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A Manufacturing Process Information Model for Design and Process Planning Integration

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Abstract

The National Institute of Standards and Technology (NIST) Design and Process Planning Integration (DPPI) project is developing an open, neutral manufacturing process object model to enable software interoperability among preliminary product design, process planning, and manufacturing execution. This object model has been used as the basis for developing the ISO 16100 standard: Industrial automation systems & integration – Manufacturing software capability profiling, Part 2: Information models for interoperability.

This paper describes an object-oriented manufacturing process information model in the Unified Modeling Language. The model comprises classes on the necessary manufacturing information, such as artifact, manufacturing activities, workpiece, manufacturing equipment, estimated cost and time, and manufacturing process sequences. Major manufacturing activities include setup, workpiece handling, loading/unloading, and processing. This model is capable of describing the hierarchical structure of the information representing manufacturing processes of an artifact by means of recursive definition. Also, the model includes the representation of concurrent activities, alternative activities, and parallel activities. Furthermore, this model provides software developers with the information foundation for developing new process planning systems such that software development time can be significantly reduced.

Keywords: *Manufacturing Process Modeling, Manufacturing Information, Object Model, Product Development, Systems Integration*

1. Introduction

The Automotive Interoperability Study estimates that the U.S. automotive industry has to spend about $\$10^9$ USD a year to overcome information barriers and poor interoperability among computer-aided design (CAD), computer-aided process planning, and computer-aided manufacturing systems. About $\$9 \times 10^8$ USD is used to repair and replace unusable data files (Brunnermeier and Martin 1999). A key solution to the problems will be standard programming interfaces that will allow information of design, process planning, and manufacturing execution to be exchanged among, and shared by, different design, engineering, and manufacturing software systems.

At the National Institute of Standards and Technology (NIST), the Design and Process Planning Integration (DPPI) project addresses the needs for improving communications between design and process planning activities, especially in the early design phase. Considerable emphasis is initially being placed on the conceptual stages of both design and process planning (Nederbragt et al. 1998). The main goal of the DPPI project is on the information exchange and interoperability between design and manufacturing process planning software systems for mechanical products. To support the seamless integration of preliminary design and preliminary process planning, the DPPI project established an open, neutral manufacturing process object model using object-oriented technology. This model supports the representation of manufacturing activities, resources, cost, and time. The ISO 16100 Part 2 (Industrial automation systems & integration – Manufacturing software capability profiling – Information model for interoperability) working draft has been developed based on this model. The ISO 16100 working draft consists of five parts: Framework for interoperability, Information models for interoperability, Interface protocols, Profiling method and templates, and Conformance test methods, criteria, and reports.

2. Related Research Work in Manufacturing Information Modeling

To achieve software interoperability, information models are necessary and critical to specify common terms and programming interfaces. In design, a product model is being developed in ISO 10303 (informally known as the STandard for Exchange of Product data – STEP) (ISO 1994). STEP includes representations of geometry, topology, dimension, tolerance, feature, material, product configuration, and so on. Manufacturing information modeling efforts have been focused on manufacturing resource capability modeling, process plan modeling, and manufacturing cost modeling. Several manufacturing models have been developed, but they are not in the standardization stage.

Manufacturing Resource Capability Modeling

A manufacturing resource information model is often used in resource selection and process capability evaluation. A manufacturing resource capability model represents the information on the function and characteristics of resources that contribute to the process capability. Several manufacturing resource capability models have been developed. A manufacturing information model supports the product realization process. It only focuses on the information of design for manufacturability on the factory level (Giachetti 1999). The two manufacturing capability models to support concurrent engineering are capable of representing the resource capability on the workstation level (Song, Chu, Cai 1999; Mollina, Ellis, Young 1995). A product and manufacturing capability model for CAD/CAPP integration focuses on information about machine tools, machining processes, operations, and cutting tools (Gao and Huang 1996). A model of manufacturing resource information focuses on milling and turning machine tools, cutting tools appropriate to the processes of milling, drilling, and so on (Jurrens, Fowler, Algeo 1995). An object-oriented manufacturing resource modeling for process planning includes shape capability, dimension and precision capability, surface finish capability, and position and orientation capability (Zhang et al. 1999). These models provide a foundation for developing the manufacturing process information model described in this paper.

Process Plan Modeling

Process plan modeling is to describe the process plan strategy of a manufacturing process. A process plan model includes a hierarchically structured process plan: generic plan, macro plan, detailed plan, and micro plan (Ming, Mak, Yan 1998). A Language for Process Specification (ALPS) has been designed as a data model to support the description of process plans used in the discrete manufacturing industry. The design goals of ALPS include the support fc decomposition, parallel tasks, synchronizat tasks, alternative tasks, sequences, resource ꞏ tions, critical task sequences, and informatic nipulation operatives (Catron and Ray 1991 model is in an entity-relationship model. Ho the model is not object oriented. STEP AP21: application protocol (AP) within STEP that sp the exchange, archiving, and sharing of nur control (NC) process plans for machined part: FDIS 1995). The model supports sequential ties. It does not support parallel or concurrent ties. It also does not support manufacturing c time information exchange.

Manufacturing Cost Modeling

Production costs are primarily committed early design stage. It is important to model aı mate the costs to guide designers to make soı cisions to lower product costs. There are thre cost-estimating methods used in industry: th metric-based approach (Milehan et al. Boothroyd and Reynolds 1989), feature-ba: proach (Ou-Yang and Lin 1997), and activit approach (Park and Kim 1995, Ioannou and S 1999). Activity-based cost (ABC) estimation i on the costs of all manufacturing activities. A guide process planners to lower manufacturi by controlling and reducing related manufa activity through identifying non-value-addin ties. The integration of cost models with man ing resource capability models and process p models has to be further developed, for an in model is necessary to enable software interope

Summary of Manufacturing Information

The abovementioned models have not bee fully integrated with each other or with a information model. Some specific issue addressed are as follows:

- Most published process plan models f detailed process planning, not the pre process planning in the early product ment stage, and need to be extended to i the following manufacturing informa hierarchical structure of manufacturin ties, workpiece information, processi and manufacturing cost.