An efficient firefly algorithm for the flexible job shop scheduling problem

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***Abstract*—This In order to accommodate the production lines to the customer and market requirements, flexible manufacturing has always been considered by researchers in various industries. One of the efficient flexible manufacturing environments is flexible job-shop problem (FJSP), which is an extended derivation of classical job-shop scheduling problem to meet the requirements of modern job-shop. Since in the literature of flexible job shop scheduling problem (FJSP), FJSP is known as an NP-hard problem, two optimization techniques including harmony search (HS) algorithm and firefly algorithm (FA) are adopted for FJSP. At the end, by implementing well-known problems of FJSP, we will study the performance of the proposed algorithms.**

Keywords—Firefly algorithm; Harmony search algorithm; Flexible job shop scheduling problem; Make-span

I. INTRODUCTION

Scheduling a FJSP consists of two sub-problems: assignment and sequencing. Assignment means allocating operations to the machines which has the potential to do these tasks, and then to sequence the assigned operations to the machines. In FJSP, operations could be processed by a set of available machines having the required potential. Since FJSP is an NP-hard problem [1], many heuristic and meta-heuristic algorithms have been proposed and used to schedule it.

In the literature of the FJSP different studies focus on the solving methodologies. Some of these cases are related to the single objective classical FJSP. Proposed Tabu Search (TS) of the Hurink et al. [2], Scrich et al. [3], Mastrolilli and Gambardella [4], biogeography-based optimization algorithm of the Rahamti and Zandieh [5] are some to mention. In addition, some of the works studied multi-objective FJSP. In this class, Kacem et al. [6] proposed a multi-objective FJSP through localization approach.

Moreover, some researches of the FJSP literature have developed the model. In this case, different concepts are inserted in the classical problem of the FJSP problem. For instance, Wang and Yu [7] considered maintenance activities to develop FJSP and Frutos et al. [8] or Fattahi et al. [9] studied operation overlapping in the model of the FJSP.

The remainder of this paper is organized as follows. First of all, developing classical FJSP model is described in Section 2. Two optimization algorithms that are used to solve the proposed problem are presented in Section 3. Finally, to evaluate the two optimization techniques, the sample problem, presented by Brandimarte [10], are implemented. Finally, the performance of the two optimization algorithms will be investigated in Section 4. In Section 5, the concluding remarks and future work are provided.

II. FLEXIBLE JOB SHOP SCHEDULING PROBLEM MODEL

A FJSP is a scheduling model in which n jobs J ($J_i, i \in \{1,2,\cdots,n\}$) are supposed to be processed onm machine M ($M_k, k \in \{1,2,\cdots,m\}$). For each job one or more operationsO_ij,j∈{1,2,⋯,n_i}, (where n_i represents the total number of operations for jobJ_i) can be considered. For each operation of one specific job a predetermined set of capable machines is considered, and each operation (O_{ij}) of that job (J_i) can be processed by one machine out of its set of capable machines (M_{ij}). For jobJ_i ,P_{ijk} denotes the processing time of operation j (O_{ij}) on machinek. Therefore, FJSP has two main goals including assigning of each operation to a suitable machine and determining the sequence of assigned operation on each machine, in order to minimize common objective functions like maximal makespan (Cmax), for more detail, Ho et. al. [11] can be used. Following assumptions are also considered:

- Operations of each job have fixed and predetermined order.
- Jobs have the same priority.
- There is no priority restriction among operations of different jobs.
- Jobs are released at time 0 and machines are available at time 0.
- Move time between operations and setup time of machines are ignored.
- At any specific time only one job can be processed on each machine
- During the process operations can't be broken off.

III. THE PROPOSED ALGORITHM

In this section, different operators of Harmony search (HS) algorithm and Firefly algorithm (FA) were developed to solve the proposed model.

A. Harmony search algorithm (HAS)

Harmony search algorithm is a new population-based optimization technique base on emulates the improvisation process of musicians. This algorithm is based on natural musical performance processes that occur when a musician searches for a better state of harmony.

Initialize HSA parameters

This step is concerned with stetting the main parameters of the HSA which are: Harmony memory size (HMS), Harmony memory consideration rate (HMCR). Pitch adjustment rate (PAR) and the Maximum number of generations (MNG).

Initialization a Harmony Memory (HM)

HM contains a set of solution and its size is equal to the HMS. In this step, HSA randomly creates a set of solutions and then add them to the HM.

Improvise a New Harmony

This step generates (improvises) a new solution from scratch according to HMCR and the PAR values where decision variables of the new solution either are selected from HM or randomly created.

Updating Harmony Memory

This step compares the fitness value of the new generated solution with the worse one in HM. The worse solution in HM will be replaced by the new one if the new one has a better fitness value.

B. Firefly algorithm (FA)

Firefly algorithm is a new swarm intelligence optimization technique base on social behavior of fireflies.FA was developed and introduced by Yang [12].This algorithm is based on this idea that the fireflies produce rhythmic flashes and by flash intensity, fireflies are attracted to each other.

Distance

Where x_i and x_j represent the position of the fireflies i and j; the distance between any two fireflies is the Cartesian distance as Eq.1.

$$r_{ij} = \| x_i - x_j \| = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2} \qquad (1)$$

Attractiveness

Firefly attractiveness is proportional to the light intensity seen by adjacent fireflies, Can be stated as Eq. 2.

$$\beta(r) = \beta_0 e^{-\gamma r^2} \qquad (2)$$

Where β_0 is the initial attractiveness at $r = 0$; and γ is the light absorption coefficient which is fixed during the execution of the algorithm.

Movement

Firefly is absorbed by a more attractive firefly jand moves towards it's as Eq.3.

$$x_i = x_i + \beta_0 e^{-\gamma r^2} (x_i - x_j) + \alpha(rand - \frac{1}{2}) \qquad (3)$$

Where the first term is the now position of a firefly, the second term is used for considering a firefly's attractiveness to light intensity seen by adjacent fireflies, The second term is used due to the attractiveness of fireflies to light intensity seen by adjacent fireflies. And the third term is used due to the random movement of a firefly. The coefficient α is a randomization parameter determined by the problem of interest, while rand is a random number generator uniformly distributed in the space [0, 1].

IV. COMPUTATIONAL RESULTS

In this section, the two introduced algorithms are implemented to solve FJSP. To do so, they are programmed in Matlab2009. Then, the results of the obtained solutions of algorithms are summarized in Table 1. The implemented problems of this evaluation are taken from the famous library of the Brandimarte [10]. This library includes ten problems from different sizes.

As the row material data shows firefly presents a better performance in one by one and non-statistical comparison. This result can be also seen in Fig.1.

Of course, this difference is not considerable statistically. To approve this claim the *Mann-Whitney* non-parametric test is implemented. The results of this test are reported in Fig.2 and Fig. 3.

TABLE I. THE OUTPUTS OF THE ALGORITHMS ON BRANDIMARTE LIBRARY

Problem Name	HS	Firefly
mk01	51	57
mk02	45	45
mk03	285	268
mk04	88	89
mk05	212	206
mk06	150	142
mk07	227	223
mk08	608	589
mk09	515	485
mk10	446	406

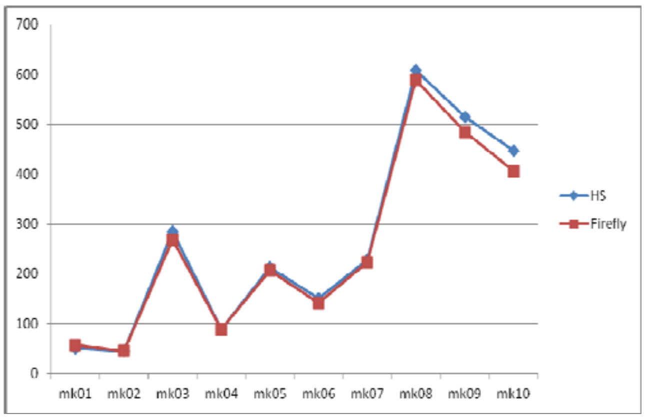

Fig.1. The comparison of the algorithms.

V. CONCLUSION AND FUTURE WORK

In this paper, two new developed meta-heuristic algorithms, called harmony search and firefly, is introduced to the environment of the scheduling problems. The selected scheduling problem is FJSP problem. Then, these algorithms are implemented on the benchmark examples of the literature. The obtained results are compared with each other through statistical methods. This comparison proves the high suitability of the firefly algorithm for the FJSP. The future work of this research can be the muit-objective version of the firefly or the fuzzy version of that.

Source	SS	df	MS	Chi-sq	Prob>Chi-sq
Groups	1.25	1	1.25	0.04	0.8501
Error	663.25	18	36.8472		
Total	664.5	19			

Fig.2. The Mann-Whitney test table.

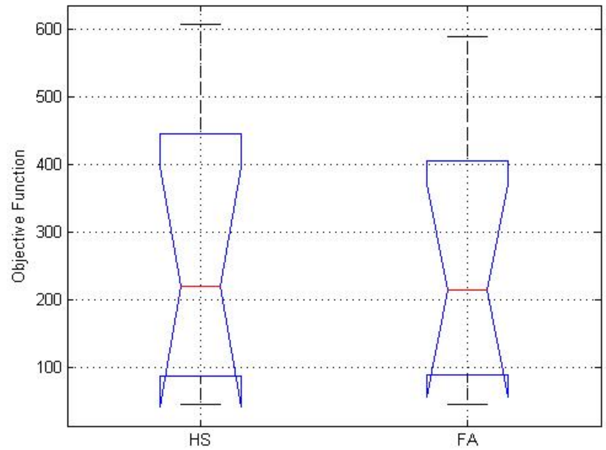

Fig.3. The box-plot of the comparison test.

REFERENCES

[1] S.H.A. Rahmati, M. Zandieh, M.Yazdani, "Developing two multi-objective evolutionary algorithms for the multi-objective flexible job shop scheduling problem," International Journal of Advance Manufacturing Technology, 64, 915-932,2013.

[2] J. Hurink, B. Jurisch, M. Thole, "Tabu search for the job shop scheduling problem with multi-purpose machine," Operations Research Spektrum, 15 (4), 205–215, 1994.

[3] C.R. Scrich, V.A. Armentano, M. Laguna,. "Tardiness minimization in a flexible job shop: a tabu search approach," International Journal of Advance Manufacturing Technology 15(1), 103–115,2004.

[4] M.M.L.M. Gambardella, M. Mastrolilli, "Effective neighborhood functions for the flexible job shop problem," Journal of Scheduling 3(1), 3–20,2000.

[5] S.H.A. Rahmati, M. Zandieh, "A new biogeography-based optimization (BBO) algorithm for the flexible job shop scheduling problem," International Journal of Advance Manufacturing Technology, 58, 1115-1129, 2012.

[6] I. Kacem, S. Hammadi, P. Borne, "Approach by localization multi-objective evolutionary optimization for flexible job-shops scheduling problems," IEEE Transactions on Systems, Man and Cybernetics Part C: Applications and Reviews, 32 (1), 1–13,2002.

[7] S. Wang, J. Yu, "An effective heuristic for flexible job-shop scheduling problem with maintenance activities," Computers & Industrial Engineering, 59: 436-447, 2010.

[8] M. Frutos, C.Ana, and F. Tohmé, "A memetic algorithm based on a NSGAII scheme for the flexible job-shop scheduling problem,", Annual Operation Research, 181, 745-765, 2010.

[9] P. Fattahi, F. Jolai, and J. Arkat,. "Flexible job shop scheduling with overlapping in operations," Applied Mathematical Modeling, 33, 3076–3087, 2009.

[10] P. Brandimarte, "Routing and scheduling in a flexible job shop by Tabu search,"Annual Operation Research, 41, 157–183, 1993.

[11] N.B. Ho, J.C. Tay, E.M.K. Lai, "An effective architecture for learning and evolving flexible job-shop schedules," European Journal of Operational Research 179, 316–333, 2007.

[12] X.S. Yang, "Firefly algorithms for multimodal optimization," in: Stochastic Algorithms: Foundations and Applications, SAGA, 5792, LectureNotes in Computer Sciences, 169–178,2009.