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DIFFICULTIES IN BI-OBJECTIVE OPTIMIZATION ALGORITHMS AND HYBRID APPROACHES FOR FLOW SHOP SCHEDULING PROBLEMS IN INDUSTRY: A PERSPECTIVE AND REVIEW

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ABSTRACT

The modern's era of scheduling is addressing the attraction and need of attaining and solving multiple objectives in the organizations, optimization algorithms have paved their way to find satisfactory solutions. The literature review focuses on the recent developed algorithms with objectives such as minimizing the completion time, tardiness, earliness and so on, with various kinds of newly developed optimization algorithms. Different types of heuristics are introduced such as GA, SA, ACO, TS DE, IA and PSO. In present study, one-machine and two-machine flow shop scheduling variants with blocking, preemption and analytical investigation of minimization of make span time is considered as the framework. This exhaustive literature is depicting the detailed explanation and perspective of scheduling problems for multi-objective optimization algorithms. This paper is referring the taxonomy of heuristics algorithms for MFSP scheduling. The research methods, hybrid models, research perspectives and challenges in field of scheduling for algorithms are explained. The present survey addresses that MFSP algorithms are contributing to optimal solutions of scheduling. The variants and hybridization for more efficient and effective algorithms has always attracted the researchers and is a deemed area of future research. Some of the challenges such as over utilization of objectives, termination criteria and others have also been described in the paper.

Keywords: *Scheduling, Multi-objective optimization algorithms, Heuristics approach,*

1. Introduction

In the authentic-time scenario, there subsist many situations in manufacturing system like due date changes,unexpected job release, machine breakdowns and morepreponderant processing times, than estimated and expected. The production cost aggregates to high proportion of any firm's expenditure,hence every firm endeavor to get a felicitous design of shop and scheduling of jobs on.There are various steps which are involved in modeling of algorithm, such as recognizing the output.A separation must be made at first that if a problem is of planning or optimization. The problem can be recognizedby analyzing the various objectives and ensuring

that there exist different options which can improve the procedure. Defining the problem consist of selecting the objective, parameters, constraints and some evaluation criteria. The process of Modeling includes the conversion of theoretical information into mathematical formulations by idealizing the real-world facts. This contains objective functions, decision variables, defines the range of variables and objective value. The formulated mathematical model can be solved with existing optimization methods or through the new novel hybrid heuristic methodsthat can developed. Models of multi-objective FSP (MFSP) are set up to captureoptimization arrangements, frequently called the Pareto optimal solutions, in knotty issues. Furthermore, there is not even an all-around acknowledged accomplishment of optimizationas that in single-objective optimization.Research on ways to deal with handling MFSP is with no uncertainty an exceptionally the imperative and testing venture and there are as yet numerous open inquiries in this area.To validate the solutions sensitivity tests or retrospective tests are used. The former computes different variations of the model and selects the best one, while the later will compare against the existing methods. Eventually after reaching a solution, the process can be terminated or can be further used with little variations to check the quality of solutions.

2.Literature Review

The proposed Allahverdi and Aldowaisanheuristic (PAAH)for the no-wait flowshop scheduling problem (FSP) with weighted sum makespan and total completion time (TCT) minimization as bicriteria [7]. Also, for a case of two-machine, a dominance relation and a branch and bound (B&B) algorithm were proposed. The experimental resultsshow the superiority of proposed algorithm when compared with the state of the art algorithms. A new multi-objective shuffled frog-leaping algorithm (MOSFLA)was proposed to search Pareto-optimal frontier for the bi-criteria permutation FSP, where the objectives like weighted mean completion time and tardiness were to be minimized at the same time [4]. The proposed algorithm was compared with conventional multi-objective genetic algorithms (MOGAs) and the experimental results indicate the superiority of the algorithm. The validation of results and effectiveness of MOSFLA was measured by using Pareto solutions, error ratio, generational distance, spacing metric, and diversity metric.Ahybrid modified global-best harmony search (hmgHS) algorithm for solving permutation FSP under blocking constraint along with makespan minimization criterions was proposed [10]. The continuous harmony vector was converted in job permutation through the implementation of largest position value(LPV) rule. The NEH_WPT heuristic was introduced to generate higher quality initial harmony memory of algorithm and for the balancing of global and local exploitations, the global search based on harmony search (HS) and insert neighborhood-based local search were hybridized. ANOVA method was used for the analysis of results and demonstrate the superiority of proposed algorithm among the state of art algorithms. A mathematical model for solving hybrid flowshop scheduling (HFS) problem with makespan (i.e., C_{max}) and processor assigning cost criteria [2]. In the problem it was assumed that there are several parallel identical processors with limitless middle storage between any two progressive stages are assigned to all of the stages in the hybrid flowshop. A new algorithm was proposed to register the principal target work makespan because of NP-hard of the problem, a genetic algorithm (GA) was additionally proposed to take care of the problem issues. The proposed GA regulate the initial sequence of jobs and task of the processors to the stages. The parameters of GA were tuned by using a full-factorial design. The implementation of tuning was done with design-of-experiments (DOE) approach. The results were investigated by the ANOVA

technique. So as to assess the proficiency and prevalence of the of the proposed GA, 20 test problems were solved and the associated outcomes were compared with the lower bound. A novel hybrid genetic algorithm (HGA) for the sequence-dependent permutation flowshop scheduling problem with an aim to minimize the makespan [13]. The proposed algorithm uses three genetic operators named as, order crossover, heuristic mutation and inversion mutation. Iterated Swap Procedure (ISP) was to generate an improved population of chromosomes in the algorithm, to produce an initial population of chromosomes the GA was amalgamate with modified NEH_RMB approach. The presented HGA was compared with some new heuristics like prediction error method (PEM), polynomial time heuristic (PH) and stochastic hybrid heuristic. The avg, min, and max performance measure (PM) values for each algorithm are calculated and ANOVA approach was utilized to get better results.The two-stage assembly flowshop scheduling problem was studied where the first stageconsists 'm' parallel identical machines called as "fabrication stage" while the second stage is assembly stage [9]. A novel meta-heuristic Grey wolf optimizer(GWO) algorithm was developed, along with numerous heuristic procedures, dispatching rules, along with a lower bound were also developed. The objective of the scheduling was to reduce makespan. Also, a local search was included in the algorithm to enhanceits performance. The execution of the lower bound was assessed by deviation of the LB (DVL) from the best solution of the algorithms, and the performance of the algorithm was calculated by relative percentage deviation (RPD). Statistical analysis ANOVA was carried out to measure the effectiveness of the proposed LB and working algorithms. An integer linear model used to minimize the makespan for the classical flowshop scheduling problem where the jobs need additional non-renewable resources for their processing [6]. The modeling was based on the model presented by Carrera (2010) for single machine environment with consumable resource constraint to minimize makespan. A Johnson algorithm was adopted for the two machines flowshop with no renewable resources constraints on the second machine. The results show Johnson algorithm was efficient to solve small problems for one no renewable resource, but when the number of resource increases then results deviates from the optimal solutions. Then the NEH algorithm was proposed to enhance the performance of results for the 'm' machines flowshop under resources constraints.The competitive memetic algorithm (CMA) for solving the multi-objective distributed permutation flow shop scheduling problem(MODPFSP) with the makespan and total tardiness criteria [11]. Two populations are employed to optimize two different objectives, and the competition among multiple search operators and the knowledge-based local search are performed. Besides, the interaction between the two populations is designed to improve the balance of the two objectives. The influence of the parameters on the performance of the CMA is investigated by using the Taguchi method of design-of-experiment.The five mathematical models namely, a mix-integer programming model (MIP) model, two quadratic MIP formulations, and two constraint programming models for the NP-hard FSS problem were developed under the no-wait conditions with due date constraints and makespan criterion [5]. A novel graph presentation of the problem was developed, and an Efficient algorithm was proposed for solving the problem.For the non-idle permutation flow shop problem (NIPFSP)a memetic algorithm with hybrid node and edge histogram (MANEH) was presented with minimizing the maximum completion time criterion [14]. A modified accelerate NEH approach combines with the hybrid initial method and random initialization to generate favorable solutions. With the implementation of random sample crossover, a hybrid node and edge histogram matrix NEHM was developed, The NEHM was built with the major arrangements in population, and

the sampling was to generate new sequences for it. Then an upgraded general variable neighborhood search technique with the simulated annealing acceptance general variable neighborhood searchwithsimulated annealing (GVNS-SA) was designed, that uses local search in the inner loop and for deciding optimal solutions for the next iterations SA probability was used. The parameters of MANEH were tuned by implementing multi-factor analysis of variance. Amulti-objective iterated local search(MOILS) algorithm for the multi-objective permutation FSP with sequence dependent setup times(SDST) to minimize makespan and total weighted tardiness [8]. A Pareto-based variable depth search was designed for multi-objective local search (LS) to increase the searching ability of MOILS. The LS provides more stability to MOILS for exploring better results and for solving the problem with different sizes. For testing the effectiveness and performance of the proposed algorithm, MOILS was compared with several multi-objectivesevolutionary optimization algorithm's(MOEAs) for the multi-objective permutation FSP.The hybrid discrete artificial bee colony(HDABC)for themulti-objectiveblocking lot-streaming flowshop(BLSFS) scheduling problem that involves in splitting a job into sublots with makespan and earliness time as minimization criteria [15]. The quality of initial population was enhanced by the randomly selected mutation operators, and a self-adaptive learning mechanism was developed to enrich the exploration ability of the algorithm. The proposed algorithm performed well when compared with the other algorithms.For the multi-objective flowshop scheduling problem as a MIP model for the makespan and total tardiness creations was frammed [4]. Then, a novel biogeography- based optimization(BBO) algorithm was developed. The algorithm utilizes various mechanisms like initialization and elitism operator, rate-calculation, migration, and perturbation. For measuring the performance, the BBO was compared with MOGA, non-dominated sorting genetic algorithm(NSGAII) and multi-objective simulated annealing(MOSA) algorithms. Three performance pointers, dominance ranking, hypervolume and binary ϵ indicators were used to analyze the experimental results. The means of statistical tests of ANOVA and LSD were carried out to analyze the results of performances.A fusion approach designed from the amalgamation of decision tree (DT) and scatter search (SS) algorithms to solve the permutation FSP [16]. The DT was used to produce initial solutions that act as an input for the SS algorithm for obtaining optimal solutions for the problem. The entropy function was utilized by DT for the conversion problem into the tree-structured arrangement. The SS gives a broad examination of the search space through broadening areas.A new mathematical model for the permutation FSP with stepwise job objective was purpose. The scheduling issues have limitations like delivery dates and cumulative Payoffs [18]. A constructive heuristic was proposed that based on hybrid iterated local search(ILS), iterated greedy search (IGS) and biased random-key genetic algorithm(BRKGA) along with several methods and heuristics for the hybridization of algorithms. The upper limits were attained by means of relaxation methods. All the algorithms are compared with each other, BRKGA incorporated with FF heuristics outperformed among the existing algorithms with finest solutions in short period of time.The VND is necessary to improve the results when compare to a simple local search in the Insert neighborhood.A hybrid flowshop batch scheduling problem with objectives to minimize the sum of total weighted completion time and total weighted tardiness [20]. The problem consists of various parameters like job release time, capability, and eligibility of processing jobs, machine availability times, stage skipping and learning effect. The two set of hybrid metaheuristics tabu search/path-relinking (TS/PR) and particle search optimization/local search algorithm(PSO/LSA) are proposed. The stage-based interdependency technique for the local search was applied in both metaheuristics. The initial

populations were generated through initial solutionfinding mechanism.Based on the experimental results the PSO/LSA performed better than TS/PR.The target function is to limit a straight mix of total weighted completion time and total weighted tardiness of the jobs. The likelihood of processing jobs having a place with a gathering in numerous groups is precisely examined, when the number of jobs assigned to each batch does not violate desired lower bounds on batch sizes.

Table 1: Summary of applications in MFSP field

Problems	Algorithms	References
Fm|SDST, batch|C_{max}	TS, Neighbourhoodfunctions	Shen and Gupta (2017) [12]
Fm|prmu, r_j|$\sum C_j$	B&B, DDE	Bai et al. (2017) [21]
Fm|SDST|F_{ave}, T	CDRs, GP	Kia et al. (2017) [19]
Fm|SDST|C_{max}, T	GTTS	Zandieh et al. (2016) [23]
FFm|nwt, block|C_{max}	ILR Approach	Fung et al. (2016) [1]
Fm|C_{max}, I_{sum}, W_w	NEH, JA	Guimaraes et al. (2016) [25]
HFm|SDST, M_j|C_{max}	SGA	Costa et al. (2014) [17]
Fm|nwt|C_{max}, F	ACO-SA	Riahi and Kazemi (2016) [26]
Fm|SDST, block|C_{max}, T	TSP-Heuristics	Gupta (1986) [22]
Fm|SDST|C_{max}, F	Heuristics	Han and Dejax (1994) [24]

Table2: Description of notations for the multi-objective problem in terms of α/β/γ

α-field(scheduling style)		β-field(constraints)		γ-field (objectives)	
F	Flow shop	prmu	Permutation	C	Total completion time
J	Job shop	r_j	Non-zero release date	F	Total flow time
O	Open shop	retr	Reentrant	T	Total tardiness
HF	Hybrid flow shop scheduling	prec	Precedence constraints	C_{max}	Maximum completion
RFF	Robotic Flexible Flow Shop	lsm	Lot streaming	L_{max}	Maximum lateness
FF	Flexible flow shop	nwt	No-wait	T_{max}	Maximum tardiness
PM	Identical parallel machine	prmp	Preemption	E_{max}	Maximum earliness
QM	Uniform parallel machine	block	Limited buffers	C_{ave}	Average completion time
		stch	Stochastic	W_w	Total weighted waiting time
				F_{ave}	Average flow time
				I_{sum}	Total machine idle time

3.Difficulties in Optimization Algorithms

As advancements are being made in every optimization algorithm in almost every field they are used, still there stand some challenges to be uplifted.

(i) Termination Condition: Stop criteria at the end of the algorithm will terminate the process and provides the solution reached till then. Now, defining an appropriate condition is important as it affects (and depends) upon

the quality of the solutions required to be generated. In between the steps, also lies some questions, which guide the process forward or revert back in case they don't met the condition. The criteria will also affect the computational time.

(ii)Computational Time: The formulation of results in a reasonable time is a decisive factor in selecting the algorithm. The complexity, number of iterations required and length of algorithm will drive the time factor. Further, the type and speed of processor used will affect the performance of algorithm.

(iv)Diversification: The algorithms must be made more diversified to find their applications in other fields as well. Moreover, algorithms must possess capability to accept dynamic environments.

(v)Over utilization of Objectives: The overuse of similar goals and parameters have confined the advancement of optimization algorithms. This has likewise offered to ascend to the shallowness in the mentality of new scientists not to find some new blends of goal, parameter, and limitations

(vi)Need for more comparative data: It is hard to locate the most optimal algorithm for specific problems as computational examinations made are just with a couple of strategies, rather should be improved the situation all the extensively characterized techniques.

4.Conclusion

The combinatorial problems referred to as NP-hard, have attracted the researchers over long, which has resulted in the application of different optimization algorithms with their various variants in wake of optimal solutions. Various algorithms are discussed namely, GA, COA, ACO, WWO, PSO, BBOand TLBO which has their capability in solving small sized problems to large complex ones. The evolutionary algorithms are mostly used in optimization problems due to their high-quality solutions. With the hybridization of algorithms and through the implementation of local search techniques these algorithms can produce optimal or near to optimal results.These algorithms are broadly utilized as a part of different field of sciences,such as computer, electronics, biology, mathematics etc. and in the various type of industries such as Aerospace, Automotive,Manufacturing, chemical etc. There are a few difficulties that should be overcome to create more powerful and proficient arrangements.

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