Simulation-based Manufacturing Interoperability Standards and Testing

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Abstract. Software applications for manufacturing systems developed using software from different vendors typically cannot work together. Development of custom integrations of manufacturing software incurs costs and delays that hurt industry productivity and competitiveness. Software applications need to be tested in live operational systems. It is impractical to use real industrial systems to support dynamic interoperability testing and research due to: 1) access issues - manufacturing facilities are not open to outsiders, as proprietary data and processes may be compromised; 2) technical issues - operational systems are not instrumented to support testing; and 3) cost issues - productivity suffers when actual production systems are taken offline to allow testing. Publicly available simulations do not exist to demonstrate simulation integration issues, validate potential standards solutions, or dynamically test the interoperability of simulation systems and other software applications. A new, dynamic, simulation-based interoperability testing facility for manufacturing software applications is being developed at National Institute of Standards and Technology (NIST).

Introduction

Manufacturing systems tend to be large, complex, and expensive to construct and operate. Due to hardware-acquisition, maintenance, and space costs, academic and research institutions cannot afford to duplicate real manufacturing systems in their laboratories. Student and researcher hands-on experiences with manufacturing systems are often limited to individual or small groups of machine tools in laboratory shops, prototype work cells, or tabletop manufacturing systems. Manufacturing research and testing could be significantly enhanced if manufacturing systems could somehow be brought into the laboratories of academic and research institutions. Computer simulation technology now allows us to construct large, realistic virtual worlds in software. The military and the entertainment industry have made extensive use of this technology for a number of years. The industrial world is just beginning to recognize the potential of this technology. Virtual manufacturing enterprises could be used by a variety of organizations involved in manufacturing for research, testing, and training [1].

Software applications for manufacturing systems developed using software from different vendors typically cannot work together without an integration. Custom integrations of manufacturing software incur costs and delays that hurt industry productivity and competitiveness. As software applications continue to evolve, interoperability is expected to remain a problem. Although NIST has developed static testing tools that, for example, check data formats, software applications must ultimately be tested in live operational systems. It is impractical to use real industrial systems to support dynamic interoperability testing and research due to: 1) access issues - manufacturing facilities are not open to outsiders, as proprietary data and processes may be compromised; 2) technical issues - operational systems are not instrumented to support testing; and 3) cost issues - productivity suffers when actual production systems are taken offline to allow testing. Currently, no publicly available facility with open interfaces exists to support dynamic interoperability testing for a broad range of manufacturing interface standards and software applications. Prohibitive development costs and other priorities prevent most software vendors, research, and standards organizations from

developing systems to support interoperability testing. New standards being developed to address interoperability issues often overlap and conflict with each other. Adequate testing facilities are not available for evaluating the suitability and effectiveness of existing and candidate standards for application to specific manufacturing domain areas. New, dynamic, manufacturing domain-specific testing capabilities are needed to evaluate the suitability of standards for selected applications, identify and resolve conflicts between standards, and evaluate compliance of vendor implementations with standards. Non-proprietary systems and neutral test case data sets are needed to support fair and open competition [7].

NIST scientists and engineers from the Modeling and Simulation Group are using simulation technology to gain first hand experience with the problems faced by industrial users, to validate standards solutions, and to establish interoperability and other testing capabilities. A major focus is the development of a new, dynamic, simulation-based interoperability testing facility for manufacturing software applications.

Simulation Based Manufacturing Interoperability Standards and testing

The simulation prototypes and testing systems with open architectures and neutral interfaces can be used to validate simulation interface standards requirements and evaluate the interoperability of software applications with evolving standards. NIST has developed a number of simulations to support simulation-based interoperability testing, including an automotive supply chain, a vehicle paint shop operation, a final assembly plant, and various shop floor operations [6, 7, 8]. The interfaces that have been incorporated into these simulations include the Simulation Interoperability Standards Organization Conference (SISO) Core Manufacturing Simulation Data Model (CMSD) [3] and the Open Application Group's specification supporting Inventory Visibility. Machining job shops have been identified and selected as high priority manufacturing product domains for implementation within the virtual manufacturing environment. System functions and test case data for selected supply chain, facilities, systems and processes were also been identified. Stand-alone simulation models of manufacturing supply chains, shops, workstations, and machining centers [4, 5] have been developed. Fig. 1 is an example of a real machine tool and its' virtual model. Relevant neutral interfaces and standards that enable integration and data transactions between simulations and with external systems have been identified and implemented. The simulation models need to be developed with monitoring, testing, and diagnostic tools to support interoperability testing. Interoperability testing services, procedures, and reports for internal and external customers need to be established.

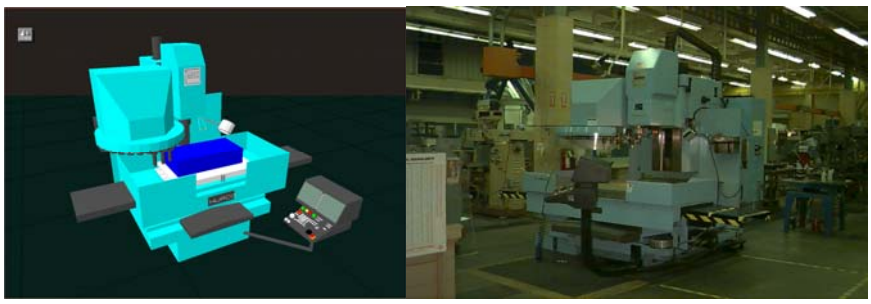

Figure 1: A Real Machine Tool and Its Virtual Model

The simulation prototypes and testing systems will establish a baseline reference environment for targeting interface standardization needs and help minimize redundant specification efforts, and provide open, neutral test-based evaluations of interface standards and conforming software applications. It enables collaboration and cost sharing between competing organizations (e.g., manufacturers and software vendors) that have difficulties cooperating or sharing information in other venues. It provides neutral models, test case data, and support tools that can be used by software developers for self-testing and academic institutions for research purposes, and shortens development

time for new standards and improves the interoperability of commercially-developed manufacturing software applications for the automotive, aerospace, and other industries. Activities include:
1. *Virtual Manufacturing System Enhancements.* Enhance current supply chain, manufacturing plant, and shop floor level simulations with functionality to support processing and interoperability testing for external inventory, process specification, bill of materials, cost accounting, product life cycle management data, etc.
2. *Testing Tool Integration.* Identify, select, and integrate appropriate testing tools to instrument the Virtual Manufacturing Systems Environment, including integration infrastructures, communications channel monitors, system and module status displays, logging and reporting tools, message and file syntax checkers, system initialization, control utilities, rollback utilities, configuration management, and writing of software for testing tools and test case data sets.
3. *Testing Facility Operations.* Working with industry, research, and Standards Development Organizations (SDO) partners to define neutral test cases, data sets; and testing policies, procedures, and checklists. Work with software vendors to set priorities and initiate interoperability testing operations for selected software products in key problem areas.

Modules of the Virtual Test Bed. The Virtual Manufacturing Environment project of the NIST Manufacturing Interoperability Program is focused on developing integrated manufacturing simulations that can be used to support future industry interoperability testing needs. It includes the following modules: Business, design, engineering, and analysis applications modules that include Order management, Computer-Aided Design and solid modeling , Process planning, Cost estimating, Cost accounting , Computer-Aided Manufacturing, Product data management, Enterprise resource planning, Material procurement, Tool and inventory management, Scheduling, and Job tracking. Manufacturing simulation modules, Neutral test case data and databases modules, System integration software applications modules, Candidate specifications and standards modules, and Interoperability monitoring, testing, and control instrumentation modules.

Technical Approach. The tasks include: first to develop test case data and stand-alone simulation models of a machined parts supply chain, machine shop, workstations and machining centers, second, to extend the simulations using selected interface specifications and standards to integrate the simulations with each other and other manufacturing software applications, third, to incorporate monitoring, testing, and diagnostic tools to enable interoperability research and testing, fourth, to provide interoperability testing facilities and services for software developers, manufacturers, research institutions, consortia, and standards organizations, and finally to expand the test bed to include simulations of other manufacturing supply chains, facilities, systems, operations, and processes as well as additional interface specifications, testing tools, and data sets.

Neutral Test Case Data. Researchers need neutral data because test data needs to be made available to many different vendors, non-disclosure agreements and proprietary data will not be compatible with an open testing environment. Researchers will concentrate on information structures and models used by machine shops, the information created should not be identifiable with a specific manufacturer, especially in the areas of cost, resource requirements, detailed designs or processes. The required data include part design, supply chain, production management, and machine tool data, product design and specifications, bill of materials, process plans, schedules, inventory, timing information, failure and repair information, quality control data, logistics, etc.

Interoperability Testing Instrumentation. This include module integration infrastructure, communications channel monitors, system and module status displays, logging and reporting tools, message and file syntax checkers, etc., system initialization, control, and rollback utilities, configuration management and build software for testing tools and test case data sets, and testing policies, procedures, and checklists.

Phase I Task Summary. The first step is to further explain the approach. The candidate manufacturing domain area need to be identified first, for example, automotive industry. Then the manufacturing scenario, simulation module functions, and test case data need to be specified. For

example, a subset of the systems contained within the selected manufacturing domain may include a part supply chain simulation, a machine shop simulation, and models of the machining and support workstations. Simulation software needs to be selected and stand alone model need to be developed for each system. Non-proprietary product design and life cycle data need to be used to populate design, engineering, analysis systems, and associated databases. The simulation models and test case data need to be validated with industry experts before it's ready to use for testing.

Summary

NIST is establishing a virtual manufacturing environment based upon simulation technology that enables dynamic interoperability testing for manufacturing software applications, candidate interface specifications/protocols, and standards. The virtual test bed will provide interoperability testing support to software developers, manufacturers, research institutions, consortia, and standards organizations for selected manufacturing product domains, facilities, systems, operations, and processes. The public facility with an open architecture for dynamic simulation-based interoperability testing of manufacturing software applications will focus initially on a machining job shop environment. In collaboration with industry, software vendors, researchers, and SDOs, needed standards, as well as dynamic model- and simulation-based manufacturing interoperability testing capabilities will be provided.

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References

[1] C. R. McLean, S. Jain, F. H. Riddick, and T. Y. Lee: *A Simulation Architecture for Manufacturing Interoperability Testing*, Proceedings of the Summer Computer Simulation Conference (2007)

[2] S. Jain and C. R. McLean: *A Simulation Architecture for Manufacturing Interoperability Testing*, Proceedings of the Summer Computer Simulation Conference (2007) Mater. Sci. Forum Vol. 83-87 (1992), p. 119

[3] C. R. McLean, T. Y. Lee, F. H. Riddick, and G. Shao: *Shop Data Model and Interface Specification,* NIST Interagency/Internal Report (NISTIR) – 7198 (2005)

[4] C. R. McLean and G. Shao: *Generic Case Studies for Manufacturing Simulation Applications,* Proceedings of the Winter Simulation Conference (2003)

[5] G. Shao, T. Y. Lee, and C. R. McLean: *Manufacturing Data Validation through Simulation,* Proceedings of the 2003 European Simulation and Modeling (2003)

[6] C. R. McLean, S. Jain, A. Craens, and D. Kibira: *A Virtual Manufacturing Environment for Interoperability Testing,* Proceedings of the Delft University of Technology Conference (2007)

[7] G. Shao, C. R. McLean, S. K. Leong: *A Simulation System with Neutral Data Interface for Shipbuilding Operation*, Proceedings of the Industrial Simulation Conference (2005)

[8] M. Johansson, S. K. Leong, Y.L. Lee, F. H. Riddick, G. Shao, B. J. Johansson, A. Skoogh, P. Klingstam,: *A Test Implementation of the Core Manufacturing Simulation Data Specification*, Proceedings of the Winter Simulation Conference (2007)