ISSN No. 0976-5697
Volume 5, No. 7, September-October 2014
International Journal of Advanced Research in Computer Science
RESEARCH PAPER
Available Online at www.ijarcs.info

Insights into Production Scheduling Complexity - A Comprehensive Study

R.Sudha
Associate Professor
Department of computer Applications
Vasavi College of Engineering(Autonomous)
Ibrahimbagh,Hyderabad
Andhra Pradesh, India.

Dr. P.Premchand
Professor
Department of Computer Science & Engg.
University college of Engineering
Osmania University, Hyderabad,
Andhra Pradesh, India

Abstract: The only permanent and inevitable phenomenon in any manufacturing unit is its dynamic environment which enforces the production manages to accommodate these changes and subsequently re plan and re schedule the tasks. Determining and maintaining a stable, efficient production schedule that quickly respond and adopt to change is not only time consuming but a difficult task. Though the purpose of process scheduling is specific to the class of a process, the conventional methods have scheduled every process equivalently based on some unrealistic assumptions about the shop floor and did not reflect on necessary scheduling parameters. Production scheduling has also become an interesting domain of research in computer science where powerful algorithms and models can be designed. This paper gives a comprehensive list of factors to be addressed for determining an optimal schedule. The complexity of production scheduling is influenced by a package of several factors which is presented in this paper with four dimensions ; scheduling decision parameters, constraints, unexpected events and scheduling objectives. The paper also discusses performance metrics for a schedule.

***Keywords**:* Schedule complexity, Scheduling Dimensions. Decision Parameters, Constraints, Objectives Performance Criteria

I. INTRODUCTION

One of the key factor that contributes to the success of any manufacturing industry is the scheduling policy adopted in the shop floor. Scheduling is a decision making process involving voluminous data about number of tasks of varied nature and functionality, resources and constraints. It comprises of identifying the suitable plan for performing the activities , their sequence and assigning the start times for each of the activity in order to meet a multifaceted criteria such as resource optimization and minimum make span etc. The critical and important issue that attracts the attention of people in any manufacturing unit, is the complexity of a scheduling task.

Research in scheduling is being carried out from the last few decades. Parunak distinguished the five challenges that make scheduling difficult namely Desirability, Stochasticity, Tractability , Chaos and Decidability[1].

Sauer,J [2] formulated the scheduling problem as set of orders, products, resources, soft and hard constraints. The problem space of scheduling problem can be represented by an AND/OR tree which can be constructed by combining the production requirements with given orders and the scheduling horizon. Finding a solution to the scheduling problem is equivalent to finding the solution of AND/OR tree where the constraints are met. If the node belongs to solution, it has the root node, all successors of AND node () and one successor of an OR node. see Figure 1

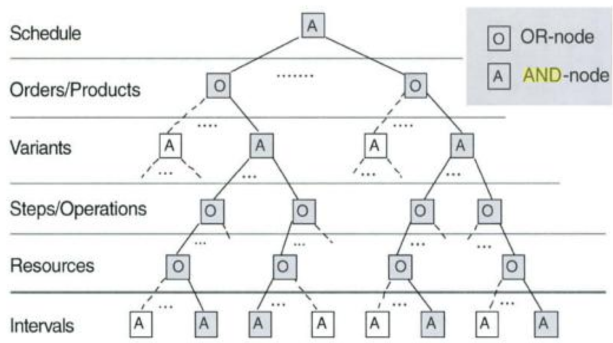

Figure 1 : problem space of scheduling (source : Sauer [2]

The number of possible solutions for such a tree can be estimated by

$$((\#RI \times \#R)^{*s} \times \#V)^{*o}$$

Where

#RI is the number of possible intervals for resources,
#R is the number of possible resources per step(operation),
#S is the number of steps(operations) per variant,
#V is the number of possible variants for products
#O is the number of orders for products

It is understood from the problem space that, , the complexity of a schedule will increase as the number of jobs or resources increase .This can be represented in the following graph

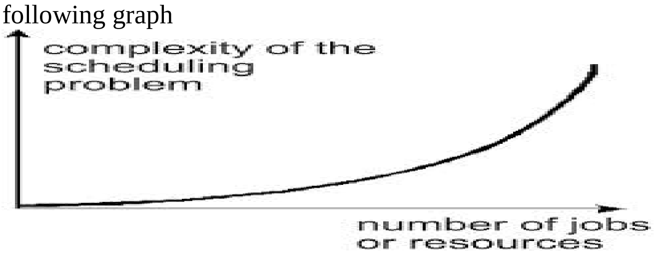

Figure : 2

The factory is not a single or isolated entity; each product has to undergo a number of operations on different machines. Each product has a given route and given processing requirements on the various machines.[3].

Every machine can do multiple tasks and each process (may be product) need multiple sequence of steps that needs multiple machines. So, allocation of machines to proper processes is increasingly demand in manufacturing system since revenue is completely around in scheduling mechanism. But the major problem here is that handling of real time constraints and criteria such sequential order, set up selection and machine selection.[4].

A good schedule can reduce the efforts in manufacturing, thus improving the competitiveness of products [5].In general, the complexity of scheduling problem are due to limited resources, un certainty in the environment, complex job mix, numerous complex and sometimes conflicting objectives, and constraints. The complexity of production scheduling is influenced by a package of several factors having four dimensions ; scheduling decision parameters, constraints, unexpected events and scheduling objectives.

a. Scheduling parameters
b. Unexpected events
c. Constraints
d. Scheduling objectives

The inputs to be considered for a production schedule originate from multiple sources and available with many forms which makes the scheduling really a tough task **.** The following table illustrates various options available for each of the schedule input and it is indeed a challenging task to carefully understand, analyze various permutations and combinations of given options and choosing an Optimal possible option. Ref Table 1 a,b,c.

Table 1 a: Classification of Scheduling Decision Parameters

Decision Parameter	**Types**	**Explanation**
Time	**Time bound**	Strict deadlines
Schedule information	**Available in advance**	The information required to schedule the activities known in advance
	Not Available	
Schedule Type [2]	**Predictive**	Creating a schedule in advance for a period of time is called predictive scheduling. Possible to estimate the make span
	Reactive	Reactive scheduling means adapting the schedule to the new situation using appropriate actions to handle each of the events.Not possible to estimate the make span
	Interactive	Combination of predictive and reactive.
Scheduling approach	**Forward scheduling**	The task begins as the order is received irrespective of the due dates
	Backward scheduling	The tasks are scheduled back from the due dates
Structure of scheduling problem	**Discrete Manufacturing**	Discrete manufacturing is the production of distinct items
	Continuous process	Continuous production is used to , produce, or process materials without interruption
Scheduling levels	**Plant level**	Entire plant level scheduling
	Floor level	Only floor level scheduling
Production Run	**Pre emptive**	The resources given to tasks can be taken away when it is suspended
	Non preemptive	Resources cannot be taken away from a task , once a task is started

Table 1 b: Classification of Scheduling Decision Parameters

Decision Parameter	**Types**	**Explanation**
Time	**Time bound**	Strict deadlines
Schedule information	**Available in advance**	The information required to schedule the activities known in advance
	Not Available	
Schedule Type [2]	**Predictive**	Creating a schedule in advance for a period of time is called predictive scheduling. Possible to estimate the make span
	Reactive	Reactive scheduling means adapting the schedule to the new situation using appropriate actions to handle each of the events. Not possible to estimate the make span
	Interactive	Combination of predictive and reactive.
Scheduling approach	**Forward scheduling**	The task begins as the order is received irrespective of the due dates
	Backward scheduling	The tasks are scheduled back from the due dates
Structure of scheduling problem	**Discrete Manufacturing**	Discrete manufacturing is the production of distinct items
	Continuous process	Continuous production is used to , produce, or process materials without interruption
Scheduling levels	**Plant level**	Entire plant level scheduling
	Floor level	Only floor level scheduling
Production Run	**Pre emptive[6]**	The resources given to tasks can be taken away when it is suspended
	Non preemptive	Resources cannot be taken away from a task , once a task is started
Resource Type	**Sharable**	Same resources can be used by more than one task
	Non sharable	Can be used exclusively
	Renewable resources	These are reusable. Ex- manpower, machines, tools.
	Non-renewable	These are consumed when used. Ex: money, raw materials, energy.

Table 1 c: Classification of Scheduling Decision Parameters

Decision Parameter	**Types**	**Explanation**
Product batch size	**Fixed batch size**	
	Variable batch size	
Product type	**Part**	Single part production
	Assembly	Assembly of multiple parts
Product process type	**Single stage**	Simple process style
	Multi stage	Complex process style
		SPT-Shortest Processing Time
		LPT-Longest Processing Time
		SSTF-Smallest Slack Time First
		SCRF-Smallest Critical Ratio First
		SPS- Shortest Processing Sequence
		LPS- Longest Processing Sequence[7]
		STPT-Shortest Total Processing Time
		LTPT- Longest Total

		Processing Time
	Dynamic	ECT-Earliest Creation Time
		SWT_-Shortest Waiting Time
		LWT- Longest Waiting Time
		LTWR-Least Total Work Remaining
		MTWR-Most Total Time Remaining
workload	**Static**	Fixed workload
	Dynamic	Varied workload

Practically, it is very difficult to optimise a Schedule over all these characteristics. From most production schedules one is chosen for emphasis depending on current production objectives. Generally, a trade off must be made to reach a balance among the objectives[8].

The second important dimension deals with the constraints**.** Constraints are anything that prevents the organization from reaching its goal. In manufacturing processes, constraints are often called as bottlenecks. As shown by the abstract model of OZONE, constraints can be imposed on activities, products, resources, demands etc [9].

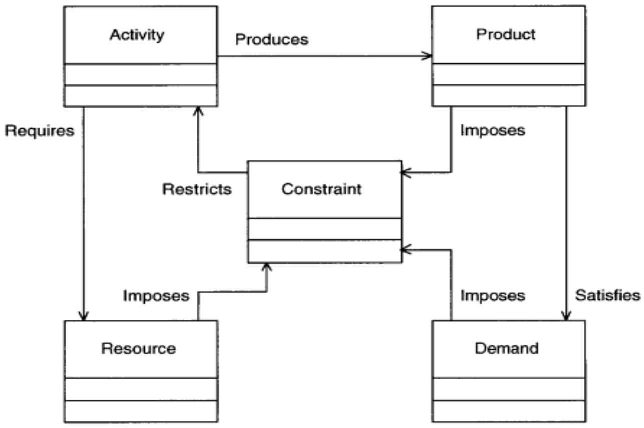

Figure -3 : Abstract domain model of OZONE The constraints can be classified as follows

Table 2 : Categories of Constraints

Type of constraints	Explanation
Organizational constraints	Set by the organization. Ex Supply of products in time, Budget etc
Physical constraints	Pertains to the functionality.
Pre requisite constraints	Some tasks demand the prior completion of other jobs
Availability constraints	Deals with availability of resources.
Temporal constraints	**Deadline constraints** : Tasks must be completed by certain deadline
	Starting time Constraints : each task may not be started by a certain time
	Process time constraints : each job may require a different amount of processing time
Compatibility constraints.	A task is T i said to be compatible with task T j if at least one of its sub-tasks of T I can be executed during the idle time of task T j.
Resource constraints	**Utilization constraints-** Resource utilization should not exceed certain limit.
	Capacity Constraints- Quantity of a resource a task needs
	State constraints- Task may require a resource to be in a particular state at beginning of task
Priority constraints	jobs may have priorities, with higher priority jobs to be done first
Interrupt ability constraints	jobs may not be interruptible
Quality constraints	Imposed by quality control people
Customized constraints	Customers may demand additional product features and ease of use.
Government Rules	Constraints on power supply, Working Hrs etc

Previously, scheduling process involved making the following assumptions[10].

a. Resources are always available
b. No unexpected events
c. Every order must be manufactured by the available resources.
d. Static environment i.e. all jobs arrive at same time.

However, the manufacturing environment is stochastic in nature and several unexpected events occur that disturbs the normal functionality and leads to chaos in the manufacturing unit effecting the performance. These un expected events are enlisted in table 3

Table 3 : Types of unexpected events

S.No	Type of event	Examples
1	**Job related**	Cancelled jobs
		New jobs
2	**Machine related**	Delayed operations due to poor maintenance of machines
		Machine breakdowns
3	**Operation related**	Delayed operations due to preemption of resources
4	**Operator related**	Some operators go absent.
		Operators begin working below average performance
5	**Time related**	Due date change
		Over or under estimation of processing times
		Variance in processing and set up times
6	**Demand related**	Urgent orders
		cancelled orders
7	**Priority related**	Changes in priority of jobs
8	**Cost**	Unacceptable cost of late jobs
		Unacceptable cost of adding additional capacity (i.e. out sourcing).
9	**Quality**	Poor quality of raw materials
10	**Resource related**	Delay in arrival of raw materials
		Unavailability of resources or substituted resources
11	**Quality Checks**	Quality controllers decide re-work is necessary.
12	**Strikes**	Man power not available due to strike
13	**Accidents**	Short circuits, Fire, Damaged Goods
14	**Natural Calamities**	Flood, Earthquakes.

Few of these unexpected events such as machine break downs can be anticipated by using some preventive maintenance S/W. However the events that are external to the manufacturing environment has to be dealt dynamically (Just In Time basis .)

All problems must be resolved to achieve an intended goal and objectives. The domain of Scheduling is no exception. It involves satisfying a multifaceted optimization criteria that can be categorized as in Table 4.

Table 4: Classification of Optimization Criteria

Criteria	Examples
Cost	Max. Return on Investment
	Min. production cost
	Reduce setup cost
Time	Min. production time
	Meet customer due dates
	Min. response time
	Min. customer wait time
	Min. job lateness
	Min. overtime
	Min. idle time
Quality	Improved service level
	Stability of the system
	Completeness
Efficiency	Max. Throughput
	Optimal usage of resources
	Maximizing delivery performance
	Min. inventory
	Min. wastage
	Ease of Implementation
Scope	Increased level of functionality

Determining and designing an efficient scheduling strategy is a tough task and identifying its performance metrics is yet another challenging task. The performance criteria can vary among manufacturing units and mean different to different people.

The operational performance criteria determined by Rahan [11] as , 1.Throughput ,the rate at which the manufacturing system generates revenue. 2- Inventory (IN) defined as the investment made to generate revenue. 3- Operating expense (OE) defined as the cost of transforming inventory into throughput

Brah identified three categories for measuring the performance i.e, in terms of completion time, due dates , cost and resource utilization[12]. Ref Table 5

Table 5 : Category Measures

Basis	Examples
completion time	Max. flow time,Total completion time,Total flow time,Mean completion time,Mean flow time, Weighted sum of completion time, Weighted sum of flow time, Jobs waiting time,Weighted job waiting time
Due dates	Max. lateness, Max. tardiness, Max. earliness,Total lateness, Total tardiness,Total earliness, Mean lateness,Mean tardiness, Mean earliness,Weighted sum of lateness,Weighted sum of tardiness, Weighted sum of earliness, No. of tardy jobs, No. of early jobs, No. of jobs in the system,
Cost & utilization	Machine idle time, Weighted machine idle time, Manpower idle time,Manpower weighted idle time, Utilization setup time

The criteria of a schedule are focused on either on scheduling product or on the scheduling process

The scheduling product is the actual schedule to be implemented and the scheduling process involves set of activities to develop, adapt and communicate schedules. [13] Ref Table 6

Table 6 : Performance Criteria for a schedule

Performance Focus	Criterion
product	Minimum schedule errors
	Minimum cost of schedule execution
	Fulfillment of constraints
	Schedule robustness
Process	Timely execution
	Reliability
	Flexibility
	Speed of schedule adaptation
	Cost and efficiency of scheduling process

De Snoo[13] presented a scheduling performance focus matrix that shows the relatively decreasing importance of scheduling product performance criteria and the relatively increasing importance of scheduling process performance criteria if uncertainty increases.

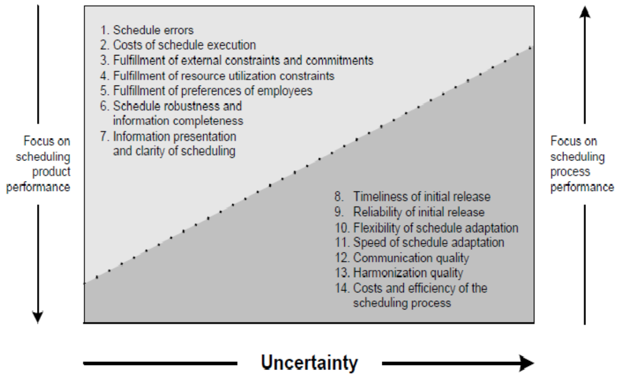

Figure 4 : scheduling performance focus matrix (Source [13])

A holistic approach is needed to improve production scheduling, given the limitations of applying information technology or analyzing problems mathematically[14]

It is understood from that the performance of a schedule depends on the issues addressed in four dimensions and change in performance criteria

Subsequently triggers changes in selecting some of these parameters which can be shown as Figure 5.

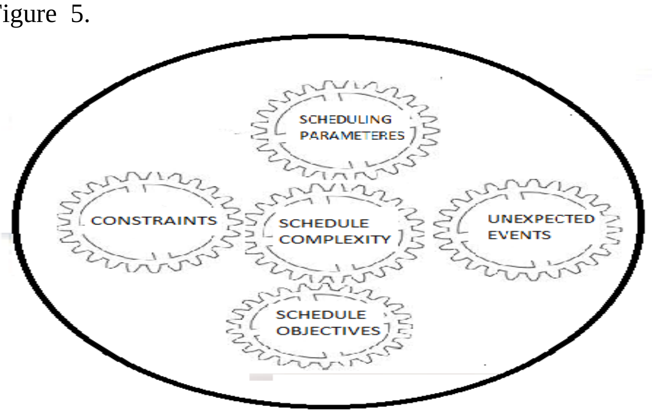

Figure 5 : Scheduling Dimensions

It is understood from that the performance of a schedule depends on the issues addressed in four dimensions and change in performance criteria

Subsequently triggers changes in selecting some of these parameters which can be shown as Figure 5.

The elements in four dimensions are closely coupled and any change in any of these dimension subsequently results some change on the other elements

Great amount of research is being carried out in production scheduling and various scheduling algorithms have been designed to enhance the performance of scheduling using many techniques . These techniques vary in their perception about the problem space and the performance criteria. Though the list of scheduling strategies is very extensive some strategies used in recent times are genetic algorithms[18], Hybrid cuckoo and Genetic Algorithms[4], heuristics[15], Expert systems[16], simulated annealing[17] and Agent based[19].

II. CONCLUSION

Scheduling is an ever challenging research area as the production scheduling encompasses a large number of problems, and within this continuum there are solutions which are more efficient than others. Any scheduling problem , enforces us to know whether a best or optimal solution can be obtained in minimum time considering the level of complexity in the problem space. The various issues contributing to the complexity of production schedule design are extensively discussed that help the production schedulers, researchers to design an efficient approach to improve production scheduling performance. Despite a great deal of research has been done about scheduling , there is still much scope for improvement and many approaches have been evolving that addresses and overcomes the bottlenecks in scheduling process. However, searching for a feasible schedule is combinatorially explosive.

III. REFERENCES

[1]. Parunak, H.V.D. (1991). Characterizing the manufacturing scheduling problem. Journal of Manufacturing Systems, 10(3), 241.259

[2]. Jurgen Sauer(1999), Knowledge based systems Techniques and applications in scheduling, knowledge based systems techniques and applications, Four volume set edited by Cornelius T. Leondes

[3]. Pinedo et al,(2004) ,Planning and Scheduling in Supply Chains:An Overview of Issues in Practice, Production And Operations Management Poms,Vol. 13, No. 1, Spring 2004, pp. 77–92

[4]. Sudha et al, (20014),An Intelligent Hybrid Scheduling Algorithm for Computer Aided Process Control of Manufacturing System,IJITR,Volume no.2, issue no. 4, pp. 1089-097.

[5]. Jun Sun, et al(1999), "An intelligent production scheduling mechanism considering design and manufacturing constraints," Third International Conference on Industrial Automation, vol.18, no.12, pp.651-667.

[6]. Vora et al(2012), Design of Real Time Scheduling Algorithms for Efficient Mass Production in various Industrial Applications.IJDI-ERET,vol 1

[7]. Kaban et al(2012),Comparison of dispatching rules in job-shop scheduling problem using simulation-A case study, International journal of simul model , 3, Pg No 129-140.

[8]. peter bubeník*, dariusz plinta(2005) Interactive Scheduling System, Management, Vol 10,pp 89-98.

[9]. Smith, S. F., and Becker, M. A. (1997). An ontology for constructing scheduling systems. AAAI Spring Symposium on Ontological Engineering, Palo Alto, CA, 120-129.

[10]. Niem-Trung, Comparison of scheduling algorithms for a multi product batch chemical plant with a generalized serial network, thesis submitted to Virginia polytechnic and state university.

[11]. Rahan, S., (1998). "Theory of constraints: A review of the philosophy and its applications". International Journal of Operations and Production Management, vol. 18, no. 4, pp. 336-355.

[12]. Brah et al(1991). "Mathematical modeling of scheduling problems". Journal of Information & Optimization Sciences, v 12, n1, P 113-137.

[13]. De Snoo et al(2011), An empirical investigation of scheduling performance criteria, Journal of Operations Management.

[14]. Herman(2007),The legacy of Taylor , Gantt & Johnson and how to improve production scheduling, ISR Technical Report.

[15]. Muthukumaran(2012), A Heuristic Scheduling Algorithm for Minimizing Makespan and Idle Time in a Nagare Cell, Advances in Mechanical Engineering, Volume 2012 (2012), Article ID 895463, 13 pages

[16]. Bo Guo et al(2011) A Production Scheduling Method Based on Interactive Simulation and Expert System. ICTE 2011: pp. 482-487.

[17]. Ashwani Dhingra et al(2010) "Multi-objective flow shop scheduling using hybrid simulated annealing", Measuring Business Excellence, Vol. 14 Iss: 3, pp.30 - 41

[18]. Pongcharoen et al(2004), The development of genetic algorithms for the finite capacity scheduling of complexproducts, with multiple levels of product structure. European journal of operational research, 152, 215 – 225.

[19]. Madurera et al(2007), a cooperative mechanism for team work based multi agent system in dynamic scheduling through meta heuristics ISAM 2007.

