



Modelling a Novel Multi-Objective Open-Shop Scheduling Problem and Solving by a Scatter Search Method

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Keywords

Open shop scheduling problems,
Tardiness and earliness time,
Makespan, Setup cost, NSGA-II,
Multi-objective scatter search

ABSTRACT

This paper proposes a novel, multi-objective integer programming model for an open-shop scheduling problem (OSSP). Three objectives are to minimize the makespan, total job tardiness and earliness, and total jobs setup cost. Due the complexity to solve such a hard problem, we develop a meta-heuristic algorithm based on multi-objective scatter search (MOSS), and a number of test problems are solved by this proposed algorithm. Finally, to prove its efficiency, the related results are compared with the results obtained by the well-known multi-objective evolutionary algorithm, called NSGA-II. The results confirm the efficiency and the effectiveness of our proposed MOSS to provide good solutions, especially for medium and large-sized problems.

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NP-hard

NSGA-II

NSGA-II

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Min Z_1 () •

Min Z_2 ()

Min Z_3 () •

s. t. •

$Z_1 \geq c(t, k) \quad \forall t, k$ () •

$t(l, k) - c(t, k) + M(1 - a_{ilk}) \geq c(t, l) \quad \forall t, k, l$ () •

$c(j, k) - t(j, k) + M(1 - x_{ijk}) \geq c(t, k) \quad \forall t, j, k$ () •

$a_{ilk} + a_{ikl} = 1 \quad \forall t, k, l$ ()

$x_{ijk} + x_{jik} = 1 \quad \forall t, j, k$ ()

$c(t, k) - t(t, k) \geq 0 \quad \forall t, k$ () $i=\{1, \dots, n\}$: j i

$mc(t) = \max\{c(t, k)\} \quad \forall t, k$ () m $j=\{1, \dots, m\}$: k

$Z_2 = \sum_{i=1}^n \max\{mc(i) - d(i)\}$ ()

$Z_3 = \sum_{k=1}^m \sum_{j=1}^m \sum_{i=1}^m s_i(j, k) x_{ijk}$ ()

() ()

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Max

k i : T_{ik}

Z_1 Z_1

i : d_i

k i : O_{ik}

() ()

Max

j k : $S_i(j, k)$

i k

()

k i : C_{ik}

i : mc_i

() $\left. \begin{matrix} 1 \text{ کار روی ماشین } k \text{ در صورتی که ماشین } i \text{ باشد} \\ 0 \text{ در غیر این صورت} \end{matrix} \right\} a_{ilk}$ ()

() $\left. \begin{matrix} 1 \text{ کار روی ماشین } k \text{ در صورتی که کار روی ماشین } i \text{ باشد} \\ 0 \text{ در غیر این صورت} \end{matrix} \right\} x_{ijk}$ ()

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(3b-7)/2



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$n \quad m \quad m \times n$

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$k \quad i$

1	2			$n \times m$
O_{12}	O_{24}	O_{ik}

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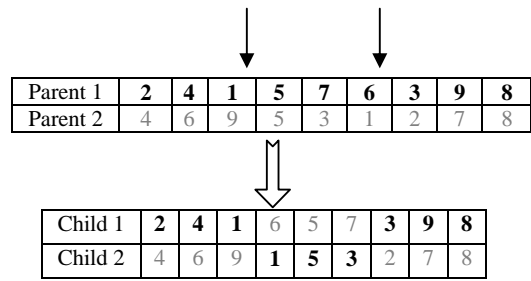
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2	5	3	6	4	1
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4	2	6	3	1	5
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$n \times m$

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4	2	6	3	1	5
1	2	6	3	4	5
5	2	6	3	4	1
2	5	6	3	4	1
2	5	3	6	4	1

(S_1, S_2, S_3)

Refset1 : S_1
 $|b_1-1|$
 Refset2 : S_2
 $|b_2-1|$
 Refset1 : S_3
 Refset2
 Refset1
 Refset2
 b_1

N []

OX []

XP
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Original trial solution 1 : $1 \ 4 \ 7 \mid 2 \ 3 \ 5 \mid 9 \ 8 \ 6$
 Original trial solution 2 : $3 \ 9 \ 5 \mid 2 \ 4 \ 6 \mid 1 \ 7 \ 8$

() Refset2 () Refset1

$|Refset|=b \leq b_1+b_2$ $b_2 \ b_1$
 Refset1
 b_1

New trial solution 1 : $9 \ 8 \ 6 \mid 1 \ 4 \ 7 \mid 2 \ 3 \ 5$
 New trial solution 2 : $1 \ 7 \ 8 \mid 3 \ 9 \ 5 \mid 2 \ 4 \ 6$

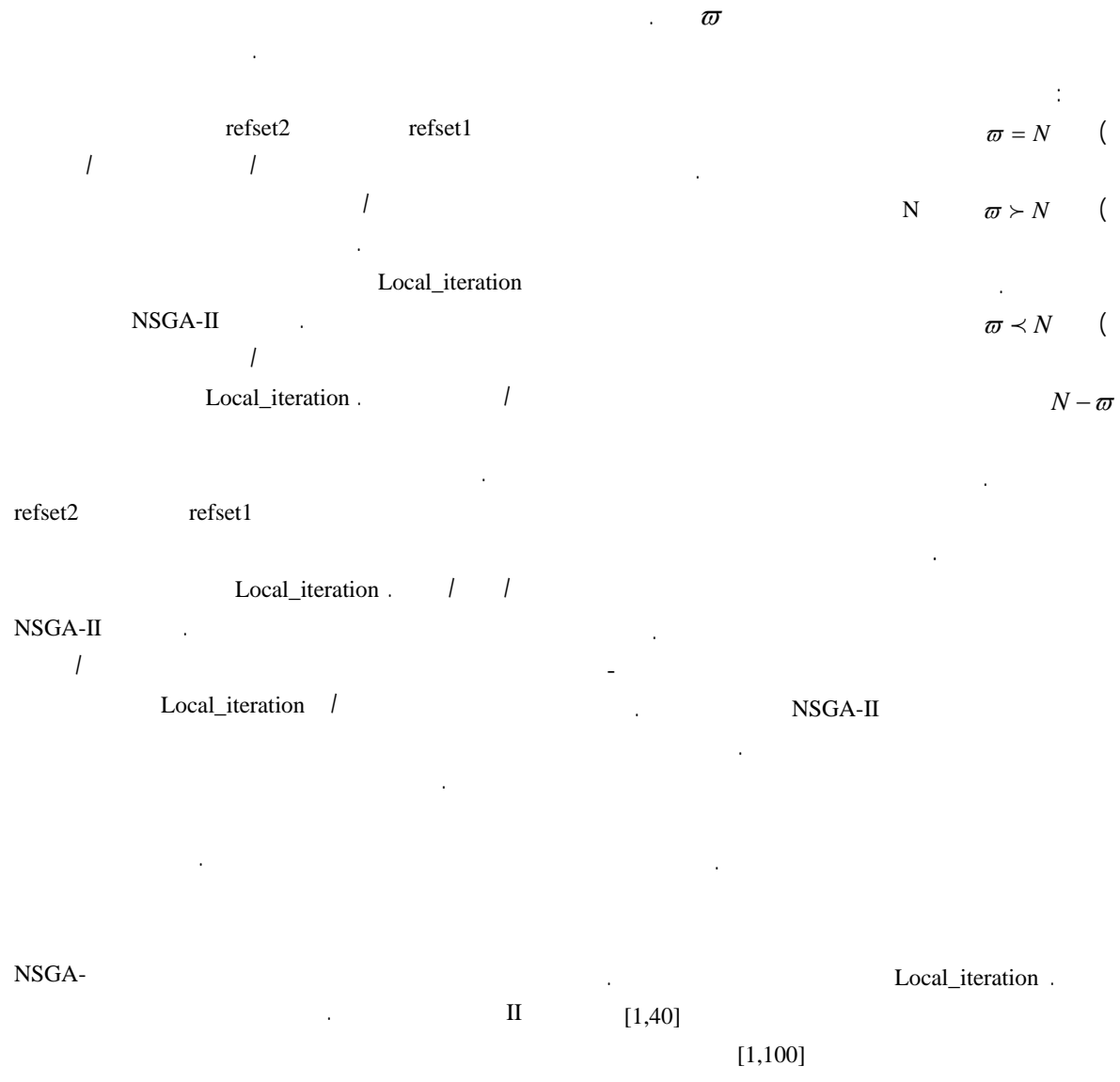
Refset1
 b_1

New trial solution 1 : $9 \ 8 \ 1 \ 7 \ 3 \ 5$
 New trial solution 2 : $1 \ 7 \ 8 \ 9 \ 4 \ 6$

Refset2 b_2 Refset2
 Refset1
 Refset1

$[0.2p_{mean}, 0.3p_{mean}]$
 $[p(1-t-r/2), p(1-t+r/2)]$
 $p_{mean} \quad p=p_{mean}(n+m-1)$
 $t \quad r$
 $t=0.4 \quad r=\{0.2, 0.6\}$

Final trial solution 1 : 9 8 1 2 4 6 7 3 5
 Final trial solution 2 : 1 7 8 2 3 5 9 4 6



() ()

NSGA-II

$t=0.4, r=0.2$

$t=0.4, r=0.6$

MOSS

NSGA-II

MOSS

NSGA-II

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NSGA-II

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NSGA-II

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NSGA-II

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NSGA-II

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$t=0.4, r=0.2$

$t=0.4, r=0.6$

MOSS

NSGA-II

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NSGA-II

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$t=0.4, r=0.2$						$t=0.4, r=0.6$					
MOSS	NSGA-II	MOSS	NSGA-II	MOSS	NSGA-II	MOSS	NSGA-II	MOSS	NSGA-II	MOSS	NSGA-II
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/	/	/	/	/	/	/	/	/	/	/	/
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[1] Sule, D.R., "Industrial Scheduling", PWS Publishing Company, 1997.

[2] Baker, K.R., Trietsch, D., "Principles of Sequencing and Scheduling", John Wiley & Sons, 2009.

[3] Low, C., Yeh, Y., "Genetic Algorithm-Based Heuristics for an Open Shop Scheduling Problem with Setup, Processing, and Removal times Separated", Robotics and Computer-Integrated Manufacturing, Vol. 25, 2009, pp. 314-322.

[4] Sha, D.Y., Hsu, C.Y., "A New Particle Swarm Optimization for the Open Shop Scheduling Problem", Computers & Operations Research, Vol. 35, No. 10, 2008, pp. 3243-3261.

[5] Andresen, M., Bräsel, H., Tusch, J., Werner, F., Willenius, P., "Simulated Annealing and Genetic Algorithms for Minimizing Mean Flowtime in an Open Shop", Mathematical and Computer Modeling, Vol. 48, Nos. 7-8, 2008, pp. 1279-1293.

[6] Chen, R., Huang, W., Tang, G., "Dense Open-Shop Schedules with Release Times", Theoretical Computer Science, Vol. 407, Nos. 1-3, 2008, pp. 389-399.

[7] Low, C., Yeh, Y., "Genetic Algorithm-Based Heuristics for an Open Shop Scheduling Problem with Setup, Processing, and Removal Times Separated" Robotics and Computer-Integrated Manufacturing, Vol. 25, No. 2, 2009, pp. 314-322.

NP-hard

NSGA-II

NSGA-II
NSGA-II

- [22] Glover, F., "A Template for Scatter Search and Path Relinking", Lecture Notes in Computer Science, J. – K. Hao, E. Lutton, E. Ronald, M. Schoenauer and D. Snyers (Eds.), Springer, 1998, pp. 13-54.
- [23] Nowicki, E., Smutnicki, C., "Some Aspects of Scatter Search in the Flow-Shop Problem", European Journal of Operational Research, Vol. 169, 2006, pp. 654–666.
- [24] Diaz, J.A., Fernandez, E., "Hybrid Scatter Search and Path Relinking for the Capacitated p -Median Problem". European Journal of Operational Research, Vol. 169, 2006, 570-585.
- [25] Silva, C.G., Climaco, J., Figueira, J., "A Scatter Search Method for bi-Criteria $\{0,1\}$ -Knapsack Problems", European Journal of Operational Research, Vol. 169, 2006, 373–391.
- [26] Beausoleil, R.P., " "MOSS" Multiobjective Scatter Search Applied to Nonlinear Multiple Criteria Optimization", European Journal of Operational Research, Vol. 169, No. 2, 2006, pp. 426-449.
- [27] Cotta, C., "Scatter Search with Path Relinking for Phylogenetic Inference", European Journal of Operational Research, Vol. 169, 2006, pp. 520-539.
- [28] Rahimi-Vahed, A.R., Javadi, B., Rabbani, M., Tavakoli-Moghaddam, R., "A Multi-Objective Scatter Search for bi-Criteria no-Wait Flow Shop Scheduling Problem", Engineering Optimization, Vol. 40, No. 4, 2008, pp. 331-346.
- [29] Jones, D.F., Mirrazavi, S.K., Tamiz, M., "Multi-Objective Meta-Heuristics: An Overview of the Current State-of-the-Art", European Journal of Operational Research, Vol. 137, 2002, pp. 1–9.
- [8] Blum, C., "Beam-ACO Hybridizing Ant Colony Optimization with Beam Search: An Application to Open Shop Scheduling", Computers & Operations Research, Vol. 32, No. 6, 2005, pp. 1565–1591.
- [9] Liaw, C-F., Cheng, C.-Y., Chen, M., "Scheduling Two-Machine Nowait open Shops to Minimize Makespan", Computers & Operations Research, Vol. 32, No. 4, 2005, pp. 901–917.
- [10] Liaw, C.-F., "An Efficient Tabu Search Approach for the Two-Machine Preemptive Open Shop Scheduling Problem", Computers & Operations Research, Vol. 30, No. 14, 2003, pp. 2081–2095.
- [11] Kononov, A., Sviridenko, M., "A Linear Time Approximation Scheme for Makespan Minimization in an Open Shop with Release Dates", Operations Research Letters, Vol. 30, No. 4, 2002, pp. 276–280.
- [12] Breit, J., Schmidt, G. and Strusevich, V. A., "Two-Machine Open Shop Scheduling with an Availability Constraint", Operations Research Letters, Vol. 29, No. 2, 2001, pp. 65–77.
- [13] Liaw, C-F., "A Hybrid Genetic Algorithm for the Open Shop Scheduling Problem", European Journal of Operational Research, Vol. 124, No. 1, 2000, pp. 28–42.
- [14] Kravchenko, S. A., "On the Complexity of Minimizing the Number of Late jobs in Unit Time Open Shop", Discrete Applied Mathematics, Vol. 100(1-2), 2000, pp. 127—132.
- [15] Liaw, C.-F., "A Tabu Search Algorithm for the Open Shop Scheduling Problem", Computers & Operations Research, Vol. 26, No. 2, 1999, pp. 109–126.
- [16] Liaw, C.-F., "Applying Simulated Annealing to the Open Shop Scheduling Problem", IIE Transactions, Vol. 31, 1999, pp. 457–465.
- [17] Seraj, O., Tavakkoli-Moghaddam, R., "A Tabu Search Method for a New Bi-Objective Open Shop Scheduling Problem by a Fuzzy Multi-Objective Decision Making Approach", International Journal of Engineering, Transactions A: Basics, Vol. 22, 2009, pp. 1-14.
- [18] Gonzalez, T., Sahni, S., "Open Shop Scheduling to Minimize Finish Time", Journal of the ACM, Vol. 23, No. 4, 1976, pp. 665–679.
- [19] Deb, K., Pratap, A., Agarwal, S., Meyarivan, T., "A Fast and Elitist Multi Objective Genetic Algorithm: NSGA-II", IEEE Transactions on Evolutionary Computation, Vol. 6, No. 2, 2002, 182–197.
- [20] Gen, M., Cheng, R., "Genetic Algorithms & Engineering Design", A Wiley Interscience Publication, New York, 1997.
- [21] Hitomi, K., Ham, I., "Operations Scheduling for Group Technology Applications", Annals of the CIRP, Vol. 25, 1976, pp. 419–422.