Scheduling a Fuzzy Flowshop Problem with Flexible Due Dates Using Ant Colony Optimization

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Abstract. Most of the work about flowshop scheduling problems assume that the problem data are known exactly at the advance or the common approach to the treatment of the uncertainties in the problem is use of probabilistic models. However, the evaluation and optimization of the probabilistic model is computationally expensive and rational only when the descriptions of the uncertain parameters are available from the historical data. In addition, a certain amount of delay on due dates may be tolerated in most real-world situations although they are handled as crisp dates in most of the previous papers. In this paper we deal with a flowshop scheduling problem with fuzzy processing times and flexible due dates. Schedules are generated by a proposed algorithm in the context of ant colony optimization metaheuristic approach.

Keywords: fuzzy processing time, fuzzy due date, flow shop scheduling, ant colony optimization, necessity measure.

1 Introduction

The flowshop scheduling problems are made up of *n* similar jobs which have the same order of processing on *m* machines. The problem is NP-hard, only some special cases can be solved efficiently [1]. Even though, the flowshop scheduling problems has often been investigated, very little of this research is concerned with the imprecise or ambiguous impressions in problem variables such as processing times and due dates. Weaknesses of modelling have been the major obstacle that prevents traditional techniques from being used in industrial applications with amazing speed increase of modern processors and new techniques of resolution such as metaheuristics [2]. In order to describe and characterize real-world problems closely it is more suitable to consider fuzzy processing time and fuzzy due date particularly in human incorporated systems since on every occasion of human interface there may be some deviation from the deterministic value and there will be difficulties in applying and validating the generated schedule. Concerning due date, solution to a problem which is modeled with crisp due dates will be invalid for any amount of delay on due dates. However, in real-world applications it is possible to see that a certain amount of delay may be tolerated. There may be situations where a schedule is also valid for same delays with less single customer satisfaction but greater acquisitions in total manner as a consequence of expanded solution space through flexible due dates.

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In this paper we used ant colony optimization (ACO) approach to generate a schedule for the cases where the processing times are uncertain and due dates are flexible in some range. Flexible due dates are handled as fuzzy due dates. The problem is denoted as fuzzy permutation flowshop (FPFS) problem. It is assumed that the planner is able to approximate the imprecise data using fuzzy sets. Initially we explain how to calculate the completion time of each job using fuzzy arithmetic. Then we focused on the scheduling criteria in order to decide which schedule is the best. We used the necessity measure in order to define a certainty level of fuzzy completion time of a job to be earlier than the flexible due date.

There is some research on FPFS problem but to our knowledge there have not been any work on FPFS using an ant colony optimization approach. The first application of fuzzy set theory on a flowshop problem as means of analyzing performance characteristics was by [3] in 1992. A multi-objective genetic algorithm for large size flowshop scheduling problems with fuzzy processing time is proposed in [4]. In [5] authors applied a fuzzy approach to the treatment of processing time uncertainty in flowshop plants and new product development process scheduling problems.

The remainder of this paper is organized as follows. In the next Section, we introduce the FPFS problem. Then we introduce the setting of the ACO algorithm in Section 3. The computational experiments are presented in Section 4. Finally we conclude the paper with a summary in Section 5.

2 Permutation Flowshop Scheduling Problem with Fuzzy Processing Time and Fuzzy Due Date

In general a $n \times m$ permutation flowshop scheduling problem is formulated as follows. Let n jobs (j=1,2,…,n) be processed on m machines (k=1,2,…,m) in the same order. Only permutation schedules are considered, where the order in which each machine processes the jobs is identical for all machines. Hence a schedule is uniquely represented by a permutation of jobs. The processing of each job on each machine is an operation which requires the exclusive use of the machine for an uninterrupted duration called the processing time. Let the processing time of job j on machine k be t_{jk}. The objective is to find a schedule that minimizes the makespan. In this paper a permutation flowshop scheduling problem with fuzzy processing times and fuzzy due dates is formulated as a fuzzy permutation flowshop scheduling (FPFS) problem.

Using fuzzy numbers for representing the uncertainty in processing times is very plausible for real world applications. If a decision maker estimates the processing time of the job j on machine k (t_{jk}) as an interval rather than a crisp value then the interval can be represented as a fuzzy number. In this paper, the fuzzy due date, $\tilde{D}_j$ is represented by the degree of satisfaction with respect to completion time of job j and denoted by a double (d_j^1, d_j^2) as shown in Fig. 1(a). d_j^2's are generated by adding acceptable delays on crisp due dates. The fuzzy processing time of job j on machine k is represented by a triangular fuzzy number (TFN) $\tilde{T}_{jk}$ and denoted by a triplet ($a_{jk}^1, a_{jk}^2, a_{jk}^3$) as illustrated in Fig.1(b).