A Performance Study for the Multi-objective Ant Colony Optimization Algorithms on the Job Shop Scheduling Problem

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ABSTRACT

Most of the research on job shop scheduling problem are concerned with minimization of a single objective. However, the real world applications of job shop scheduling problems are involved in optimizing multiple objectives. Therefore, in recent years ant colony optimization algorithms have been proposed to solve job shop scheduling problems with multiple objectives. In this paper, some recent multi-objective ant colony optimization algorithms are reviewed and are applied to the job shop scheduling problem by considering two, three and four objectives. Also in this study, four criteria: makespan, mean flow time, mean tardiness and mean machine idle time are considered for simultaneous optimization. Two types of models are used by changing the number of ants in a colony and each multi-objective ant colony optimization algorithm is applied to sixteen benchmark problem instances of up to 20 jobs $\times$ 5 machines, for evaluating the performances of these algorithms. A detailed analysis is performed using the performance indicators, and the experimental results have shown that the performance of some multi-objective ant colony optimization algorithms depend on the number of objectives and the number of ants.

Keywords

ant colony optimization, job shop scheduling problem, multi-objective problem, non-dominated solution, pareto optimal front, performance indicator

1. INTRODUCTION

The job shop scheduling problem (JSSP) is NP-hard [10] and also one of the most complex combinatorial optimization problems. It is defined as the process of assigning a set of tasks to resources over a period of time [13]. Many methods have been developed to solve the single objective optimization problem, in order to optimize the time required to complete all jobs, i.e. considering a single objective to minimize the makespan criterion. However, most real world applications of scheduling require the simultaneous optimization of multiple objectives. During the past few years most researches have proposed to solve job shop scheduling problems which consist of multiple objectives. Ant colony optimization (ACO) is a metaheuristic which can be used to solve the combinatorial optimization problems such as the traveling salesman problem, the job shop scheduling problem and the quadratic assignment problem, etc [8]. In the recent years, several papers reviewed the MOACO algorithms and conducted different kinds of experimentation. Garcia-Martinez et al. [9] reviewed and experimentally compared the MOACO algorithms when applied to the bi-objective traveling salesman problem. Angus and Woodward [3] reviewed the MOACO algorithms but did not carry out an experimental study. Also, Lopez-Ibanez and Stutzle [12] reviewed and provided an experimental study to understand the effects of various algorithmic components for the MOACO algorithms when applied on the bi-objective traveling salesman problem. Further, our previous study [4] reviewed and performed experimentation in order to analyze the performance of MOACO algorithms when applied to the traveling salesman problem. In fact, all these papers have focused on solving the traveling salesman problem. Hence, in this study a different problem domain is considered for solving to understand the behaviour of MOACO algorithms. Therefore, the job shop scheduling problem is selected as the problem domain in this study.

The aim of this paper is to review some recent multi-objective ant colony optimization (MOACO) algorithms and evaluate their performance by changing the number of objectives and ants. Further, MOACO algorithms are applied on several benchmark problem instances of the job shop scheduling problem by considering two, three and four objectives and a detail analysis has been performed using performance indicators. This paper is organized as follows: Section 2 reviews some preliminaries about the multi-objective optimization problem, the job shop scheduling problem, ant colony optimization algorithm and MOACO algorithms. The experimentation with parameter values, problem instances and performance indicators are presented in Section 3. Section 4 presents the analysis of the experimental results. Finally, Section 5 provides the conclusion.

2. PRELIMINARIES

2.1 Multi-objective optimization problem

A general multi-objective optimization problem (MOOP) [7] can be formulated as follows, which consists of more than one objective to be minimized or maximized simultaneously. MOOP includes a