MULTIOBJECTIVE COMBINATORIAL PROBLEMS OPTIMIZATION USING METAHEURISTIC ALGORITHMS: LITERATURE SURVEY WITH THE CASE STUDY OF COURSE TIMETABLING AND MULTI JOB SHOP SCHEDULING PROBLEMS

M. Nandhini¹, S. Kanmani²

Research and Development Centre, Bharathiar University, Coimbatore, Tamil Nadu-46, India.

Department of Information Technology, Pondicherry Engineering College, Puducherry-14, India.

ARTICLE INFO

Corresponding Author:
M. Nandhini
Research Scholar, Research and Development Centre, Bharathiar University, Coimbatore, Tamil Nadu-46, India.
mnandhini2005@yahoo.com

Keywords: Optimization, Multiobjective, combinatorial problems, course timetabling, multi job shop scheduling

ABSTRACT

In this paper, common searching algorithms used for optimizing soft constrained multi objective combinatorial problems have been surveyed with the case study of course timetabling problem and multi job shop scheduling problem over the period of 30 to 40 years.

INTRODUCTION

Several algorithms have been used to solve combinatorial problems (CPs) as in Figure 3.1 but each of them has its own limitations and advantages. In this section, existing combinatorial optimization techniques (COT) to solve CPs such as course timetabling problems (CTP) and multi job shop scheduling problem (MJSSP) with single and multi objectives have been explained.

Figure 1 Common Search Algorithms

EXACT ALGORITHMS

Many exact algorithms have been used for optimizing CPs. Yet theoretical result is far from satisfaction due to its complexity and there exists neither a universally accepted algorithm for all CPs problems nor an algorithm for solving NP-hard problems.

Exact techniques, such as enumeration, where every possible solution is explored in order to find the optimal solution, Branch and Bound technique where the known upper bounds or lower bounds for the solution are used to restrict the search space. Also, large integer linear programming, a zero-one integer program formulation, decomposition and Lagrangian relaxation are used to optimize the CPs.

However, due to the computational complexity, enumeration is not practical even for problems of moderate sizes. The efficiency of Branch and Bound is dependent on the quality of the upper and lower bounds for restricting the search space. The computational cost and time of integer linear programming takes significant effort. In some cases, hybrid of any of the two exact methods were used to get the benefits of each. Even then the conflict in constraints, multiple objectives of multi objective combinatorial optimization (MOCO) problem make the computation complex and unpredictable. Some of the exact algorithms used to optimize CTP and MJSSP have been surveyed in the following section.

Exact Algorithms for CTP


Exact Algorithms for MJSSP

Some of the Exact algorithms proposed for job scheduling problems such as Giffler and Thompson (1960),
The term “meta-heuristic” was first used by (Fred Glover 1986) to describe a heuristic that is superimposed on another heuristic. Characteristics of Metaheuristics are: ‘problem-specific’ solution algorithm, which require knowledge and experience about the problem domain and fine tuning of parameters. The classification of metaheuristics algorithms is given in Figure 2.

Voss et al (2010) describe a metaheuristics as “an iterative master process that guides and modifies the operations of subordinate heuristics to efficiently produce high-quality solutions”. This is applied when the problems have large size and to find optimal solution quickly. They begin with some initial solutions and entertain search strategies that try to avoid getting stuck in local minima. They can be broadly classified into local search algorithms and population search algorithms as given in Figure 2.2. In the next section, in respect of metaheuristics used for solving CTPs and MJSSPs are surveyed.

2.1 Local Search Algorithms

Local search algorithms are named as ‘problem-specific’ solution algorithm, which require knowledge and experience about the problem domain and fine tuning of parameters. The classification of metaheuristics algorithms is given in Figure 2.

2.2 Population Search Algorithms

In the following section, the survey on two population based search algorithms such as GA and PSO are done over a period of twenty years to study the concepts adopted for solving CTP and MJSSP problems.
week. GA with random feasible solutions to form initial population, mutation of assigning new timeslots and rooms at random and cycle crossover operator were employed to generate feasible offspring. A large data sample was used to test the algorithm. The experiments carried out show that the algorithm was able to obtain promising results.

Konstantinou and Coakley (2004) employed repairing the schedule, and schedule perturbations; Lewis and Paechter (2004) proposed number of crossover operators such as sector-based, day-based, student-based and conflict-based crossover, and repair function to preserve feasibility during crossover and mutation; Kremena Roychak and Milena Karova (2006) used random walk selection and adaptive threshold selection; Ghaemi Vakili and Aghagolzadeh Ghaemi (2007) employed intelligent operators and cooperative genetic operators; Wutthipong Chinnasri and Nidapan Sureerattanan (2010) performed the comparison between different selection strategies on GA with CTP and proved that roulette wheel selection works better than rank and tournament selections.

Panagiotis Adamidis and Panagiotis Arapakis (1999) used elitism, adaptive operator probabilities and adjusted the operator probabilities after the creation and evaluation of each generation, depending on the convergence of the population.

Wang Xiao Yun et al (2008), proposed an improved GA which improves selection rate by dynamic variation’s select rate and using elitist strategy with dissimilarity chromosome; Sapru et al (2010) used single point crossover by selecting random pairs of timetable chromosome, novel guided mutation operator, Ryhdian Lewis and Ben Paechter (2007) designed a method for measuring population diversities and distances between individuals with the grouping representation and used an additional stochastic local search operator to solve timetabling problem. More research on GA applied to course timetabling can be found in Lewis and Paechter (2005).

GA based Population Search Algorithms for JSSP


Garen (2002) proposed multi objective JSS using GA with new representation of solution and standard recombination operators of Syswerda’s uniform crossover. They showed the usefulness of the proposed method with some instances.

Isao et al (1996) described an GA for JSSP with Job-based order crossover to preserve the characteristics of the problem. To recover the schedules from infeasibility, transforming them into active schedules were proposed. Also, a mutation for maintaining a diversity of population without disrupting characteristics was introduced and proved its usefulness by applying the proposed method to Fisher’s and Thompson’s 10x10 and 20x5 problems.


Hence, from this survey, it is summarized that many researches were carried out on CTP and MJSSP by proposing an alternative for the existing operators, introducing adaptive penalty function and change in GA components probability etc.,

PSO based Population Search Algorithms for JSSP

Rui Zhang (2011) presented a PSO algorithm based on local perturbations on JSSP; Xia Weijun et al (2004) arranged the jobs according to the increment order of process on the machine in their hybrid optimization algorithm for the JSSP; Voratas and Thongchai (2011) introduced two-stage PSO algorithm for JSSP with random key representation and constructed the solutions using a permutation with m-repetitions of job numbers.

Hence, it is observed from the study that the research work on PSO for MJSSP is related to adoptions in the representation of schedule, defining objective function, operators evaluation etc.,

Hybrid Metaheuristics

Hybrid of any two metaheuristics algorithms can be done to add the benefit of one algorithm with the other. Coupling GA with local search means usually that solutions created by genetic operators are subject to a local search which tries to improve their fitness. When introducing a local search procedure in GA, a limited effort should be devoted to improve chromosomes by local search. (Salwani Abdullah and Hamza Turabiab 2012). The local search proposed so far is based on small modifications of the current individual as far as they produce improvement in the associated objective function. Memetic algorithm, defined as GA with LS, follows every step of a GA, but it adds local improvement in the chromosomes of each generation of the population. Because of this, it reduces the search space in which the optimal solution is to be found. (Burke et al 1996).

Hybrid Metaheuristics for CTP

Paechter et al (1996) implemented a memetic algorithm for the lecture timetabling problem with several types of mutation strategies; Kostuch (2005) employed a three-phase approach for the CTP which has combined graph colouring and simulated annealing; Yang and Jat (2011) introduced GA with guided search strategy for storing information extracted from good individuals of previous generations and used LS to improve the search efficiency and Kamrul Hasan et al (2007) proposed hybrid GA that includes a heuristic job ordering local search with GA. Everyone proved their contribution with better experimental results.

Salwani Abdullah et al (2007) proposed hybrid evolutionary approach with roulette wheel selection, random mutation and Randomized Iterative Improvement Local Search Algorithm to find out the best individual in the population.

Salwani Abdullah and Abdul Razak Hamdan (2008) introduced a three phase hybrid approach. In which they have combined randomized iterative algorithm with
composite neighbourhood structure and a SA based acceptance criterion to generate the solutions and hill climbing approach to improve the solution further and found the better results with this approach.

Salwani Abdullah and Turabieh (2008) proposed GA with LS to solve University CTP. In GA, the adaptations such as constructive heuristic to create a timetable, tournament selection, single-point crossover and mutation operator to perform random changes and repair function to recover solutions from infeasibility are introduced. To improve some selected best timetables, a LS heuristic was applied which tried to change the assignment of events to timeslots, and accepts the change if the new schedule is better than the old one. The changes were attempted for every event and timeslot pairs in the solution. Experimental results proved its worth by producing the optimal timetables.

Salwani Abdullah et al (2009) investigated GA combined with a sequential LS for the curriculum based CTP with two phases: the construction phase, to construct an individual and the improvement phase, to improve the solution. Construction phase was proposed with 3 consecutive heuristics namely a large degree heuristic, a neighborhood search and a TS. They have used single point crossover and repair function in GA with sequential LS to improve the timetable, before moving to the next generation and proved its ability by producing the best known results for some of the benchmark problem instances.

Raghavjee and Pillay (2010) proposed hybrid GA to solve the school timetable problem with two phase approach; first phase focused on producing feasible timetables, while the second GA phase improves the quality of timetables found during the first phase and employed two mutation operators; first is a simple mutation that swaps two cells in the timetable, provided that the two cells belong to the same class, second mutation operator is a hill-climbing mutation that tries to gradually improve the timetable (for a number of trials) by swapping teachers and proved with good quality timetables.

Shengxiang Yang and Sadaf Naseem Jat (2011) introduced hybrid approach of GA with a guided search strategy and LS techniques for University CTP and proved its ability by comparing with set of state-of-the art methods from the literature.

Hybrid Metaheuristics for MJSSP
José Fernando Gonçalves et al (2002) presented a hybrid approach with GA and a LS heuristic and was tested on a set of standard instances of MJSSP taken from the literature and compared with other approaches of Aarts et al (1994), Croce et al (1995) They proved the effectiveness of the proposed algorithm with the computational results.

Chaoyong Zhang et al (2005) designed genetic SA to solve JSSP. It included metropolis acceptance criterion into crossover operator and a new crossover operator, named precedence operation crossover, for the operation-based representation and its results validate the effectiveness of the proposed algorithm.

Tamilarasi and Anantha Kumar (2010) proposed a hybrid GA with SA approach to solve MJSSP. They obtained better results than simple GA and other hybrid GA which was proposed by Gonçalves et al (2002).

Hence, the research contributions for optimizing CTP and MJSSP using local search and population search with GA and SA algorithms are analyzed.

4 Limitations Of Existing Work
In the past years, evolution of the population in GA took place with the vast introduction of GA operators particularly on selection, crossover and mutation and variety of representation of chromosomes on various applications like travelling salesman problem, multi job shop scheduling, timetabling etc.

The application of GAs to constrained optimization problems has been hindered by the inefficiencies of reproduction and mutation. When feasibility of generated solutions is impossible to promise and feasible solutions are very difficult to find, supportive local search operators are combined with GA.

To date, no efficient general-purpose heuristics have been developed for these problems. Although the existing algorithms in the literature can increase the convergence rate and search capability of the simple GA to some extent, the crossover and mutation operators used in these algorithms were not sufficiently exploited the characteristics of the problem structure.

Most of genetic operators only change the form of encoding and are difficult to integrate the merit of the parent individuals. To have diverse search space within reachable limit, domain specific crossover operator may be introduced. To balance the exploration and exploitation abilities, local search like steepest ascent hill climbing may be applied simultaneously with GA architecture.

CONCLUSION
Thus the common searching algorithms used for optimizing soft constrained multi objective combinatorial problems with the case study of course timetabling problem and multi job shop scheduling problem for the period of 30 to 40 years are surveyed.

REFERENCES


Figure 2 Classification of Metaheuristics Algorithms