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A hybrid genetic algorithm with variable neighborhood search for dynamic integrated process planning and scheduling

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ABSTRACT

Integrated process planning and scheduling (IPPS) which is a hot research topic has provided a blueprint of efficient manufacturing process, but in real production the machining environment changes dynamically because of external and internal fluctuations. These disturbances which include machine breakdowns, rush order arrivals and so on, will make the optimal process plan and schedule may become less efficient or even infeasible. The dynamic IPPS (DIPPS) can better model the practical manufacturing environment but is rarely researched because of its complexity. In this paper, a new dynamic IPPS model is formulated, the combination of hybrid algorithm (HA) and rolling window technology is applied to solve the dynamic IPPS problem, and two kinds of disturbances are considered, which are the machine breakdown and new job arrival. A hybrid genetic algorithm with variable neighborhood search (GAVNS) is developed for the dynamic IPPS problem because of its good searching performance. Three experiments which are adopted from some famous benchmark problems have been conducted to verify the performance of the proposed algorithm, and the computational results are compared with the results of improved genetic algorithm (IGA). The results show that the proposed method has achieved significant improvement for solving the DIPPS.

1. Introduction

Process planning and scheduling are two of the most important functions, which are usually performed sequentially in traditional manufacturing systems as pre-production activities. These have become the obstacles to improve the productivity and responsiveness of the manufacturing systems and to cause several problems (Kumar & Rajotia, 2003). To solve this problem, process planning and scheduling are interrelated and should be considered simultaneously (Moon & Seo, 2005). The integrated process planning and scheduling (IPPS) becomes a hot research topic and attracts more and more attentions from researchers and engineers. The merits of IPPS are to increase the production feasibility and optimality by combining both the process planning and scheduling functions.

In traditional manufacturing systems, both the process plan and the schedule are prepared for a static production environment with available manufacturing resources. However, in real production, the manufacturing environment which changes frequently often involves uncertainties and disturbances such as machine breakdowns, rush order arrivals, and order cancellations. As a result, the process plan and schedule prepared in the planning stage may become less efficient or even infeasible due to these changes. These changes can cause deviations to the original process plans and schedules and will finally affect the performance of the whole manufacturing system (Jain & Elmaraghy, 1997; Wong, Leung, Mak, & Fung, 2006a). To cope with the unexpected disturbances, it is necessary to consider the process plan and the schedule dynamically. Therefore, the dynamic IPPS which can better model the practical manufacturing environment becomes more and more important.

However, process planning and scheduling tasks are very complicated and time consuming, if applied to dynamically changing manufacturing environments. So, the researches on dynamic IPPS are rare. Most researches focused on the dynamic job shop scheduling problem (JSP) or dynamic flexible job shop scheduling problem (FJSP) which only considers the machine flexibility. Zhang, Rao, and Li (2008) proposed an improved genetic algorithm of double offspring produced, extending the successful experience of the static scheduling problem to dynamic scheduling problem and proposed a rolling scheduling strategy based on improved genetic algorithm. Zandieh and Adibi (2010) proposed a variable neighborhood search to address a dynamic JSP and an event-driven policy is selected. Zhang, Gao, and Li (2013) proposed

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a rolling scheduling strategy based on hybrid genetic algorithm and tabu search algorithm for solving dynamic FJSP.

This paper focuses on the dynamic IPPS problem. To facilitate the dynamic and adaptable manufacturing activities in manufacturing system, a new methodology with appropriate architecture is needed (Nejad, Sugimura, & Iwamura, 2011). Because the combination of the Genetic Algorithm (GA) and rolling scheduling strategy had been applied on the dynamic FJSP, we trust that it is also a promising approach for dynamic IPPS problem. Based on this analysis, a new rolling scheduling strategy based on hybrid algorithm (HA) for dynamic IPPS problem has been presented in this paper. Two kinds of disturbances are considered, which are the machine breakdown and new job arrival. A hybrid genetic algorithm and variable neighborhood search (GAVNS) is developed because of its good searching capability. Two efficient neighborhood structures are employed in VNS. Experimental results demonstrate the proposed method can solve the dynamic IPPS effectively.

The remainder of this paper is organized as follows. Section 2 gives a literature review. The dynamic IPPS is formulated in Section 3. In Section 4, the proposed method is presented. Experimental studies and discussions are reported in Section 5. Section 6 is conclusion and future researches.

2. Related works

The best way for IPPS is to merge both process planning and scheduling functions into one. However, as process planning and scheduling individually are non-polynomial (NP)-hard, the resulting problem is also NP-hard, it is difficult to find optimal solutions in reasonable time (Khoshnevis & Chen, 1991). Therefore, many approach have been developed and studied for the problem. Agent-based approach and algorithm-based approach are the two main approachs.

Agent-based approach has been widely used for IPPS problem. Gu, Balasubramanian, and Norrie (1997) proposed a multi- agent system where process routes and schedules of a part are accomplished through the contract net bids. Lim and Zhang (2003, 2004) introduced a multi-agent based framework for the IPPS problem. This framework can also be used to optimize the utilization of manufacturing resources dynamically as well as provide a platform on which alternative configurations of manufacturing systems can be assessed. Wong et al. (2006a), Wong, Leung, Mak, and Fung (2006b, 2006c) proposed an agent-based negotiation called MAN (Multi Agent Negotiation) and a hybrid-based MAS architecture called HAN (Hybrid-based Agent Negotiation). A hybrid contract net protocol (HCNP) has been established in both MAN and HAN. Li, Zhang, Gao, Li, and Shao (2010) proposed an agent-based approach for the IPPS problem. An optimization agent based on an evolutionary algorithm is used to manage the interactions and communications between agents to enable proper decisions to be made. Leung, Wong, Mak, and Fung (2010) proposed an IPPS approach utilizing ant colony optimization (ACO) algorithm based on multi-agents system (MAS) in order to minimize makespan evolving job shop environment. Zhang and Wong (2013) proposed a distributed genetic algorithm (DGA) and the multi-agent system (MAS) is adopted to accommodate the algorithm. It is called the MAS-DGA system. A new agent-based architecture is proposed to accommodate subpopulations, support the traditional GA and provide channels for individuals' immigration.

Algorithm-based method is another important mechanism for the problem. Kim, Park, and Ko (2003) proposed a symbiotic evolutionary algorithm for IPPS. Li and McMahon (2007) proposed a unified representation model and a simulated annealing-based approach have been developed to facilitate the IPPS problem. Zhao, Hong, Yu, Yang, and Zhang (2010) proposed a hybrid particle swarm optimization algorithm and fuzzy logic for IPPS. Instead of choosing alternative machines randomly, machines are being selected based a fuzzy inference system (FIS). Li, Gao, Shao, Zhang, and Wang (2010) formulated the Mathematical model of IPPS and proposed an efficient modified genetic algorithm for IPPS. Li, Gao, and Shao (2012) proposed an active learning genetic algorithm for IPPS. Li, Gao, and Li (2012) proposed a hybrid GATS algorithm with game theory for multi-objective IPPS. Lihong and Shengping (2012) proposed an improved genetic algorithm for IPPS. New initial selection method for process plans, new genetic representations for the scheduling plan combined with process plans and genetic operator method are developed. Li, Gao, and Wen (2013) proposed an efficient modified particle swarm optimization algorithm for process planning. Lian, Zhang, Gao, and Li (2012) proposed an imperialist competitive algorithm for IPPS. Zhang, Gen, and Jo (2014) proposed a hybrid sampling strategy-based multi-objective evolutionary algorithm (HSS-MOEA) to deal with the IPPS problem. Jin, Zhang, and Shao (2015) proposed a hybrid honey bee mating optimization algorithm for IPPS. VNS is utilized to simulate the workers' brood caring action to avoid premature convergence and to find more excellent broods in HBMO. Yu, Zhang, Chen, and Zhang (2015) proposed a new IPPS method which contains the static phase and dynamic phase, a hybrid algorithm based on genetic algorithm (GA) and particle swarm optimization (PSO) is presented for IPPS problem.

The procedure of generating a new feasible schedule in response to the unexpected disturbances is usually known as reactive scheduling or rescheduling (Aytug, Lawley, McKay, Mohan, & Uzsoy, 2005). The rescheduling solutions generally take the form of either generating an entirely new feasible schedule that is executed until the next disruption occurs (total rescheduling) or modifying the existing schedule (affected operations rescheduling) (Li, Shyu, & Adiga, 1993). The advantage of the total rescheduling approach is similar to that of generating the original schedule and the scheduling efficiency is higher; in which a different set of operations are considered. On the other hand, the affected operations rescheduling method only reschedules the operations which are affected directly or indirectly by a disturbance so that the initial schedule is preserved as much as possible, the scheduling stability is better and short calculation time (Abumaizar & Svestka, 1997; Mason, Jin, & Wessels, 2004). Jain and Elmaraghy (1997) used genetic algorithm to obtain an original schedule and rescheduling was achieved by using a set of dispatching rules, the current status of the shop and job priorities. If an operation is interrupted due to disturbances, it will first find an alternative available machine based on the job's priority, otherwise, preemption is allowed to complete the operation. Raheja and Subramaniam (2002) provided a comprehensive review of the literature on the reactive recovery of job shop schedules. Vieira, Herrmann, and Lin (2003) presented a framework to understand and study the rescheduling problems. Aytug et al. (2005) provided a good review on various types of rescheduling problems. Zhang et al. (2008) proposed an improved genetic algorithm of double offspring produced to reserve the original schedule as much as possible. And the total rescheduling strategy is used to solve the dynamic scheduling. Zhang et al. (2013) proposed a rolling scheduling strategy based on hybrid genetic algorithm and tabu search algorithm for solving dynamic flexible job shop scheduling problem. Shen and Yao (2015) develops a multi-objective evolutionary algorithm (MOEA)-based proactive–reactive method for dynamic flexible job shop scheduling problem, the method is able to handle multiple objectives including efficiency and stability simultaneously. Kundakcı and Kulak (2016) proposed efficient hybrid Genetic Algorithm (GA) methodologies for dynamic job shop scheduling problem, Tabu Search (TS) with various neighborhoods is applied for the local search.