Available online at www.sciencedirect.com
ScienceDirect
Int. J. Production Economics 112 (2008) 48–61
international journal of production economics
www.elsevier.com/locate/ijpe

Contribution to reusability and modularity of manufacturing systems simulation models: Application to distributed control simulation within DFT context ☆

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Received 5 December 2005; accepted 4 December 2006
Available online 19 April 2007

Abstract

Requirements for manufacturing control evolve from traditional centralised approaches where decision making is hierarchically broadcasted to more complex distributed control architectures involving autonomous entities and processes. Moreover, manufacturing processes are facing standardisation and globalisation such as promoted by the demand flow technology (DFT) concepts. In order to evaluate these new architectures, discrete-event simulation seems the most appropriate tool. However, complexity of distributed architectures and DFT standardisation requires introducing modularity and reusability in the modelling process. This paper deals with a methodological approach, based on ASDI (analysis-specification-design-implementation), to develop a library of generic simulation components that can be, as automatically as possible, instantiated into a modular simulation model. This approach is illustrated using an industrial case study where simulation aims at evaluating the impact of operator's flexibility induced by DFT context.

Keywords: Discrete-event simulation; Model reusability; Model modularity; Distributed control; ASDIs

1. Introduction

Today manufacturing systems need to be adapted to the internal (e.g., machine breakdown) as well as the external disturbances (e.g., changes in demands or product specifications). Consequently, research in manufacturing system control has moved away from traditional centralised approaches where decision making was hierarchically broadcasted from the higher decisional levels down to the operational units to more distributed architectures. In this way, heterarchical architectures promote production control by distributing every decision capacities in autonomous entities, without any centralised view of the shop floor status. To ensure the consistency of a decision making, more pragmatic approaches are based on hybrid control which combines the predictability of the centralised control with the agility and robustness against disturbances of the heterarchical control. Holonic

☆This paper was not presented at any other revue.

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doi:10.1016/j.ijpe.2006.12.067

Manufacturing Systems (HMS) has been suggested as a concept for these future manufacturing systems (Koestler, 1967).

In order to evaluate these new manufacturing systems or to choose a management production organisation rather than another, Law and Kelton (1991) showed that discrete-event simulation is the more adaptable method (in the following, the term simulation will always be related to discrete-event simulation). While simulation has much strength, it is difficult to identify in a given model the different flows that are processed by the system. Consequently, decisional and physical systems cannot be separated in the model which is a serious limitation for evaluation of several control policies without a complete simulation model redesign. It emphasises the need for an underlying modelling discipline or structured approach (Douglas et al., 2002) to guarantee modularity and thus facilitate modification on the model. Moreover, nowadays the majority of companies are evolving towards a standardisation of their various physical and decisional processes to ensure coherence and interoperability of their processes. In this way, Trane Company, which is our industrial case study, chose to implement the demand flow technology (DFT) principles (Costanza, 1996) to standardise all its 29 production sites. DFT methodology is a particular implementation of Just-in-Time concepts, where all production lines are structured in the same way in every shop floor. Consequently, all shop floor production lines have to be modelled in a similar way. This fact justifies the need of reusability of process models to be used in simulation. Effectively, it is obvious that the time savings in simulation model design can be obtained if it is possible to reuse some simulation model modules to construct new assembly line models.

In this paper, we propose a structured approach (ASDI-dc) to build reusable and modular simulation models for manufacturing systems with distributed control. This approach is based on the ASDI (analysis-specification-design-implementation) Kellert and Force (1998a, b) methodology, which implements the object-oriented concepts and a systemic modelling framework to the simulation techniques. The main goal of our study will be to give a framework to generate automatically specific models from generic ones by using standards objects and automated functions in DFT context. According to the Trane objectives, this framework could be used by a person who is not necessarily an expert in software tools. The remainder of this paper is organised as follows. In Section 2, we highlight the reusability and modularity challenges in distributed control context. Section 3 presents the proposed methodological approach. Section 4 describes an industrial application related to an assembly line manufacturing. In Section 5 we will discuss the credibility of the reuse and the modularity. Conclusions and open issues for future research will be presented in Section 6.

2. Reusability and modularity challenges

In order to face requirements for distributed control in simulation models, this section stresses reuse and modularity challenges, and presents a comparative study between some simulation modelling methodologies.

2.1. Simulation models modularity

The concept of modularity in software development refers to the encapsulation of key subsystems, objects and components behind well-defined and relatively stable interfaces. This facilitates the integration of these components with multiple applications, as well as the evolution or possible re-implementation of these components with minimal impact on the applications using them.

Nowadays, the concept of modularity has been introduced as a logical choice in the complex systems organisation and it can be applied:

- to gather elements (model elements, meta-model elements, as meta-meta-model elements),
- to classify group modelling elements in different subject areas,
- to allow the representation of the extension of such groups (ability to describe a group as an extension of other group),
- to allow nesting of such groups (in order to clarify organization),
- to allow the representation of the dependencies between such groups (ability to describe the fact that elements defined in a group).

In the area of system modelling, modularity is used to improve system understanding, to reduce the model complexity, and to facilitate the reuse of standardised components. For example, systemic view subdivides the manufacturing system into three main subsystems: The physical factory subsystem,