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Designing function blocks for distributed process planning and adaptive control

Lihui Wang *, Yijun Song, Qiaoying Gao

Centre for Intelligent Automation, University of Skövde, PO Box 408, 541 28 Skövde, Sweden

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ABSTRACT

The objective of this research is to develop methodologies and a framework for distributed process planning and adaptive control using function blocks. Facilitated by a real-time monitoring system, the proposed methodologies can be applied to integrate with functions of dynamic scheduling in a distributed environment. A function block-enabled process planning approach is proposed to handle dynamic changes during process plan generation and execution. This paper focuses mainly on distributed process planning, particularly on the development of a function block designer that can encapsulate generic process plans into function blocks for runtime execution. As function blocks can sense environmental changes on a shop floor, it is expected that a so-generated process plan can adapt itself to the shop floor environment with dynamically optimized solutions for plan execution and process monitoring.

1. Introduction

Recently, reconfigurable manufacturing system (RMS) has emerged as a promising manufacturing paradigm that allows flexibility not only in producing a variety of parts, but also in reconfiguring the system itself. The manufacturing processes involved in an RMS are complicated, especially at machining shop floors where a large variety of products are handled dynamically in small batch sizes. The dynamic RMS environment usually has geographically distributed shop floor equipment. It requires a decentralized system architecture that enables distributed shop floor planning, dynamic resource scheduling, real-time monitoring, and remote control. It should be responsive to unpredictable changes of distributed production capacity and functionality. An ideal shop floor should be the one that uses real-time manufacturing data and intelligence to achieve the best overall performance, with the least unscheduled machine downtime. However, traditional methods are inflexible, time-consuming, and error-prone, if applied directly to this dynamic environment. In response to the above needs and to coordinate the RMS activities, a new distributed process planning (DPP) approach supported by real-time manufacturing intelligence is proposed in this research to achieve the adaptability during process planning and its execution control.

Aiming at the emerging RMS paradigm, our research objective is to develop methodologies and a framework for distributed process planning and adaptive control, capable of linking to dynamic scheduling functions. This framework is supported by a real-time monitoring system for adaptive decision-making. Within the context, the monitoring system is used to provide runtime information of shop floor devices from bottom up for effective decision-making at different levels. Compared with the best estimation of an engineer, this approach assures that the correct and accurate decisions are made in a timely manner. The ultimate goal of the research is to realize both the flexibility and dynamism of shop floor operations that meet the RMS requirements. In this paper, the focus is on a function block designer for process plan encapsulation with adaptive decision-making algorithms.

Following a brief literature review and description of the entire research, this paper presents principles of function blocks, internal structure, and execution control chart (ECC) of the function blocks, as well as details of architecture design and implementation. Finally, it is validated through a case study on how a generic process plan can be generated and encapsulated in the function blocks.

2. Brief literature review

From design to manufacturing of a product, a series of tasks must be accomplished, including machining operation selection

* Corresponding author.
E-mail address: lihui.wang@his.se (L. Wang).

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and sequencing, setup planning, machine/cutter selection, cutting parameter optimization, tool path planning, and NC code generation. As commonly referred to as process planning, the tasks are knowledge intensive, complex and dynamic in nature, which make process planning intricate and difficult.

There are many factors that affect process planning task. Part geometry, tolerance, surface finish, raw material, lot size, and the available resources all contribute to the decision-making, during process planning. It is complicated and time-consuming due to the variety of resource and operation selections together with their combinations. Maintaining the consistency of all process plans and keeping them optimized are usually difficult, especially for job shops.

In the past, a number of approaches have been reported in the literature, trying to solve problems in process planning. Recent efforts include object-oriented approach (Zhang et al., 1999), Petri net-based approach (Lee and Jung, 1995), artificial neural network-based approach (Devireddy and Ghosh, 1999), knowledge-based approach (Stori and Wright, 1996), genetic algorithm-based approach (Zhang et al., 1997), and feature-driven approach (Wang and Norrie, 2001). These reported approaches and their combinations have been applied to several specific problem domains, such as setup planning (Ong and Nee, 1996), process sequencing (Yeo et al., 1998), tool selection (Lim et al., 2001), cutting parameter selection (Arezoo et al., 2000), and tool path planning (Boogert et al., 1996).

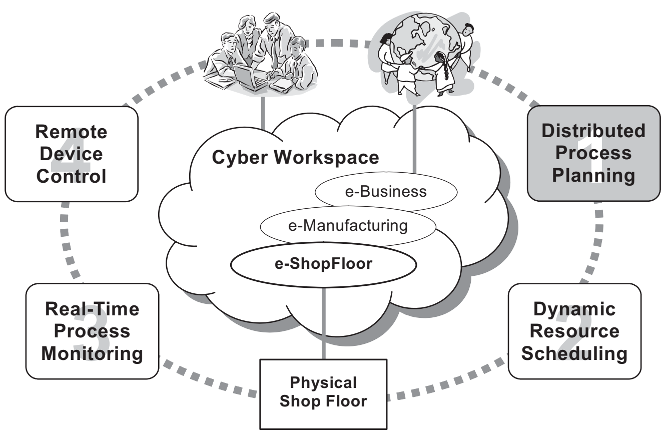

Fig. 1. Distributed process planning in a shared cyber workspace.

Despite the achievements in solving complex decision issues in process planning, these reported approaches and systems are limited to static problems through decisions made in advance. Their adaptability to unpredictable changes on shop floors remains insufficient. Most process planning systems available today are centralized in architecture, and off-line in data processing. It is difficult for a centralized off-line system to make adaptive decisions, in advance, without knowing actual runtime conditions on shop floors. To be responsive to sudden changes, a distributed and adaptive approach is considered suitable for handling the dynamic situation, especially for job shop operations.

Our approach to addressing uncertainty in job shop operations relies on combining IEC-61499 function blocks (IEC, 2005), with a distributed process planning concept. Function blocks are defined as an IEC standard for distributed industrial process measurement and control systems, particularly for PLC control. One major use of function block is in the system design of a distributed autonomous system with intelligent control components. Some early research efforts utilizing function blocks include holonic control (Wang et al., 2001), reconfiguration of real-time distributed systems (Brennan et al., 2002), function block-oriented engineering support systems (Thramboulidis and Tranoris, 2001), and Web-based engineering and maintenance of distributed control systems (Schwab et al., 2005). Other researchers focused their efforts on implementation of IEC-61499 in the process control systems. For example, Olsen et al. (2005) introduced their implementation of a real-time distributed control model using a Java-based platform. A control application was distributed across two devices by the support of a MANAGER function block, which can provide device management services. Strasser et al. (2004) implemented a function block library, for close-loop control. Hussain and Frey (2004) reported how IEC-61499 can model a flexible and reconfigurable distributed

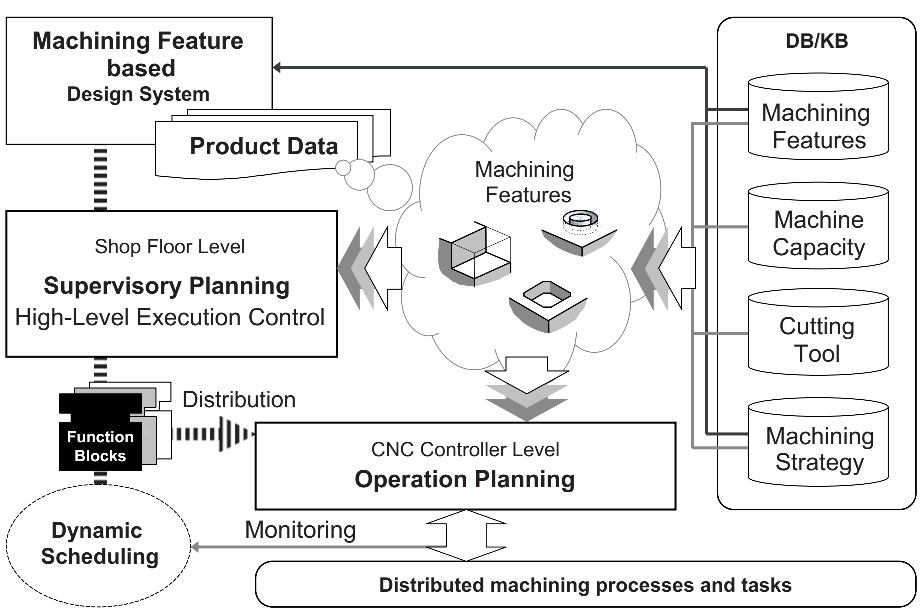

Fig. 2. Concept of distributed process planning.