A Scatter Search Method for Fuzzy Job Shop Scheduling Problem with Availability Constraints

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Abstract—**In the last decade job shop scheduling problems have been subject to intensive research due to their multiple applications. Job shop scheduling is known as a strongly NP-complete problem. In the job shop scheduling problems, processing times and due dates are very dynamically due to both human and machine resource factors. Fuzzy sets are used to model the uncertain processing times and due dates in recent years. In this study, a fuzzy job shop scheduling problem with availability constraints is considered. A Scatter Search (SS) method is proposed to solve these problems. The feasibility and effectiveness of the proposed scatter search method is demonstrated by comparing it with the hybrid genetic algorithm (HGA).**

Index Terms—**Fuzzy job shop scheduling problems, availability constraints, scatter search method, hybrid genetic algorithm.**

I. Introduction

In a classical job shop with *m* machines and *n* jobs scheduling problems each job has its own predetermined route to follow and the objective is to minimize the makespan [1]. This problem has received an enormous amount of attention. In a classical job shop scheduling problems, the processing time for each job and due dates are usually assumed to be known exactly, but in many real world applications, processing times and due dates are very dynamically due to both human and machine resource factors.

As a result, in recent years, fuzzy sets are used to model the uncertain processing times and due dates for the job shop scheduling problems in the literature. Some of these studies are given as follow.

Manuscript received March 06, 2011; revised March 21, 2011. This work was supported by the Selcuk University Scientific Research Coordination Centre (BAP).

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Sakawa and Mori [2] proposed an efficient genetic algorithm for job-shop scheduling problems with fuzzy processing time and fuzzy due date. Sakawa and Kubota [3] introduced job shop scheduling problem with fuzzy processing time and fuzzy due date. On the basis of the agreement index of fuzzy due date and fuzzy completion time, multi-objective fuzzy job shop scheduling problems, the authors formulated as three-objective ones which not only maximize the minimum agreement index but also maximize the average agreement index and minimize the maximum fuzzy completion time. Ghrayeb [4] presented bi-criteria genetic algorithm approach to solve fuzzy job shop scheduling problems in which the integral value and the uncertainty of the fuzzy makespan, which are conflicting objectives, are minimized. Fayad and Petrovic [5] proposed a multi-objective genetic algorithm for fuzzy job shop scheduling problem. They used the fuzzy sets to model uncertain due dates and processing times of jobs. They considered the objectives, average tardiness and the number of tardy jobs. Rodriguez et al. [6] presented an evolutionary algorithms fuzzy job-shop problem, a variation of the job-shop problem where the duration of tasks may be uncertain and where due-date constraints are flexible and also Rodriguez et al. [7] considered a job shop problem with uncertain durations and flexible due dates and introduce a multi-objective model based on lexicographical minimization. They used a genetic algorithm and a decoding algorithm to solve the problem. Xie et al. [8] considered an artificial neural network for fuzzy due date's job shop scheduling problem. The performance criterion is to maximize the minimum degree of satisfaction over given job. Li et al. [9] presented a robust procedure to solve multi-objective fuzzy Job Shop scheduling problems with more realistic constraints such as fuzzy processing time, fuzzy due date and alternative machine constraints for jobs. On the basis of the agreement index of fuzzy due date and fuzzy completion time, multi-objective fuzzy Job Shop scheduling problems, the authors have formulated as three-objective ones which not only maximize the minimum agreement index but also maximize the average agreement index and minimize the maximum fuzzy completion time. Kılıç and Kahraman [10] proposed a metaheuristic technique for job shop scheduling problem and a fuzzy ant colony optimization algorithm. Lei [11] presented a multi-objective job shop scheduling problems with fuzzy processing time and due date in such a way to provide the decision-maker with a group of Pareto optimal solutions. Niu et al. [12] proposed a Particle swarm optimization combined with genetic operators for job shop scheduling problem with fuzzy processing time. Lei [13] presented the fuzzy job shop scheduling problem with availability constraints. The objective is to find a schedule that maximizes the minimum agreement index subject to periodic maintenance, non-resumable jobs and fuzzy due-date. Lei [14] considered fuzzy job shop scheduling problem with preventive maintenance with *n* resumable jobs processed on *m* machines and proposed swarm-based neighborhood search to solve the problem. Lei [15] suggested a random key genetic algorithm for fuzzy job shop scheduling problems to maximize the minimum agreement index and to minimize the maximum fuzzy completion time.

Machine availability constraints mean that machines can be unavailable for preventive maintenance, periodic repair or random breakdown [13]. These constraints have been considered in job shop scheduling problems [16]-[13].

In this study, a scatter search method is proposed to solve the fuzzy job shop scheduling problem with availability constraints. The feasibility and effectiveness of the proposed SS method is demonstrated by comparing it with the HGA. The aim of this study is to minimize the tardiness and earliness.

The rest of this paper is organized as follow. Section 2 presents the formulation of the fuzzy job shop scheduling problem with availability constraints. Sections 3 and 4 are devoted to the scatter search method and hybrid genetic algorithms. Section 5 presents experiments and results. Section 6 presents the conclusion and suggestions for future research.

II. Fuzzy job shop scheduling problem

The job shop scheduling problem consists in scheduling a set of jobs $\{J_1, \ldots, J_n\}$ on a set of physical resources or machines $\{M_1, \ldots, M_m\}$, subject to a set of constraints. Each job J_i, $i = 1, \ldots, n$, consists of *m* tasks $\{\theta_{i1}, \ldots, \theta_{im}\}$ to be sequentially scheduled [6]. In the real world applications, exact duration of task is unknown. Consequently the classical job shop scheduling problems are not adequate to deal with this type of situations [6].

Fuzzy sets have become a very popular to solve these types of problems.

In this study, *n* and *m* are represent the number of jobs to be scheduled and the number of machines, respectively; $\tilde{t}_{ij}$ and $\tilde{d}_j$ represent the fuzzy processing times of job *i* on machine *j*, and the fuzzy due date of job *j*, respectively; and $\tilde{T}_j$, and $\tilde{C}_j$ represent the fuzzy tardiness of job *j* and the fuzzy completion time of job *j*, respectively [17].

Fuzzy processing times $\tilde{t}_{ij}$ are modeled by triangular membership functions and represented by a triplet $(t_{ij}^1, t_{ij}^2, t_{ij}^3)$, where t_{ij}^1 and t_{ij}^3 are lower and upper bounds of the processing time and t_{ij}^2 is the most possible processing time. The membership function of a triangular fuzzy processing time is shown in Fig. 1 [18]. The due date $\tilde{d}_j$ of each job is modeled by a trapezoid fuzzy set and represented by a doublet $\left(e_j^1, e_j^2, d_j^1, d_j^2\right)$, where its fuzzy membership function is shown in Fig 2 [17]-[13].

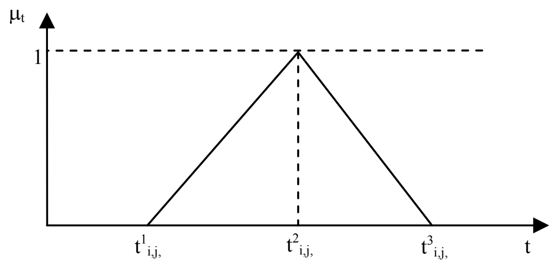

Fig. 1. Fuzzy processing time

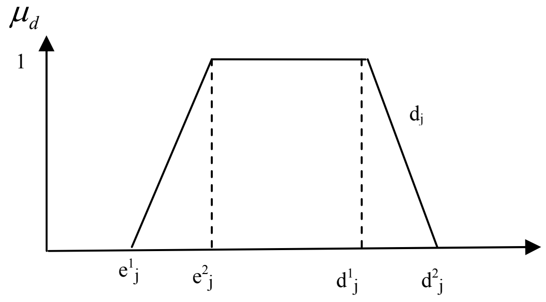

Fig. 2. Fuzzy due date

The completion time of a task is found by adding the task's duration to its starting time. The addition of the two triangular fuzzy numbers $S_j = (s^1_{ij}, s^2_{ij}, s^3_{ij})$ and $tj = (t^1_{ij}, t^2_{ij}, t^3_{ij})$ is shown by the following formula [18].

$$S_j + t_j = (s^1_{ij} + t^1_{ij}, s^2_{ij} + t^2_{ij}, s^3_{ij} + t^3_{ij}) \quad (1)$$

Also the following ranking methods are used in the study.

$$C_1(S) = (s^1_{ij} + 2 s^2_{ij} + s3ij)/4,$$

$$C_2(S) = s^2_{ij} \text{ and } \quad (2)$$

$$C_3(S) = s^3_{ij} - s^1_{ij}$$

In this study, the following objective is considered;
Maximize minimum agreement index;

$$maksZ = AI_{\min} = \min_{i=1....n} AI_i \quad (3)$$

Maximizes the minimum value of Agreement Index (*AI)* of fuzzy completion time $\tilde{C}_j$ with the respect to the fuzzy due date $\tilde{D}_j$ defined as a value area of membership function intersection divided by the area of $\tilde{C}_j$ membership function [2]-[17]. The AI is given as follows;

$$AI(C,D) = \frac{area(D \cap C)}{area(C)} \quad (4)$$

For trapezoid due date $d_j = \left(e_j^1, e_j^2, d_j^1, d_j^2\right)$, if C_j lies in the interval $\left[e_j^2, d_j^1\right]$, the grad of satisfaction is equal to 1.

ISBN: 978-988-19251-4-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

In other cases, the grad of the satisfaction diminishes with the increasing of the tardiness or earliness [13].

During the planning horizon, some maintenance operations occur on each machine. Each maintenance operation has a fixed predefined time interval. If an operation of a job must be reprocessed fully after maintenance operation, the job is *non-resumable* but if an operation of a job may continue its processing after maintenance operation, the job is *resumable* [13]-[16]. In this study, only *resumable* jobs are considered.

We make a number of assumptions about the structure of our fuzzy job shop scheduling problem with availability constraints problems.

- All numerical data (processing time, due dates, maintenance) are positive integers,
- The number of jobs and machines are known and fixed,
- Each operation is processed by only one machine,
- Each machine can be carrying out at most one job at the same time,
- Setup times and remove times are included in the processing times and,
- Operation can be interrupted (resumable) etc.

III. Scatter search method

Scatter search is an evolutionary method that has been successfully applied to combinatorial optimization problems [17]. Scatter search method was first introduced in Glover [19] as a heuristic for integer programming [20]. Scatter search uses a reference set to combine its solutions and construct others. SS generates a reference set from a population of solutions. Then the solutions in this reference set are combined to get starting solutions to run an improvement procedure, whose result may indicate an updating of the reference set and even an updating of the population of solutions [21].

Several scatter search methods have been proposed for solving scheduling problems in the literature. Maenhout and Vanhoucke [22] presented a scatter search algorithm for the nurse scheduling problem. The objective is to minimize the total preference cost of the nurses and the total penalty cost from violations of the soft constraints. Nowicki and Smutnicki [23] proposed the new approximate algorithm, which applies some properties of neighborhoods, refers to the big valley phenomenon, and uses some elements of the scatter search as well as the path relinking technique for flow-shop scheduling problem. Engin, Kahraman and Yılmaz [17] proposed a scatter search method to solve the multi-objective fuzzy flow shop scheduling problem. The objectives are minimizing the average tardiness and the number of tardy jobs.

Tavakkoli-Moghaddam et al. [24] developed a meta-heuristic algorithm based on scatter search for manufacturing cells, in which parts may visit different cells. The objective is to minimize the makespan, intracellular movement, tardiness, and sequence-dependent setup costs, simultaneously.

The proposed SS method consists of five methods [25]. These are;

Diversification-generation method: generates a collection of diverse trial solutions, using an arbitrary trial solution as an input [26].

Improvement method: transforms a trial solution into one or more enhanced trial solutions (Neither the input nor the output solutions are required to be feasible, though the output solutions will usually be expected to be so. If no improvement occurs in the input trial solution, the “enhanced” solution is considered to be the same as the input solution) [17] - [20].

Reference set update method: builds and maintains a reference set consisting of the *b* “best” solutions, organized to provide efficient accessing by the other parts of the method. Solutions gain membership degrees to the reference set according to their quality or their diversity [20].

Subset generation method: operates on the reference set to produce a subset of its solutions as a basis for creating combined solutions [27].

Solution combination method: transforms a given subset of solutions produced by the subset generation method into one or more combined solution vectors [28].

The flow chart of the proposed SS method is presented Fig. 3 [17].

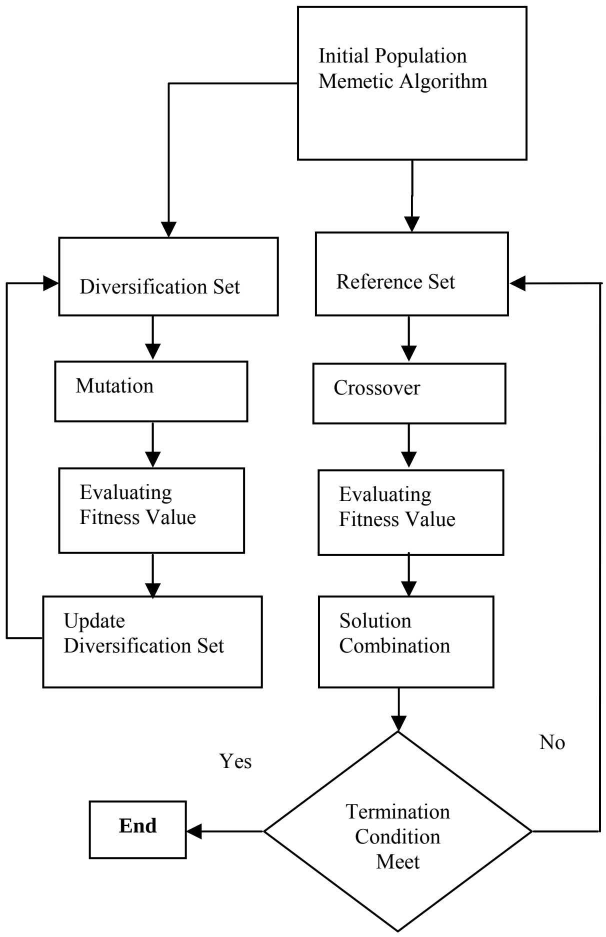

Fig.3. Flow chart of the proposed SS method

In the proposed SS method, the initial population is generated based on a memetic algorithm [29].

ISBN: 978-988-19251-4-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

IV. HYBRID GENETIC ALGORITHM

Genetic Algorithm (GA) was invented by John Holland [30]. GA uses a collection of solutions called population. Each individual in the population is called a chromosome. A chromosome is representing a solution to the problem. The chromosomes can be produced through successive iterations, called generations and the population size remains fixed from generation to generation. The chromosomes are evaluated using the value of the fitness function, during each generation [31]. In this study a hybrid genetic algorithm is used for comparing the performance of the proposed scatter search method. The hybridization can be done in a variety of ways including [32]-[17].

1) Incorporate heuristics into initialization to generate well-adapted initial population. In this way, a hybrid genetic algorithm with elitism can guarantee to do no worse than the conventional heuristic does.
2) Incorporate heuristics into evaluation function to decode chromosomes to schedules.
3) Incorporate local search heuristic as an add-on extra to the basic loop of genetic algorithm, working together with mutation and crossover operators, to perform quick and localized optimization in order to improve offspring before returning it to be evaluated.

We adopt the parameter settings proposed by [17]. The parameters of HGA are given in Table 1.

TABLE I
HGA PARAMETERS [17]

GA Parameter			Value
Initial population			50
Selection operator			Modified elite group technique
	Superior	%50	25
Group Proportion %	Middle	%15	6
	Inferior	%35	14
Crossover operator			Order Crossover
Mutation operator			Inversion mutation
Probability of crossover			0.20
Probability of mutation			0.50
Termination condition			50

V. EXPERIMENTS AND RESULTS

The proposed scatter search method is compared with a HGA [17].

In this study, full factorial design of experiment has been used. The application involves five parameters with different possible values each. These parameters are shown in Table 2 [17].

TABLE II
THE PARAMETERS PROPOSED BY SS FOR FUZZY JOB SHOP SCHEDULING PROBLEM WITH AVAILABILITY CONSTRAINTS

Parameter	**Range**
Initial population size	10, 20, 30, 40, 50
Reference Set Size (Ref Set Size)	0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9
Sub set size	2, 4, 6, 8, 10
Stopping Criterion 1	25, 75, 125, 175, 225, 250
Stopping Criterion 2	25, 75, 125, 175, 225, 250

The best parameter sets for proposed SS are found as shown in Table 3.

TABLE III
THE BEST PARAMETER SET FOR THE PROPOSED SS ALGORITHM

Parameter	**Value**
Initial population size	30
Reference Set size(Ref Set Size)	0.3
Sub set size	6
Stopping Criterion 1	225
Stopping Criterion 2	25

Also, the stopping criterion is selected to be 25 (iteration number) as a constant.

The algorithm was implemented in Borland Delphi and the computational experiments were performed on an Intel i7-720QM with 1.6 (max 2.8) GHz Quad Core processor and 4 GB memory. Four benchmark problems are used. Problems 1, 2 and 3 from [3]- [13] and 4 from [2]- [13] are the problem with 10 jobs and 10 machines. Problems 5 and 6 from [13] are the problem with 15 jobs and 10 machines.

The fuzzy job shop scheduling problem with availability constraints problems are solved by the proposed SS and HGA. The improvement rate is calculated as;

$$improvement\ rate = \frac{SS - HGA}{HGA} \tag{5}$$

The computational results are recorded in Table 4. As it seen in which *average* indicates the average value of the best solutions found in all runs, *best* denote the best solution and *worst* denote the worst solution [13].

TABLE IV
COMPUTATIONAL RESULTS OF HGA AND SS ALGORITHMS.

Problem	Algorithm	*average*	*best*	*worst*
1	HGA	0.39	0.59	0.26
	SS	0.67	0.97	0.51
	Improvement rate	**0.72**	**0.66**	**0.98**
2	HGA	0.35	0.46	0.25
	SS	0.52	0.91	0.39
	Improvement rate	**0.49**	**0.96**	**0.58**
3	HGA	0.42	0.60	0.26
	SS	0.74	0.96	0.54
	Improvement rate	**0.77**	**0.60**	**1.11**
4	HGA	0.55	0.69	0.40
	SS	0.73	0.88	0.59
	Improvement rate	**0.34**	**0.29**	**0.47**
5	HGA	0.21	0.38	0.11
	SS	0.44	0.49	0.40
	Improvement rate	**1.09**	**0.29**	**2.64**
6	HGA	0.14	0.22	0.09
	SS	0.32	0.40	0.27
	Improvement rate	**1.25**	**0.81**	**2.07**

The improvement rates of proposed SS with respect to HGA for agreement index are presented in Table IV. From Table IV, it can be found that the proposed SS obtains the best value of *best*. For all problems, proposed SS has the best *average* value of the objective than HGA. And for all

ISBN: 978-988-19251-4-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

problems proposed SS has the less worst value of the objective than HGA.

VI. Conclusion

In this study, a scatter search method is proposed to solve the fuzzy job shop scheduling problem with availability constraints. Fuzzy processing times are modeled by triangular membership functions and the due date of each job is modeled by a trapezoid fuzzy set. The proposed SS method is compared with a HGA [17]. For all the six problems the proposed SS method is obtained the best value for agreement index. The proposed SS method is a good problem solving technique for fuzzy job shop scheduling problem with availability constraints. For further research, the proposed SS method can be applied to fuzzy job shop scheduling with other constraints problem.

References

[1] M.L. Pinedo, Scheduling Theory, Algorithm, and Systems, Third Edition, Springer, 2008.

[2] M. Sakawa, T. Mori, An efficient genetic algorithm for job-shop scheduling problems with fuzzy processing time and fuzzy due date, Computers & Industrial Engineering 36, 325- 341, 1999.

[3] M. Sakawa, R. Kubota, Fuzzy programming for multi-objective job shop scheduling with fuzzy processing time and fuzzy due date through genetic algorithms, European Journal of Operational Research 120, 393- 407, 2000.

[4] O. A. Ghrayeb, A bi-criteria optimization: minimizing the integral value and spread of the fuzzy makespan of job shop scheduling problems, Applied Soft Computing 2/3F , 197–210, 2003.

[5] C. Fayad, S. Petrovic, A Fuzzy Genetic Algorithm for Real-World Job Shop Scheduling, M. Ali and F. Esposito (Eds.): IEA/AIE , LNAI 3533, pp. 524 – 533, Springer-Verlag Berlin Heidelberg, 2005.

[6] I.G. Rodriguez, C.R. Vela, J. Puente, An Evolutionary Approach to Designing and Solving Fuzzy Job-Shop Problems, J. Mira and J.R. Alvarez (Eds.): IWINAC, LNCS 3562, pp. 74–83, Springer-Verlag Berlin Heidelberg, 2005.

[7] I.G. Rodriguez, J. Puente, C.R. Vela, A Multi-objective Approach to Fuzzy Job Shop Problem Using Genetic Algorithms, D. Borrajo, L. Castillo, and J.M. Corchado (Eds.): CAEPIA , LNAI 4788, pp. 80–89, Springer-Verlag Berlin Heidelberg, 2007.

[8] Y. Xie, J. Xie, J. Li, Fuzzy Due Dates Job Shop Scheduling Problem Based on Neural Network, J. Wang, X. Liao, and Z. Yi (Eds.): ISNN, LNCS 3496, pp. 782.787, Springer-Verlag Berlin Heidelberg, 2005.

[9] F. Li, Y. Zhu, C. Yin, Song, X., Fuzzy Programming for Multiobjective Fuzzy Job Shop Scheduling with Alternative Machines through Genetic Algorithms, L. Wang, K. Chen, and Y.S. Ong (Eds.): ICNC, LNCS 3611, pp. 992 – 1004, Springer-Verlag Berlin Heidelberg, 2005.

[10] S. Kılıç, C. Kahraman, Metaheuristic Techniques for Job Shop Scheduling Problem and a Fuzzy Ant Colony Optimization Algorithm, StudFuzz 201, 401–425, Springer-Verlag Berlin Heidelberg, 2006.

[11] D. Lei, Pareto archive particle swarm optimization for multiobjective fuzzy job shop scheduling problems, Int J Adv Manuf Technol 37:157–165, 2008.

[12] Q. Niu, B. Jiao, X. Gu, Particle swarm optimization combined with genetic operators for job shop scheduling problem with fuzzy processing time, Applied Mathematics and Computation 205 , 148–158, 2008.

[13] D. Lei, Fuzzy job shop scheduling problem with availability constraints, Computers & Industrial Engineering 58, 610–617, 2010.

[14] D. Lei, Scheduling fuzzy job shop with preventive maintenance through swarm-based neighborhood search, Int J Adv Manuf Technol, DOI 10.1007/s00170-010-2989-4, 2010.

[15] D. Lei, Solving fuzzy job shop scheduling problems using random key genetic algorithm, Int J Adv Manuf Technol, 49: 253–262, 2010.

[16] P.H. Mauguiere, J.C. Billaut, J.L. Bouquard, New single machine and job shop scheduling problem with available constraints, Journal of Scheduling, 8, 211- 231, 2005.

[17] O. Engin, C. Kahraman, M.K. Yılmaz, A scatter search method for multiobjective fuzzy permutation flow shop scheduling problem: a real world application, U.K. Chakraborty (Ed.):Comput. Intel. In Flow Shop and Job Shop Sched., SCI 230, PP. 169- 189, 2009.

[18] O. Engin, Ş. Gözen, Parallel machine scheduling problems with fuzzy processing time and fuzzy due date: An application in an engine valve manufacturing process, J of Mult.- Valued Logic and Soft Computing, 15, 107- 123, 2009.

[19] F. Glover, Heuristics for integer programming using surrogate constraints. Decision Sciences 8: 156- 166, 1977.

[20] R. Marti, M. Laguna, F.G. Glover, Principles of scatter search. European Journal of Operational Research 169: 359- 372, 2006.

[21] F. Herrera, M. Lozano, D. Molina, Continuous Scatter Search: An analysis of the integration of some combination methods and improvement strategies. European Journal of Operational Research 169: 450-476, 2006.

[22] B. Maenhout, M. Vanhoucke, New Computational Results for the Nurse Scheduling Problem: A Scatter Search Algorithm, J. Gottlieb and G.R. Raidl (Eds.): EvoCOP 2006, LNCS 3906, pp. 159 – 170, Springer-Verlag Berlin Heidelberg, 2006.

[23] E. Nowicki, C. Smutnicki, Some aspects of scatter search in the flow-shop problem, European Journal of Operational Research 169, 654–666, 2006.

[24] R. Tavakkoli-Moghaddam, N. Javadian A. Khorrami, Y. Gholipour-Kanani, Design of a scatter search method for a novel multi-criteria group scheduling problem in a cellular manufacturing system, Expert Systems with Applications 37, 2661–2669, 2010

[25] C.G.D. Silva, J. Climaco, J. Figueira, A Scatter Search Method for Bi-criteria {0.1}-Knapsack Problems. European Journal of Operational Research 169: 373-391, 2006.

[26] R.A. Russell, W. C. Chiang, Scatter Search for the Vehicle Routing Problem with Time Windows. European Journal of Operational Research 169: 606-622, 2006.

[27] W.N.N. Hung, X. Song, BDD Variable ordering by scatter search. IEEE. 368- 373, 2001.

[28] W.N.N. Hung, X. Song, E.M. Aboulhamid, M.A. Driscol, B.D.D. Minimization by scatter search. IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems 21, 8: 974- 979, 2002.

[29] M A Bajestani, M. Rabbani, A R. Rahimi-Vahed, G. B. Khoshkhou, A multi-objective scatter search for a dynamic cell formation problem. Computers & operations research 36: 777- 794, 2009.

[30] D.E. Goldberg, Genetic Algorithms in Search, Optimization, and Machine Learning, the University of Alabama, Addison Wesley Publishing, 1989.

[31] C. Kahraman, O. Engin, İ. Kaya, M.K. Yılmaz, An application of effective genetic algorithms for solving hybrid flow shop scheduling problems, International Journal of Computational Intelligence Systems, 1, 134- 147, 2008.

[32] Cheng, R., Gen, M., Tsujimura, Y. A tutorial survey of job shop scheduling problem using genetic algorithms Part II hybrid genetic search strategies, Computers and Industrial Engineering 36, 343- 364, 1999.

ISBN: 978-988-19251-4-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)