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A Modified Ant Colony Optimization algorithm for the Distributed Job shop Scheduling Problem

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Abstract

The Distributed Job shop Scheduling Problem (DJSP) deals with the assignment of jobs to factories geographically distributed and with determining a good operation schedule of each factory. The objective is to minimize the global makespan over all the factories. This paper is a first step to deal with the DJSP using three versions of a bio-inspired algorithm, namely the Ant Colony Optimization (ACO) which are the Ant System (AS), the Ant Colony System (ACS) and a Modified Ant Colony Optimization (MACO) aiming to explore more search space and thus guarantee better resolution of the problem. Comprehensive experiments are conducted to evaluate the performance of the three algorithms and the results show that the MACO is effective for the problem and AS and ACS algorithms in resolving the DJSP.

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1. Introduction

Manufacturing industry is facing multiple challenges: ensuring profitable growth, improving productivity and reducing costs while responding quickly to customer demands. To remain competitive and for closer proximity to the market, industrial companies are increasingly merging to distributed ones and thus, the structure of their shops changes from simple configurations to distributed ones. Distributed workshops are becoming a popular thematic to study in the field of scheduling problems: Distributed Flow shop ([1],[2],[3], etc.), Distributed Job shop ([4],[5], etc.), Distributed Process Planning ([6],[7], etc.).

In this paper, we focus on the Distributed Job shop Scheduling Problem (DJSP), which can be considered as an extension of the simple Job shop Scheduling Problem (JSP). It can be treated as a set of $f$ factories, which are geographically distributed in different areas. Each factory contains $m$ machines on which certain number of jobs have to be processed. It is clear that Distributed Scheduling problems are much more complicated than classical scheduling.

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ones since two decisions have to be taken: allocating jobs to suitable factories and sequencing the operations on machines with the objective of minimizing one or more predefined performance criteria. Garey et al. [8] proved that the JSP is strongly NP-hard. Hence, the DJSP is ordinarily NP-hard and the case of the simple JSP can be obtained when $f = 1$. In this paper, we are dealing with the DJSP assuming that all factories are identical due to the complexity of the problem in such a system. We are seeking to minimize the maximum completion time (makespan, denoted as $C_{max}$) of DJSP, which is the maximum makespan among all factories using three versions of the Ant Colony algorithm. The rest of the paper is organized as follows. Section 2 gives the specifications of the DJSP. Then a short literature review of the limited existing works on DJSP is provided. The disjunctive graph is one of the most popular models used to represent the JSP is described in section 3 applied to our problem. Section 4 proposes an effective way to assign jobs to factories. Section 5 sketches the proposed algorithms. Section 6 conducts the numerical experiments. And finally, Section 7 concludes the paper and suggests few future research directions.

2. Problem statement and state-of-the-art

Scheduling problems have become a popular issue for researchers and industrialists in the last three decades, particularly the JSP since it is one of the most difficult tasks [9], [10], [11] and [12] are pioneer researches in the literature that dealt with the JSP. Due to the trend of globalization, the JSP has evolved from the classical JSP to the Distributed one and becomes increasingly, one of the most important issues to raise. In the literature, few researchers dealt with the DJSP and resolution methods employed are limited. Formally the DJSP can be stated as follows: a set $J = \{j_1...j_n\}$ of independent jobs, each of which consists of an ordered set of operations. Each operation must be executed on a specific machine from a set $M = \{i_1...i_m\}$ of machines geographically distributed on $f$ identical factories. Note that each factory has the same set $M$ of $m$ machines. Researchers are beginning to study the DJSP recently. We can find Jia et al. [13] which have studied the DJSP and proposed a Genetic Algorithm (GA) approach in order to facilitate collaboration between geographically distributed plants. In their next paper, to solve the same problem in a multi-factory network, authors in [14] presented a Modified Genetic Algorithm (MGA) in which two-step encoding method was used to encode the factory candidates and to affect jobs and operations. Later [14], they refined their previous approach and proposed a GA integrated with Gantt Chart (GC) to derive the factory combination and schedule. Recently, the problem of DJSP have been mathematically formulated by Naderi and Azab [15] with two different Mixed Integer Linear Programming models (MILP). In addition, three well-known heuristics were first adapted to the problem; these are Shortest Processing Time first (SPT), Longest Processing Time first (LPT) and Longest Remaining Processing Time (LRPT). Then, three Greedy Heuristics have been deployed (GH1, GH2 and GH3). In their next paper [5], authors have differently treated the problem. Different forms of a developed simulated annealing have been designed and implemented and to further improve the algorithm, two additional mechanisms of local search and restart phase were designed. The algorithm has been hybridized as well with a greedy heuristic. In [16], detailed literature review of DJSP is given and a classification of the employed techniques is made. The main objective of the DJSP is to find an optimal scheduling minimizing a specified criterion which is generally time related such as makespan, maximum tardiness or total tardiness. In our case, we are aiming to minimize the maximum completion time (makespan) among all factories. There are various constraints on both jobs and machines. The DJSP entails the following assumptions:

- All jobs are independent and available for processing at time 0 and all machines are continuously available.
- Once a job is assigned to a factory it cannot be transferred to another factory as the remaining operations must be completed in the same plant.
- All factories are able to process all jobs.
- There are no precedence constraints among the operations of different jobs.
- Each operation needs to be processed during an uninterrupted time of a fixed processing period and a given machine.
- A job can be processed by at most one machine at a time and a machine can process at most one job at a time.
- It is assumed that a job does not visit the same machine twice and neither the release times nor due dates are specified.
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