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An object-oriented simulation framework for real-time control of automated flexible manufacturing systems

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Abstract

This paper describes an object-oriented simulation approach for the design of a flexible manufacturing system that allows the implementation of control logic during the system design phase. The object-oriented design approach is built around the formal theory of supervisory control based on Finite Automata. The formalism is used to capture inter-object relationships that are difficult to identify in the object-oriented design approach. The system resources are modeled as object classes based on the events that have to be monitored for real-time control. Real-time control issues including deadlock resolution, resource failures in various modes of operation and recovery from failures while sustaining desirable logical system properties are integrated into the logical design for simulating the supervisory controller.

Keywords: Object-oriented simulation; Flexible manufacturing systems; Real-time control

1. Introduction

Performance evaluation of discrete parts manufacturing plant design is quite difficult and has to date been tractable mostly through simulation models. Current commercial software for the simulation of manufacturing system designs does not incorporate models of the sensory data collection and electronic control systems that will eventually drive the operation of the factory that the simulation is modeling.

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This leaves the control system design architecture as a separate design task to be performed later. Consequently, the impact of the control system on system performance is evaluated after the construction of the plant. Integration of control system design into plant simulation models requires modeling the plant in terms of events that will have to be monitored, recorded, and used for control. In principle, the software used to control the simulated factory operations could also be used to drive the operations of the actual factory after it is constructed.

The traditional hierarchical decomposition approach to the design and control of manufacturing systems includes the strategic level (initial design) at the top, followed by the tactical (system configuration) and operational levels (part dispatching) towards the bottom. The control systems as they are referred to in this paper, reside below the operational decisions layer and deal with real-time control of the manufacturing system, which includes deadlock resolution and recovery from resource failures.

1.1. Background

There have been several significant manufacturing system simulation approaches that address real-time control issues. The RapidCIM project (Joshi, Smith, Wysk, Peters, & Pegden, 1995) develops a plug-and-play shop floor control design environment based on a simulation model of a target system and a simulation model of its controller. It is based on the control system architecture described by Smith, Hoberecht, and Joshi (1996), and an automatic control code generator for message passing between workstation controller and equipment developed by Smith and Joshi (1993). In RapidCIM, the control modules are integrated within the simulation. It is anticipated that, after debugging a control module, it can be plugged into the actual physical environment and serve as the shop floor control system. This is accomplished by using the simulation software package Arena Real-Time (System Modeling Corporation, 1999), which advances the simulation of the control logic in real-time based on messages passed back and forth with the actual system. Originally developed for discrete event systems, RapidCIM has recently been extended to hybrid systems, which consist of both discrete event and continuous processes (Moreno-Lizaranzu, Wysk, Hong, & Prabhu, 2001).

Deuermeyer, Curry, Duchowski, and Venkatesh (1997) develop an automatic deadlock detection scheme for general-purpose simulation systems and offer deadlock detection/recovery algorithms for grouped and overlapping resources using a graph-theoretic description. The methodology described assumes that only a single unit of one or more resources is required for processing of a part. Venkatesh, Smith, Deuermeyer, and Curry (1998) extend this formalism to systems where multiple units of one or more resources are required for processing.

The recent extensive survey by Narayanan et al. (1998) summarizes the efforts in the last decade towards the development of object-oriented simulation of manufacturing systems. From the real-time control simulation perspective, OOSIM project (Bodner et al., 1993) addresses deadlock issues within their described framework. While resource failures have been integrated into a number of the simulations, the scope has been limited to measuring system performance, i.e. resource utilizations (Borenstein, 2000). There has been no significant work in addressing the issue of recovering from failures while sustaining required logical properties of the system such as deadlock-freeness and proper termination of activities in the simulation of manufacturing systems.