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Review on Branch and Bound technique in Flexible Manufacturing System Scheduling

S H Bhatt, Dr. M B Kiran, A B Bhesdadiya, A P Singh, P V Shah
Pandit Deendayal Petroleum University

ABSTRACT

The complete scheduling of flexible manufacturing system completely involves sequencing of the job and then scheduling of that job.The important feature of any scheduling technique which demarcates itself from other techniques is how fast it computes the problem and how close it is to optimum solution. So in this paper the review on scheduling using optimisation technique, branch and bound is focused which has attracted attention of both academics and industrial sector due to its characteristic of removing sequences (branches) which would not result to optimum solution and hence improving the computation time. This technique finds its application in many areas like flow shop programming, travelling salesman problem, nonlinear programming, nearest neighbour search etc. The objective of writing this paper is finding out how effective branch and bound technique is and which areas this technique is satisfactorily applied till date. It is concluded at the end that the use of hybrid techniques with combination of genetic algorithm(GA), artificial intelligence(AI), branch and bound (B&B) etc. approaches in FMSs will be dominating in future study.

KEYWORDS

Branch & Bound, Flexible Manufacturing System, Scheduling

INTRODUCTION

The developments in computer and automation industries over last three decades gave birth to flexible manufacturing system. As of today's market scenario which demands low cost solutions and frequentchange in product mix and design, FMS is a perfect solution to the manufacturing environment.Generally, this type of technology is adopted for medium and low volume industries such as automobile, aircrafts, steel and electronics.

FMS in a simple way is defined as manufacturing system that comprises of machine tools, robots, buffers, fixtures, automated guided vehicles (AGVs), and other material-handling devices. The schematic diagram of FMS is shown below in figure [1]. Apart from this FMSs have been defined as, an arrangement of machines interconnected by a transport system[2].FMS can handle a large and constantly changing variety of part types[4]. The FMS majorly comprises of fixtures and pallets, inspection system, machining centre, robots, storage facilities, material handling systems. Likewise, FMS can be classified into different types based on flexibility, number of machines, and kind of operations. In FMS important topic is to formulate scheduling problem to maximise the performance measures such as machine utilisation, make span, tardiness, mean flow time, throughput etc. Therefore, it is important to define the scheduling and its significance. Scheduling is a method of resource allocation in a specified sequence so as to get the maximum output of the given input. In other words,optimised utilisation of resources in the shop floor is scheduling. Hence the performance of the

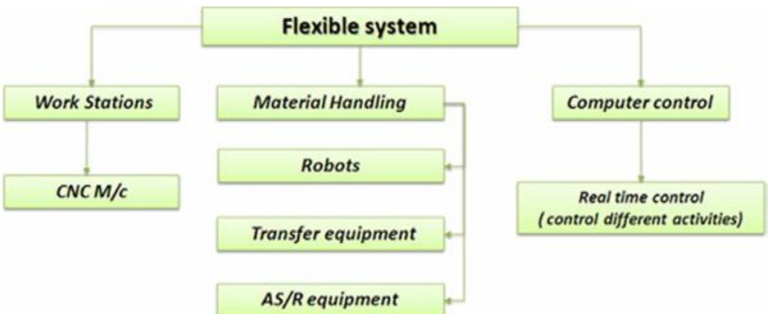

Fig 1: Flexible manufacturing system configuration [1]

FMS highly depends on the selection of the right scheduling policy. The significance of the scheduling are as follows [34]

- Better utilization of the production equipment, reduction of stocks (ex: Work in progress—capital shorter through put times)
- To reduce costs: Reduction of piece per unit costs
- To increase Technical Performance:
  - Increased production levels
  - Greater product mixture
  - Simultaneous product mixture manufacturing
  - Integration of the production system into the factory's logistical system
  - Shorter or zero change over or reset of times
- To improve Order Development:
  - Shorter lead times/delivery times
  - Determination of production capacities
- To assist future Corporate Security:
  - Increased Competitiveness
  - Increased Quality
  - Improved Company Image

The FMS implementation problem can be classified into four categories as design, planning, scheduling and control problem. Looking to the significance of scheduling, it has to be addressed in a proper manner to optimize the performance of the system. The study of scheduling problems can be addressed using majorly:

- Mathematical Model
  - Mixed Integer linear programming
- Branch and Bound/ OR based Approach
- Approximation method/ AI based approach
  - Artificial intelligence (constraint satisfaction approach, neural networks)
  - Local search methods
  - Fuzzy Logic
  - Expert System

The objective of this paper is to survey the scheduling study based on traditional approach and branch and bound approach.

Review on Traditional FMS scheduling

FMS is a large scale complex system consisting of many interconnected hardware and software components. The scheduling of raw material to the components like AGVs, machines can be carried out using soft computing techniques. The job assignment and job sequencing plays a vital role in scheduling the FMS. Majorly the dispatching rule or priority rule such as FCFS (First come, first served), SPT (Shortest processing time) EDD (Earliest due date) CR (Critical ratio, Time remaining until due date/ processing time remaining) S/O(Slack per operation) are used. Another way of denoting the scheduling problem is N/M/F/P where N is the number of jobs to be scheduled; M is the number of machines; F refers to the job flow pattern and P is performance measures that are to be appropriately minimized or maximized. The job to be scheduled is said to be static if jobs are available at beginning of the scheduling and dynamic if they are continuously changing over time. Where as in deterministic problem all parameters are known with certainty and if at least one parameter is probabilistic, problem is defined as stochastic. Depending on the way of job routed the job shop is classified as an open shop or close shop. The other effective dispatching rules are based on processing time and total work content of the jobs in the queue for the next operation on a job which is found to minimize flow time by quite an extent. No single rule is effective in minimizing all performance measures.These rules give the accurate solution but the only drawback is they don't give the solution for NP hard problems.

Review on Branch and Bound scheduling

In a manufacturing system, the scheduling problem is to synchronize resources (raw material) and material flow, to manufacture a different type of products in certain time period. Scheduling rules are used to select the next product to be produced from a set of products from waiting line. These rules can also be used to introduce raw material into the system; to route product parts in the system and assign job to the shop floor [18].

As the system is complex it's not very useful to find an optimal solution from industries point of view since changes occur rapidly (Batch size, new parts, change in product) there is no point in designing such scheduler. In place of this we should use flexible scheduling tool to monitor the system for making decisions. Future more automatic scheduler tool for some operations, it should be operator friendly and react to the real time changes. Then it has to be expressed in form of parameters and chosen according to the objective of the system, in this type of NP hard problems of FMS, proper branching and bounding are needed to produce optimal solution [14] [18].

When you are dealing with large sequencing problems it is never feasible to compute all the permutations as it would take a lot of time. So here comes the use of Branch and Bound Technique which discards permutations not likely to give an optimal solution. All the permutations are viewed as branches of tree. The vertex of the tree starts with the first sequence of permutations (1, 2, ... n). Then, comes the second sequence of permutation as branches to the earlier permutation. The discarding of permutations is done by technique called 'bounding' which finds lower bound for a given permutation. Lower bound is the irreducible minimum of processing time for a particular class of permutation in case of job shop programming, e.g. all sequences starting with job 2, all sequences starting with 3-1etc.

The algorithm of B&B is based on efficient estimation of the lower and upper bounds of a branch of the search space.[5][7].

B&B algorithm operating principles

• The algorithm splits the search space into littler spaces, then minimizing f(x) on these littler spaces; this type of splitting is called branching.

• Branching alone would account into brute-force numbering of candidate solutions and testing them all. To keep on improving the performance of brute-force search, a B&B algorithm keeps a track of bounds on the minimum that it is trying to find, and uses these bounds to thin out the search space, eliminating candidate solutions that it can prove will not contain an optimal solution. [6][8]

Backtracking in scheduling

If a scheduling solution exists for a set of activities, but the standard scheduling function is unable to find it (for example, due to a complex set of sequencing constraints), then use backtracking scheduling to find a solution.

Backtrack scheduling is able to reverse its previous actions. During the process scheduler might make a scheduling decision that later causes an issue; for example, a preceding activity in a sequencing relationship might be scheduled at a day and time that, later in the process, does not leave sufficient time to schedule its succeeding activities. When scheduler finds it cannot schedule a succeeding activity, it will unscheduled previously scheduled activities and make different scheduling decisions until a solution is reached.

As backtrack scheduling is a more complex process than standard scheduling, it requires more processing time. Consequently, you should use it on small sets of activities [19].

Applications

This type of approach are used for a large number of NP-hard problems:Integer programming,Nonlinear programming,Travelling salesman problem (TSP) [7][14] , Quadratic assignment problem (QAP), Maximum satisfiability problem (MAX-SAT),Nearest neighbour search[15] ,Flow shop scheduling,Cutting stock

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problem,False noise analysis (FNA), Computational phylogenetic ,Set inversion ,Parameter estimation ,0/1 knapsack problems,Feature selection in machine learning[16] , 12Structured prediction in computer vision[17] .

Branch-and-bound may also be a build for various heuristics. For example, when you are expecting a solution which is considered good for that production system this happens when difference between lower and upper bound is very less and branching stops which bring down the level of transposition required.

The branch and bound technique used for scheduling finds its use in many areas. But the large scale application of this technique is in job shop programming where performance measures like flow time, makespan, utilization, tardiness, etc. are checked to find the optimum sequence. This technique is not only limited to single criterion environment, but also to multi-criteria environment where two different performance measures like flow time and makespan are optimized simultaneously. This technique also finds application in scheduling vehicle trips by transportation companies by optimizing the sum of the costs associated with the duties of the vehicles used in the solution. Similarly scheduling of thermal generating units can be done by using B&B technique where cost and computation time can be optimized. Assigning of staff member possessing more than one skill (multi –skill scheduling problem) can be done by B&B technique. Multiprocessor scheduling i.e. selecting a sequence of jobs on m processors also finds its way through B&B technique. Other approaches include comparing B&B with Tabu search technique, previous B&B with heuristic B&B formed etc.

Basically, the scheduling problems that can be solved by branch and bound technique are classified as:

1. Job shop scheduling problems – to select a proper sequence of jobs to be machined.
2. Multiprocessor scheduling – to select a proper sequence of jobs on any number of processors.
3. Scheduling of thermal generating units.
4. Multiple depot vehicle scheduling problems -to find a proper assignment of trips to vehicles.
5. Multi-skill project scheduling problem -scheduling a project where resources have more than one skill.
6. Others – cause branch and bound technique has many other applications.

Table 1. B&B approaches in FMS scheduling problems

Year Of Publication	Authors	Types of scheduling problem						Number of performance measures	Performance measures
		1	2	3	4	5	6		
1966	G.B. McMahon ,P.G. Burton	✓						4	Makespan ,Min. number of nodes , Mean computing time , Frequency of min number of nodes observed
1974	Theodor Siegel	✓						1	Makespan
1989	G. Carpaneto , M.Dell Amico, M. Fischetti, P. Toth				✓			3	Average time, Max time , Average nodes
1991	A.M.A Hariri and C.N Potts	✓						3	Median computation time ,Median number of nodes ,Number of unsolved problems

1992	Peter Brucker, Bernd Jurisch, Bernd Sievers	✓						3	Makespan ,CPU time , Number of nodes explored
1993	Chem-Lin Chen, Shun-Chung Wang			✓				2	Computation time , Cost
1995	J.A.Hoogeveen ,S.L Van De Velde	✓						4	Makespan ,Tardiness , Earliness ,Number of nodes explored
1995	Amit Nagar, Sunderesh S. Heragu and Jorge Haddock	✓						2	Weighted flowtime and weighted schedule makespan
2006	Christian Artigues and Dominique Feillet	✓						1	Makespan
2006	Odile Bellenguez-Morineau and Emmanuel N´eron					✓		4	Average time, Average deviation on unresolved instances , Number of unresolved instances , Max and Average number of nodes explored
2007	Said Ashour And S.R. Hermath	✓						3	Mean Computer Time, Max. Min. & Mean number of nodes explored (with and without backtracking) ,Mean Efficiency
2011	Satoshi Fujita		✓					1	Makespan
2014	Subrata Talapatra, Shamsur Rahman, Chandnee Das, Utpal Kumar Dey	✓					✓	3	Makespan , Execution time ,Idle time (using Gantt chart)
2014	R. Helen and R.Sumathi	✓						1	Total Tardiness
2016	Onur Ozturk , Mehmet A. Begen and Gregory S. Zaric	✓						2	Average nodes explored, Average computation time

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CONCLUSION

This paper has reviewed a number of reported researches that use branch and bound as a technique for scheduling FMS. The advantage of B&B technique over other techniques is that it gives an optimum solution if the problem is of limited size and computation can be done in reasonable time. The disadvantage of B&B is that it can be extremely time consuming if the problem size is large. The earlier B&B algorithm used to first find the complete sequence and then try to improve it. But there has been a great development when it comes to new heuristic B&B techniques which have lessened the computation time and also helped to find near optimum solution for larger problems. When this B&B technique was compared with Tabu search it showed mixed results i.e. it got optimum solutions where Tabu search could not but failed to get optimum solutions at few instances. This suggests that there is great future scope for all the hybrid techniques which combine genetic algorithm (GA), artificial intelligence(AI), branch and bound (B&B) etc. techniques.

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