KNOWLEDGE BASED DYNAMIC SCHEDULING/ RESCHEDULING IN MANUFACTURING AND UNCERTAIN ENVIRONMENT

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ABSTRACT

The generation of new and modified production schedules is becoming a necessity in today's complex manufacturing and uncertain environment. Uncertainties in the production environment and mathematical modeling limitations inevitably result in deviations from the generated schedule. This makes rescheduling essential. The proposed study revises only those operations that must be rescheduled and can be used in conjunction with the existing scheduling method to improve the efficiency of manufacturing systems. In our findings we have focused on how the system can react to the uncertainty and reestablish itself. Certain issues such as knowledge representation, constraint management, rescheduling, abstractions from reasoning process and search techniques etc. have also been discussed in detail.

Keywords: Dynamic Behavior, Rescheduling, Knowledge-domain, Time window etc.

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1. INTRODUCTION

Dynamic scheduling and rescheduling are considered to be two interesting research areas, especially as far as their interdependent relationship is concerned. In fact rescheduling is an extension of scheduling. This means that if unforeseen events occur, with a consequent change in demands, then, dynamic scheduling must be followed by real-time rescheduling immediately. In fact, rescheduling is practically mandatory in order to minimize the effect of such disturbances in the performance of the system. For this to happen, a dynamic scheduling system must react to actual situation promptly and efficiently, to produce revised effective schedule and realize dynamic reactive rescheduling.

Process Planning and Scheduling play an important role in a production manufacturing system. In scheduling, the assignment of machine tools over the time to different machines is performed. The scheduling objective is to satisfy the production constraint and to minimize the time factor, hence production cost. A good scheduling strategy may help companies to respond to the market demands quickly and to run the plant efficiently. This helps them to be more competitive in the market.

Many manufacturing facilities generate and update production schedules, which plans that state when certain controllable activities should take place. In dynamic, stochastic manufacturing environments, managers, production planners, and supervisors must not only generate high-quality schedules but also react quickly to unexpected events and revise schedules in a cost-effective manner. In fact, the manufacturing environment is full of various forms of uncertainty; this affects production in many ways. Processing time and yield will vary, machines will break, people will get sick, product specification will be unavailable, customers will place rush orders or cancel orders, supplier will deliver late and not according to specifications – the unrest goes on.

In the manufacturing domain, many scheduling job shops and approaches have been developed and adopted earlier but these approaches are still looking at methods to improve. The reactive scheduling algorithms enable appropriate reactions to unexpected events to re-establish a consistent state of the schedule. The events can be external (for example, short-term acceptance of a high-priority order) or internal (for example, machine breakdown). The possible solution approaches range from simple integrated algorithms for the handling of specific events to complete lei stand[1] systems specialized for rescheduling in the case of unforeseen circumstances. Though a wealth of literature can be found in area of scheduling yet scheduling and particular rescheduling are such complex problems that no algorithm approach will solve them in a satisfactory manner in near future, The mathematical analysis of scheduling algorithm was stimulated by various researchers as Johnson (1954), Bellman (1956), Szwarc (1974), Maggu and Das(1977), Singh T.P. (1985,2008,2010) etc. Johnson considered n jobs 2 machines flow-shop with the objective of minimization of total elapsed time and extended the algorithm to special case of 3 machine problem. Szwarc discussed the polynomial methods in algorithmically approach adopted for solving the specially structured n jobs m machines job shop problem. Maggu and Dass established equivalent job block theorem rescheduling field. Singh T.P extended the work of various researchers taking the different parameters as transportation, time, break down interval, arbitrary time , weights in jobs, due date, rental cost etc in both deterministic and fuzzy environment, thus making the problem wider and applicable in more realistic situations. No doubt these investigators resulted in larger no. of more or less efficient algorithms which unfortunately, are restricted in applicability or rather peculiar situations. Often these mathematical models are declined because the existing models do not represent exactly the real world problem and the cost for adopting such models would be very high.

The aspects of real world scheduling proves that the challenges are centered around some key factors via the dynamic behavior of the system and uncertainty in environment for which rescheduling is required. An understanding of the type of uncertainty faced by the scheduler, how the uncertainty develops and how the uncertainty is being handled and how various type of uncertainty react? The scheduler does not know whether all jobs will be completed today as expected or any rush order will appear or machine will break down tomorrow. When a machine fails, the expected duration of the breakdown has to be considered. The scheduling procedure itself is essentially the same as in the planning phase. A rescheduling policy is needed to implement a predictive-reactive scheduling strategy.

[1] A leitstand is a “computer-aided graphical decision- support system for short-term interactive and automatic production scheduling and control.”

It is difficult to guarantee that the preventive maintenance will avoid all breakdowns or processes will be corrected before they go out of control or people will always remember all the necessary steps and perfect in data recording. It is also hard to simulate all new ideas and suggestions in advance and removes uncertainty when modifications are introduced. It is argued that scheduling is essentially a problem of decision making under uncertainty and that as such uncertainty is a key factor in both schedule representation and generation. The general approach to uncertainty is to react and reschedule. The scheduling problem starts the moment they arrive at the plant and gets information what happens overnight. What was to happen, determining the immediate and pending state of demand of resources like material, communicating with shift supervisors and top management, machine maintenance, repair and so on. The problem of uncertainty is three fold, there is uncertainty associated with the requirement of a good schedule, there is uncertainty associated with how a decision will affect the ultimate solution and there is executional uncertainty due to stochastic and dynamic nature of the application domain.

Why Knowledge Based System?

A knowledge-based approach requires a large store of specific data. Thus it is necessary to choose a particular domain to carry out experiment. In several projects it has been observed that the knowledge based technology in the form of expert system is appropriate for complex scheduling problems. There are mainly four advantages why this system is preferred in some applications:-

1- In knowledge based system it is easier to apply heuristics to reduce the inherent complexity in scheduling.
2- This system offers the possibility to reason with incomplete information, uncertainty or inexact knowledge.
3- In this system, the existing knowledge is described explicitly and should therefore be easier maintainable.
4- Knowledge based approaches try to reduce the search space by using experience and heuristic knowledge of a human production planner.

1.1. Literature Survey:- A number of different knowledge based techniques, methods and tools were developed in recent years as can be seen in number of papers and projects (Smith & Fox,1987)(Opal , Bansana 1993), Jose Lazaro etal (1993)etc. The schedule tools were developed with the intension to reuse them in new applications. This intention could get limited success as they are restricted to some areas of scheduling problem. Dorn J. (1993) created a task oriented design scheduling model. Krueger (1992) through its survey on different approaches in software reuse stated that the abstraction process is the main criterion for software reuse. Since in knowledge based system we generate abstractions from the reasoning process, we have made an attempt to model reusable entities that describe reasonable process. Mahesh, V .Etal (2009) in their study discussed the integration of scheduling system with material requirement planning (MRP) and Capacity requirement planning (CRP), but the approach could not deal the problem arising due to uncertain environment .Jose Lazaro etal solved scheduling problem for discrete manufacturing using some A I techniques and explain the use of constraint relaxation to find a solution. Jain & Elmaraghy(1997) presented a scheduling approach based on genetic algorithms and highlighted some rescheduling algorithm in order to complement the currently used computer based technique. In this paper we have combined both concepts due to Jose Lazaro etal, Jain & Elmaraghy and the abstraction of reuse concept from reasoning process thus making the problem in wider and more befitting situations. Various issues such as knowledge domain, constraint management, dynamic behavior of system under different uncertainties etc have been discussed in details.

The paper is structured as follows: - The second section describes the type of system we are dealing with. The third section discusses dynamic scheduling knowledge. Fourth shows their representations. In the fifth section a simple and incremental search of a scheduling solution is outlined. The sixth section describes the way unexpected events can be handled by the system particular rescheduling. Finally, some conclusions are outlined.

2. MODEL AND ASSUMPTIONS OF THE PROBLEM:-

The system is designed for a job-shop manufacturing facility with **Mi** machines equivalent regarding their functions in which **Oj** orders with due dates and release date are to be manufactured. Each order produces a variable quantity of products and associated to each product, there is a unique process plan. The process plan may admit several routs depending on the number of similar available machines

Assumptions:-

1- The system assumes that some orders may have been scheduled previously and some of them may be in process while scheduler is working. Those orders are not be considered by the scheduler unless the disturbance comes up.
2- We assume that only one resource is required to perform an operation.
3- Set up times, load and unload times are not included.
4- Preemptive scheduling is not considered.

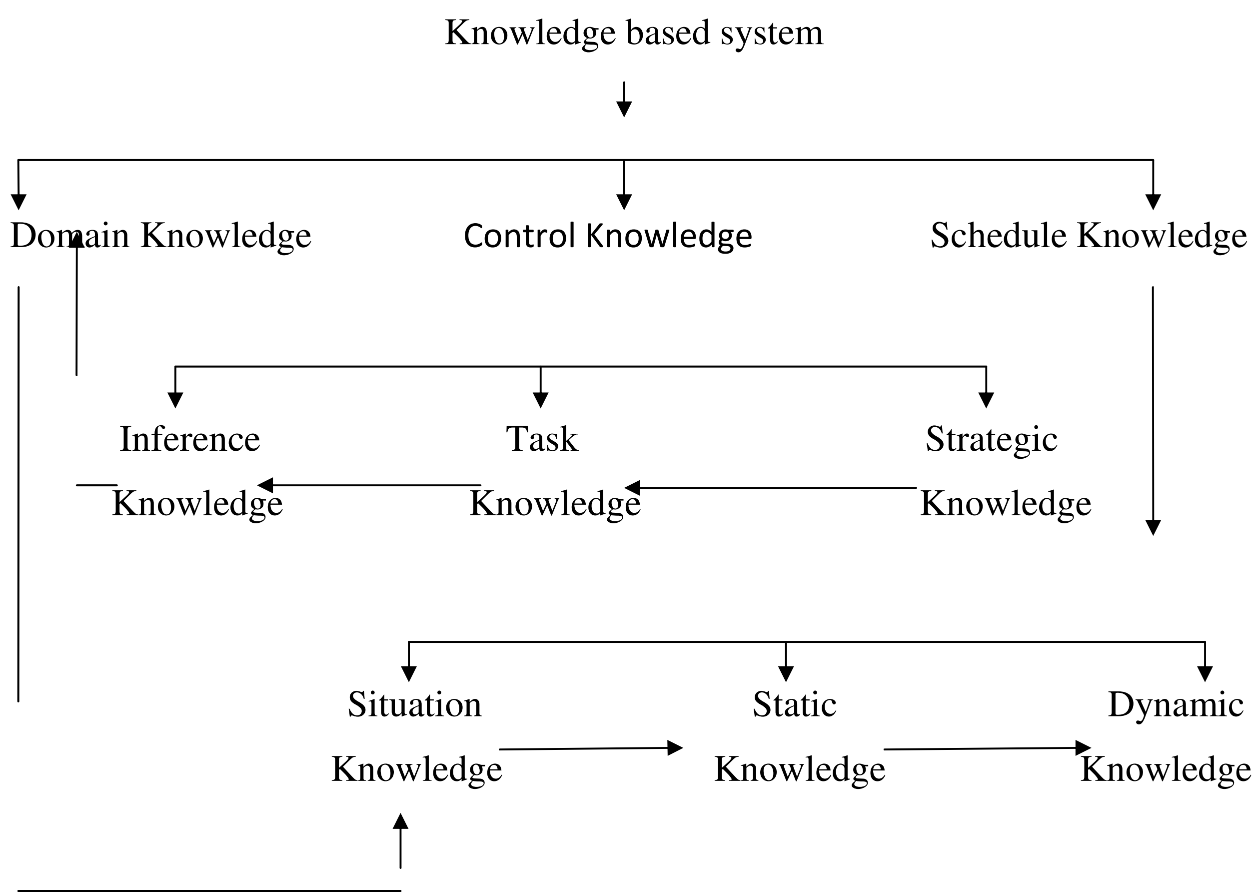
3. DYNAMIC SCHEDULING KNOWLEDGE:

Different kinds of knowledge are required in solving a scheduling problem. The knowledge based systems require a separation of domain and control knowledge.

- The Domain Knowledge contains static information about the application environment e.g. the set of orders, the possible products, their specifications, available resources, the objects, their properties and relations. Objects are partly physical objects like resources of production process and partly virtual objects like schedule. Using an object oriented representation, machines personal, tools, energy and other material can be represented as sub class of resources and enable thereby the description of task that handle resources. Relations between objects can be interpreted as constraints.
- Inference knowledge describes how basic reasoning capabilities use domain knowledge to generate control knowledge for task model. Control knowledge is an evaluation value for its schedule, the weight-age of a job or a sequence constraint between two operations.
- Task knowledge describes how elementary inferences can be combined to achieve a certain goal. A task is fixed strategy for achieving a goal based on some assumptions about domains.
- Strategic knowledge is used to find which goals are relevant to solve a particular problem. In strategic model we can choose between different heuristics e.g. shortest

processing time (SPT), earliest due date (EDD) that are used to select the next job to be scheduled.

- The situation knowledge represents the current state of scheduling.
- The schedule knowledge is divided into static and dynamic approaches for rescheduling. Hard soft constraints belong to this knowledge.



Modes of Expertise

4. REPRESENTATION:

There are several ways to represent the system/ manufacturing plant with all the activities, resources and concepts involved in scheduling. In simple form we represent the type of relationship between activity and a generic operation as follows:

{activity	{ operation
[start]	[is an activity]
[end]	[in order]
[duration]	[next operation order]
[in resource]	[previous operation order]
[next activity resource]	[time window begin]
[previous activity resource] }	[time window end] }
	{load}

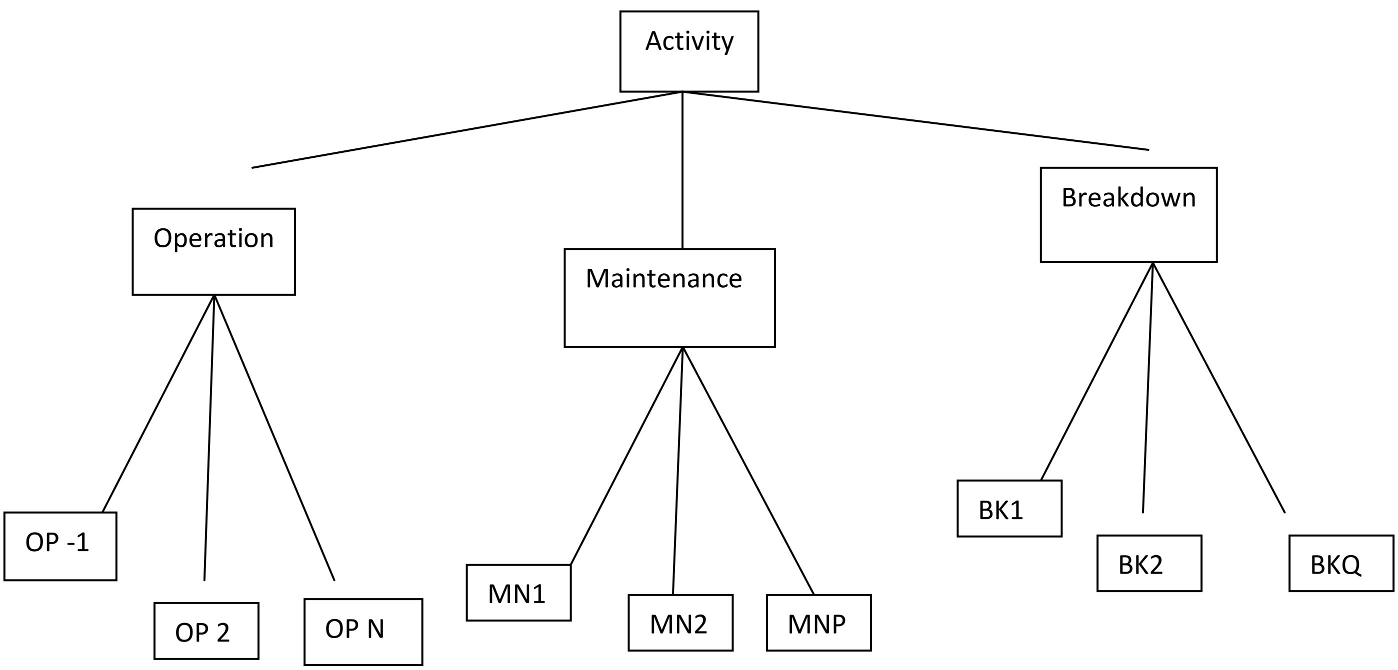


Fig. 1 – Network of activity concept.

5. INCREMENTAL SOLUTION:

The manufacturing scheduling problem may be supposed as a special case of one of the formulations of constraints satisfaction problem (CSP). In which finding one solution is enough. All instances of this CSP consist, at least of any incremental module and a back tracking mode.

A well-known manufacturing scheduling problem is the classical job shop scheduling where a set of jobs and a set of machines are given. Each machine can handle at most one job at a time. Each job consists of a chain of operations, each of which needs to be processed during an uninterrupted time period of given length on a given machine. The purpose is to find the best schedule, i.e., an allocation of the operations to time intervals on the machines that has the minimum total duration required completing all jobs.

In our scheme, scheduling decisions are initially taken order by order. The system considers both the release date and due date of every order and propagates them forwards and backwards in time to obtain interval, without interfering with temporal constraints. The interval is called time window. Allocating operations inside those intervals guarantees that the order will be produced before the due date. After that, an order selected from a pool of five dispatching rules (already implemented) is calculated. At this point in the process, the user can manually modify the sequence produced by the system in order to allow four special characteristics. Then each operation from the release date to the due date is successfully considered for scheduling taking into account the workload already scheduled. Parts of those previous assignments are considered movable while others are considered fixed to encourage plan stability. Besides it, the system has the possibility to schedule maintenance activities which may also belongs to different classes with different durations in that case the resource to be maintained is selected by user according to the type of maintenance and the existing schedule, the most suitable time is assigned by the system.

5.1: Backtracking:

The above described strategy may result in a dead-end (bottlenecks) due to lack of resources or because of the result of a heuristic character of the whole problem solving process, the optimal path of the search is not reached. In the former case, there is not a proper solution and some kind of constraint relaxation is required. In the latter case some form of reassignment may lead to a better situation than that currently under examination. If even that does not work, the system will have to relax some more constraints.

6. DYNAMIC BEHAVIOR OF THE SYSTEM:

Due to the dynamic character of real manufacturing process or flexible manufacturing scheduling (FMS), scheduling can't be something fixed in practice. The management of real manufacturing process is located in a highly complex and dynamic environment. There exists interaction inside the organization and interaction between the manufacturing process and it´s environment. The underlying interdependencies are numerous and not always transparent. Due to the complexity and the dynamic behaviour of the system under investigation there is a time gap between an action/decision and the evidence of its consequences what makes the decision process even more difficult. Very often decisions which are crucial for the success of a manufacturing process have to be generated under lack of time. Due to this fact decision making in innovation management is a very difficult and risky task.

Several types of random variables (uncertainties) that affect the actual shop output should be taken into account if scheduling is to be realistic. There is a frequent appearance of particular situations such as arrival of rush order, resource breakdown, operation failure and lack of raw material etc which originate disturbances and produce an alteration of schedule. Following observations have been observed in real situations.

1- Machines/Resources Break down.
2- The arrival of rush orders.
3- Increased order priority i.e. the change in due dates.
4- Order cancellation.
5- Deterioration of processing time in production setting.

Due to the above said uncertainties it seems in convenient to build a system that not only allows the operator to include and/or modify in the computed schedule but also can react to the appearance of several kinds of incidents during the manufacturing process. Manual modifications of the schedule are mentioned automatically by the system to avoid inconsistencies such as improper route allocation or assignment to an unavailable resource. The criteria for rescheduling in case of incidents are that such a process should affect only orders directly involved in the event. Although this criterion restrains the domain for rescheduling, it also reduces its complexity and computing name. In this section we shall discuss the first three uncertainties only.

7. RESOURCES BREAKDOWN RESCHEDULING ALGORITHM:

The selection of the most appropriate scheduling/rescheduling algorithms or the timing of the rescheduling action for a given assignment is not a trivial task, which, however, can be supported by simulation-based evaluation. Previous studies in the literature mostly consider only two main goals defined for the rescheduling action:

- Make the schedule executable/feasible again,
- Improve the efficiency performance measure due to adaptation of the schedule to the situation occurred. In the recent years, as the third goal, several studies deal with the effect of the rescheduling also from the stability point of view.

Notations

Let R	:	Resources that break down
[a, b]	:	(estimated) Breakdown interval
[O]	:	Set of affected operation by resource breakdown
[Oi- ,Oi+]	:	Time window of operation i
[Di]	:	Duration of operation i
n	:	Number of affected operations determine set.

Find Set {Oi} where each operation Oi is allocated on resource R during interval [a,b]

Shift O ņ last operation affected by resource breakdown.

If shift O n = success.

Then delete O n from set {Oi}

End if

Order set { Oi} by urgency criterion

i = 0

While { Oi } not empty do Select alternate resource for operation Oi with free space > = Di on interval [Oi-, Oi+]
If alternate resources for Oi does not exist
then unscheduled Oi and next operations of its order.
else reallocate Oi on alternate resource
end if
delete operation Oi from set {Oi}
i= i+1
end while compute new priorities for unscheduled order.
re- schedule unscheduled orders by general method
end procedure resource breakdown rescheduling.

7.1. Discussion and Analysis.

1. If a resource breakdowns, all operations assigned to that machine during the time interval estimated as necessary for repairing it, must be unscheduled.
2. Then classify by an urgency criterion.
3. After that, the system tries to reallocate them on alternative resources following the urgency sequence.
4. If an operation of list can't be reallocated, unscheduled the order temporarily starting from the critical operation.
5. After considering every operation in the list of affected activities, some orders may have been unscheduled.
6. The rescheduling process continues by revaluating the priorities of those unscheduled order, taking into account only time and dates from critical operations.
7. The system will schedule again those orders following general method.

Utilization of machines is an important issue to be considered while rescheduling manufacturing resources e.g. in the case of a breakdown, if the affected task has a choice of more than one machine it is rerouted to the least utilized machine. Machine and task status are updated continuously while running the schedule. Here we identify two phases before rescheduling is invoked one is planning phase, where an initial schedule is to be generated and the second is control phase, where schedule progress is monitored and abnormal states are identified.

7.2. Increased Priority:

Whenever the priority of any order is increased, all the succeeding tasks of this order are advance in time. The next task of this order will start as soon as the preceding task is completed. The tasks of this high priority order are marked urgent so that to ready of the remaining tasks of this order becomes fixed in time. The increased priority case is handled in the following ways:

Run schedule obtained from stage 1 starting at time T=0, 1, 2----- until the Schedule is completed.

At any time t, IF there is an increase in priority then
Find the order whose priority is increased.
Assign the highest priority to this order and revise the task status.
Assign the same priority to all the tasks belonging to this order

IF the increased priority task is currently not loaded on any machine
IF machine required by increased priority task is free, assign task to the machine.
ELSE pre-empt the machine and start the high priority task immediately and update the system status.
ENDIF
ELSE advance all the remaining tasks to start immediately.
ENDIF

7.3. Rush Order Arrival :

When a new order arrive, it is first determined whether it is a rush or a normal order. If it is a normal order, due dates are assigned and it is merged into the current schedule. If it is a rush order, then the highest priority is assigned to it after that it is treated similar to an increased priority order. Once a rush order arrives during the scheduling execution process, all the tasks that have already started should be identified as executed. This rule should also be implemented on the complete reschedule, so that the reactive schedule does not change the schedule history;

otherwise, the reactive schedule can generate ‘‘wrong’’ tasks that start before the disruptive event, which do not exist in the original schedule. The entire machine required by rush order are released whenever they are required.

7.4. At a Glance:

In a nut shell the scheduling using knowledge based system appears as follows:
Starting with input of some tasks (e.g. scheduling, rescheduling), goals (e.g. due dates) and events (e.g. Insertion of rush orders, cancellation of already scheduled order, machine breakdown) a new scheduling problem arises. The new problem is defined by the task, goals, and events, current situations (e.g. Existing schedules and the available capacities). The user has possibilities to solve the new problems partly or entirely by manual scheduling. Alternatively the system can analyze value problem and select the most appropriate algorithm (static or dynamic) to solve it. The user can choose whether the result should be entered in knowledge base new schedule or not i.e. the user may alter this proposal or confirm it.

8. Concluding Remarks :

Rescheduling, also called reactive scheduling, requires the modification of the existing schedule during the manufacturing process to adapt to the changes such as rush order arrivals, order cancellations, or machine breakdowns. For this type of uncertainty, there is not enough information prior to realization of the uncertain parameters that will allow a protective action, so almost all the methods in the literature aim to resolve a rescheduling problem once the disruptive events occur. The reactive scheduling actions are based on various underlying strategies. It can rely on simple techniques or heuristic rules to seek a quick schedule consistency restoration.

1- This type of representation is powerful enough to include all of the relevant features of the factory/system which have been able to identify as needed.

2- If processing time is fairly different among similar resources there is a great uncertainty with respect to the time interval in which the operation can be performed, but if the time interval is not known it is difficult to evaluate the most suitable resource for the operation. We have tackled this problem by assuming that equivalent machine requires the same amount to perform an identical operation for a given product.

3- The strategy may result in a dead-end (bottle-neck) due to lack of resources or because the system is not on optimal path. In such a case there is not a proper solution and some kind of constraint relaxation is required, while in latter case some form of re-assignment may need to a better situation.

4- Main trades offs the proposed algorithms were decided in favor of its average complexity. With a small devaluation of the quality of solution, excessive search is avoided and practical application can be considered. The quality loss can be reduced within suitable limits by adapting heuristics, meta-heuristics and parameters to the application environment.
5- In order for a controlling mechanism to perform in a dynamic production environment, it must consider dispatching rules as well as the system performance.
6- The above technique provides high flexibility for scheduling and rescheduling, the user can create his/herown scheduling algorithms and extensions.

Further Work:

An evaluation method based on fuzzy logic can be described. The evaluation may be considered the importance of job, the difficulty to schedule a job, the quality of schedule itself by measuring constraint violations and relaxation constraints.

More research is needed to compare the performance of systems under predictive-reactive rescheduling policies to their performance under dynamic scheduling. This will yield additional insight into the advantages and disadvantages of rescheduling in different problem settings.

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