A New Approach to the Permutation Flow Shop Scheduling

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Abstract: ***In this project, the permutation flow shop scheduling problem is considered. One of the established methods for two machine scheduling problem is modified and extended to provide a solution for permutation flow of scheduling problem. The solution methodology consists of a square matrix (taking n jobs as rows and n machines as Column's). The job sequence generated by applying the Johnson's method in multi-stages. On processing time to minimize make span. Comparing the new method with other existing heuristic method like NEH method.***

Keywords: Machining Time, Starting Time, Finishing Time. Flow Shop Scheduling, Heuristics, Make span

1. Introduction

1.1 Important Definitions

1.1.1 Heuristics

Heuristic refers to experience-based techniques for problem solving, learning, and discovery. Heuristic methods are used to speed up the process of finding a good enough solution, where an exhaustive search is impractical.

1.1.2 Flow shop

The flow shop defines a set of N jobs and M machines. A Number of operations have to be done on every job. These operations have to be done on all jobs in the same order, i.e., the jobs have to follow the same sequence. The machines are assumed to be set up in series.

In flow shop scheduling problem, there are N jobs; each requires processing on M machines. The order in which the machines are required to process a job is called process sequence of that job. The process sequences of all the jobs are the same. But the processing times for various jobs on a machine may differ.

1.1.3 Scheduling

Scheduling is considered to be a major task for shop floor productivity improvement. Scheduling is the allocation of resources applying the limiting factors of time and cost to perform a collection of tasks.

1.1.4 Sequencing

Sequencing is the order in which the jobs are done.

1.1.5 Make span

It is the time difference between the start and finish of a sequence of jobs or tasks. The total elapsed time between first operations of the first job in first machine to the last operation of the last job on the last machine is called make span.

2. Basic concepts

2.1 Solutions

2.2 Initial solution

The initial solution can be obtained by various methods for instance they are the priority dispatching rules, the diverse insertion and random methods, etc. The initial solution method affects the scheduling solution quality such that the better initial solution is the better TS solution.

2.3 Current solution

The current solution refers to the best solution at the start of the current iteration and it is updated after each iteration with the best solution obtained in that iteration.

2.4 Best solution

The solution that gives the best solution to a problem after all the iterations are over.

2.5 Move

Each solution visited during the search has an associated neighborhood. The basic operation to reach one of the neighboring solutions is called a move. The best neighbor which is not either CDS (or) NEH or satisfies a given aspiration criterion is selected as new seed solutions. "The best" neighbor is one whose objective function is minimum.

2.6 Techniques

There are varieties of search techniques that relay on the estimate provided by heuristic functions. In all cases -the quality (accuracy) of the heuristic is important in real life application of technique.

3. Generate and Test

It is a very simple strategy.

1) Generate a possible solution
2) Test solution to see whether it is possible.

4. Permutation flow of scheduling problem

It is the problem of scheduling n-jobs on m-sequential Machines. Each machine is capable of processing at most one job at a time, and once a job is started it must proceed to completion. The n-jobs are independent, simultaneously available at time zero, and the machine sequences of all the jobs are same. In addition, each job has known finite processing time on each machine, and the processing times are independent of the order in which operations are carried out.

In engineering, a heuristic is an experience-based method that can be used as an aid to solve process design problems, varying from size of equipment to operating conditions. By using heuristics, time can be reduced when solving problems. There are several methods which are available to engineers. These include Failure mode and effects analysis and Fault tree analysis. The former relies on a group of qualified engineers to evaluate problems, rank them in order of importance and then recommend solutions. The methods of forensic engineering are an important source of information for investigating problems, especially by elimination of unlikely causes and using the weakest link principle.

4.1 Permutation flow of sequencing problem

The flow shop sequencing problem is a production planning problem: n jobs have to be processed in the same sequence of m machines. The processing time of job I on machine j is given as Tji (i=1,…n,j=1,…m)This times are fixed and some them may be non zero if some job is not proceed on a machine. The problem consists of minimizing the time between execution of first job on the first machine and the completion of execution of last job on the last machine. This time is called lead time (or) makespan.

5. Johnson's Rule

5.1 What is Johnson's rule?

Johnson's rule is a method of scheduling jobs in two work centers. Its primary objective is to find an optimal sequence of jobs to reduce makespan (the total amount of time it takes to complete all jobs). It also reduces the number of idle time between the two work centers. Results are not always optimal, especially for a small group of jobs.

Preconditions

The time for each job must be constant.
Job times must be mutually exclusive of the job sequence.
All jobs must go through first work center before going through the second work center.
There must be no job priorities.

Johnson's rule is as follows:

List the jobs and their times at each work center.
Select the job with the shortest activity time. If that activity time is for the first work center, then schedule the job first.
If that activity time is for the second work center then schedule the job last. Break ties arbitrarily.
Eliminate the shortest job from further consideration.
Repeat steps 2 and 3, working towards the center of the job schedule until all jobs have been scheduled.
Given significant idle time at the second work center (from waiting for the job to be finished at the first work center), job splitting may be used.
Each of five jobs needs to go through work center A and B. Find the optimum sequence of jobs using Johnson's rule.

Example:

Job time (hours)		
Job	work center A	work center B
A	3.2	4.2
B	4.7	1.5
C	2.2	5.0
D	5.8	4.0
E	3.1	2.8

1. The smallest time is located in Job B (1.50 hours). Since the time is in Work Center B, schedule this job last. Eliminate Job B from further consideration.

?	?	?	?	B

2. The next smallest time is located in Job C (2.20 hours). Since the time is in Work Center A, schedule this job first. Eliminate Job C from further consideration.

C	?	?	?	B

3. The next smallest time after that located in Job E (2.80 hours). Since the time is in Work Center. B, schedule this job last .Eliminate Job E from further consideration.

C	?	?	E	B

4. The next smallest time after is located in Job A (3.20 hours). Since the time is in Work Center A, schedule this job first. Eliminate Job A from further consideration.

C	A	?	E	B

5. The only job left to consider is Job D.

C	A	D	E	B

6. NEH Algorithm

The Nawaz, Enscore and Ham (NEH) heuristic procedure is based on the idea that Jobs with high processing times on all the machines should be scheduled as early as possible. NEH is divided into simple steps: It is a constructive heuristic.

Step 1: Sort the n jobs in non-increasing order of their total processing times.
Step 2: Take the first two jobs and schedule them in order to minimize the partial makespan as if there were only these two jobs
Step 3: For k= 3 to n do Step 4
Step 4: Insert the kth job at the place, which minimizes the partial makespan among the k possible ones.

The method carries out a series of sequential steps for the final obtaining of the make span. But the NEH method is a time consuming process.

7. Proposed Solution Method

In this paper, the heuristic method for a single machine schedule problem developed and modified and extended to provide a solution procedure for the flow-shop scheduling problem. The objective of the problem is to minimize make span, which is the elapsed time between the start of the first operation of the first scheduled job and the finish of the last operation of the last scheduled job. Hence, the purpose is to find a good permutation sequence for the problem, i.e. the common sequence of the jobs on all machines that minimizes the makespan.

8. Objective of method

- Find the optimum sequence in PFS.
- The proposed method is similar to Johnson method.
- This is carried out in Multi stage approach to determine the sequence of jobs.

The process

First step:

The least process time of the first column is identified and transforms the respective row bearing the least number to the first row.

Second step:

Similarly find the least process time in the last column and shift the entire row down.
Repeat the procedure and applying this to the entire table we arrive at a processing time matrix where we have Upper triangle arranged in ascending order and lower triangle arranged in descending order. The make span obtained by this method is much optimal than the make span we have obtained in the older methods.

Consider a FSP:-A problem with 5 job's and 5 machines.

JOB	M/C1	M/C2	M/C3	M/C4	M/C5
1	8	13	9	6	4
2	14	10	11	12	15
3	10	7	8	11	2
4	7	8	14	9	2
5	3	9	5	13	8

By applying above rules The Flow Shop Sequencing for the Scheduled problem is 5-4-2-1-3.

JOB	M/C1	M/C2	M/C3	M/C4	M/C5
5	3	9	5	13	8
4	7	8	14	9	2
2	14	10	11	12	15
1	8	13	9	6	4
3	10	7	8	11	2

By calculating

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
5	0-3	3-12	12-17	17-30	30-38
4	3-10	12-20	20-34	34-43	43-45
2	10-24	24-34	34-45	45-57	57-72
1	24-32	34-47	47-56	57-63	72-76
3	32-42	47-54	56-64	64-75	76-78

Make span for 5-4-2-1-3=78

By this the make span obtained for the proposed method is 77.

Check for the N.E.H method:

The summation of time for job 1=40
The summation of time for job 2=52
The summation of time for job 3=38
The summation of time for job 4=40
The summation of time for job 5=38

Sequence for N.E.H method=2-1-4-3-5

Stage1: The sequences are 2-1 & 1-2 For2-1

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
2	0-14	14-24	24-35	35-47	47-62
1	14-22	24-37	37-46	47-53	62-66

Make span for 2-1 =66
For 1-2

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
1	0-8	8-21	21-30	30-36	36-40
2	8-22	22-32	32-43	43-55	55-70

Make span for 1-2 =70

Here the sequence 2-1 has the optimal scheduling time compare to 1-2. According to the sequence 2-1-4-3-5, The next stage carries on job no 4 to obtain minimum make span.

Stage2: THE sequences are4-2-1, 2-4-1&2-1-4.
For 4-2-1

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
4	0-7	7-15	15-29	29-38	38-40
2	7-21	21-31	31-42	42-54	54-69
1	21-29	31-44	44-53	54-60	69-73

Make span for 4-2-1 =73.

For 2-4-1

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
2	0-14	14-24	24-35	35-47	47-62
4	14-21	24-32	35-49	49-58	62-64
1	21-29	32-45	49-58	58-64	64-68

Make span for 2-4-1 =68

For 2-1-4

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
2	0-14	14-24	24-35	35-47	47-62
1	14-22	24-37	37-46	47-53	62-66
4	22-29	37-45	46-60	60-69	69-71

Make span for 2-1-4 =71

Here the sequence 2-4-1 has the optimal scheduling time compare to 2-1-4 & 4-2-1. According to the sequence 2-1-4-3-5, The next stage carries on job no 3 to obtain minimum make span.

Stage 3: THE sequences are 2-4-1-3, 2-4-3-1, 2-3-4-1, 3-2-4-1.

For 2-4-1-3

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
2	0-14	14-24	24-35	35-47	47-62
4	14-21	24-32	35-49	49-58	62-64
1	21-29	32-45	49-58	58-64	64-68
3	29-39	45-52	58-66	66-77	77-79

Make span for 2-4-1-3 =79.
For 2-4-3-1

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
2	0-14	14-24	24-35	35-47	47-62
4	14-21	24-32	35-49	49-58	62-64
3	21-31	32-39	49-57	58-69	69-71
1	31-39	39-52	57-66	69-75	75-79

Make span for 2-4-3-1=79.
For 2-3-4-1

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
2	0-14	14-24	24-35	35-47	47-62
3	14-24	24-31	35-43	47-58	62-64
4	42-31	31-39	43-57	58-67	67-69
1	31-39	39-52	57-66	67-73	73-77

Make span for 2-3-4-1=77
For 3-2-4-1

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
3	0-10	10-17	17-25	25-36	36-40
2	10-24	24-34	34-45	45-57	57-72
4	24-31	34-42	45-59	59-68	72-74
1	31-39	42-55	59--68	68-74	74-78

Make span for 3-2-4-1=78

Here the sequence 2-3-4-1 has the optimal scheduling time compare to 3-2-4-1, 2-4-3-1 & 2-4-1-3. According to the sequence 2-1-4-3-5, the next stage carries on job no 5 to obtain minimum make span.

Stage 4: THE sequences are 5-2-3-4-1, 2-5-3-4-1, 2-3-5-4-1, 2-3-4-5-1, 2-3-4-1-5.

For 5-2-3-4-1

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
5	0-3	3-12	12-17	17-30	30-38
2	3-17	17-27	27-38	38-50	50-65
3	17-27	27-34	38-46	50-61	65-67
4	27-34	34-42	46-60	61-70	70-72
1	34-42	42-55	60-69	70-76	76-80

Make span for 5-2-3-4-1 =80

For 2-3-4-1-5

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
2	0-14	14-24	24-35	35-47	47-62
3	14-24	24-31	35-43	47-58	62-64
4	42-31	31-39	43-57	58-67	67-69
1	31-39	39-52	57-66	67-73	73-77
5	39-42	52-61	66-71	73-86	86-94

Make span for 2-3-4-1-5 =94
For 2-3-4-5-1

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
2	0-14	14-24	24-35	35-47	47-62
3	14-24	24-31	35-43	47-58	62-64
4	42-31	31-39	43-57	58-67	67-69
5	31-34	39-48	57-62	67-80	80-88
1	34-42	48-61	62-71	80-86	88-92

Make span for 2-3-4-5-1 =92.
For 2-3-5-41

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
2	0-14	14-24	24-35	35-47	47-62
3	14-24	24-31	35-43	47-58	62-64
5	24-27	31-40	43-48	58-71	71-79
4	27-34	40-48	48-62	71-80	80-82
1	34-42	48-61	62-71	80-86	86-90

Make span for 2-3-5-41 =90.
For 2-5-3-4-1

JOB'S	M/C-1	M/C-2	M/C-3	M/C-4	M/C-5
	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T	S.T-F.T
2	0-14	14-24	24-35	35-47	47-62
5	14-17	24-33	35-40	47-60	62-70
3	17-27	33-40	40-48	60-71	71-73
4	27-34	40-48	48-62	71-80	80-82
1	34-42	48-61	62-71	80-86	86-90

Make span for 2-5-3-4-1 =90.

Here the sequence 5-2-3-4-1 has the optimal scheduling time compare to 2-5-3-4-1, 2-3-5-4-1, 2-3-4-5-1, 2-3-4-1-5.

Here in the NEH method the sequence 5-2-3-4-1 has optimal value which is 80.

By this we can consider that the proposed method has the optimal value which is 78 compared to NEH method. With this the proposed method is correct and time saving method than NEH method.

9. Conclusions

The proposed solution for PFSP yields better result than original NEH method.

As shown using an example, the proposed method generates a minimum makespan sequences as compared to the NEH method and hence we have more options of job sequences that can be implemented for greater production. Experimental studies show that the proposed method for PFSP results in sequences with lower makespan which is 78 as compared to those obtained from NEH method which is 80.

10. Future Scope

Proposed method is considered to be the best known method for PFSPs. Hence, this proposed method has a great scope in industry where n jobs are required to be scheduled on m machines for greater production, efficient planning of resources and maintaining proper control over the industry.

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