



Near optimal process plan selection for multiple jobs in networked based manufacturing using multi-objective evolutionary algorithms



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ABSTRACT

The networked manufacturing offers several advantages in current competitive atmosphere by way of reducing the manufacturing cycle time and maintenance of the production flexibility, thereby achieving several feasible process plans. In this paper, we have addressed a Multi Objective Problem (MOP) which covers-minimize the makespan and to maximize the machine utilization while generating the feasible process plans for multiple jobs in the context of network based manufacturing system. A new multi-objective based Territory Defining Evolutionary Algorithm (TDEA) to resolve the above computationally challenge problem have been developed. In particular, with two powerful Multi-Objective Evolutionary Algorithms (MOEAs), viz. Non-dominated Sorting Genetic Algorithm (NSGA-II) and Controlled Elitist-NSGA-II (CE-NSGA-II) the performance of the proposed TDEA has been compared. An illustrative example along with three complex scenarios is presented to demonstrate the feasibility of the approach. The proposed algorithm is validated and the results are analyzed and compared.

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1. Introduction

Currently, rapid developments in information and communication technologies have profoundly influenced manufacturing research and its applications. However, the products' functionality and complexity are intensifying and organizations need to sustain the advantage of huge competitiveness in the market. Some of the advantages provided by the global economic competition are short manufacturing cycle time, in-time information, consistent knowledge flow, etc. In order to meet rapidly expanding demands of global customers, the traditional manufacturing systems have to transform themselves. It can be attained through the adoption of a new manufacturing paradigm known as network based manufacturing or networked manufacturing. In networked manufacturing the jobs come from different customers having competitive relationships i.e., the job scheduling concentrates on satisfying the individual objective of each job. Here, the machines are geographically distributed over different enterprises. As a new and advanced manufacturing paradigm, networked manufacturing pattern suits the global trends towards knowledge-based economy and global manufacturing. In networked manufacturing, the mode of production has been changed from make-to-stock to make-to-order, in

which the active participation of customers submitting jobs to the manufacturing system are emphasized (Yan, 2000).

Process planning and scheduling are the two most important functions to be engaged to process the jobs in a manufacturing system. Process planning specifies which manufacturing resources, operations, and routes that are needed to produce a product. The scheduling is the allocation of resources in the shop over time to manufacture the various parts (Zhang, Saravanan, & Fuh, 2003). Generally, in traditional manufacturing system, process planning and scheduling functions were carried out in a sequential way. Although traditional approach has its own advantages, it is not adequate and hinders improvement in the productivity and responsiveness in today's dynamic manufacturing environment. Several problems arise due to the traditional manufacturing approach as is clearly stated (Saygin & Kilic, 1999). To overcome these problems, some researchers have realized that there is a need to integrate both the functions to achieve better performance of the system.

1.1. Integration of process planning and scheduling functions

The basic idea of the integration approach for process planning and scheduling functions was first introduced by Chrysosolouris and Chan (1985) and Chrysosolouris, Chan, and Cobb (1984). Later, with the integration approach, the performance of the manufacturing system has been improved. Subsequently, several issues involved in integration of manufacturing functions are

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addressed (Khoshnevis & Chen, 1989, 1990). In their work, a dynamic feedback mechanism was introduced for effective coordination among various resources. With their proposed heuristic approach, they found significant impact on the system performance with reduction in the number of late parts, total tardiness, and flow times. Larsen (1993) proposed the integration model and developed the concept of dynamic feedback system for finding the alternative process plans of the networked manufacturing system. Through their approach, the flexibility of the manufacturing system has been improved. A framework was developed by (Saygin & Kilic, 1999), in the context of flexible manufacturing system environment and the integration approach for process planning and scheduling have been applied for generating the flexible process plans. An agent based framework for the integration of process planning and production scheduling functions has been proposed by (Chan, Zhang, & Li, 2001). By implementing the Integrated, Distributed, and Cooperative Process Planning System (IDCPPS) the performance of the manufacturing system has been improved. A simulated annealing and modified genetic algorithm has been developed (Li & McMahon, 2007; Shao, Li, Gao, & Zhang, 2009) to optimize various performance of the system. Consequently, they proposed the IPPS approach for effective performance of the system. The online hybrid agent-based negotiation procedure for multi-agent system to integrate process planning with scheduling have been addressed by Wong and Leung (2006) and Mak and Fung (2006). Through their negotiation procedure communication between the resources was achieved and the performance of the distributed environment has been improved. An N-person non-cooperative game-theoretic approach to generate the optimal process plans for multiple jobs in a networked based manufacturing system has been presented (Zhou, Xiao, Jiang, & Huang, 2010). To generate more effective and efficient solutions of the game, a hybrid adaptive genetic algorithm has been developed. The extension of the above work has been carried over by Manupati, Sujay, Cheikhrouhou, and Tiwari (2012). In their work, a Hybrid-DNA based evolutionary algorithm was developed for obtaining feasible process plans of multiple jobs. Finally, their results showed the significant improvement over other algorithms and better performance of the system.

1.2. Advantages of networked manufacturing over traditional manufacturing

The job scheduling problem in networked manufacturing environment is distinct from the monolithic approach. Therefore, the concept of traditional job scheduling is extended and updated; following characteristics are considered for effective production and scheduling. As mentioned by Li and Chaoyong (2010), in case of traditional manufacturing system, process planning and scheduling functions aim to acquire overall optimal results for all jobs which is different than individual optimal results for each job. In networked based manufacturing, owing to the role played by the competition factor among different jobs, the objective for process planning and scheduling is slightly different than that in traditional manufacturing, which must strive for individual optimal results for each job.

In traditional manufacturing, the machines associated to jobs are limited and constrained to a single workshop or enterprise. However, for networked based manufacturing jobs and machines are not situated in one workshop or enterprise but they are lying in different workshop or enterprise which are globally located at larger distances. Thus it can be inferred that for networked based manufacturing situation, it is similar to one found in flexible manufacturing system where many possible machines, operations is feasible. Alternatively, we can say that in networked manufacturing, how to generate the optimal process plan for each job in

presence of several dynamic constraints by considering the present status of machines, tools, and fixtures at a given manufacturing place is posing a genuine challenge.

The nature of real-life production environment is stochastic and it is best represented by considering more than one objective function simultaneously. Therefore, finding the performance of the real system is a challenging task and it has been considered as a complex problem according to today's situation. Therefore, effective algorithms with significant computational effort to solve to optimality are required for large instances.

1.3. Multi-objective based integration approach to address process planning and scheduling

Considering the above mentioned characteristics and the requirements of networked manufacturing, it is necessary to integrate the process planning and scheduling functions more tightly for significant improvement of the performance of the manufacturing system. Thus, more flexible optimization strategies need to be adapted to enable more dynamic interactions and information sharing between the two functions. Currently, in the area of multi-objective based integrated process planning and scheduling problems, MOEAs have captured the interest of many researchers. A mathematical model of an MOP has been formulated (Li and Chaoyong, 2010), to resolve the complexity of the problem and to obtain the short manufacturing times an evolutionary-algorithm based approach has been developed. Further, with different experimental studies the feasibility of the proposed approach has been verified. A multi-objective GA (NSGA-II) has been adopted (Chaubey, Benyoucef, & Tiwari, 2010) to generate the optimal process plans in a reconfigurable manufacturing system. The allocation of jobs having operations to process on various machines for scheduling have been performed to find the total completion time of the jobs and total manufacturing cost. A manufacturing cell formation problem to optimize the performance measures such as work-in-process, inter cell moves, and total machinery investment has been proposed (Neto & Filho, 2010). In their work, a genetic algorithm based multi-objective heuristic approach has been implemented in order to approximate the true Pareto optimal set. Thereafter, an integration of dispatching rules by shifting bottleneck procedure using multi-objective memetic algorithm for a job shop scheduling problem has been addressed (Cheng, Chiang, & Fu, 2011). Various performance measures like minimization of makespan and total tardiness have been considered to improve the system performance. Accordingly, they have compared their proposed approach with eight classical job shop problem instances, and found promising results.

Motivated by the complexity of the problem and its relevance known from literature, the issues raised above have been taken into account in order to find the efficient and feasible solutions, particularly in the context of networked manufacturing environment. In this research, a framework to integrate the process planning and scheduling functions has been presented. In order to obtain good approximate solutions, three most popular and efficient multi-objective based meta-heuristics namely Non-Dominated Sorting Genetic Algorithm-II (NSGA-II), Controlled Elitist-NSGA-II (CE-NSGA-II), and Territory Defining Evolutionary Algorithm (TDEA) are applied. Numerical experiments are carried out with three complex scenarios having different job complexities to demonstrate the performance of the proposed multi-objective algorithms. Thus we were able to develop and implement efficient evolutionary algorithms for obtaining the feasible process plans and scheduling plans in the context of networked manufacturing environment.

In Section 2, we give a detailed description of the problem with the basic assumptions and developed a mathematical model along with the constraints. In Section 3, we presented a framework to integrate the process planning and scheduling functions. Section

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