博士論文概要

論文題目

Study on Evolutionary Scheduling Problems in Integrated Manufacturing System
統合化生産システムにおける進化的スケジューリング問題に関する研究

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The industry is undergoing profound change following the rapid development of internet technique, with knowledge and information being on the forefront of business success. An enterprise of the future will be highly computerized, and its competitiveness will be expressed with information-related measures. Much tighter integration will be seen across diverse functional areas such as product development, manufacturing, supply chain, and customer satisfaction as well as external liaisons. An enterprise of the future is likely to be agile, extended, virtual, model and knowledge-based, and integrated in time and space.

In Integrated Manufacturing System (IMS), all the manufacturing steps and their supporting processes in product development and production have been integrated into a single relational database. The new system has led to an increase in productivity through better manufacturability and support for rapid plan or schedule making. Hence, there is a new challenge come to forth, how to obtain a feasible optimal schedule quickly based on the information from the relational databases. For this reason, I put effort to optimize evolutionary scheduling problem arising in IMS system.

During the last four decades, there has been a surge of research activity in the field of Evolutionary Computation (EC). There have been advances in many areas, and evolutionary computation has been applied to quite a few real world problems. However, especially in manufacturing area, most of the research in the field has been focused on various aspects of optimization and problem solving artificial benchmarks. In short most of the research has largely ignored the fact that often optimization is a process exist in real world, all the related information can affect initial acceptable optimal solution.

These shortcomings have also been present in the area of scheduling. Most scheduling problems in the real world face both inevitable constraints such as due date, capability, transportation cost, set up cost and available resources, generally speaking, we should obtain an effective "flexibility" not only response to the real complex environment but also to satisfy all the combinatorial constraints.

Future events into consideration before they happen, in order to overcome all the noduses above, something should be done, and also it deserves some time in this dissertation.

Generally speaking, there are two truisms for solving real world optimizing problems, one is to improve solution tools which means proposing some special technique, choosing some effective algorithm, etc., another is to specify the description of the problem which means making a specific mathematical model, deciding accurate constrains, etc.. In other words, the object of this research is to gain some valuable improvement not only on the algorithm design but also on the modeling of combinatorial scheduling problem in this study.

In this research, three activities have been accomplished on manufacturing scheduling problem and evolutionary technique.

1. For the activity on modeling, it addresses the previous researches on complex integrated Resources Selection and Operation Sequence (iRS/OS) problem and Advanced Planning and Scheduling (APS) problem in IMS environment, in order to reconstruct the mathematical model by 0-1 integer programming with some additional objective functions in real world. Moreover, it expands the previous research work, and clarifies the formulation of the mathematical model.

2. For the algorithm design, it firstly addresses the previous methods solving the Job-shop Scheduling Problem (JSP), combining some effective local search method for improving the efficiency of traditional Genetic Algorithm (GA) as one of EC technique. Furthermore, it extends the conventional
Ant Colony Optimization (ACO), and propose a parallel hybrid Ant Colony Optimization (ph-ACO) for solving JSP problem.

3. Following the complication growing in challenge, an effective encoding method is proposed which is adaptive in multistage operation-based Genetic Algorithm (moGA) corresponding to the flexibility in flexible Job-shop Scheduling Problem (fJSP), integrated Resource Selection and Operation Sequence (iRS/OS) problem, and APS problem. Certainly for improving the efficiency, it combines some other technique such as local search and fuzzy logic to build a hybrid moGA.

In Chapter 1, Introduction, it briefly describes the background of IMS system, and the importance for obtain optimal scheduling based on the related database information. Afterwards, it introduces the limitation of the previous evolutionary scheduling, and presents the motivation to formulating this research work.

In Chapter 2, Evolutionary Computation, it introduces the general forms of GA. Basic mechanism and components of GA such as genetic representation, evaluation function and genetic operators were described in detail. Some knowledge on multiobjective Genetic Algorithm is also introduced to provide some technical support in later research.

In Chapter 3, Job-shop Scheduling Problem, it addresses the recent researches on solving classical JSP problem, especially GA and other metaheuristic method like ACO. Then, some randomized dispatching heuristics is hybridized with ACO, and a special transition rule is proposed for finding optimal schedules. Moreover, a special critical path local search is also combined to improve the solutions. To improve the efficacy of our algorithm and avoid the early convergence in local optimal solution, we parallelize the hybrid ACO to build a parallel hybrid Ant Colony Optimization (ph-ACO) algorithm. Some numerical examples are demonstrated to show the performance of the hybrid ACO, and it can be found that hybridizing ACO with LRM and LRT can both improve the efficiency of the algorithm obviously. Furthermore, it also decides the appropriate parameter setting of $\beta$ is around 2. Finally, after comparing with hybrid Genetic Algorithm (hGA) by solving some bench mark problems, the result shows the proposed ph-ACO performs better than traditional ACO and hGA., and can even obtain the optimal solutions in many cases. The 16 benchmark test problems provide a valuable demonstration for the effectiveness of the proposed ph-ACO when comparing with the other two approaches.

In Chapter 4, flexible Job-shop Scheduling Problem, it expands from the traditional Job-shop Scheduling to flexible Job-shop Scheduling Problem, which possesses wider availability of machines for all the operations. Considering the two states of the problem, two definitions (total and partial) of flexibility are offered to separate the different availability information of machines. For solving this problem, a new multistage operation-based representation is proposed to make the chromosome simpler. By using this approach, all the crossover and mutation methods can be applied to this optimal strategy. The efficiency has been improved after using the new representation, and effective bottle neck shift local search is also combined to build a hybrid moGA. Some typical benchmark cases are selected for making comparison with previous well known GA and other metaheuristic method such as Particle Swarm Optimization (PSO), the experimental result indicate the proposed hybrid moGA is more effective for finding optimal solutions in the benchmark cases when comparing with PSO and other previous GA approach.

In Chapter 5, integrated Resource Selection and Operation Sequence problem, it considers an iRS/OS problem in IMS system. Several kinds of objectives are taken into account, in which the makespan for orders
should be minimized; workloads among machine tools should be balanced; the total transition times between machines in a local plant should also be minimized. To solve this multiobjective iRS/OS model, a new two dimensional vectors-based coding approach has been proposed to improve the efficiency by designing a chromosome containing two kinds of information, i.e., operation sequences and machine selection. Base on such kind of chromosome, we use adapted multiobjective Genetic Algorithm to find the Pareto optimal solutions. Moreover a special technique called left-shift hillclimber has been used as one kind of local search to improve the efficiency of our algorithm. Finally, the experimental results of several iRS/OS problems indicate the promising effectiveness of the proposed approach for finding optimal solutions. Further more comparing with previous approaches, moGA performs better for finding Pareto solutions.

In Chapter 6, Advanced Planning and Scheduling Problem, it extends the research to Advanced Planning and Scheduling which includes a range of capabilities from finite-capacity scheduling at the shop floor level through to constraint-based planning in IMS environment. It mainly supports the integrated, constraint-based and optimal planning of the manufacturing system to reduce lead times, lower inventories, and increase throughput in IMS system. The objective is to find the optimal resource selection for assignments, operations sequences, and allocation of variable transfer batches, in order to minimize the total makespan, considering the setup time, transportation time, and operations processing time. The plans and schedules are designed considering flexible flows, resources status, capacities of plants, precedence constraints, and workload balance. In this chapter, an effective Fuzzy Logic Controller (FLC) is combined with moGA to improve the efficiency for finding optimal solutions. The experimental results of various APS problems have offered to demonstrate the effectiveness of moGA by comparing with the previous methods. Our proposed hybrid moGA can obtain remarkable better solution in makespan comparing with previous approach, and also the FLC can greatly improve the efficiency of our algorithm by improving the convergence for finding optimal solutions.

In Chapter 7, Conclusions, after analyzing the structure of Integrated Manufacturing System (IMS), and extracted the mathematical model from the scheduling problems in this field.

Precise mathematical models are formulated for two kinds of scheduling problems (iRS/OS, APS) and clarified all the constrains corresponding to real world case in IMS, such as lot size, unit load size, transportation, due date, and so on.

According to the flexibility in fJSP, iRS/OS and APS problems, a multistage operation-based Genetic Algorithm (moGA) is proposed as an effective approach for representing the information of flexible resources assignment in combinatorial scheduling problem. In terms of characters of different problem, different effective local search technique are combined to obtain active schedule, i.e. critical path local search, left shift local search. Moreover, some effective Fuzzy Logic Controller (FLC) is used to improve the efficiency of genetic convergence.

For future study, we would like to expand our research to Integrated e-Supply Chain in Agile and Environmentally Conscious Manufacturing System.