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Experimental Investigation of Iterative Simulation-Based Scheduling in a Dynamic and Stochastic Job Shop

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Abstract

A vital component of modern manufacturing systems is the scheduling and control system, which determines companies' overall performance in their respective supply chains. This paper studies iterative simulation-based scheduling mechanisms for manufacturing systems that operate in dynamic and stochastic environments. Also assessed are the issues involved when these mechanisms are used to make higher-level scheduling decisions, such as dispatching rule selection, instead of generation of a full schedule. A typical simulation-based system is outlined and tested under various experimental conditions. Examined are the effects of stochastic events such as machine breakdowns and processing time variations on the system performance, and the effectiveness of the simulation-based approach from the control point of view is evaluated. Finally, different levels of two important factors (look-ahead window and scheduling period) are compared for the iterative approach. Computational results show that, although simulation-based scheduling proves effective when these parameters are properly set, the overall performance diminishes due to the dynamic and stochastic nature of the system, which degrades the multi-pass improvement capability of the simulation runs. Experimental results also support the initial expectation in that frequent updates to the higher-level schedule may not be necessary when these decisions are naturally "adaptive" to the unexpected system changes.

Keywords: *Scheduling and Control, Simulation Methods and Models*

Introduction

Effective production scheduling is becoming an increasingly important component of the supply chain environment that most companies face in today's competitive markets. Discrete-event simulation is a decision support tool that has been proposed to achieve effective scheduling. During the last decade, a significant body of literature has accumulated in this area, mainly either proposing simulation-based scheduling schemes or testing existing schemes in different settings. Most studies in this area share two common characteristics: (1) They use static and deterministic environments where all jobs are available for scheduling and no uncertainty is considered. In these cases, simulation is used as a search heuristic for improved scheduling decisions. (2) Simulation is mostly used to assist with constructing a *complete* schedule of all jobs rather than other types of scheduling decisions; however, a simulation-based scheduling scheme might perform differently in a dynamic and stochastic environment and/or when the main scheduling decision is different from constructing an off-line static and complete schedule. The main goal in this paper is to investigate how simulation-based schemes perform under dynamic and stochastic conditions through a comprehensive experimental study when simulation is used to identify scheduling policies rather than to generate a complete schedule.

Two questions are addressed: (1) Are simulation-based schemes still effective in a *dynamic and stochastic* environment? It is already known that the performance of "optimization-based algorithms" used to generate schedules fine-tuned (or even optimal) with respect to deterministic assumptions deteriorates quickly with the introduction of uncertainty (see Lawrence and Sewell 1997 for processing time uncertainty). This study will show if this is a valid conclusion for simulation-based methods, which are believed to be more flexible, adaptable, and realistic. (2) Is there a difference in the performance when simulation is used to make higher-level decisions? This study evaluates two simulation-based methods: (a) to select the best priority rule among candidates (rule selection), and (b) to fine-tune parameters of a heuristic (parameter tuning). From this perspective, simulation results will not generate a static complete schedule. One can interpret this as a mechanism to separate the higher-level (or more critical) policies

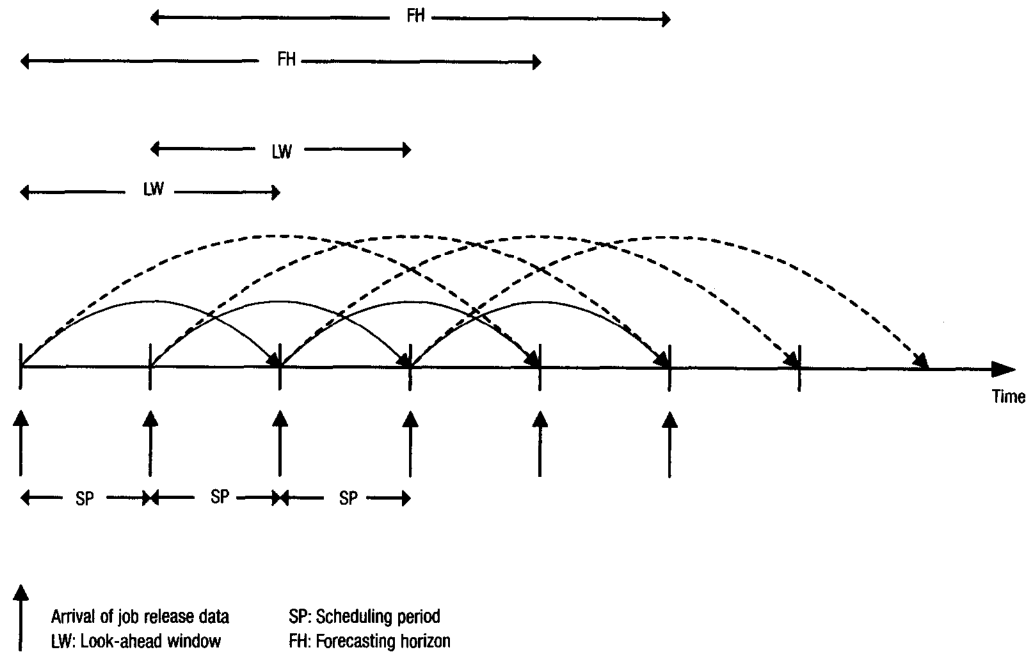

Figure 1
Schematic View of Relations Between Forecasting Horizon, Scheduling Period, and Look-ahead Window

rather than making detailed decisions such as sequencing all jobs and determining start times for operations.

A typical environment is explained where simulation-based schemes can be employed to address the above questions. In this environment, the scheduling and control activity is viewed as an intermediate component of a more global planning system in which decisions regarding production planning and master scheduling are made at a higher level. The scheduling and control level deals with the lower level, short-term decisions using the data provided by the higher levels. Specifically, it is assumed that a *planning module* provides a master schedule of upcoming jobs (called *job release data*). The time span of the job release data is called the *forecast window*. The scheduling module uses simulation runs to make (higher-level) scheduling decisions such as dynamic rule selection and parameter tuning. The length of the simulation runs is usually called the *simulation window* or *look-ahead window*, which may or may not equal the forecast window. The time interval between two successive points in time when the scheduling decisions are made is commonly called the *scheduling period*, which in turn determines the frequency of simulation activation. Simulation-based schemes are usually used in a rolling-horizon basis; that is, if new four-week job release data are available every week, for instance, and decisions are made for 2 weeks using simulation, then only the first-week decisions are implemented, and at the beginning of the next week new decisions are made for the following four weeks using the fresh job release data (see *Figure 1*).

The details of an (iterative) simulation-based mechanism that has been used in past studies are outlined, and the implementation of two specific algorithms for this mechanism is explained. The alternative to simulation-based scheduling will be a well-studied and widely used approach: priority dispatching. Only top-performing priority rules are considered for the problem, job shop scheduling with weighted tardiness objective, which is a surrogate measure of customer service. These priority rules are dynamic and state-dependent and have inherent flexibility to utilize up-to-date information and accommodate changes. We expect to find somewhat different results from previous findings in which fine-tuned static schedules obtained through simulation were compared against these myopic rules under static and deterministic conditions. The contention is that these rules will work well under highly dynamic and stochastic conditions as compared to simulation-based schemes; however, deteri-