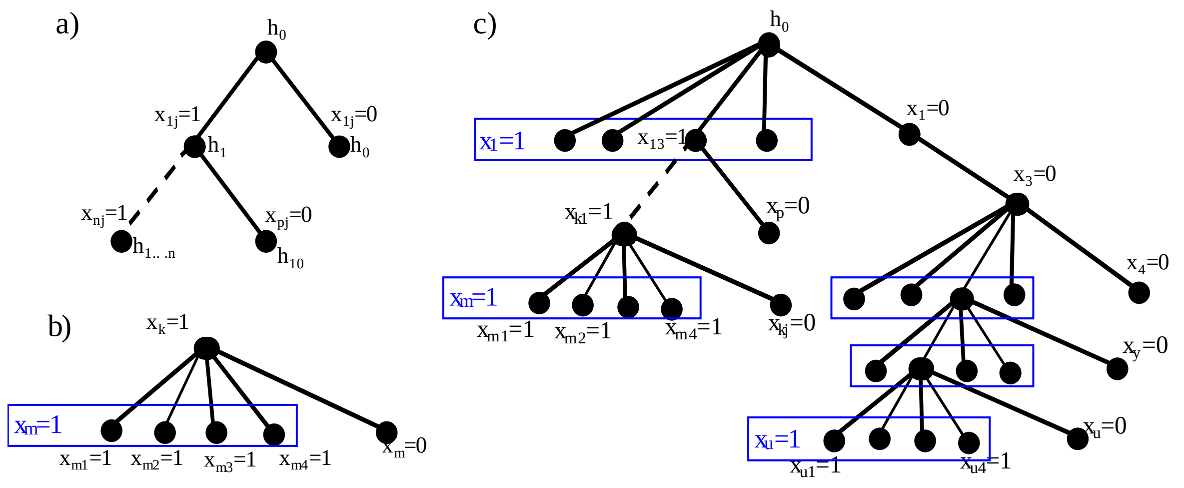

Fig. 2. Modify method for searching solutions tree for multi-knapsack problem

In Engine Room we have to assign tasks to large number of operators therefore also introduced algorithm requires modification. To next considerations was accepted the most often situation in E.R. - four operators who are assigned tasks.

Spread of operators number (four) causes, that every task, if the constrains permit, could be assign to every of four operators. So, in a situation, when the task parameter x_{ij} admits value 1, we have four additional solution variants (fig.2b).

The searching of the possibility solutions for many operators is started like for one. The assigned is begun from operator who possesses the smallest competences to execute the task. If any of constrains do not permit to assign it to him, the task is tried to assign next of operator, who has one larger competence from among remaining operators'.

The assigning the task to operator gives the new admissible solution. For this is checked the value of the objective function (sum of tasks' weights for every of operators) and compared with the best result obtain to this time. If the appointed value of objective function is larger then exists so far, the new value and the solution (Schedule) are stored as the best.

3. Computer application of tasks scheduling in engine room

In order to check presented the mathematical model of this problem and way to solution of decision-problem what meet chief engineer was implemented prototype of computer application.

On the figure 3 is shown, that interface of which consists the parameters, defined individual for users in tasks scheduling before starting the process of search the problem solution.

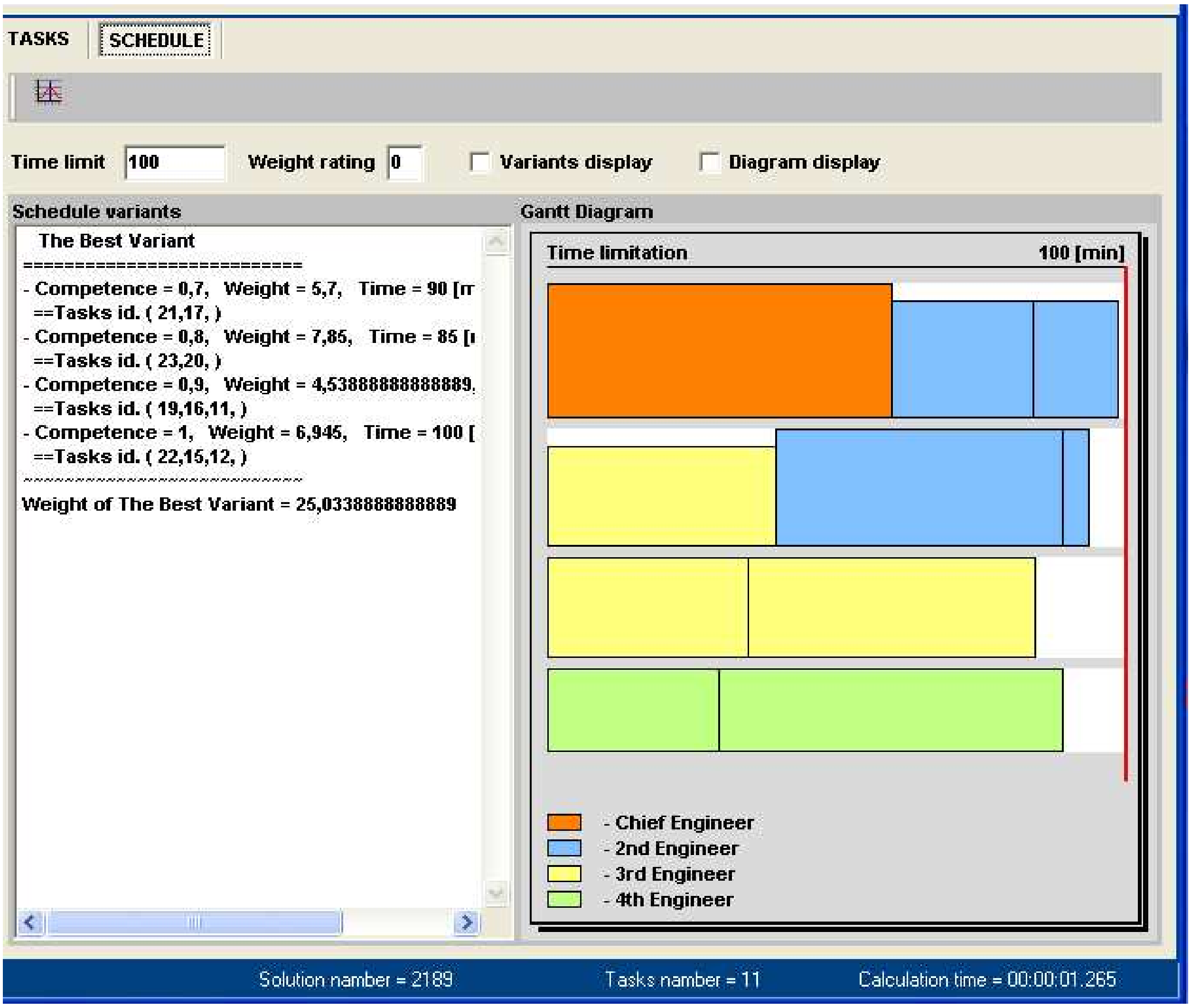

Fig. 3. Fragment of application interface representative the best solution and Gantt's diagram of assigning few operating tasks optimization

The two fundamental for optimization process parameters it:

- "Limit time", that is the time, when the tasks have to execute (e.g.: time to leave the port, etc.),
- "Weight rating", that is weight criterions (parameter ρ in equations 3 and 5).

The main area of this interface is partite on two units. The best result is displayed in first "Schedule variants" of them. There are displayed the following information:

- there are displayed the assigned tasks, for checks correctness of working are displayed the identification number only,
- sum of the really tasks executed times for every of operator,
- sum of the task weights for every of operator,

the sum of weights for total schedule also, which is the coefficient of quality of the solution.

In the second "Gantt Diagram" are showed the visualizations of received results in form of Gantt's graphs for every of operators. Every of operators have appeared as e white "rectangle", which dimensions illustrate:

- available time (the length of rectangle),
- competence what possesses the operator (the height of rectangle).

In "State bar" being in bottom edge of interface, are displayed three additional information needed to analysis of received results: number of analyzed solutions, the number of analyzed tasks, the time of calculations what use the process to finding the best solution.

4. Conclusions

It is described the mathematical model of two-criterions optimization of operation tasks assign in Engine Room and the searching the best from among admissible solutions and in peculiarly:

- objective function consider the most essential element, what chief engineer makes allowance for during tasks scheduling, as: weight of task, competence every operators, the available time,
- defined elementary constrains, what appear during schedule of operational tasks in E.R.,
- the searching algorithm for four operators was chosen and modified,
- prototype of computer application what uses introduction mathematical model was implemented.

In the next works will be checked whether the objective function and constrains are sufficient for solution this problem. As well whether the accepted method of solution search will be sufficiently and fast to use in tasks scheduling in Engine Room.

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