Dynamic Scheduling for Discrete Production Systems by Multi Objective Dispatching Rule Synthesis based on Data Envelopment Analysis and Reinforcement Learning

申請者

CHEN, Xili

情報生産システム工学専攻
生産情報制御研究

2011年 7月
Today's highly competitive marketplace requires that manufacturers provide higher productivity and quality workflows, as well as quicker response corresponding to the changes in customer demands. Responding to these needs, Multi Objective Dynamic Scheduling (MODS) has been increasingly attracting practitioners' interests in recent years. Composite Dispatching Rule (CDR) is a heuristic method for practical dynamic scheduling which is studied particularly for Discrete Production Systems (DPS) due to its easiness in implementation. A CDR is commonly used for MODS and it is derived from the synthesis of multiple elementary dispatching rules, each of which contributes to optimization of particular scheduling objectives considered.

However, development of effective composite rules for MODS is a time-consuming work, and also it is subjecting to some technical challenges which include: how to improve the production performance of a rule by composing a set of proper elementary rules toward the optimization of concerning scheduling objectives, and how to tune the respective weighting factors of elementary rules to cope with Work-In-Process (WIP) fluctuation of machines in online scheduling. Furthermore, job dispatching also encounters practice issues while taking operational criteria from marketing perspectives into account. The difficulty in considering operational criteria arises from the fact that these criteria cannot be readily measured in a quantitative manner because these criteria are usually given as requirements of customer group based production priority control. Dynamic scheduling complied with the effects of such operational criteria is rarely discussed in the research area of dispatching rules.

The focus of this dissertation is to propose a set of innovative methods that can be easily applied by scheduling practitioners to develop effective composite rules that solves the aforementioned issues for MODS in DPS. Three key problems were addressed in this study. (1) Methodology for selection of proper elementary rules to represent the concerning multi objective scheduling, and thus improving the production performance of the resultant composite rule (Chapter 3); (2) Dispatching algorithm that simultaneously taking account of hetero-criteria which include quantitative scheduling objectives of production performance and qualitative criterion of production priority (Chapter 4); (3) Methodology for dynamic weight tuning of CDR with respect to machine status to improve production performance (Chapter 5). To solve these problems, Global Criterion Approach (GCA) is adopted as a measure to evaluate the efficiency of the proposed methods.

This dissertation is organized into 6 chapters.
Chapter 1 describes the background, motivation, and objectives of the research study.

Chapter 2 gives a literature review on MODS in DPS. Furthermore, CDR based heuristic method for solving the multi objective dynamic scheduling problem is introduced.

Chapter 3 describes the procedure of choosing a set of elementary rules from a pre-defined rule library, to address optimization of multi-objective scheduling. Elementary rules are the basis of a composite dispatching rule. The correctness in elementary rule selection directly affects the production performance of the resultant composite rule. The major consideration is that when composite rule is derived from the combination of a set of Pareto efficient elementary rules, the result can potentially provide a better solution space. The Pareto efficient elementary rule set refers to the rules that are relatively efficient over all the objectives concerned. Each Pareto efficient rule stands on the edge of the current solution space, which is constructed from candidate rules, whose performance with respect to various objectives are pre-justified from thorough simulation results. The relative efficiency of each candidate rule is searched by the Data Envelopment Analysis (DEA) concept. More specifically, the method applies a Linear Programming technique on a library of simulation results, to determine the most suitable set of elementary rules. The rules with the max relative efficiency are regarded as Pareto efficient and are selected to construct the composite rule.

To testify the effectiveness of the proposed procedure, a three objectives dynamic scheduling problem encountered at an injection machine from a plastic manufacturer is simulated. The simulation results show that the method is superior to other rule selection methods by having the smallest GCA value.

Chapter 4 presents an algorithm for dispatching under a job group based production priority control scenario. It simultaneously considers optimizing quantitative criteria of production performance and qualitative criterion of production priority. Scheduling in practice often involves operational criteria that are requested from the marking perspectives. The operational criteria usually are qualitative and may vary timely corresponding to marketing strategies. However, most studies on scheduling are confined to optimize criteria of production performances. The operational criterion discussed in this dissertation is customer oriented production priority policies, which consider that some jobs ordered by specific customer group may be treated as more important than the others. Therefore, the production performance of these jobs groups should be highly
prioritized. The proposed dispatching algorithm firstly generates an original schedule using composite rule that solely considers optimizing scheduling objectives associated with production performance. Secondly, priority rules that represent schedulers’ preferences on the relative importance of customer groups are applied to adjust the original schedule to address consideration of operational criterion. Finally, Analytic Hierarchy Process (AHP) model, which is a widely applied technique for decision making of multiple criteria, is built to perform unified prioritization of jobs by integrating the schedules adjusted by priority rules. The job with highest unified priority is going to be dispatched.

To demonstrate the effectiveness of the proposed algorithm, dynamic scheduling at the injection machine problem is illustrated as a numerical example. Four scenarios are set up to represent different situations of customer oriented production priority control policies. The simulation results show that operational criterion can be properly conveyed into online job dispatching tool using the proposed algorithm.

Chapter 5 presents the proposed heuristic method for automated tuning of weights of CDR with respect to machine status to improve production performance. Estimation of weight values by only using simulation based method is time-consuming and impractical in a job shop production system and in case that the number of weight increases. The key idea for automated tuning of weights is to classify the machine status into recognizable patterns using criterion of WIP ratio to cope with WIP fluctuation, and then provide an automatic mechanism to tune the weight values of the composite rule by making an inquiry to the existing scheduling knowledge using information on perceived pattern of machine status during online dispatching. The scheduling knowledge for mapping WIP patterns of machine status and optimal weight values is trained by reinforcement learning using offline simulation.

To demonstrate the effectiveness of the proposed method, a typical dynamic job shop case study is applied. The results validate that the proposed method can produce better results than other methods for solving weight setting problem of composite rule. Case study also demonstrates that using the proposed elementary rule selection and weight tuning methods can generate effective composite rule for the concerned scheduling problem. Furthermore, the methods can reduce the scheduler’s effort by automatically tuning the weights using reinforcement learning.

Chapter 6 concludes the dissertation and gives a discussion to future research on rule based heuristic methods for multi objective dynamic scheduling.