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Recent advances in hybrid evolutionary algorithms for multiobjective manufacturing scheduling

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ABSTRACT

In real manufacturing systems there are many combinatorial optimization problems (COP) imposing on more complex issues with multiple objectives. However it is very difficult for solving the intractable COP problems by the traditional approaches because of NP-hard problems. For developing effective and efficient algorithms that are in a sense "good," *i.e.*, whose computational time is small as within 3 min, we have to consider three issues: quality of solution, computational time and effectiveness of the nondominated solutions for multiobjective optimization problem (MOP).

In this paper, we focus on recent *hybrid evolutionary algorithms* (HEA) to solve a variety of single or multiobjective scheduling problems in manufacturing systems to get a best solution with a smaller computational time. Firstly we summarize *multiobjective hybrid genetic algorithm* (Mo-HGA) and *hybrid sampling strategy-based multiobjective evolutionary algorithm* (HSS-MoEA) and then propose *HSS-MoEA combining with differential evolution* (HSS-MoEA-DE). We also demonstrate those hybrid evolutionary algorithms to *bicriteria automatic guided vehicle* (B-AGV) dispatching problem, *robot-based assembly line balancing problem* (R-ALB), *bicriteria flowshop scheduling problem* (B-FSP), multiobjective scheduling problem in *thin-film transistor-liquid crystal display* (TFT-LCD) module assembly and *bicriteria process planning and scheduling* (B-PPS) problem. Also we demonstrate their effectiveness of the proposed hybrid evolutionary algorithms by several empirical examples.

1. Introduction

In real manufacturing and logistics systems there are many *combinatorial optimization problems* (COP) imposing on more complex issues, such as complex structure, nonlinear constraints, and multiple objectives to be handled simultaneously. By analyzing the system, we can formulate a *multiobjective optimization problem* (MOP) which is one of the important and complex COP models, where it can have a major impact on the productivity of a production process. Moreover, the COP models make the problem intractable to the traditional optimization techniques such as CPLEX because most of scheduling problems fall into the class of NP-hard combinatorial problems (Gen & Lin, 2014; Gen, Zhang, & Lin, 2015). In order to develop effective and efficient solution algorithms that are in a sense "good," *i.e.*, whose computational time is small as within 3 min, or at least reasonable for NP-hard combinatorial problems met in practice, we have to consider the following issues: quality of solution, computational time and effectiveness of the nondominated solutions for MOP (Yu & Gen, 2010). Metaheuristics provide a sufficiently good solution to an optimization problem, especially with incomplete or imperfect information or limited computation capacity environment. When also treating real-time based manufacturing systems for producing various semiconductor devices, we have to get the best real-time based schedule in a few minutes (Wang, Chien, & Gen, 2015). In the past decade, the study of how to apply *genetic algorithms* (GA), as one of typical metaheuristics, to scheduling problems in the real-world has been a subject engaging the curiosity of many researchers and practitioners in the area of management science, operations research, and industrial & systems engineering. A major reason for this interest is that genetic algorithms are powerful and broadly applicable stochastic search and optimization techniques that

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really work for many optimization problems that are very difficult to solve by conventional techniques (Gen & Cheng, 2000). Also, genetic algorithms have been widely used to solve intractable scheduling problems in real-world semiconductor production systems (Wu, Hao, Chien, & Gen, 2012). However there is a limitation for applying metaheuristics including GA because those methods are depending on the system analysis for the ill-structured complex problem in the large-scale and/or distributed systems.

The semiconductor based industry has grown rapidly and subsequently production planning problems have raised many important research issues. Because of short product lifecycles, it is crucial to rapidly respond to various customer needs and deliver products on time in high-tech manufacturing industries such as the various semiconductor devices including IC chips, LSI chips and microprocessors, *hard disc device* (HDD) and *thin-film transistor-liquid crystal display* (TFT-LCD). Manufacturing scheduling of TFT-LCD module assembly system is a key issue to enhance manufacture efficiency that could satisfy customer demand on time. By focusing on realistic settings, a module assembly process was formulated for treating in the HDD and TFT-LCD industries as a generalization of the *flexible job-shop scheduling problem* (FJSP) and *assembly line balancing* (ALB) model, respectively. On a flexible job-shop floor, workstations employ non-identical *parallel machines scheduling* (PMS) model and *reentrant flowshop scheduling* (RFS) model that exhibit distinct production velocities (Chou, Chien, & Gen, 2014). An operation can be processed using an available machine from a given workstation. For example, the TFT-LCD module assembly scheduling problem can be divided into two subproblems: the routing (*i.e.*, assigning each operation to machines) and scheduling problems (*i.e.*, determining the start time of each operation to machines). However, to find the optimal solutions of manufacturing scheduling gives rise to complex combinatorial optimization, unfortunately, most of them fall into the class of NP-hard combinatorial problems (Chamnanlor, Sethanan, Chien, & Gen, 2014; Chamnanlor, Sethanan, Gen, & Chien, 2015; Sangsawang, Sethanan, Fujimoto, & Gen, 2015).

Since the 1960s, many algorithms with population-based, fitness-oriented, and variation-driven properties in *evolutionary algorithm* (EA) have been proposed. There has been being an increasing interest in imitating living beings to solve the hard optimization problems. A *genetic algorithm* (GA) in EA is a typical generic population-based metaheuristics (Deb, 2001; Gen & Cheng, 1997, 2000; Goldberg, 1989; Michalewicz, 1994). EAs are algorithms that perform optimization or learning tasks with the ability by evolving with biological mechanisms: reproduction, mutation, recombination, and selection. They have three main characteristics:

(1) Population - EAs maintain a group of solutions, called a population to optimize or learn the problem in a parallel way. The population is a basic principle of the evolutionary process.
(2) Fitness - Every solution in a population is called an individual or chromosome and EAs prefer fitter individuals which is the foundation of the optimization and convergence of the algorithms.
(3) Variation-driven - Individuals will undergo a number of variation operations to mimic genetic gene changes, which is fundamental to searching the solution space (Gen, Cheng, & Lin, 2008; Yu & Gen, 2010).

As applied FJSP to the manufacturing scheduling problems for TFT-LCD module assembly system and HDD re-entrant flowshop scheduling, many researchers proposed several evolutionary algorithms with different local search methods. Kacem, Hammadi, and Borne (2002a) proposed multiobjective evolutionary optimization with a localization, Kacem, Hammadi, and Borne (2002b) also proposed Pareto-optimality approach with hybridization of evolutionary algorithms and fuzzy logic, Zhang and Gen (2005) proposed multistage-based genetic algorithm for solving multiobjective FJSP model, Gao, Gen, and Sun (2006) developed new HGA to solve the multiobjective FJSP with non-fixed availability constraints, and Gao, Sun, and Gen (2008) developed HGA with *variable neighborhood descent* (VND) algorithm for the FJSP. Gen, Gao, and Lin (2009) proposed a multistage-based GA with bottleneck shifting for the multiobjective FJSP and Gao, Gen, and Sun (2009) expanded HGA to memetic algorithm for scheduling a preventative maintenance in semiconductor manufacturing.

Even if EAs have attracted significantly attention with respect to above complexity scheduling problems, it has a disadvantage in which we have to design a specialized chromosome, *i.e.*, genetic representation with encoding and decoding routines for each scheduling problem depending the problem's specificity. So that means each class of EAs doesn't have a wide range of applications on manufacturing scheduling. Recently Gen and Lin (2014) surveyed multiobjective evolutionary algorithm for manufacturing scheduling problems. In order to design an effective EA with the problem's specificity, we have to consider the following issues: (1) how to design a representation and a way of population initialization satisfying the problem constraints with an encoding routine; (2) how to evaluate an individual by a fitness function with a decoding routine; (3) how to improve population by evolutionary operators.

In this paper we will survey recent advances in hybrid evolutionary algorithms for solving various multiobjective manufacturing scheduling problems. The rest of this paper is organized as follows: Section 2 summarizes the basic concept for a multiobjective optimization problem (MOP) and multiobjective genetic algorithms (MoGA) with several fitness assignment mechanisms. In Section 3 we summarize multiobjective hybrid genetic algorithm (Mo-HGA) and hybrid sampling strategy-based multiobjective evolutionary algorithm (HSS-MoEA) and then propose HSS-MoEA combining with differential evolution (HSS-MoEA-DE). In Section 4 we introduce those applications to bicriteria AGV dispatching model by random key-based hybrid evolutionary algorithm (RK. HEA), robot-based assembly line balancing model by Hybrid GA, bicriteria flowshop scheduling problem (B-FSP) by HSS-MoEA, multiobjective scheduling model in TFT-LCD module assembly by MoHGA-TOPSIS (technique for order preference by similarity to the ideal solution) and bicriteria process planning and scheduling (B-PPS) model by HSS-MoEA-DE. Finally, the conclusions of this paper are drawn in Section 5.

2. Multiobjective genetic algorithms

2.1. Multiobjective optimization problems

The *multiobjective optimization problems* (MOP) have been receiving growing interest from researchers with various backgrounds since early 1960 (Hwang & Yoon, 1981). There are a number of scholars who have made significant contributions to the problem. Among them, Pareto is perhaps one of the most recognized pioneers in the field. Recently, GAs have been received considerable attention as a novel approach to MOPs, resulting in a fresh body of research and applications known as *evolutionary multiobjective optimization* (EMO). The basic features of GAs are the multiple directional and global searches by maintaining a population of potential solutions from generation to generation. The population-to-population approach is hopeful to explore all Pareto solutions. GAs are essentially a kind of metastrategy methods.