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A case study on Machine scheduling and sequencing using Meta heuristics

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ABSTRACT
Modern manufacturing systems are constantly increasing in complexity and become more agile in nature such system has become more crucial to check feasibility of machine scheduling and sequencing because effective scheduling and sequencing can yield increase in productivity due to maximum utilization of available resources but when number of machine increases traditional scheduling methods e.g. Johnson's ,rule is becomes in effective Due to the limitations involved in exhaustive enumeration, for such problems meta-heuristics has become greater choice for solving NP hard problems because of their multi solution and strong neighbourhood search capability in a reasonable time.
Keywords - Manufacturing systems, Meta-heuristics, productivity

I. INTRODUCTION

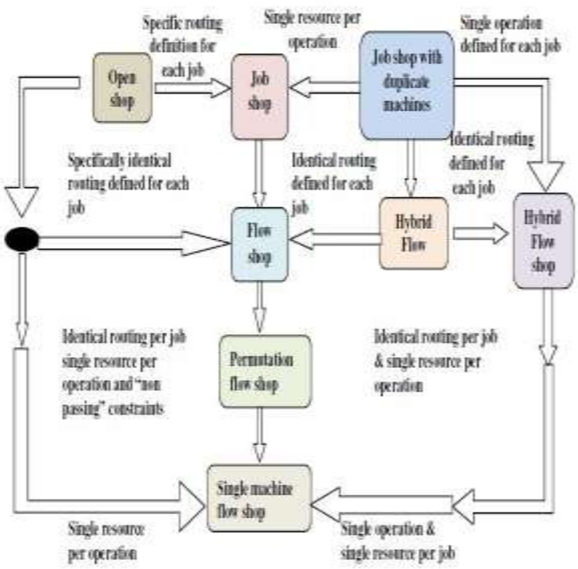
Production scheduling is a key for organizational productivity, which prepares a calendar for producing components/products. The scheduling problems are classified into single machine scheduling, flow shop scheduling job shop scheduling, open shop scheduling, and hybrid scheduling. In this paper, the open shop scheduling problem is considered. The open shop scheduling problem is alternatively called as moderated job shop scheduling problem (Panneerselvam [1]), since all the machines will not have 100% utilization all the time hence the machines which have similar processing capabilities will be grouped and a batch of single operation jobs will be scheduled on these machines while doing so the organization may be keen in optimizing any one of the following measures of performances

- ¬ Minimizing the sum of the completion times of all the jobs.
- ¬ Minimizing total tardiness.
- ¬ Minimizing total lateness.
- ¬ Minimizing the total number of tardy jobs.
- ¬ Minimizing makespan.

Classification of Scheduling Problems

According to French (1982), the general scheduling problem is to find a sequence, in which the jobs (e.g., a basic task) pass between the resources (e.g., machines), which is a feasible schedule, and optimal with respect to some performance criterion. Graves (1981) introduced a functional classification scheme for scheduling problems. This scheme categorizes problems using the following dimensions:
a) Requirement generation
b) Processing complexity
c) Scheduling criteria
d) Parameter variability
e) Scheduling environment

(a) Based on requirements generation, it can be classified as an open shop or a closed shop. An open shop is "build to order" and no inventory is stocked and when orders are filled from existing inventory it is called closed shop. Closed shop can further classified into job shop and flow shop and detailed classification of scheduling problem is shown in



1.1 Classification of scheduling problems based on requirement generations

(b) Processing complexity refers to the number of processing steps and workstations associated with the production process. This dimension can be decomposed further as follows:

(i) One stage, one processor
(ii) One stage multiple processors
(iii) Multistage flow shop
(iv) Multistage job shop

The one stage, one processor and one stage, multiple processors problems require one processing step that must be performed on a single resource or multiple resources respectively. In the multistage, flow shop problem each job consists of several tasks, which require processing by distinct resources; but there is a common route for all jobs. Finally, in the multistage, job shop situation, alternative resource sets and routes can be chosen, possibly for the same job, allowing the production of different part types.

(c) Scheduling criteria, states the desired objectives to be met. “They are numerous, complex, and often conflicting”. Some commonly used scheduling criteria include the following: Minimize total tardiness, Minimize the number of late jobs, Maximize system/resource utilization, Minimize in-process inventory, Balance resource usage, Maximize production rate etc.

(d) The dimension ‘parameters variability’ indicates the degree of uncertainty of the various parameters of the scheduling problem. If the degree of uncertainty is insignificant (i.e. the uncertainty in the various quantities is several orders of magnitude less than the quantities themselves), the scheduling problem could be called deterministic. For example, the expected processing time is six hours, and the variance is one minute. Otherwise, the scheduling problem could be called stochastic.

(e) The dimension, scheduling environment, defined the scheduling problem as static or dynamic. Scheduling problems in which the number of jobs to be considered and their ready times are available are called static. On the other hand, scheduling problems in which the number of jobs and related characteristics change over time are called dynamic.

II. Mathematical model and problem descriptions

Assumption

- Once an operation is started on the machine it must be completed before another operation can begin on that machine
- All processing time on the machine are known, deterministic, finite and independent of sequence of the jobs to be processed.
- The first machine is assumed to be ready whichever and whatever job is to be processed on it first.
- Each job is processed through each of the m machines once and only once.

Problem descriptions

A general job shop problem suppose having n jobs {J_1, J_2, J_3 --------- J_n} to be processed through m machine {M_1, M_2, M_3 ----------- M_m}. Technological constraints demand that each job should be processed through the machine in a particular order and gives an important special case named as flow shop. Thus in case of flow shop jobs pass between the machine in the same order i.e. if J_1 must be processed on M_1 before machine M_2 then the same the true for all jobs. This technological constraint therefore gives the form like :

Job	processing order
J_1	M_1 M_2 M_3 ……………… M_m
J_2	M_1 M_2 M_3 ……………… M m
………………………………………………	
J_n	M_1 M_2 M_3 ……………… M m

For a general job shop problem defined above the number of possible sequences are $(n!)^m$, where n is number of jobs and m is the number of machines. With the above technological constraints in case of flow shop number of different sequence reduces to (n!). This reduced number is quite large for even moderate size problems and recognized to be NP hard (Garey et al., 1976; Gonzalez and Sahni, 1978; Pinedo, 2005 and several others)[3,4,5]. There has been an attempt to solve this problem with typical objective function being the minimization of average flow time, minimizing the time required to complete all the jobs or makespan, minimizing average lateness values or tardiness, minimizing maximum tardiness, and minimizing the number of tardy jobs.

III. Case study

In a manufacturing shop generally a number of job passes through a number of machine .let in a manufacturing shop there are three shop namely M_1, M_2, M_3..And each job must passes through it only once. The processing time of each job is given below

JOBS	Duration (Hours)		
	Machine M_1	Machine M_2	Machine M_3
J_1	17	19	13
J_2	15	11	12
J_3	14	21	16
J_4	20	16	20
J_5	16	17	17

Palmer heuristics approach

A heuristic developed by Palmer (1965)[6], in an effort to use Johnson’s rule, is built around the notion of a slope index. The slope index gives a large value to jobs that have a tendency of progressing from small to large operating times as they move through the stages. The sequence of operations is given by priority to jobs having the strongest tendency to progress from short times to long times. This means that the job sequence can be generated based upon an non-increasing order of the slope indices.

Let *S* (*j*) be the slope index for job *j* and O^t_j be the operating time of job *j* at stage *t*. Palmer's slope index is calculated as follows:

$$S(j) = -\sum_{t=1}^{k} \left\{ [k-(2t-1)] O_j^t \right\}$$

Let assign +2 to M_3 , 0 to M_2 and -2 to M_1 then we have to calculate slope S(J) of each job

$S(J_1)$ ={17×(-2)+(19×0)+(13×2)}=-8
$S(J_2)$ ={15×(-2)+(11×0)+(12×2)}=-6
$S(J_3)$ ={14×(-2)+(21×0)+(16×2)}=4
$S(J_4)$ ={20×(-2)+(16×0)+(20×2)}=0
$S(J_5)$ ={16×(-2)+(17×0)+(17×2)}=2

Then we have to arrange the job according to decreasing order of their slope

J_3-J_5-J_4-J_2-J_1

J_3 starts at 0 finishes at 14 at machine M_1 then goes to M_2 now goes to M_2 takes 21 finishes at 35,goes to M_3 takes another 16 finishes at 51.

J_5 starts at M_1 at 14 takes another 16 finishes at 30 then goes to M_3 wait till 35 takes another 17 finishes at 52. M_3 is already available so takes another 17 finesse at 69.

J_4 starts at M_1 at 30 takes another 20finishes at 50 then goes to M_2 wait till 52 takes another16 finishes at 68 . then goes to M_3 wait till 69 takes another 20 finishes at 89.

J_2 starts at M_1 at 50 takes another 15finishes at 65 then goes to M_2 wait till 68 takes another11 finishes at 79 . then goes to M_3 wait till 89 takes another 12 finishes at 101.

J_1 starts at M_1 at 65 takes another 17finishes at 82 $M_2$is already available so takes another 19fineses at 101 goes to M_3 takes another 13 finishes at 114.

So makespan associated with this sequence is 114. Since this heuristics solution need not be optimal so we have to find the goodness factor in order to know how good it is.

Goodness factor is defines as a ratio of difference between heuristic solution and optimum solution to optimum solution. Since we don't know the optimum solution so we can replace optimum solution with lower bound.

Lower bound of M_1=total processing time at m_1 +minimum (sum of processing time of m_2 +m_3)=82+23=105

Lower bound of M_2= total processing time at m_2 +minimum processing time of m_1 + minimum processing time of m_3=84+14+12=110

Lower bound of M_3=total processing time at m +minimum (sum of processing time of m_1 +m_2) =26+78=104

Maximum bound is best one so we choose lower bound 110. So goodness factor {(114-110)÷110}=0.0364 e.g. 3.64%.

If we willing to accept the solution about 3.64% of optimum then we should go for palmer heuristics.

Campbell, Dudek, and Smith(CDS)

Campbell, Dudek, and Smith (1970) develop one of the most significant heuristic methods for flow shop problems with makespan criterion, in the following denoted by CDS. Its strength lies in two properties: (1) it uses Johnson's rule in a heuristic fashion, and (2) it generally creates several schedules from which a "best" schedule can be chosen. In so doing, k – 1 sub-problem are created and Johnson's rule is applied to each of the sub-problems. Thus, k – 1 job sequences are generated. Since Johnson's algorithm is a two-stage algorithm, a k stage problem must be collapsed into a two-stage problem. Let g be a counter for the k – 1 sub-problems, the operating times for the "first" stage are denoted as *a*(*j*, *g*), where *j* denotes the job and *g* denotes the *g*-th sub problem. Similarly, *b*(*j*, *g*) denotes the "second" stage operating times of job j and sub-problem g. Given these notations, the operating times are calculated by the following two formulas:

$$a(j,g) = \sum_{t=1}^{g} O_j^t$$

$$b(j,g) = \sum_{t=k-g+1}^{k} O_j^t$$

For each of the sub-problems, Johnson's algorithm provides a job sequence using the values a(j, g) and b(j, g). Once Johnson's sequence is created, the problem is then returned to the consideration of all k stages. Since in the given problem there are three machine (k=3) so number of possible job sequences is (k-1) is 2. Since Johnson's algorithm is a two-stage algorithm, a k stage problem must be collapsed into a two-stage problem.

	M_1+M_2	M_2+M_3
J_1	36	32
J_2	26	23
J_3	35	37
J_4	36	36
J_5	33	34

For this sub problem job sequence according to Johnson's algorithms [8]

The smallest one in the above mention table is 23 so J_2 goes to extreme right row then next smallest number is 32 so J_1 goes to 2nd extreme right row in this manner we fill the remaining vacant row according to Johnson's algorithms.

J_5	J_3	J_4	J_1	J_2

So makespan associated with this sequence is 115.

b.

	M_1	M_2
J1	17	13
J2	15	12
J3	14	16
J4	20	20
J5	16	17

For this sub problem job sequence according to Johnson's algorithms.

J_3	J_5	J_4	J_1	J_2

So makespan associated with this sequence is 114.
From above discussed two sequences best one is J_2-J_5-J_4-J_1-J_2 because of their minimum completion time i.e. 114
Since we already defined goodness factor and we have lower bound is 110.
So goodness factor {(114-110)÷110}=0.0364 e.g. 3.64%.
If we willing to accept the solution about 3.64% of optimum then we should go for palmer heuristics.

IV. Conclusion

Meta heuristics approach tends to move relatively quickly towards very good solutions, so it provides a very efficient way of dealing with large complicated problems. It is very useful in cases where traditional methods get stuck at local minima and common area of application is combinatorial optimization problems. However is does not guarantee for optimum solution but if we willing to accept 0 to 4% of optimum solution then this types of methods is very useful.

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