SOLVING A HYBRID JOB SHOP SCHEDULING PROBLEM WITH SPACE CONSTRAINTS AND REENTRANT PROCESSES BY USING AN IMPROVED HYBRID GENETIC ALGORITHM: A CASE STUDY

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In this paper, several concepts and techniques of a job shop manufacturing system are adjusted and utilized in a real-world pipe spool fabrication shop scheduling problem. In the present study, an improved hybrid genetic algorithm is developed to create a feasible and active schedule for the operational level of pipe spool fabrication shop with the aims of minimizing maximum completion time of all jobs. In the proposed algorithm, an enhanced solution encoding and decoding are used to represent a schedule for the fabrication shop. In order to generate high-quality initial solutions, an operation order-based global selection is designed, where this operator considers operations processing time and workload of machines while assigning machines to each of the proper operations. In the reproduction phase of this algorithm, the precedence preserving order-based crossover, uniform crossover, swapping operator, and intelligent mutation operator are used to produce the offspring and mutants for the sequencing and job routing sub-problems. In addition, a local search operator is utilized to explore the neighborhood of the solution in order to improve the solution quality further. Stepwise delineation of the proposed approach is presented and a set of benchmark problem instances that is collected from the literature, are solved. Computational outcomes demonstrate the efficacy and effectiveness of the proposed algorithm as compared to other approaches from the literature. Finally, the proposed algorithm is implemented with the collected data from an industrial fabrication shop. The principal results indicate that the productivity of pipe spool fabrication shop, with particular constraints, is increased 85.27% by applying the proposed metaheuristic approach.

Keywords: hybrid genetic algorithm; flexible job shop scheduling; hybrid job shop scheduling; pipe spool fabrication shop

1. INTRODUCTION

Scheduling of operations is one of the most crucial issues in the planning and managing of manufacturing and industrial systems. Pipe spool fabrication shop is an intermediate phase in the piping processes of construction projects, which produces pipe spools. The delivery of pipe spools at the right time, in order to be installed on the site, is very important. Therefore, effective scheduling and controlling of the fabrication shop has a direct effect on the productivity and successfulness of the whole construction project. Pipe spool fabrication shop is similar to hybrid job shop scheduling environment with parallel machines or workforces in some work centers. Scheduling of classic job shop is considered as one of the prominent *NP*-hard combinatorial optimization problems, where it can be specified with a set of jobs that should be performed on a set of machines in predefined sequences, i.e., sequencing problem. However, the scheduling of flexible job shop as a generalization of classical job shop is a more difficult problem. The flexible job shop scheduling problem (FJSP), in addition to the operations sequencing (sequencing sub-problem), is dealing with the selection of suitable machines among the available parallel machines for performing operations (job routing sub-problem). This means that each job has different routes for processing along the production line. Numerous exact and approximate approaches have been developed for solving these scheduling problems (Caliş and Bulkan, 2013, Jain and Meeran, 1999). Among those techniques, genetic algorithm (GA), which was introduced by John Holland in the 1970s, has received the most attention from the researchers in past decades. The original GA was developed and adjusted by many researchers to deal with practical applications and benchmarking purposes. However, in many cases, studies have been limited considering the efficiency and performance of the algorithms, specifically at the academic level.

In the classical job shop scheduling, most of the research attempts has been focused on developing efficient algorithms for benchmarking purposes (Bagheri et al. , 2010, Kacem et al. , 2002a, Pezzella et al. , 2008, Piroozfard et al. , 2017, Piroozfard et al. , 2016a, Zhang et al. , 2011). However, limited research has been directed towards real-world modeling of scheduling problems (Chen et al. , 2012, Sels et al. , 2011, Vaghefinezhad and Wong, 2012). In this research, we aim at

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   Constraint-directed Search Mark Fox,1987   **Constraint-directed Search** Mark S. Fox,1983 This thesis investigates the problem of constraint directed reasoning in the job shop scheduling domain The job shop scheduling problem is defined as selecting a sequence of operations whose execution results in the completion of an order and assigning times i e start and end times and resources to each operation The number of possible schedules grows exponentially with the number of orders alternative production plans substitutable resources and possible times to assign resources and perform operations The acceptability of a particular schedule depends not only on the availability of alternatives but on other knowledge such as organizational goals physical limitations of resources causal restrictions amongst resources and operations availability of resources and preferences amongst alternatives By viewing the scheduling problem from a constraint directed search perspective much of this knowledge can be viewed as constraints on the schedule generation and selection process In this thesis we present a system called ISIS ISIS uses a constraint directed search paradigm to solve the scheduling problem ISIS provides a knowledge representation language SRL for modeling organizations and their constraints hierarchical constraint directed scheduling of orders which includes constraint directed bounding of the solution space context sensitive selection of constraints and weighted interpretation of constraints analytic and generative constraint relaxation and techniques for the diagnosis of poor schedules   *Principles and Practice of Constraint Programming - CP97* Gert Smolka,1997-10-15 This book constitutes the refereed proceedings of the Third International Conference on Principles and Practice of Constraint Programming CP 97 held in Linz Austria in October November 1997 The volume presents 37 revised full papers carefully selected from a total of 132 submissions also included are the abstracts of two invited talks and three tutorials The papers address all current aspects of constraint programming Among the topics covered are constraint matching constraint languages set constraints constraint search constraint satisfaction problems scheduling constraint routing temporal constraints constraint graphs local search object oriented constraint programming etc   **Combinatorial Optimization Problems in Planning and Decision Making** Michael Z. Zgurovsky,Alexander A. Pavlov,2018-09-24 The book focuses on the next fields of computer science combinatorial optimization scheduling theory decision theory and computer aided production management systems It also offers a quick introduction into the theory of PSC algorithms which are a new class of efficient methods for intractable problems of combinatorial optimization A PSC algorithm is an algorithm which includes sufficient conditions of a feasible solution optimality for which their checking can be implemented only at the stage of a feasible solution construction and this construction is carried out by a polynomial algorithm the first polynomial component of the PSC algorithm an approximation algorithm with polynomial complexity the second polynomial component of the PSC algorithm also for NP hard combinatorial optimization problems an exact subalgorithm if sufficient conditions were found fulfilment of which during the algorithm execution turns it into a polynomial complexity algorithm Practitioners and software

developers will find the book useful for implementing advanced methods of production organization in the fields of planning including operative planning and decision making Scientists graduate and master students or system engineers who are interested in problems of combinatorial optimization decision making with poorly formalized overall goals or a multiple regression construction will benefit from this book   *Principles and Practice of Constraint Programming* Gilles Pesant,2015-08-12 This book constitutes the refereed conference proceedings of the 21st International Conference on Principles and Practice of Constraint Programming CP 2015 held in Cork Ireland in August September 2015 This edition of the conference was part of George Boole 200 a celebration of the life and work of George Boole who was born in 1815 and worked at the University College of Cork It was also co located with the 31st International Conference on Logic Programming ICLP 2015 The 48 revised papers presented together with 3 invited talks and 16 abstract papers were carefully selected from numerous submissions The scope of CP 2014 includes all aspects of computing with constraints including theory algorithms environments languages models systems and applications such as decision making resource allocation schedulling configuration and planning   **Principles and Practice of Constraint Programming** Thomas Schiex,Simon de Givry,2019-09-23 This book constitutes the proceedings of the 25th International Conference on Principles and Practice of Constraint Programming CP 2019 held in Stamford CT USA France in September October 2019 The 44 full papers presented in this volume were carefully reviewed and selected from 118 submissions They deal with all aspects of computing with constraints including theory algorithms environments languages models systems and applications such as decision making resource allocation scheduling configuration and planning The papers were organized according to the following topics tracks technical track application track multi agent and parallel CP track testing and verification track CP and data science track computational sustainability and CP and life sciences track   **Knowledge-Based Systems, Four-Volume Set** Cornelius T. Leondes,2000-07-11 The design of knowledge systems is finding myriad applications from corporate databases to general decision support in areas as diverse as engineering manufacturing and other industrial processes medicine business and economics In engineering for example knowledge bases can be utilized for reliable electric power system operation In medicine they support complex diagnoses while in business they inform the process of strategic planning Programmed securities trading and the defeat of chess champion Kasparov by IBM s Big Blue are two familiar examples of dedicated knowledge bases in combination with an expert system for decision making With volumes covering Implementation Optimization Computer Techniques and Systems and Applications this comprehensive set constitutes a unique reference source for students practitioners and researchers in computer science engineering and the broad range of applications areas for knowledge based systems   **Optimization: Techniques And Applications (Icota '95)** G Z Liu,1995-09-01 With the advent of powerful computers and novel mathematical programming techniques the multidisciplinary field of optimization has advanced to the stage that quite complicated systems can be addressed The conference was organized to provide a

platform for the exchange of new ideas and information and for identifying needs for future research The contributions covered both theoretical techniques and a rich variety of case studies to which optimization can be usefully applied

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