Available online at www.sciencedirect.com

ScienceDirect

Journal of Computational Design and Engineering 4 (2017) 46–59

www.elsevier.com/locate/jcde

A single-machine scheduling problem with multiple unavailability constraints: A mathematical model and an enhanced variable neighborhood search approach

Maziar Yazdani[a,*], Seyed Mohammad Khalili[a], Mahla Babagolzadeh[b], Fariborz Jolai[a,1]

[a]*School of Industrial Engineering, College of Engineering, University of Tehran, Tehran, Iran*
[b]*Department of Industrial Engineering, Ferdowsi University of Mashhad, Mashhad, Iran*

Received 22 January 2016; received in revised form 5 July 2016; accepted 9 August 2016
Available online 3 October 2016

Abstract

This research focuses on a scheduling problem with multiple unavailability periods and distinct due dates. The objective is to minimize the sum of maximum earliness and tardiness of jobs. In order to optimize the problem exactly a mathematical model is proposed. However due to computational difficulties for large instances of the considered problem a modified variable neighborhood search (VNS) is developed. In basic VNS, the searching process to achieve to global optimum or near global optimum solution is totally random, and it is known as one of the weaknesses of this algorithm. To tackle this weakness, a VNS algorithm is combined with a knowledge module. In the proposed VNS, knowledge module extracts the knowledge of good solution and save them in memory and feed it back to the algorithm during the search process. Computational results show that the proposed algorithm is efficient and effective.

Keywords: Single machine scheduling; Availability constraint; Variable neighborhood search; Knowledge module

1. Introduction

Generally in scheduling problems it is assumed that machines are continuously available over the planning horizon. However, this assumption may not be true in many practical situations. For instance, a machine may not be available during the planning horizon due to maintenance activities [1], tool changes [2], or breakdowns. Since, machines require preventive and curative maintenance [3], operators take breaks, and worn out parts require changing. Not only managers are increasingly faced with the costs caused by the temporary unavailability of resources, but also they are constantly concerned with difficult decisions regarding balancing resources' unavailability and production. Nowadays, accounting for machine unavailability has become a promising research area. For instance, in the airline industry, scheduled maintenance has reduced production time by about 15% [4]. Low et al. [5] mentioned two applications related to the aerospace industry where micro drilling tools need to be changed periodically and the machine cannot be used during this time. They have emphasized the wide applicability of the problem in real manufacturing environments such as computer centers, NC-machines and IC-testing industries. Rapine et al. [6] considered the case of an automated machine which requires the intervention of an auxiliary resource (i.e., an operator that removes jobs or adds chemicals) whose unavailability blocks the machine. Accordingly, managers have to schedule their machines effectively in order to maximize their profits while avoiding conflicts between scheduled maintenance and planned production.

In this paper, we study a scheduling problem on a single machine with multiple unavailability periods and distinct due

*Corresponding author. Fax: +98 21 88013102.
E-mail addresses: Maziyar.yazdani@ut.ac.ir (M. Yazdani), M.Khalili@ut.ac.ir (S.M. Khalili), Mahla_golzade@yahoo.com (M. Babagolzadeh).
[1]fjolai.ut.ac.ir
Peer review under responsibility of Society for Computational Design and Engineering.

http://dx.doi.org/10.1016/j.jcde.2016.08.001

dates where the objective is to minimize the sum of maximum earliness and tardiness of jobs. It is shown that this problem is strongly NP-hard, and in order to optimize the problem exactly, a mathematical model is proposed. In addition, with respect to high complexity of this problem, metaheuristic algorithms are proposed to obtain optimal or near-optimal solutions for the considered problem. Variable neighborhood search (VNS) is a powerful metaheuristic algorithm for solving complex combinatorial optimization problems which was first introduced by Mladenovic [7]. VNS, through using a systematic change of neighborhood structures, is capable of evading local optimum. Therefore during past decade, it has been used for solving a wide spectrum of complex optimization problems such as graph coloring [8], spanning tree [9] and job shop scheduling [10]. However, it should be mentioned that VNS and other metaheuristic algorithms have some weaknesses. For instance, they guide their optimization algorithm through utilizing objective function or fitness [11]. Random nature of these algorithm's operators is another weakness of them [12]. To overcome this shortcoming, recent researches [13–17] concentrated on proposing algorithms that have emphasized on the interaction between evolution and learning. This paper intends to combine VNS algorithm with a knowledge module and proposes a knowledge-based variable neighborhood search.

The paper has the following structure. In the next section, a brief review of relevant literature is provided. Section 3 presents the mathematical formulation of the considered problem. In Section 4, we describe the proposed algorithm. Section 5 reports the experimental design. Finally, last section is devoted to conclusion and future research.

2. Literature review

As mentioned former, this paper deals with a single machine scheduling problem with multiple unavailability periods where the objective function minimizes the sum of maximum earliness and tardiness of jobs, in addition, a knowledge-based VNS is proposed as the solution method. Accordingly, the relevant literature is provided in three separate but complementary streams: single machine scheduling problems with unavailability constraints, machine scheduling problems with the focus on the maximum earliness and tardiness of jobs, and recent applications of VNS in scheduling problems.

2.1. Single machine scheduling problems with unavailability constraints

A comprehensive review of literature in scheduling problems with unavailability constraints has been conducted by Schmidt [18]. Angel-Bello et al. [19] proposed a mixed integer programming model for scheduling problem with availability constraints and sequence-dependent setup costs. Moreover, they presented a valid inequality and an efficient heuristic approach in order to lessen the computational time. Rustogi and Strusevich [20] considered single machine problems with generalized positional deterioration effects and machine maintenance where decisions are made regarding possible sequences of jobs and on the number of maintenance activities to be included into a schedule in order to minimize the overall makespan. Zammori et al. [21] focused on the single machine scheduling problem, in which jobs and maintenance tasks are jointly considered to find the optimal schedule. Wang and Liu [22] presented an integrated optimization model for production scheduling and preventive maintenance (PM) in a single machine with its time to failure has a Weibull probability distribution. Yin et al. [23] considered the problem of scheduling of independent and simultaneously available jobs without preemption on a single machine, where the machine has a fixed maintenance activity. Xu et al. [24] considered a single-machine scheduling problem with workload-dependent maintenance duration, and the objective is minimize total completion time. Cui et al. [25] addressed the problem of finding robust production and maintenance schedules for a single machine with failure uncertainty, where both production and maintenance activities occupy the machine's capacity, while production depletes the machine's reliability and maintenance restores its reliability. Luo et al. [26] considered the problem of scheduling a maintenance activity and jobs on a single machine, where the maintenance activity must start before a given deadline and the maintenance duration increases with its starting time. Hfaiedh et al. [27] aimed to minimize the maximum delivery time under the non-resumable scenario of jobs in a single machine scheduling problem with release dates and tails, provided that the machine is unavailable during a fixed interval. Bai et al. [28] studied a single machine slack due date assignment (usually referred to as SLK) scheduling problem with deteriorating jobs and a rate-modifying activity, where the deterioration effect manifest such that the job processing time is a function of its starting time in a sequence. Vahedi-Nouri et al. [29] considered a single machine scheduling problem with the learning effect and multiple availability constraints that minimizes the total completion time. Li and Zhao [30] studied single machine scheduling with a fixed non-availability interval, where the processing time of a job is a linear increasing function of its starting time, and each job has a release date. Kacem et al. [31] considered the maximization of the weighted number of early jobs on a single machine with non-availability constraints. They dealt with the resumable and the non-resumable cases. Gu et al. [32] investigated two single-machine scheduling problems with a new type of aging effect, which is dominated by the processing speed of the machine, while during the whole scheduling horizon, the machine is subject to an optional maintenance, and the duration of the maintenance depends on the length of the uptime before it. Liu et al. [33] investigated a single-machine scheduling problem with periodic maintenance, in which the pursued objective is to minimize the number of tardy jobs. Wang [34] proposed a bi-objective optimization model for the problem of production scheduling and preventive maintenance in a single-machine context with sequence-dependent setup times, while during the setup times, preventive maintenance activities are supposed to be performed simultaneously. The two objectives are to minimize the total expected completion time of jobs and to minimize the maximum of expected times