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Research Paper

Hybrid Ant Colony Optimization-Genetics Algorithm to Minimize Makespan Flow Shop Scheduling

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Abstract

Flow shop scheduling is a scheduling model in which the job to be processed entirely flows in the same product direction / path. In other words, jobs have routing work together. Scheduling problems often arise if there is n jobs to be processed on the machine m, which must be specified which must be done first and how to allocate jobs on the machine to obtain a scheduled production process. In research of Zini, H and ElBernoussi, S. (2016) NEH Heuristic and Stochastic Greedy Heuristic (SG) algorithms. This paper presents modified harmony search (HS) for flow shop scheduling problems with the aim of minimizing the maximum completion time of all jobs (makespan). To validate the proposed algorithm this computational test was performed using a sample dataset of 60 from the Taillard Benchmark. The HS algorithm is compared with two constructive heuristics of the literature namely the NEH heuristic and stochastic greedy heuristic (SG). The experimental results were obtained on average for the dataset size of 20 x 5 to 50 x 10, that the ACO-GA algorithm has a smaller makespan than the other two algorithms, but for large-size datasets the ACO-GA algorithm has a greater makespan of both algorithms with difference of 1.4 units of time.

Keywords : *Flow shop scheduling, Ant Colony Optimization Algorithm (ACO), Genetics and Hybrids*

1. Introduction

A major contributor in the development of competitive markets is manufacturing companies. The problem that many companies encounter in manufacturing is scheduling, where to maintain efficiency and productivity, manufacturing companies require good production scheduling. Scheduling is the allocation of resources to activities from time to time that are considered as the main tasks undertaken to improve the productivity of the company. Companies are always required to maintain efficiency by lowering production costs with short processing times, requiring a good scheduling system by sequencing optimized workmanship based on certain criteria[1]–[4].
Flow shop scheduling is a scheduling model where jobs that will be processed entirely flow in the same product direction/path[5], [6]. In other words, the job has a cooperative routing. Scheduling problems often arise if there is n jobs to be processed on the machine m, which must be specified which must be done first and how to allocate jobs on the machine to obtain a scheduled production process[7]–[11].
In a flow shop scheduling model a manufacturing process often has to pass many operations requiring different types of machines in each operation. If the route that must be passed for each job is the same, then this form of configuration is also called the flow shop model. The machines in this model are arranged in series and when a job is finished processing on one machine, the job will leave the machine to then fill the queue on the next machine for processing[12]–[14].
Flow shop scheduling plays an important role to get the most optimal solution on the performance of the company's production system, where the purpose of flowshop scheduling is to minimize the time of completion of the job (make span) and prevent tardiness which is the delay of completion of a job[15]–[17].
Shabtay, 2012[18] research was conducted to minimize makespan in flow shop problem by using Johnson algorithm. This algorithm performs an analytical approach used to solve n-jobs with 2-machine problems. In this study the algorithm presented is based on converting engine problems to 2-machine problems. Based on testing and comparison with other relevant methods[19], [20], the proposed algorithm is offered as a competitive alternative to practical applications when solving n-jobs problems with m-machines.
Rajendran and Ziegler (2013)[21] research was conducted to minimize the makepan in the flow shop problem using the ACO algorithm and the M-MMAS algorithm which is an additional version of the ACO algorithm. The second algorithm called PACO is newly developed in this study. The effectiveness of the ACO algorithm is evaluated taking into account the benchmark problem and the upper limit value for make span, which is given by Taillard. The results of the performance experiments show that the ACO algorithm is superior to heuristics for 83 of 90 problems.
Research conducted by Ta, 2015[22] is done determining the production schedule, batch of work and delivery routes for each group, so the number of delays can be minimized. The heuristic algorithm is proposed and evaluated on a set of random data. The results of computational testing performed where the first result shows that Tabu Search greatly improve the initial solution given Greedy Algorithm.
Genetic algorithm hybridization with Ant Colony Optimization Algorithm to complete the proposed TSP and then evaluated with some data, both random data and sample data from the TSP library[3], [23]. The GA evolution process along with the ant colo-

ny's instinct in finding the shortest route to finding food is fully combined and formulated as a new optimization method called GACO. Experimental studies show that with little data, it shows no significant. But on big data, it can improve performance both in GA and ACO. In this case, the solution of the proposed hybridization method has increased significantly. However, since this only focuses on how to combine GA and ACO procedurally, some parameters from both sides must be optimally set for better results and performance in the future[24].

Verma, 2015 studies with NEH Heuristic and Stochastic Greedy Heuristic (SG) algorithms were obtained to process datasets from the Taillard Benchmarks problem as samples of 50 × 10 and 100 × 10 data, the results showed that the Harmony Search algorithm HS) has an average deviation of 2.34% and 1.03% and 5.07% respectively and 2.21% for the NEH Heuristic algorithm which is considered too high for flow shop scheduling[25].

Based on the background and research above, the authors conducted this thesis research with the title of ACO-GA Hybrid Algorithm To Minimize Makespan Flowshop Scheduling.

2. Methodology

The work methodology carried out in this research is as follows:

a. Input flow shop dataset.
b. Initialize ACO parameters.
c. The calculation of make span time on each Job (ant) (Genetic algorithm).
d. Calculation of the change of probability of ant trace intensity between nodes.
e. Calculation of ant trek intensity updates between nodes for the next cycle.
f. If the stop is met or the maximum number of iterations is done, take the job/operation sequence that has the smallest makespan time, otherwise return to step 2.
g. Show the optimal process sequence as a result of scheduling

3. Results and Discussion

The determination of make span time is done by genetic algorithm with the following steps:

a. Population Initialization

Chromosome representation on flow shop scheduling with encoding process is as follows:

1) Determine the job-job as well as the machine to be used.
2) Set the process time of each job on each machine.
3) Determine the order of the job process to 1 to n.

Suppose chromosome 1 job to 1 on machine-1 to machine 3 with time machine-1 = 70, machine-2 = 60, machine-3 = 50 is as follows: K-1: 1.1 1.2 1.3 180

Chromosome 2nd job to 2 on machine 1 to machine 3 with time machine 1 = 30, machine-2 = 20, machine-3 = 40 is as follows: K-2: 2.1 2.2 2.3 90

3rd job chromosome 3 on machine 1 to machine 3 with time machine 1 = 30, machine-2 = 20, machine-3 = 50 is as follows: K-3: 3.1 3.2 3.3 100

4th job chromosome 4 on machine-1 to machine 3 with machine time -1 = 65, machine-2 = 40, machine -3 = 55 is as follows: K-4: 4.1 4.2 4.3 160

For the next chromosome is done with crosslinking (crossover).

b. Crossover

If the selection process has been implemented and the new parent has been selected, then the next stage of the genetic algorithm operator is crossover. Crossover is a way to combine parent genes to produce new offspring. The crossover used in this study is a two point crossover. In this crossover is done by swapping the gene values at the same gene position of the two parent. The following are the steps of the crossover process:

1) Crossover between chromosomes on Parent 1 is chromosome 1 with chromosome 2 by exchanging randomly selected gene values:

K-1: 1.1 1.2 1.3 with 180 makespan value
K-2: 2.1 2.2 2.3 with a makespan value of 90
Chromosome 1 Parent 1 with Chromosome 2 Parent 1 in positions 1 and 3:

Table.1. Two Point Crossover Simulation

1.1	1.2	1.3
2.1	2.2	2.3

And the following is the result of the crossover generation process of two parent individuals:

Children 1 Parent 1

2.1	1.2	2.3

Makespan = 30 + 60 + 50 = 140

Children 2 Parent 1

1.1	2.2	1.3

Makespan = 70 + 20 + 50 = 140

2) The chromosome crossover process of two individual parent-3 with parent-4 by exchanging gene values:

K-3: 3.1 3.2 3.3 with 100 makespan value
K-4: 4.1 4.2 4.3 with a makespan value of 160
Chromosome 1 Parent 2 with 2nd Parent Chromosome 2 in positions 1 and 3:

3.1	3.2	3.3
4.1	4.2	4.3

And the following is the result of generation crossover process from parent 2:

Children 1 Parent 2

4.1	3.2	4.3

Makespan = 65 + 20 + 55 = 140
Children 2 Parent 2

And the following is the result of generation crossover process from parent 2:

Children 1 Parent 2

4.1	3.2	4.3

Makespan = 65 + 20 + 55 = 140
Children 2 Parent 2

3.1	4.2	3.3

Makespan = 30 + 40 + 50 = 120

3) Mutation

The mutation process is performed using reciprocal exchange mutation method using random number (Pm). The mutated chromosome as much as the value of the mutation probability of 10% is randomly selected. The process of mutation is done by swapping two genes without the help of another chromosome to avoid the stuck condition. In this case it is done by selecting one of the genes randomly i.e. genes with penalty value 1 then the value of the selected gene is randomized to the value of its final range, the number of genes 3 with the random value between 1 and 3 and the chosen number 2.65, then the number the random is 3. For example the selected chromosome is as in table below

2.1	1.2	2.3

Makespan = 30 + 60 + 50 = 140

Furthermore, on the chromosome mutations in gene number 3, where the value of genes randomly selected between 1.1 to 3.3 and selected value of 1.13. The mutated chromosome is obtained as in table below.

2.1	1.2	1.1

Makespan = 30 + 20 + 70 = 120

The resulting chromosome of mutation in table above obtained a Makespan value of 120, this result is better before mutation.

4) Termination

Termination is the process of repeating the initial step of population initialization for chromosome formation according to genetic parameters. Furthermore, the chromosomes are formed sequences of scheduling process that will be processed further with the ACO algorithm. The results of genetic process of flow shop scheduling can be seen as in Table 2.

Table.2. Chromosomal Population First Generation Genetic Process Results

Kr/Gen	Gen-1	Gen-2	Gen-3	*Make span*
Kromosom-1	2.1	1.2	1.1	160
Kromosom-2	1.1	2.2	1.3	140
Kromosom-3	4.1	3.2	4.3	140
Kromosom-4	3.1	4.2	3.3	120

Data processed by ACO is a process scheduling matrix Flow Shop process of genetic process with 4 jobs on 3 machines with different time. The initialization result of the flow shop scheduling population to be processed with ACO algorithm can be seen below.

Suppose chromosome 1 job to 1 on machine-1 to machine 3 with time machine-1 = 70, machine-2 = 60, machine-3 = 50 is as follows:
1.1 = 70, 1.2 = 60, 1.3 = 50

Chromosome 2nd job to 2 on machine 1 to machine 3 with time machine 1 = 30, machine-2 = 20, machine-3 = 40 is as follows:
2.1 = 30.2.2 = 20.2.3 = 40

3rd job chromosome 3 on machine 1 to machine 3 with time machine 1 = 30, machine-2 = 20, machine-3 = 50 is as follows:
3.1 = 30.3.2 = 20.3.3 = 50

4th job chromosome 4 on machine-1 to machine 3 with machine time -1 = 65, machine-2 = 40, machine -3 = 55 is as follows:
4.1 = 65.4.2 = 40.4.3 = 55

From explanation above, can be seen the sequence of Job process in the form of chromosomes are:

Chromosome-1:
Job-2 → machine-1 (30)
Job-1 → machine-2 (60)
Job-1 → machine-1 (70) makespan = 160

Chromosome-2:
Job-1 → machine-1 (70)
Job-2 → machine-2 (20)
Job-1 → machine-3 (50), makespan = 140

Chromosome-3:
Job-4 → machine-1 (65)
Job-3 → machine-2 (20)
Job-4 → machine-3 (55) makespan = 140

Chromosome-4:
Job-3 → machine-1 (30)
Job-4 → machine-2 (40)
Job-3 → machine-3 (50) makespan = 120

Table.3. Distance between Points (d_{ij}) on Graf G Chromosome

Point	M-1	M-2	M-3
J-1	70	60	-
J-2	30	-	40
J-3	30	20	50
J-4	65	40	55

Information:
Gen-11: Job-1 Machine-1
Gen-12: Job-1 Machine-2
Gen-13: Job-1 Machine-3
Gen-21: Job-2 Machine-1
Gen-22: Job-2 Machine-2
Gen-23: Job-2 Machine-3
Gen-31: Job-3 Machine-1
Gen-32: Job-3 Machine-2
Gen-33: Job-3 Machine-3
Gen-41: Job-3 Machine-1
Gen-42: Job-3 Machine-2
Gen-43: Job-3 Machine-3

1. Initialize the price of ant algorithm parameters:

a. τ_{ij} = 0,01
b. q_0 = 1
c. α = 1.0
d. β = 1.0
e. m = 4
f. ρ = 0,5
g. $NCmax$ = 2

There is one rule in determining the value of parameters in the ant algorithm as described previously α and β values must be greater or equal to 0 while the value of ρ must be between 0 and 1. From the graph given can be obtained the distance between points (dij). Table 4 below will show the value of dij.

Table.4. Flow Shop Scheduling Matrix

Point	M-1	M-2	M-3
J-1	70	60	-
J-2	30	-	40
J-3	30	20	50
J-4	65	40	55

The visibility (ηij) between the points represented will be $\frac{1}{d_{ij}}$ shown by Table 5 below.

Table.5. Inter-Point Visibility (ηij) in Graph G

Point	M1	M2	M3
J1	1/70	1/60	-
J2	1/30	-	1/40
J3	1/30	1/20	1/50
J4	1/65	1/40	1/55

Table.6. Visibility Value between Points (ηij) in Graph G

Point	M1	M2	M3
J1	0.014	0.016	-
J2	0.033	-	0.025
J3	0.033	0.050	0.020
J4	0.015	0.025	0.018

The intensity of the inter-pheromone (τij) will be shown by Table 7 below:

Table.7. Inter-Point Pheromones on Graph G

Point	M1	M2	M3
J1	0,01	0,01	-
J2	0,01	-	0,01
J3	0,01	0,01	0,01
J4	0,01	0,01	0,01

The value of the visibility parameter (η) and the intensity of the pheromone (τ) is later used in the probability equation and is the parameter affecting the ants in the next point selection (transition rule). Search for next destination node with probability calculation:
a. Probability for Chromosome-1 = 2.1 1.2 1.1
Cycle -1:
Initial Tabu Contents:
2.1 1.2 1.1
For t = 1
Number of ants per node =
M-1 = 1
M-2 = 1
M-3 = 1
1st Ant:
- Tabu list = 2.1
- The probability of node 2.1 to each of the following nodes is:
= (0.01 * 0.033) + (0.01 * 0.016) + (0.01 * 0.014)
= 0.00063
Thus we can calculate the probability of node 2.1 to each node as follows:
Point 2.1 = 0
Point 1.2 = (0.01) 1.00. (0.016) 1.00 / 0.00063 = 0.253
Point 1.1 = (0.01) 1.00. (0.014) 1.00 / 0.00063 = 0.222
The results of makespan for cycle 1 are as in Table 3.9.

Table.8. ACO Results Cycle 1

Ant	Kromosom	*Make spane*
1	2.1 1.1	100
2	1.1 2.2	90
3	4.1 4.3	120
4	3.1 4.2	70

From Table 8 can be obtained chromosome with the smallest make-up value on Chromosome-4 is 70. Next result of ACO conjecture is included in Table 8.

Table.9. Value of Chromosome Make Span (job)

Kr	Node-1	Node-2	Node-3	Make span
1	2.1	1.2	1.1	100
2	1.1	2.2	1.3	90
3	4.1	3.2	4.3	120
4	3.1	4.2	3.3	70

From Table 9, it can be seen that chromosome-4 (Job-4) has the smallest make span. Then the calculation will continue until the ant has completed its journey to visit each node. This will be repeated until it matches the defined Ncmax or has converged.

4. Conclusion

In this research we have analyzed the performance of hybrid algorithm Ant Colony Optimization (ACO) with Genetics to minimize the makespan of Flowshop scheduling, where the processed dataset is from E. Taillard Benchmarks for basic scheduling problems. The comparative algorithm used is NEH Heuristic and Stochastic Greedy Heuristic (SG) algorithm in Zini H and ElBernoussi, S. (2016). The results obtained by the performance on the overall size of the ACO-GA dataset algorithm resulted in smaller makespan than the above two algorithms except for a dataset greater than 100 x 50.

References

[1] H. Bräsel, A. Herms, M. Mörig, T. Tautenhahn, J. Tusch, and F. Werner, “Heuristic constructive algorithms for open shop scheduling to minimize mean flow time,” *Eur. J. Oper. Res.*, vol. 189, no. 3, pp. 856–870, 2008.

[2] M. Nejati, I. Mahdavi, R. Hassanzadeh, N. Mahdavi-Amiri, and M. Mojarad, “Multi-job lot streaming to minimize the weighted completion time in a hybrid flow shop scheduling problem with work shift constraint,” *Int. J. Adv. Manuf. Technol.*, vol. 70, no. 1–4, pp. 501–514, 2014.

[3] K. Kouser and A. Priyam, “Feature selection using genetic algorithm for clustering high dimensional data,” *Int. J. Eng. Technol.*, vol. 7, no. 2, pp. 27–30, 2018.

[4] R. Rahim, I. Zulkarnain, and H. Jaya, “Double hashing technique in closed hashing search process,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 237, no. 1, p. 12027, Sep. 2017.

[5] R. H. Ahmadi and U. Bagchi, “Improved lower bounds for minimizing the sum of completion times of n jobs over m machines in a flow shop,” *Eur. J. Oper. Res.*, vol. 44, no. 3, pp. 331–336, 1990.

[6] I. Ribas, R. Companys, and X. Tort-Martorell, “Efficient heuristics for the parallel blocking flow shop scheduling problem,” *Expert Syst. Appl.*, vol. 74, pp. 41–54, 2017.

[7] S. Agrawal., A. Gautam, D. K. Chauhan, L. M. Tiwari, and S. Kapoor, “A flow shop scheduling problem with transportation time and separated setup time of jobs,” in *Procedia Engineering*, 2012, vol. 38, pp. 1327–1332.

[8] X. Zhang and S. Van De Velde, “Approximation algorithms for the parallel flow shop problem,” *Eur. J. Oper. Res.*, vol. 216, no. 3, pp. 544–552, 2012.

[9] A. S. Ahmar *et al.*, “Modeling Data Containing Outliers using ARIMA Additive Outlier (ARIMA-AO),” *J. Phys. Conf. Ser.*, vol. 954, no. 1, 2018.

[10] B. Nair B J and R. Reghunath, “Coding and functional defect region prediction of placental protein in an embryo cell of first trimester using ANN approach,” *Int. J. Eng. Technol.*, vol. 7, no. 1–9, p. 167, Mar. 2018.

[11] U. Khair, H. Fahmi, S. Al Hakim, and R. Rahim, “Forecasting Error Calculation with Mean Absolute Deviation and Mean Absolute Percentage Error,” *J. Phys. Conf. Ser.*, vol. 930, no. 1, p. 12002, Dec. 2017.

[12] D. R Vora and K. Iyer, “EDM – survey of performance factors and algorithms applied,” *Int. J. Eng. Technol.*, vol. 7, no. 2–6, p. 93, Mar. 2018.

[13] C. Saranya Jothi, V. Usha, and R. Nithya, “Particle swarm optimization to produce optimal solution,” *Int. J. Eng. Technol.*, vol. 7, no. 1.7 Special Issue 7, pp. 210–216, 2018.

[14] R. Rahim, Nurjamiyah, and A. R. Dewi, “Data Collision Prevention with Overflow Hashing Technique in Closed Hash Searching Process,” *J. Phys. Conf. Ser.*, vol. 930, no. 1, p. 12012, Dec. 2017.

[15] W. Yu, Z. Liu, L. Wang, and T. Fan, “Routing open shop and flow shop scheduling problems,” *Eur. J. Oper. Res.*, vol. 213, no. 1, pp. 24–36, 2011.

[16] C. M. V. S. Prasad, K. R. Rao, D. S. Kumar, and A. V. Prabhu, “Performance evaluation of power optimization in wireless sensor networks using particle swarm optimization,” *Int. J. Eng. Technol.*, vol. 7, pp. 404–408, 2018.

[17] R. Rahim, I. Zulkarnain, and H. Jaya, “A review: search visualization with Knuth Morris Pratt algorithm,” in *IOP Conference Series: Materials Science and Engineering*, 2017, vol. 237, no. 1, p. 12026.

[18] D. Shabtay, “The just-in-time scheduling problem in a flow-shop scheduling system,” *Eur. J. Oper. Res.*, vol. 216, no. 3, pp. 521–532, 2012.

[19] R. Rahim, S. Nurarif, M. Ramadhan, S. Aisyah, and W. Purba, “Comparison Searching Process of Linear, Binary and Interpolation Algorithm,” *J. Phys. Conf. Ser.*, vol. 930, no. 1, p. 12007, Dec. 2017.

[20] D. Abdullah, R. Rahim, D. Apdilah, S. Efendi, T. Tulus, and S. Suwilo, “Prime Numbers Comparison using Sieve of Eratosthenes and Sieve of Sundaram Algorithm,” in *Journal of Physics: Conference Series*, 2018, vol. 978, no. 1, p. 12123.

[21] C. Rajendran and H. Ziegler, “Ant-colony algorithms for permutation flowshop scheduling to minimize makespan/total

flowtime of jobs," *Eur. J. Oper. Res.*, vol. 155, no. 2, pp. 426–438, Jun. 2004.

[22] Quang Chieu Ta, J.-C. Billaut, and J.-L. Bouquard, "Heuristic algorithms to minimize the total tardiness in a flow shop production and outbound distribution scheduling problem," in *2015 International Conference on Industrial Engineering and Systems Management (IESM)*, 2015, pp. 128–134.

[23] M. H. Aghdam and P. Kabiri, "Feature selection for intrusion detection system using ant colony optimization," *Int. J. Netw. Secur.*, vol. 18, no. 3, pp. 420–432, 2016.

[24] G. F. Deng and W. T. Lin, "Ant colony optimization-based algorithm for airline crew scheduling problem," *Expert Syst. Appl.*, vol. 38, no. 5, pp. 5787–5793, 2011.

[25] M. Verma, M. Gupta, B. Pal, and K. K. Shukla, "A stochastic greedy heuristic algorithm for the orienteering problem," in *Proceedings - 5th IEEE International Conference on Computer and Communication Technology, ICCCT 2014*, 2015, pp. 59–65.