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Time windows and constraint programming to deal with strong restriction in the due date of productive systems

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ABSTRACT

The APS (Advanced Planning and Scheduling) systems are widely used by companies; however, the traditional APS systems cannot deal with problems whose the due date is a strong restriction. The problem derives from the way companies use their scheduling heuristics. This paper addresses this problem by using the concept of time windows with the constraint programming mechanism. A procedure is shown to generate the time windows and how they can be used for the APS systems. The APS heuristic approach that uses the concepts of time windows with constraint programming is introduced to solve problems for which the due date is a strong restriction. These heuristics, with tasks allocation either at the beginning or at the end of the task time window, eliminate the need for a priority scheme. To illustrate the advantage of the proposal, some examples are presented.

1. Introduction

Many companies operate in batch production, as is the case of manufacturing industries. However, with the increasing demand for personalized products with more functionalities and reduced costs, the maintenance of the productive process at a high level of productivity is not trivial. That is, if on the one side there are new solutions in the organization of the productive processes such as virtual enterprises, sophisticated planning and scheduling techniques, and machine with multi functional functionalities to assure more flexibility in the execution of the tasks, there is also the occurrence of unexpected events such as faults, disruptions in the supply chains, and unplanned changes in demands. These systems are becoming more and more complex and, without some formal approach, it will be impossible to predict their behavior under abnormal situations.

Therefore, in this work, the manufacturing industry is approached as an array of multipurpose equipment, used for different production steps within the different production sequences that compose the productive processes. This system is approached as a class of discrete event system to explore its techniques and formal methods (Fattori, Junqueira, Santos Filho, & Miyagi, 2011; Garcia Melo, Junqueira, & Eigi Miyagi, 2010; Riascos & Miyagi, 2010). When any unexpected event arises in this kind of equipment array, the review of product sequences should be decided upon in the short-term also considering that there are restrictions on capacity and storage.

The objective is to propose the use of scheduling heuristics within APS systems by employing time windows to solve constraints when delivery dates are important. This work is an upgraded version of the work entitled "*Advanced Planning and Scheduling Systems based on Time Windows and Constraint Programming*" (Pessoa, Montesco Estombelo, Junqueira, Santos Filho, & Miyagi, 2013) presented at the IFAC Workshop on Intelligent Manufacturing Systems (IMS2013) held in Sao Paulo, Brazil, in which the proposal is explained in more detail, and new production examples are discussed. The first one is to explain how to calculate the number of batches and the accumulated demands for generating time windows. The second one is to demonstrate how the time windows are generated, and to explain why the traditional advanced planning and scheduling systems (APS systems) cannot deal with problems in which due date is a strong restriction. This paper also discusses the importance of using time windows in the production planning phase, and two new procedures are introduced. One deals with the generation of the time windows at the planning stage and the other deals with the proposed heuristics.

The paper is organized as follows: Section 2 presents the fundamental concepts used to develop the work. Section 3 presents time windows generation and the heuristics proposed. In Section 4, two

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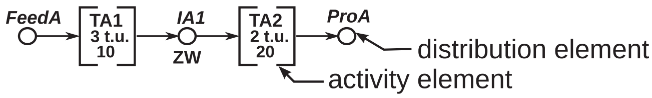


Fig. 1. Productive process example in PFS.

Table 1
Demands for products.

Products	Demand	Delivery
ProdA	15	10
	45	15
	15	35
	45	40

examples are provided to illustrate the contribution of this work. Finally, Section 5 presents the conclusions.

2. Fundamental concepts

2.1. Advanced planning and scheduling system

The APICS association (APICS, 2012) defined an APS system as any computer program that uses advanced mathematical algorithms or logic to perform optimization or simulation of finite capacity scheduling, sourcing, capital planning, resource planning, forecasting, demand management, and others. The main feature of APS systems is task allocation based on simple heuristic tools. Tasks, often referred to as jobs, correspond to parts or batches of parts that need to be processed in a set of machines (Sadeh, 1991).

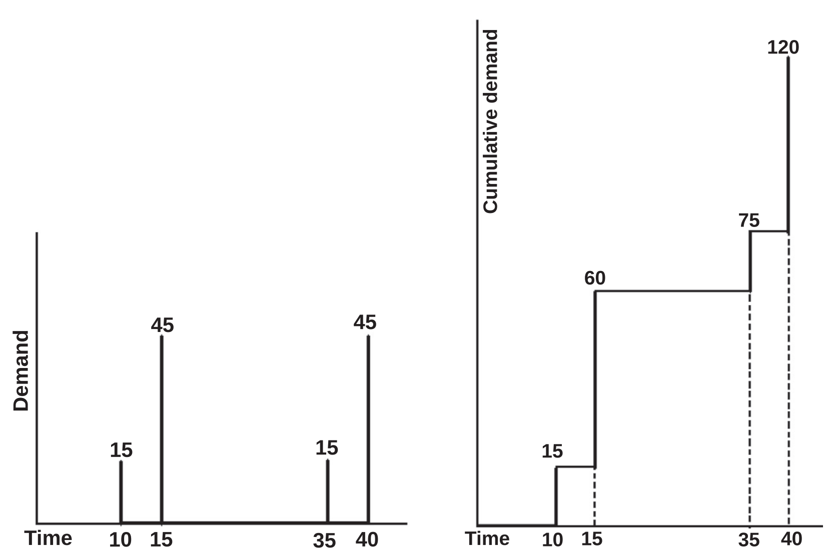
Advanced planning and scheduling systems (APS systems) emerged in the late 1990s and apply the concept of finite capacity scheduling. That is, APS adopts a scheduling method that considers resource requirements for a finite supply of available resources to generate a realistic production plan. According to Sadeh (1991), scheduling deals with the allocation of resources over time to perform a collection of tasks. The authors (Lee, Jeong, & Moon, 2002; Lin, Hwang, & Wang, 2007; Wiers, 2009) confirm the importance of the APS systems to the survival of enterprises. APS systems can optimize supply chains to reduce costs, improve product margins, assure lower inventories and to increase manufacturing yields. APS systems are scheduling systems that can be used both for planning and for generating scheduling for the shop floor tasks (Rodrigues, Gimeno, Pessoa, & Montesco, 2004). According to Steger-Jensen, Hvolby, Nielsen, and Nielsen (2011), APS systems are the most interesting approach in supply chain planning and optimization scheduling. They obtain rapid solutions when programming production is based on planned data. Also, they allow the user to modify the planning data in order to obtain a new scenario which is fundamental to assure an intelligent, flexible and agile behavior by manufacturing systems. According to Ivert (2012a) other factors influencing the use of APS systems are the amount of uncertainties on the shop floor, and the ability of operators to perform certain corrective actions.

Therefore, three basic heuristics of an APS system are considered herein to evaluate the results:

- Forward heuristic, in which tasks are allocated from the beginning of the production planning horizon. The heuristic allocates all the tasks of the first priority product table, and if not feasible, the tasks that are next in the priority product table are allocated.
- Backward heuristic, in which tasks are allocated from the end of the production planning horizon. The heuristic allocates all the tasks of the last priority product table, and if not feasible, the tasks that are next in the priority product table are allocated.
- Watch heuristic, in which tasks are allocated from the beginning of the production planning horizon. However in this case, the heuristic tries to allocate the first task of the first priority product and, if impossible, the task closest to the start of the production planning horizon is allocated.

2.2. Time windows

A task time window is a time interval whose limits determine when the task can be allocated or processed so that it defines a domain for the task starting and finishing time. It starts at the task earliest starting time (*Est*) and ends at the task latest finishing time (*Lft*): in other words, in a time scale, they are the limits at which the batches can be executed to comply with the due dates, and each batch has its own time window. In batches of task production with delivery priority dates, it is possible to determine, for each batch, the latest instant of time at which this batch should be ready. This latter instant becomes the maximum delivery date for a production batch.



(a) Initial demand of *ProA*. (b) Cumulative demand of *ProA*.

Fig. 2. Initial demands.