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APPLICATIONS OF MULTI-OBJECTIVE OPTIMIZATION ALGORITHMS FOR SCHEDULING: 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:Decision models, Heuristics approach, Multi-objective optimization algorithms, Scheduling

I.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. The algorithms can be coded and executed with optimization software's.The collected relevant data should be well defined before initializing the mathematical computation in the software's. The software used for coding is selected so it is compatible, fast, and reliable with respect to the algorithm. Some frequently used software's are LINGO, MATLAB, CPLEX, GAMS, FORTRAN and languages for coding are java, C, C# and C++.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.

II.LITERATURE REVIEW

A meta-heuristic which is the combination of Branch and Bound (B&B) and Genetic algorithm (GA) for resolving the two-machine FSP problem with makespan and average flowtime criterion was presented [2]. The meta-heuristic utilized the B&B procedure to produce data that shows regardless of whether certain partial schedules, when finished into full ones, will yield optimal results, and this data helps in guiding GA for finding optimal results. The two modified versions of the meta-heuristic were generated and were compared against original B&B, GA, and a heuristic. The first modification involves B&B procedure and dynamic schedule disruption (DSD) operator to interrupt sub-optimal schedules, while the second modifications use only DSD operator to interrupt schedules that located in the worst half of the population. The results validate that the proposed meta-heuristic and its modified versions provide superior results than the compared algorithms.Thehybrid harmony search(HSS) algorithm with job sequence mapping scheme and VNSwas proposed for the PFSP problem aimed at makespan minimization [7].The smallest order value (SOV) was introduced after inspecting the consequence of several job sequence mapping schemes to make the algorithm more appropriate for the PFSP. The NEH heuristic mechanism merging with chaotic sequence were used as initialization scheme, that shooting up the solution's quality of initial harmony memory. For obtaining better results quality and speed-up convergence performance of the algorithm, an opposition-based learning(OBL) technique during the selection process and best individual in harmony memory were adopted. At last, by influencing utilization of VNS, the proficient insert and swap structures are consolidated into the HHS to sufficiently give emphasis to local exploitation capacity. The factual outcomes and examinations in view of Carlier's instance set, Reeves, and Yamada's instance set and in addition Taillard's instance set to validate the superiority of the HHS algorithm for solving PFSP.The two-machine flow shop scheduling problem was addressed where the individual jobs processing times are uncertain and objective to minimize makespan [3]. The problem was formulated as robust scheduling problem were two elective casing works for organizing processing time vulnerability were discussed that is through a set of discrete processing time situations and through a set of

independent processing time intervals. For discrete situations, the Branch and Bound (B&B) algorithm and some heuristic approaches were proposed.A flexible-resource flow shop scheduling (FRFS) problem was examined,where the objectives like job sequence and operation starting time of jobs were determined [1]. A Tabu search (TS) heuristic incorporated with searching strategies was proposed for the FRFS problem. TS heuristic that generates 70% of optimal results for the problem.The multi-objective Genetic algorithm (MBGA) for the bi-objective permutation flow shop scheduling with blocking constraint was proposed [10]. The goal of scheduling was to found optimal Pareto solutions for minimizing the makespan and flow time. Non-Dominated sorting genetic algorithm (NSGA-II) was used for finding locally Pareto-optimal frontiers for the problem and the NEH heuristic was used for generating initial populations. The MBGA was compared against Strength paretoevolutionary algorithm(SPEA-II).An Assembly Flow shop scheduling problem with two-stages was explored. The first stage consists of m independent machines and in the second stage, there are multiple indistinguishable assembly machines toassemble the components [5]. The scheduling problem consists batched delivery system and multi-objectives, where the sum of tardiness and delivery cost has to be minimized. Due to the NP-hard problem, a mix-integer programming (MIP) modelwas proposed. The MIP model wasn't able to find the solutions of large size problems at reasonable time. Then the imperialist competitive algorithm (ICA) and the hybrid imperialist competitive algorithm (HICA) were proposed for solving large-size problems. The relative percentage error(RPE) and wilcoxon signed-rank test were conducted to equate the performance of proposed algorithms ICA and HICA. During the experiment, it was observed that run-time of ICA is less than HICA, but results indicate that the HICA has better performance than the ICA.A permutation flow shop scheduling (PFSP) with makespan criteria was addressed and a hybrid metaheuristic was proposed for the problem [4]. The metaheuristic was designed by the combination of four constructive heuristics: the Nawaz–Enscore–Ham (NEH) heuristic, the CDS heuristic, Palmer's heuristic and Gupta's heuristic along with the company of two metaheuristics: TheGenetic algorithm(GA) and variable neighborhood search (VNS). The designed algorithm was so called as NEH_{VNS}, where the initial population was generated through constructive heuristics and improved via GA. The results demonstrate the effectiveness of the proposed metaheuristic for achieving high-quality solutions.The self-adaptive discrete invasive weed optimization (SaDIWO) to resolve an FSP with blocking under total tardiness minimization criteria was addressed [8]. A constructive heuristic FPDNEH was presented to produce high-quality initial solutions. The FPDNEH heuristic consists a dispatching rule fitting processing times and due dates (FPD) that generate priorities list among jobs, and NEH heuristic insertion procedure was applied to produce final schedules. A self- adaptive insertion-based spatial dispersal was introduced that provide guidance to global and local exploitations. Then, a VNS with speed-up mechanism was inserted to aggrandize the local exploitations. The DOE approach was used to tune the parameters of the proposed algorithm.Several experiments and analyses tests were conducted to validate the performance of the proposed algorithm with state-of-the-art algorithms. The ANOVA approach was used for the analyses purpose.An effective modified migrating bird optimization (EMBO) to minimizing total flowtime for an HFS problemwas presented that hybridized with lot streaming [6].A Permutation-based representation of solutions was employed and introduced shortest waiting time rule (SWT), a new decoding rule that schedules arriving of jobs at various stages for perfectly. The performance modification of MBO algorithm was enhanced by using

several mechanisms and search strategies like a combined neighborhood search strategy was built that bring together two different neighborhood operators, and for increasing the probability of finding better arrangements two competitive mechanisms were presented. The scout phase based on the Glover operator and an all-around planned local search was connected to the individuals caught in local optimums and enables the algorithm to investigate potential promising areas. Taguchi method of Design of experiments (DOE) was applied for setting the parameters of the proposed algorithms and statistical validity of results wereanalyzed by using ANOVA method and was equated with other advanced algorithms.A synchronousflow shop scheduling problem with setup times and additional resources was studied [9]. The problem was NP-hard even for two-machines on account of disjoint job families, infinite resources and equivalent setup times. The complexity results were introduced for the subproblems of finding an ideal resource task for job permutation and for discovering ideal job permutation for resource sequence. Further, two decomposition algorithms were designed for the problem. The job premutation and their equivalent optimal resource tasks were determined by the first decomposition algorithm, whereas the second decomposition algorithm determines resource sequences that minimize setup times and assign jobs to resources. Both the algorithms were evaluated by improved benchmark instances. Additionally, a heuristic for the synchronous FSP without setup times was developed as a by-product of the proposed algorithms. The second decomposition algorithm generates outstanding results for those cases where setup time have a major effect on objective function.A mixed integer linear programming (MILP) model was formulated for the [N-1] (1) + N(m) hybrid flowshop scheduling (HFS) with lot streaming problem to make a schedule that minimizes the makespan [11]. There was one machine in each of the first (N-1) stages and m machines in stage N. The model gives optimal makespan with an optimal number of sub-lots, sub-lot sizes, sub-lot sequence, and job sequence. Although the mathematical model performs well, the computational time for large problems is long and optimum solutions become elusive. Hence, an algorithm was proposed. The percentage deviation (PD) of the objective function value of the algorithm is calculated considering the objective function value of the mathematical model as lower bound. The average percentage deviation (APD) for different small size problem sets is also calculated.

Table 1: Review of Methods in Literature

Ref.	Methodology and Software	Input	Conclusion
[15]	NSG, Microsoft Visual C ++ 6.0	Assembly time, processing time,completion time of process and assembly	Co-operation of global exchange and neigh-borhood search
[13]	Mathematical models along with new Constructive heuristics, CPLEX	Number of jobs and machines,processing anddeparturetime	PBFSP and DBFSP

[14]	MIP model with priority rules, CPLEX	Processing times, due date, job selections	Sequence allocation, mean flow time, tardiness
[12]	I-ICA, GAMS, CPLEX, MATLAB	Travel time, capacity of vehicle, processing time	two integrated models, delivery methods

An Efficient Heuristics for the hybrid flowshopscheduling with missing operations(HFSMO) problem with makespan minimization [16]. Initially, investigation of the HFSMO problem was composed to compare its hardness level with the other traditional HFS problems, that demonstrates the HFSMO problem isn't exactly identical to the other established HFS problems. Furthermore, a number of modification methods, dispatching rules and improvement heuristics were proposed for the problem that were equated with previously existing ones. Through the values of average relative percentage deviation (ARPD) and average computational time (ACT), it was observed that the proposed heuristics are more efficient than the existing ones. The scheduling problem of a permutation flow-shop, which was combined with distributed assembly system known as (DAPFSP) problem was studied [17]. A Backtracking search optimization algorithm (BSA) with a Hyper-heuristic approach called as (BS-HH) algorithm was proposed for minimizing makespan in the problem. The low-level heuristics (LLHs) were designed and implemented in the BS-HH for finding its optimal sequences so that finest solutions can be achieved for the DAPFSP problem. The BS-HH was compared against the state-of-the-art algorithms and the optimality of the solutions was evaluated on the bases of ARPD, Taguchi method and t-test.

III.MULTI-OBJECTIVE OPTIMIZATION ALGORITHMS

In the hypothetical world of research, there are two sorts of problems, to be specified as single objective problems and multiple objective problems.In the scheduling problems,it consists anumber of objectives which has to be minimized for obtaining respectable results for the problems. The objectives like make-span, flow-time, tardiness, lateness, earliness, achieving due dates; decreasing job disruptions, energy consumption, scheduling costs etc.Now, a term called heuristic is characterized as an approach, which makes the on-looking problem easier, gives an answer, which might be correct or an estimated one. Working in reverse i.e. assuming an answer and taking care of the problem is a heuristic. These quicken the way toward achieving an answer and to some degree relies on the experience about the specific problem. All the optimization algorithm are heuristics and some of them are described below.

(i)Genetic Algorithm(GA)

The GA inspired and originated from the natural selection process, it is a meta-heuristic approach to produce high-quality results in order to achieve optimization by using a crossover, inversion, mutation and selection operators. GA is an approach to produce off-springs from the parent population called chromosomes, which consists of a gene. The selection operator selects the fitter chromosomes to reproduce, crossover, interchange

the two chromosomes, mutation, randomly vary the gene values in between chromosomes thus maintaining the diversity in new population and inversion, rearranges the genes in their respective arrayed order.

(ii) Cuckoo Optimization Algorithm (COA)

The COA was inspired by the lifestyle of cuckoo's birds that uses special technique for egg laying and breeding. The cuckoos simply replace their own eggs with the host bird eggs. In the algorithm, there is a habitat area for each individual bird where they can lay their eggs. On the off chance that the eggs survive, they develop and become mature cuckoos. At that point for reproduction purposes, cuckoos move toward best territory, found up to now. The preoccupation happened while pushing toward objective environment influences the populace to look more territory than the case populace moves clear on a line. After some migration, all cuckoo populace assembles a similar territory which is the zone's best position.

(iii) Ant Colony Optimization (ACO)

ACO is based on the ability of ants to find the shortest paths from their nest to food locations using pheromone trails. Thus, ACO algorithms solve the combinatorial optimization problems by mimicking real ants' behavior. Each step in this constructive process is determined by the pheromone trails in real ants. Cooperation between ants depends on the common structure of shared pheromone matrix update principles. General ACO algorithms can gain higher quality solutions but need more computational time.

(iv) Water Wave Optimization (WWO)

The WWO was inspired by the shallow water wave theory. In WWO algorithm, the solution space is equivalent to the seabed area while the depth of seabed depth figures out the fitness of a point in the space. In the population, each wave has two characteristics: wave height h and wave length λ. From the theory of the shallow water wave, if there is shorter distance between the seabed and the wave then the fitness level is higher, the wave length λ become shorter, and the wave height h become higher. The meta-heuristic uses three operators: propagation creates high fitness waves that search small areas and low fitness waves that search large areas. The refraction operator enhances the diversity and thus decreasing premature convergence, and the Breaking operator is for intensively exploiting the local area around a promising point.

(v) Particle Swarm Optimization (PSO)

PSO is based on the observations of the social behaviors of bird flocking. The initial solutions are generated with a randomized velocity and new solutions are gained by competition and corporation between particles. The best previous experience of particles among themselves and best experience of all other members decides optimal solutions. This is similar to human behaviors in making adecision where people consider their own best past experience and the best experience of the other people around them. PSO has quick convergence and easy implementation.

(vi) Biogeography Based Optimization (BBO)

The BBO is a bio-motivated and population-based optimization approach where the virtuousness of the habitat is measured by using (HSI). Suitability index variable (SIV) is used for characterizing the attributes of the natural habitat and expressed as one dimension in a solution. The BBO entails two main operators, migration and mutation. The migration operator distributes information between two existing habitats in order to modify SIV, whereas habitat attributes based on a mutation probability is modified by using mutation operator.

(vii) Teacher Learning Based Optimization (TLBO) The TLBO is a naturally inspired population method, where theclass of learners will represent the population. The best learner in the process is selected as a teacher, as only a teacher is considered with thebest knowledge and then increments the knowledge level of the students known as learners, so as to obtain the good marks. Here, the capability of a teacher to deliver and the quality of the class present also plays an important factor in order to increase the average of the class. There are two phases which constitute the whole process namely, teacher's phase i.e. grabbing knowledge directly from the teacher and learner's phase, which motivates the grabbing knowledge between the learners. In the teacher phase, the teacher approaches to impart all of his knowledge among the class which is impractical in reality. This is because of the difference in the capability of delivering by teacher and that of understanding by the students. The learner phase on the other hand, inputs the knowledge from teaching phase and then further, increases it by interaction among the learners.

IV.CHALLENGES 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.

(iii)Quality of Solution: The quality of solutions produced is always under scrutiny. The algorithms must be modeled, keeping the optimal solutions in mind. The solution generated once, should require minimum optimization.

(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 over use of the same objectives and parameters have restricted the development of optimization algorithms. This has also given rise to the shallowness in mindset of new researchers not to discover some new combinations of objective, parameter and constraints

(vi)Need for more comparative data: It is difficult to find the most optimal algorithm for certain problems as computational comparisons made are only with few methods, rather must be done for all the broadly classified methods. This makes it easy for the new researcher to choose either to modify the less optimal one or choose the best to use with other parameters. The same work won't be repeated with other method.

V.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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