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Automatic notation of the physical structure of a flexible manufacturing system

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Abstract

It is essential to have a generic notation that can be associated to any problem involved in the flexible manufacturing systems (FMS). Such a notation must allow any potential actor who has to deal with one of these points (researcher or industrialist) to present his FMS and the problem to be solved without ambiguity and in a unanimously recognized format. In this paper we propose a notation that both relies on basic elements given by the modelizer and on analyzed complex structures. Examples of notation are presented, as well as a presentation of the automatic notation software under development. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Production management; Modeling; Generic notation; Control

1. Introduction

Researchers in the production management field need a notation that can be associated to any problem linked to flexible manufacturing system (FMS): be it modeling, designing, planning, scheduling, control, simulation, evaluation, logistic, etc. This notation must allow to present a FMS and the problem to be solved without ambiguity and in a unanimously recognized format.

Using a common notation, it will then be possible to constitute common knowledge bases referencing various FMS specified problems and, in the long run, to associate them to already known resolution methods, be they exact or heuristic. This knowledge base could be an essential reference tool for anyone who, facing a problem, would want to know if solutions exist and find helpful bibliographical references.

Just the same, a generator based on this notation can produce the control software adapted to a specific FMS. This dedicated software needs then to be copied on the computers in charge of controlling each actuator in the FMS, then compiled and executed.

Whatever the FMS physical structure, the notation should allow to indifferently describe any resource involved in the FMS, be it a processing or a handling resource. The proposed notation is based on a generic model and integrates notation principles currently available in the literature. Lastly, any FMS notation can be automatically generated using a computer aided interface.

The following section first presents the definitions and notations recognized in our research field

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and then highlights the purposes of the proposed notation. Section 3 defines the notation, its basic elements and the analyzed complex structures. Lastly, Section 4 develops three examples of notation as well as a presentation of the automatic notation software under development.

2. Context of the study

Many authors propose FMS notation or classification. Most of those notations appear too general and too weak to accurately describe a real FMS configuration. In this section, we first give a review of some of the principal notations and then we present the aim of the proposed notation with regard to its further use.

2.1. Current definitions and notations

There exists many FMS definitions in the literature (e.g., [1–5]). All consider that a FMS includes three subsystems:

- a *transformation system* composed of computer numerically controlled (CNC) machines with tool changing capability and local or global storage structures,
- an *automated material handling system* which ensures the transportation/handling of products between CNC machines and/or storage areas,
- a *computer control system* in charge of planning, controlling and following the behavior of the production process.

In this definition, the control system is well differentiated from the others. One can notice that during the FMS production phase it is essential to know where the computers are. But, during the analyze phase that only addresses the modeling or scheduling problems associated to the FMS, only the first two subsystems are taken into account.

The studied models agreed on the definition of a basic element of the FMS transformation subsystem ([1,3,5,6]). This element is a computer controlled production unit that includes a single CNC machine (with tool changing capability), a handling unit (a robot or a pallet loading system) and an internal stock (Fig. 1).

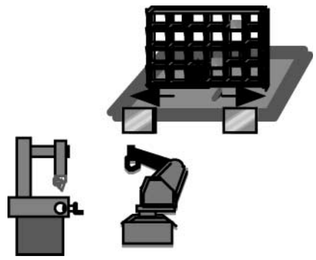

Fig. 1. Basic element in the model.

This basic element is defined in various ways (Table 1): flexible machining cell in [1], flexible manufacturing module in [6] or single flexible machine in [3,5]. Afterwards, this basic element is combined with others and connected to the material handling subsystem.

Beyond a general definition, some authors also proposed a FMS classification. This classification supplements the systematic notation, initially suggested by Graham et al. [7] and supplemented by Blazewicz et al. [8], Hall et al. [9] and Vignier et al. [10]. This notation allows the description of any scheduling problem using three fields $\alpha|\beta|\gamma$ where:

- α specifies the type and the number of resources present in the system,
- β describes the jobs and the characteristics of the resources,
- γ defines the criterion to be optimized.

In this notation, field α allows the description of the physical configuration of the FMS. This notation proves sufficient when the studied system corresponds to a flow-shop type simple configuration for which only processing resources are taken into account. However, when modeling a FMS of hybrid flow-shop type (FH), job-shop (J), hoist scheduling problem (HSP) or open-shop (O) in which transport resources ensure product transfer between processing resources, this notation has limits and does not allow to simply and accurately transcribe the physical configuration of the FMS. One can notice that the approach suggested in [5] provides a first solution towards a more complex notation. Nevertheless, this last one remains limited to