The 35th IEEE Conference on Decision and Control (CDC), Kobe, Japan, December, 1996.

Intelligent Manufacturing System Control: Reference Model and Initial Implementation

Hui-Min Huang
Manufacturing Engineering Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899
U.S.A.
huang@cme.nist.gov; http://isd.cme.nist.gov/

Abstract

This paper describes the concept of a task within a control architecture called Intelligent Systems Architecture for Manufacturing (ISAM). The paper also describes the approach for modeling and developing the tasks and the controllers for ISAM based applications.

1. Architectural Overview

An architecture for intelligent manufacturing systems describes the structure of such systems, including the components that comprise the systems, the functionality of the components, and the relationships and interactions among the components. A reference-model architecture further emphasizes that the architectural model needs to be generic and applicable to multiple types of problems. An open system allows components, possibly developed by different people, to be easily integrated and function harmoniously. Major efforts in this area include the U.S. Air Force Next Generation Controller (NGC) program [1], which developed a specification for an open architecture standard. The European Open System Architecture for Controls within Automation Systems project (OSACA) [2] and the Japanese Open System Environment for Controller (OSEC) project [3] address the open architecture issues related to the cell, individual machine, or subsystem controllers.

Researchers in the Manufacturing Engineering Laboratory of the National Institute of Standards and Technology are developing an open system reference-model architecture called the Intelligent Systems Architecture for Manufacturing (ISAM). ISAM is intended to facilitate the organization, interconnection, and intelligent control of manufacturing systems. ISAM is based on concepts from the NIST Real-time Control System (RCS) architecture [4, 5, 6, 7] and is a hierarchical control architecture. ISAM prescribes a canonical form that is capable of modeling application systems to any level of control authority. Each level has a pre-defined level of authority. Each level can have multiple controller nodes. Figure 1 illustrates ISAM hierarchy. The level names indicate a smooth transition from the broader to the narrower scopes of authority from the higher to the lower levels. All the controller nodes have a generic functionality, but employ different algorithms that are consistent with the node's assigned boundary of authority.

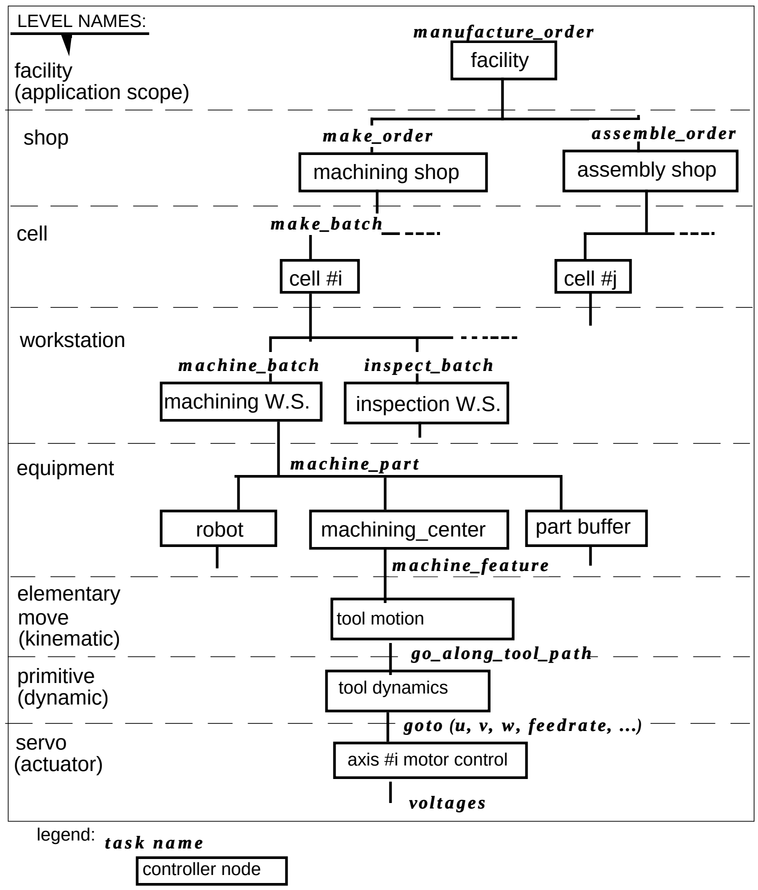

Figure 1: Controller Nodes and Tasks in an ISAM Hierarchy

2. Task and Task Decomposition

A manufacturing system performs assigned tasks. Tasks and the decomposition of tasks within the architecture are part of the key concepts in ISAM. Manufacturing system goals, described in terms of tasks, are entered from the highest level of the system's ISAM controller. In Figure 1, the highest level controller, known as the facility controller, receives a production order as a highest-level task. The knowledge base of this controller contains the information about how to fulfill this order. The task is decomposed into subtasks including make_order and assemble_order. These subtasks will be executed by the subordinate controllers, namely, the machine shop, and the assembly shop.

This task decomposition process continues through all the control levels. At each level, the tasks are decomposed into subtasks with finer resolutions and shorter time span before being passed down to the next lower level. This process typically results in electrical or mechanical signals as the output of the lowest control level. The axis #i motor control output in Figure 1 illustrates such an effect. These signals drive the actuators to approach the overall system goals. Figure 2 illustrates that a task received at the workstation level is decomposed spatially and temporally before it is executed. The execution results in subtasks for the equipment level planning and execution. These subtasks are represented by dots on the horizontal lines leading from the EX_i modules of Figure 2.

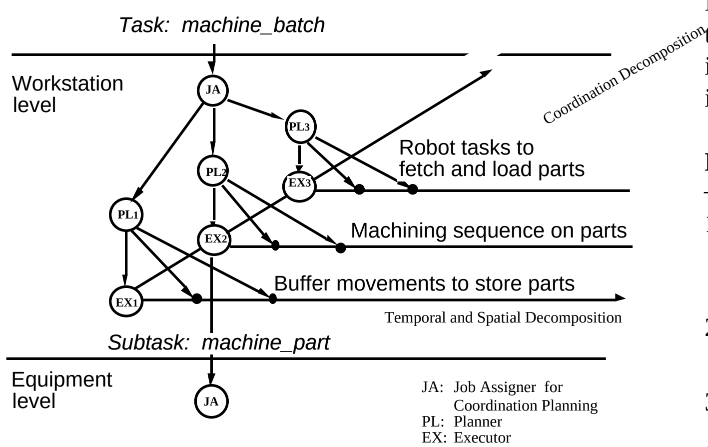

Figure 2: Task Decomposition in ISAM

3. The Development Approach: Generic Control Node, Task Model, and Task Tree

A small-scale first implementation of ISAM is under way at the NIST National Advanced Manufacturing Testbed (NAMT). The following summarizes the approach:

ISAM originates as a reference-model and contains generic functions that can be inherited by specific applications. Therefore, the implementation effort uses the object oriented technology. A generic control node contains a behavior generation function responsible for planning and executing the tasks that a node receives from its superior node. The node also issues sub-commands for the node's subordinates. Application specific and level specific control nodes are derived from the generic node.

The developers are also studying the applicability of the object oriented concepts to the generation of the task structure for ISAM. In ISAM, each controller node can perform a set of tasks. The performance of a task requires a set of information and generates another set of information as a result. The researchers plan to develop a conceptual task frame model to capture all the information for individual tasks. Application specific and level specific algorithms and information slots will be added to the reference task frame to suit the specific requirements. These task frames can also be reused by other similar applications.

The study of specific manufacturing problems will result in a set of operational scenario descriptions. The descriptions will be analyzed and formally represented as tasks, using the task frame model. The tasks for an ISAM application form a hierarchical task tree, which is a significant portion of the knowledge base for the application.

The researchers use this implementation to study and demonstrate part of the architectural concepts, including tasks and task execution. Findings will help further evolve the ISAM architecture. The researchers also plan to expand the testbed to systematically study the additional architectural issues. The ultimate goal is an architectural framework for intelligent manufacturing.

References

1 Albus, J.S., et al., "NIST Support to the Next Generation Controller Program," NIST Interagency Report, NISTIR 4888, Gaithersburg, MD, 1991.

2 OSACA, Project Web Page, http://www.isw.uni-stuttgart.de/projekte/osaca/english/osaca.htm.

3 OSEC, Project Web Page, http://mlgw.mli.co.jp/OSE.

4 Albus, J.S., "Outline for a Theory of Intelligence," *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. 21, No. 3, May/June 1991, pp. 473-509.

5 Huang, H., "An Architecture and a Methodology for Intelligent Control, "*IEEE Expert*, Vol. 11, No. 2, April 1996, pp. 46-55.

6 Proctor, F., et al., "Validation of Standard Interfaces for Machine Control," Intelligent Automation and Soft Computing: Trends in Research, Development, and Applications, Vol. 2, TSI Press, Albuquerque, NM, 1996.

7 Huang, H., Quintero, R., and Albus, J.S., "A Reference Model, Design Approach, and Development Illustration toward Hierarchical Real-Time System Control for Coal Mining Operations," Book Chapter in *Control and Dynamic Systems*, Volume 46, Academic Press, 1991, pp.173-254.