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A SIMULATION-OPTIMIZATION FRAMEWORK TO SOLVE THE WORKFORCE SCHEDULING PROBLEM IN COMPLEX MANUFACTURING AND LOGISTIC CONTEXTS

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ABSTRACT

We present a new approach to solve the workforce scheduling problem in complex applicative contexts such as manufacturing and logistic processes.

We consider systems where several activities require to be carried out by different types of operators, characterized by their skills. We assume the request of such skills is not fixed and may be varied in order to match the time/cost objectives of the organization. In particular, we look at the problem of minimizing the labor cost while meeting deadlines and industrial plans.

We employ a set of specific simulators to overcome the intractable complexity of deriving the analytic expressions linking the resources availability to the real activities processing times.

All these issues are addressed by a simulation-optimization approach which decomposes the problem into three nested problems: the workforce planning, the activities scheduling and their time estimation by simulation. We illustrate our framework and we retrieve some preliminary results.

1 INTRODUCTION

A key success factor for many large enterprises is the ability of properly managing labor cost and timetables. This is true both from an economical and a qualitative point of view and is the reason why workforce planning and scheduling tools are now getting more and more developed.

Nevertheless, the effectiveness of a given solution approach is highly linked to the characteristics and constraints of the system under consideration. In manufacturing and logistic settings, several flows typically involve various activities carried out in different working areas. Moreover, resources, machines and operators are usually shared between activities and scarce, thus giving birth to difficult planning, scheduling and resource allocation problems that have been usually tackled separately.

However, within the considered context, the problem of providing the right number of workers with the right skills at the right time is inherently linked to the schedule of production and distribution activities. The result is a huge problem requiring a proper representation of processes complexity, a feasible operators/task assignment and a suitable activities scheduling.

In the following, the problem is formalized and a simulation-based solution framework is proposed.

2 PROBLEM DEFINITION

The problem is based on two basic definitions: the skills and the activities. A skill represents the ability of an operator to perform certain tasks, thus identifying a worker type. An activity is any non-interruptible elementary time-consuming operation.

Activities can be linked by some precedence constraints, but have variable starting times that can be modified in order to create optimal schedules satisfying release and deadlines constraints, as well as other

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restrictions. Indeed, activities may or may not require exclusive resources, such as machines or dedicated spaces, and are generally carried out by different types of operators, selected for their skills.

A basic assumption of our approach is that the number of skills required is not fixed and therefore there exist many feasible combinations of operators guaranteeing the completion of an activity. This leads to variability in its processing time. Such aspect heavily characterizes our procedure. Assuming it is not possible to derive analytic functions expressing the link between allocated skills and time to complete the activities, we have based our solution method on the use of a set of ad hoc simulators.

The result is a new simulation-optimization problem facing the trade-off between time and cost objectives of the organization. On the one hand it aims at reducing the labor cost, minimizing the number of necessary skilled operators, on the other, it encourages an optimal activities scheduling, trying to parallelize the tasks and decrease the overall completion time.

3 SIMULATION-OPTIMIZATION FRAMEWORK

The proposed framework is composed of three main nested blocks, as shown in Figure 1.

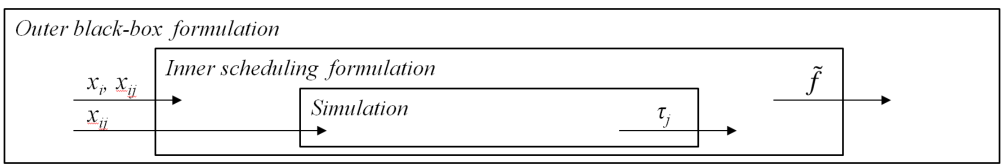

Figure 1: Framework structure

The most external one is a black-box optimization formulation having as objective function the sum of two terms, the first accounting for the workforce cost $f(x)$, the second indicating the time goals, denoted by $\tilde{f}$ and result of the computations of inner blocks. Considering the sets S of all the skills and A of all the activities, the decision variables x_i for each $i \in S$ and x_{ij} for each $i \in S$ and $j \in A$ represent respectively the total number of available operators with skill i and the number of operators with skill i to be allocated to activity j at the moment of its start (varying between lower and upper limits l_{ij} and u_{ij}).

A compact formulation of the outer problem is the following:

$$\min f(x) + \tilde{f}$$

$$l_{ij} \leq x_{ij} \leq u_{ij} \quad i \in S, \quad j \in A$$

$$\max_{j \in A} x_{ij} \leq x_i \leq \sum_{j \in A} x_{ij} \quad i \in S$$

The second block consists of a scheduling formulation: the decision variables are the activities starting times while the objective function is $\tilde{f}$. In particular, if we consider $\tilde{f}$ being the overall makespan, we can prove our problem to be incorporated into the standard definition of Resource Constrained Project Scheduling Problem (Brucker et al. 1999), with some additional constraints.

The third block is key for computing the parameters used by the inner formulation. Taking the x_{ij} as inputs and running a parallel simulation for each activity j, the processing times τ_j are calculated and the scheduling procedure enabled.

REFERENCES

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