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An optimization-oriented method for simulation-based job shop scheduling incorporating capacity adjustment function

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Abstract

Aiming at the elimination of tardy jobs in a job shop production schedule, an optimization-oriented simulation-based scheduling method which incorporates capacity adjustment function is proposed. In order to determine the pertinent additional capacities and to control job allocations simultaneously, the proposed method incorporates the parameter-space-search-improvement method into the scheduling procedure. Furthermore, the proposed method includes a local search method in order to shorten the computation time to select an approximate optimal solution on the parameter space. The effectiveness of the proposed method from a practical viewpoint is demonstrated by using scheduling data obtained from a practical large-scale system.

Keywords: Scheduling; Simulation; Capacity adjustment; Optimization; Parameter-space-search-improvement method

1. Introduction

In make-to-order production, the most important requirement for production scheduling is to fulfill the customer due-date for each job. Make-to-order production is usually realized on a job shop production environment. It is not easy task to fulfill all the customer due-dates since all jobs, which naturally differ in due-dates from each other, have different routings with different process times and therefore the required capacity in each work center constantly changes time by time.

Production planning activity generally consists of upper-level production planning activity and production scheduling activity that makes the detailed manufacturing schedule on the basis of the production plan (Gaither, 1996). It is a general principle that the master production schedule and the capacity plan which are determined by the upper-level planning department are not to be changed in the scheduling department. However, in practice, they are often changed, by making full use of intuition and accumulated experiences in the scheduling department. Distinct improvements in scheduling may be gained by shifting capacity from one time-bucket in a work center to another or supplementing capacity.

When the tardy jobs occur in a scheduling process, the scheduling personnel tries to resolve the tardiness problem by taking the following measures step by step (Fuyuki et al., 1998a).

(a) To try to improve the scheduling result by changing operational order of jobs, lot

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splitting and so on in order to prevent the tardy job within the capacity given to each work center.

(b) To try to reduce the tardy jobs, if they are unavoidable, by supplementing capacity of the factory to some extent within the limit that the upper-level planning department grants. To be more concrete, overtime work, change of off days to work days and manpower movement between work centers are some examples of capacity supplement measures.

(c) To request that the upper-level department, in case measure (b) is not efficient enough, makes a change in the due-date of the jobs and the given capacity of the related work centers.

Measure (a) is considered to correspond to a minimization problem of tardy jobs under the given production planning condition, and the measure (b) to a capacity supplement determination problem aiming at the elimination of tardy jobs under the condition that the scheduling generation method is fixed.

Many researches on a minimization problem of tardy jobs under the given production planning condition in a practical production environment have been carried out (Conway et al., 1967; Pinedo, 1995). As for the research on capacity adjustment, various types of planning by infinite/finite capacity requirement planning method in production planning level have been actively discussed for several decades. In recent years, the unification method between production planning and production scheduling has been proposed. The aim of the method is to enhance production management quality by introducing higher capability of capacity adjustment and operational order setting.

As for research on the above mentioned item (b) of detailed scheduling, capacity adjustment methods in considering job operation sequences are limited (Asano and Ohta, 1999; Leon and Wu, 1992). In job shop production scheduling, it is generally difficult to decide when, to which machine and in what amount to add capacities so as to minimize of the number of tardy jobs after suppressing the added amount of the capacity.

Aiming at the elimination of tardy jobs in a job shop production schedule, an optimization-oriented method for simulation-based job shop scheduling incorporating capacity adjustment function is proposed in this paper. In order to determine the pertinent additional capacities and to control job allocations simultaneously the proposed method incorporates the parameter-space-search-improvement method (Fuyuki et al., 1998b, 1999) into the scheduling procedure.

"The parameter-space-search-improvement method" (called the PSSI method, hereafter) is a best solution finding framework based on a simulation method. It introduces a very few number of parameters which can systematically manipulate the relevant variables and the best solution is sought for on the parameter space spanned by the introduced parameters. In previous papers, we have introduced four parameters; two of them a and b are used to control the upper limit to the additional capacity and the balance of the capacity distribution among machines (Arakawa et al., 2001). The best capacity addition plan is sought for on the parameter space $a \times b$, while c_1 and c_2 are used to control the job allocation procedure. The best schedule with respect to due-date related criterion is sought for on the parameter space $c_1 \times c_2$.

We first describe the 'direct' optimization-oriented procedure on the four-dimensional space $a \times b \times c_1 \times c_2$. The 'direct' optimization-oriented procedure is a merger of the procedures separately treated on the two-dimensional spaces $a \times b$ and $c_1 \times c_2$. By using scheduling data obtained from a practical large-scale system, we investigate the performance of the proposed procedure with respect to the number of tardy jobs and the added amount of the capacity. Next we propose a new method which adopts a local search method in the procedure instead of the enumeration method in order to shorten the computation time. We finally demonstrate that the computation time has dramatically reduced to the level required for practical use, and in addition there is a possibility of finding an approximate optimal solution, because the finer grid spacing may be used locally in the local search method.