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Work Scheduling Method By Applying Knowledge Engineering Supported By Mathematical Programming Technique

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Abstract In work scheduling problems, scheduling constraints are not absolutely rigid ; they may be changed depending on the scheduling aspect effected. In order to cope with changes in scheduling constraints and assignment strategies and to optimize scheduling results quickly, this paper will propose a new scheduling method which combines knowledge engineering and mathematical programming techniques.

Keywords scheduling, production line, mathematical programming, knowledge emgineering

1 . INTRODUCTION

Previously, most scheduling systems have employed a mathematical programming approach. However, scheduling systems developed by the mathematical programming approach are not of much practical use, because there is little flexibility for changes of various scheduling constraints. Recently, the development of practical scheduling systems has gradually become active again, because knowledge engineering techniques allow flexibility[1].

In previous studies[2][3], the solving method itself is constructed based on either the knowledge engineering technique or the mathematical programming technique. However, in order to maintain flexibility and get optimal scheduling results, it is very effective to combine knowledge engineering and mathematical programming techniques.

This paper proposes a new scheduling method based on the combination of both techniques.

2 . WORK SCHEDULING PROBLEM

If all constraints can be fixed rigidly in advance and the scheduling problem can be clearly formulated, it is possible to achieve the scheduling automatically according to a conventional scheduling method such as mathematical programming technique. However, in actuality, it is difficult to fix all constraints in advance.

a) Difficulties associated with prior fixation of scheduling constraints : For example, in scheduling a production job, some machines may require maintenance as an extra job. However, because of the production quota, the actual scheduling is often achieved by postponing a portion of the maintenance jobs till next month.

b) Change of the problem itself : The scheduling problem varies due to changes in the environment, for example, changes of problem size, work characteristics or machine abilities. In conventional scheduling methods, however, since scheduling know-how is coded in a program, it is practically impossible to arbitrarily modify it.

As stated above, the constraints cannot be easily determined in advance; furthermore, the problem itself changes according to environmental circumstances. Therefore, it is difficult to achieve the scheduling using only the rigid conventional method.

The object of our research is to develop a high speed and easy maintenance scheduling method capable of easily coping with changes in scheduling know-how and constraints.

3 . WORK SCHEDULING METHOD

3.1 Fundamental Idea

As a general rule, when human schedulers make optimal schedules, they allocate jobs assignments relative to time. However, if there is some difficulty with resources or jobs, those resources or jobs take priority. That is, they repeat the following cyclic procedure to get optimal scheduling results ; first, they extract a partial problem to be solved next judging from the schedule status, then they solve the problem, and from this result the next partial problem is extracted again. Based on the above schedulers' procedures and their know-how, this paper proposes a new scheduling method by applying knowledge engineering supported by mathematical programming technique.

3.2 Allocating Procedure

An allocation period is divided into several sub-periods in order to be unnecessary to consider more than two jobs allocation to each resource within each sub-period. The job allocation can be accomplished according to the linear programming algorithm. However, since the problem is solved by subdividing the allocation period into sub-periods, the dependence between jobs cannot be completely take into consideration. To overcome this difficulty, knowledge engineering is employed as follows.

After job allocations are effected to a sub-period, subsequent sub-period is checked to find out jobs which seem to be difficult to be allocated. And, the difficult partial problems are solved preferentially. The extraction of the difficult partial problems and the selections of solving algorithms are done by experts' know-how, and the allocation strategy is implemented by knowledge engineering. The outline of the allocation procedure is shown in Fig.1. As shown in this figure, the job allocation is effected by repeating the cyclic procedures, which are consisted of recognition of schedule status, selection of an allocation strategy, and accomplishment of allocation according to the strategy. The experts can find difficult partial problems based on experiences, which are represented as strategy rules. Concrete allocation strategies are shown below.

(1) Strategy associated with jobs

Strategy1-a : The allocation is sequentially achieved in a job-by-job fashion beginning from a job which has smaller number of candidate resources.

Strategy1-b : The allocation is sequentially achieved in a job-by-job fashion beginning from a job which has greater number of days necessary for the job.

(2) Strategy associated with resources

Strategy2-a : Let us consider such a case that each job can be proceeded only by resources which have qualifications for the job proceeding. And, if a resource don't proceed such a job for a certain period, the qualifications are invalidated. The allocation is sequentially achieved in a resource-by-resource fashion beginning from a resource which has smaller number of candidate jobs necessary for maintaining the qualifications.

Strategy2-b : Each resource should be maintained once during a certain period. Maintenance job allocation is sequentially achieved in a resource-by-resource fashion beginning from a resource whose maintenance job deadline is the earliest .

Strategy2-c : The allocation is sequentially achieved in a resource-by-resource fashion beginning from a resource which has smaller number of candidate jobs.

(3) Strategy associated with periods

Strategy3 : When none of the above strategies is applicable, the job allocation is proceeded in the order of the day. That is, next sub-period is extracted and the allocation is effected for this sub-period.

3.3 Classification of Scheduling Know-how

Know-how is classified into three categories corresponding to the three allocation steps (Fig.1).

Scheduling constraints are used to recognize the state of the scheduling, and they are represented by "frame-like" expression.

Strategic know-how is used to decide strategy.

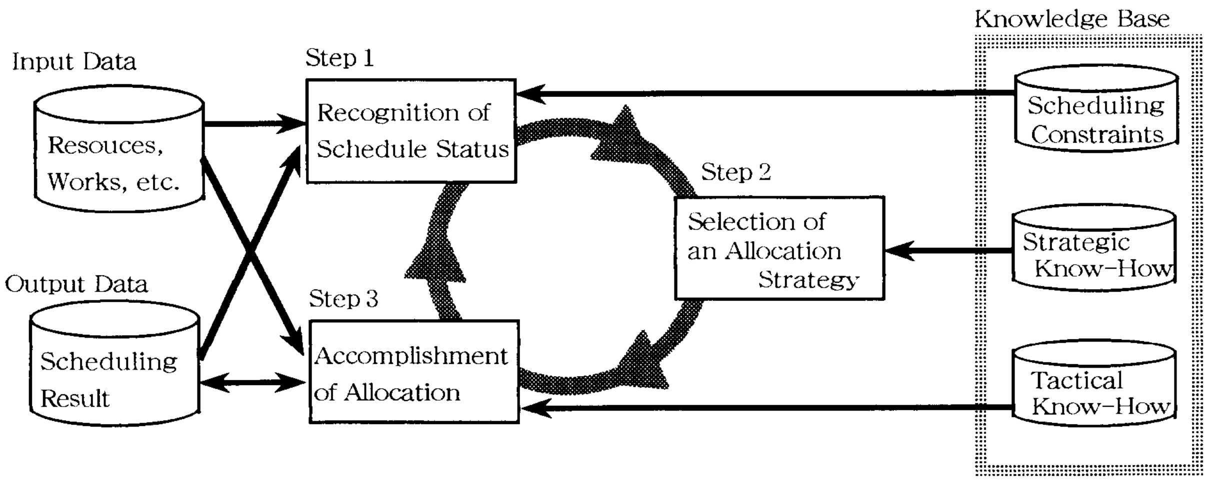


Fig.1 Procedure of work scheduling

Deciding scheduling strategy means to extract a partial problem and to select a scheduling algorithm for solving the partial problem. The strategic know-how is represented by "IF THEN rule" .

Tactical know-how is used to judge the quality of allocation. Generally speaking, the items to judge the quality are rarely changed, but the significance of items may vary according to the scheduling circumstances. Therefore, each item significance is represented as weight parameter ($w^{(k)}$: described later).

3.4 Scheduling Algorithm Associated With Periods

The proposing method gets optimal scheduling result by the cyclic repetition of the partial problem extraction and the problem solving. Even if each partial problem result is optimal, the result is not always optimal for the whole scheduling problem. Therefore, the allocation of boundary parts between mutual problems should be considered elaborately when the partial problem is solved.

(1) Optimization method for the scheduling of the associated period

At first, the method extracts all candidate resources for each job within the period. Then, it evaluates in a comprehensive fashion the advantage degree for each combination of all apparatuses and jobs. This evaluation is performed by using the tactical know-how (Fig.2(a)). Based on the matrix created as described before, the system attempts to solve a NXN optimal allocation problem in the linear programming, which is formulated concretely as below.

i : resource (=1,2,...,M)

j : job (=1,2,...,N)

k : evaluation item of the advantage degree for the combination of a resource and a job (=1,2,...,K)

$C_{ij}^{(k)}$: advantage degree for the combination of i-resource and j-job considering for the standpoint of k-item

$W^{(k)}$: significance weight of k-item for evaluation

X_{ij} : determining variables
= 1 if j-job is allocated to i-resource
= 0 if j-job is not allocated to i-resource

Using above notations, work scheduling problem is formulated as:

$$\sum_{i=1}^{M}\sum_{j=1}^{N}\left(X_{ij} \sum_{k=1}^{K} C_{ij}^{(k)} \cdot W^{(k)}\right) \rightarrow \text{Max.} \qquad \text{(Eq.1)}$$

subject to

$$\sum_{j=1}^{N} X_{ij} = 1 \quad i = 1,2,\ldots,M \qquad \text{(Eq.2)}$$

$$\sum_{i=1}^{M} X_{ij} = 1 \quad j = 1,2,\ldots,M \qquad \text{(Eq.3)}$$

There are multidimensional evaluation items. In the proposing method, total advantage degree is evaluated by the scholar value (sum total of $C_{ij}^{(k)} \cdot W^{(k)}$ for all k-items).

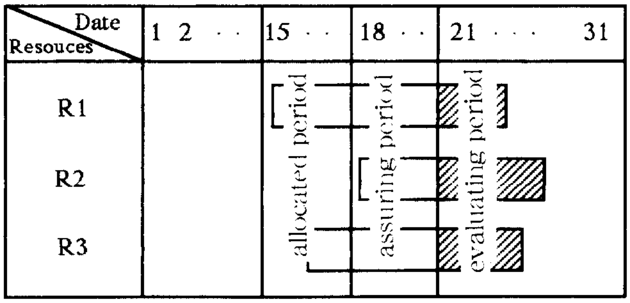
(2) The method to prevent the destruction of the above optimal allocation

Near future period neighboring the just allocated period is called as "assuring period". When optimal allocation in the just allocated period is proceeded, resources are also allocated temporarily for all jobs which should start within the "assuring period". Because almost all jobs in the just allocated period don't end within the period, many reallocations are needed in case of not considering temporal allocation. (See Fig.2(b)) We call the farther future period neighboring the "assuring period" as "evaluating period of resources' remaining ability". For all jobs within this period, we calculate the number of jobs which would become unable to be proceeded because of no free resources. And, by minimizing the total number the ability is exhausted as little as possible. This minimization is performed by considering the number as one of the evaluation items in Eq.1.

The fundamental idea of allocation algorithms associated with jobs and with resources is similar to that associated with periods.

Works / Resouces	W1	W2	W3	W4
R1		9	9	10
R2	10			10
R3	3	2	9	1
R4	8	8		

(a) Optimal scheduling for the associated period



(b) Prevention of optimal allocate destruction

Fig.2 Scheduling algorithm

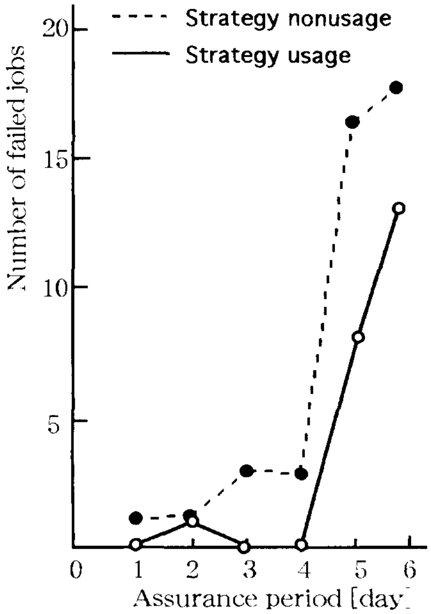


Fig.3 Effect of assigning strategy

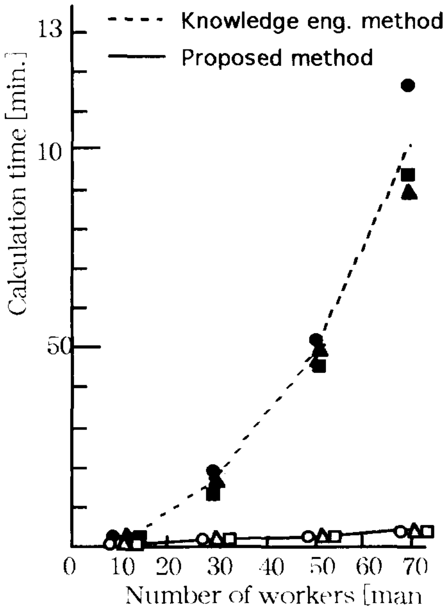


Fig.4 Calculation time

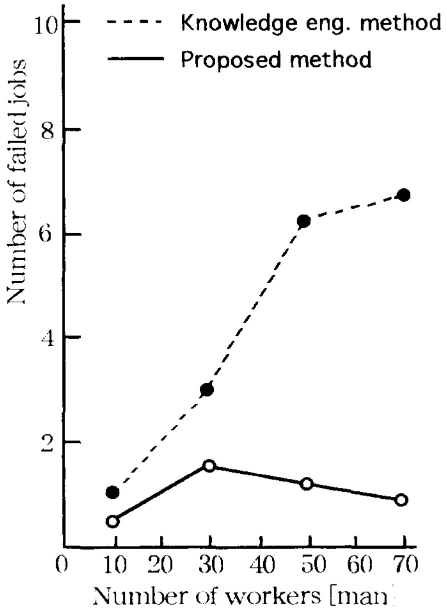


Fig.5 Unassigned job number

4. EVALUATION OF THE PROPOSING METHOD

4.1 The Effect of The Strategy Usage

In this model, resources represent workers, and the total scheduling period is one month. Each job is proceeded during few days and it must be done by a licensed worker who has qualifications for the job.

The quality of scheduling result was evaluated by the number of failed jobs to be allocated. Fig.3 shows that the strategy usage reduces the number of failed jobs and that the usage keeps the number in low level over the wide range of the assuring period.

4.2 Comparison with The Typical Knowledge Engineering Method

(1) Calculation Time

The method can solve schedule problems speedily at a stable time even if the size of the problem becomes large (Fig.4). On the contrary, the calculation time for the knowledge engineering method increases exponentially and the deviation of the time becomes larger as the problem size grows bigger.

(2) The Quality of The scheduling Result

In knowledge engineering method, the number of failed jobs increases as the problem size becomes bigger (Fig.5). In the proposed method, on the other hand, the number of failed jobs can be reduced over the wide range of the problem size.

(3) *System Maintainability*

The proposed method has separated (a) optimal allocating algorithms, and (b)partial problem extracting know-how. The program was also divided into two parts corresponding to the above two. The former part can be maintained by system engineers, and the latter part can be maintained by system users. The knowledge engineering program was made only by "IF THEN rules". Therefore, the number of rules became large and it is difficult to retain the consistency.

5. CONCLUSION

New work scheduling method, which combines knowledge engineering and mathematical programming techniques, was proposed. This method is flexible for changes of scheduling constraints and can get optimal scheduling result in high speed calculation. And evaluation experiments showed the effectiveness of the method.

REFERENCES

[1] A.Tate : 'A Review of Knowledge-based Planning Technique', Proceeding of 5th Technical Conference of BCS, PP.89-111 (1985)

[2] G.Bruno, et al. : 'A Rule Based System to Schedule Production', IEEE Computer (1986)

[3] I.P.Goldstein, et al. : 'NUDGE, A Knowledge-Based Scheduling Program', Proceedings of 5th IJCAI (1987)