Prototype Implementation Based on the Machine Shop Information Model

Y. Tina Lee
Yan Luo
Guodong Shao
Manufacturing Systems Integration Division
National Institute of Standards and Technology
Gaithersburg, MD 20899-8260 U.S.A.

ABSTRACT: Interoperability between manufacturing software applications and simulation is currently extremely limited. A machine shop information model has been developed at the National Institute of Standards and Technology (NIST) as a part of system interoperability efforts. The primary objective is to develop a standard-data-interface structure for exchanging shop data among various manufacturing software applications, including simulation. The information model, when completed, will satisfy the following needs: 1) to support data requirements for the entire simulation of manufacturing life cycle, 2) to enable data exchange between simulation and other manufacturing software for machine shops, 3) to provide for the construction of machine shop simulators, and 4) to support testing and evaluation of machine shops' manufacturing software. The model is presented in both graphical form, in UML (Unified Modeling Language), and textual form, in XML (eXtensible Markup Language). The interface data include organizations, calendars, work, resources, schedules, parts, and process plans within a machine shop environment. To facilitate the implementation of the machine shop information model, custom-built software programs are being developed at NIST. The development of these software applications has been executed using document object model, XML path language, open database connectivity database engine, and machine shop information model's C++ data structures. A graphical user interface (GUI) system has also been generated to execute various functions, such as import, export, translator execution, and simulation execution. This paper presents research activities performed at NIST to support the implementation of the machine shop information model. Topics included in this paper are database development, parsers and translator development, prototype implementation, and standardization.

1. Introduction

Interoperability between manufacturing software applications and simulation is currently extremely limited. Neutral information models provide a foundation for data representation, transfer, and integration. Manufacturing enterprises use several tools to build such models including IDEF1x (Integrated Computer Aided Manufacturing Definition Language 1 Extended) (Appleton 1985), EXPRESS (ISO 10303-11) (ISO 1994), UML (Unified Modeling Language) (URL 2005), and XML (eXtensible Markup Language) (W3C 2005).

McLean 2005 describes an interface information model, developed at NIST, to represent machine shop data for manufacturing simulation. The primary objective is to develop a standard-data-interface structure for exchanging shop data among various manufacturing software applications, including simulation. The information model, when completed, will satisfy the following needs:

- to support data requirements for the entire simulation of manufacturing life cycle
- to enable data exchange between simulation and other manufacturing software for machine shops
- to provide for the construction of machine shop simulators
- to support testing and evaluation of machine shops' manufacturing software

Database management systems such as the Structured Query Language (SQL) Server, Oracle, DB2, and Access, have been used to manage enterprise data for many years. Nevertheless, custom translators are needed to transfer data between an existing database system and an XML representation of that data.

This paper presents research activities performed at NIST to support the implementation of the machine shop information model. Topics included in this paper are database development, parsers and translator development, prototype implementation, and standardization.

2. Information Model and Database Model

NIST's machine shop data model was developed to support both NIST's System Integration of Manufacturing Application (SIMA) (Carlisle 2001) program and the Software Engineering Institute's Technology Insertion Demonstration and Evaluation (TIDE) program (McLean 2002). The model is presented in both graphical form, in UML, and textual form, in XML. The model has been developed with two goals in mind: 1) to support the integration software applications at pilot facility, the Kurt L. Lesker Company's machine

shop (Lesker 2005), and 2) as a standard data interface between manufacturing simulators and other manufacturing software applications. The model contains twenty major entities. They are: organizations, calendars, resources, skill-definitions, setup-definitions, operation-definitions, maintenance-definitions, layout, parts, bills-of-materials, inventory, procurements, process-plans, work, schedules, revisions, time-sheets, probability-distributions, references, and units-of-measurement.

Using Microsoft Access, a database model has been developed to map onto the XML model's entities (Lee 2003). The database provides the possibility of data sharing in a distributed simulation environment. There were three major objectives of the database implementation:

- to demonstrate the feasibility of the information model
- to develop a pilot database system and then to migrate to a large database management system
- to support the integration of manufacturing applications and simulations used in machine shops

The database contains a set of relational tables that can be represented in a tree-shape structure. *Shop-data* is the database model's very top level, thus the model's first level relationship expresses the connections between entity *shop-data* and the other major entities. The design view of the *shop-data* table is presented in Table 1. Each element in the machine shop information model is represented as a table in the database model. Attributes and child-elements of an element are presented as fields in the corresponding table. Cardinality relationships are specified with the fields. Currently, there are about five hundred relational tables included in the machine shop database model.

Table 1: Data structure of *shop-data*

Field	**Data Type**	**Description**
INDEX	Number	[1], system use
type	Enumeration	[0..1]
identifier	Number	[1]
number	Text	[1]
name	Text	[0..1]
description	Text	[0..1]
REFERENCE-KEYS	Text	[0..1], reference-keys.SOURCE
REVISIONS	Text	[0..1], revisions.SOURCE
ORGANIZATIONS	Number	[0..1], organizations.SHOP-DATA
CALENDARS	Number	[0..1], calendars.SHOP-DATA
RESOURCES	Number	[0..1], resources.SHOP-DATA
SKILL-DEFINITIONS	Number	[0..1], skill-definitions.SHOP-DATA
OPERATION-DEFINITIONS	Number	[0..1], setup-definitions.SHOP-DATA
SETUP-DEFINITIONS	Number	[0..1], setup-definitions.SHOP-DATA
MAINTENANCE-DEFINITIONS	Number	[0..1], maintenance-definitions.SHOP-DATA
LAYOUT	Number	[0..1], layout.SHOP-DATA
PARTS	Number	[0..1],parts.SHOP-DATA
BILLS-OF-MATERIALS	Number	[0..1], bills-of-materials.SHOP-DATA
INVENTORY	Number	[0..1], inventory.SHOP-DATA
PROCUREMENTS	Number	[0..1], procurements.SHOP-DATA

PROCESS-PLANS	Number	[0..1], process-plans.SHOP-DATA
WORK	Number	[0..1], work.SHOP-DATA
SCHEDULES	Number	[0..1], schedules.SHOP-DATA
TIME-SHEETS	Number	[0..1], time-sheets.SHOP-DATA
REFERENCES	Number	[0..1], references.SHOP-DATA
PROBABILITY-DISTRIBUTIONS	Number	[0..1], probability-distributions.SHOP-DATA
UNITS-OF-MEASUREMENT	Number	[0..1], units-of-measurement.SHOP-DATA

3. Custom-built Software Programs

The information model/XML schema can serve as a neutral, vendor-independent, data format for representing and exchanging machine shop data. With the neutral data format, XML parsers, and/or translators, machine shop data can be represented in working forms (structured, in-memory representations), in database tables, or in XML instance documents. To facilitate the implementation of the machine shop information model, custom-built software programs are being developed at NIST. Four of programs that have been developed based on the machine shop information model and database model are listed as follows:

- *XML Parser*: converts XML schema data structures to C++ data structures.
- *XML Translator*: converts an XML instance document to a machine shop database. The converted C++ data structures are used to develop this translator.
- *Database Translator*: converts a machine shop database to an XML instance document. The same C++ data structures are used to develop this translator.
- *Arena Converters*: transfer data between Rockwell Software's Arena model database and an XML document.

The development of these software applications has been executed using document object model (DOM) (W3C 2005), XML path language (W3C 2005), open database connectivity database engine (MSDN 2005), and machine shop information model's C++ data structures. The data transfer is currently limited to those data in the scope of the information model. A graphical user interface (GUI) system has also been generated to execute various functions, such as import, export, translator execution, and simulation execution.

4. Prototype Implementation

Discrete-event simulation tools offer considerable flexibility when used to model the behavior of manufacturing systems. These models can be built using provided GUI and some common programming languages. Simulation data can sometimes be imported from another simulation systems through exchange files or databases. These import activities are often performed through internal and/or external interfaces. Internal interfaces allow data be imported/exported with functions or data formats provided by the simulation system. External interfaces rely on standards, neutral data formats, or widely accepted data formats.

To demonstrate the data exchange role of the machine shop information model, prototype implementations are being performed at NIST. Different simulation systems use different modeling constructs and distribution methods. While demonstrating data exchange, only machine shop operation related data are addressed and those data specially defined for a particular simulation system are ignored.

A prototype based on the Rockwell Software's Arena, Version 5.0 (Rockwell 2005) is introduced here. We selected the truck assembly line model from the Arena sample models library. New truck chassis enters the line at a constant rate. They are conveyed down the line from one work position where five processes are performed: *arrival*, *assembly-line-1*, *turn*, *assembly-line-2*, and *exit*. Each process has two to fourteen activities. The *arrival* process executes every 9.5 minutes. *The assembly-line-1* process performs operations related to axes, air tanks, etc. The *turn* process performs turning operations at two turning stations. *The assembly-line-2* performs operations related to bumper, radiator, engine, etc. The *exit* process completes assembly activities by exiting from conveyor, delivery to truck store, and collecting statistics data. An XML instance document, which contains *parts*, *work*, *resources*, *operation-definitions*, *schedules*, *units-of-measurement*, and *process-plans* is manually generated to support this truck assembly line operation. The XML document is then loaded into an Arena model database using the customer-built Arena utilities mentioned previously. As a result, an Arena

simulation model can be generated dynamically from the model database using internal ActiveX dynamic link libraries. Figure 1 presents a screen capture of the described Arena simulation model.

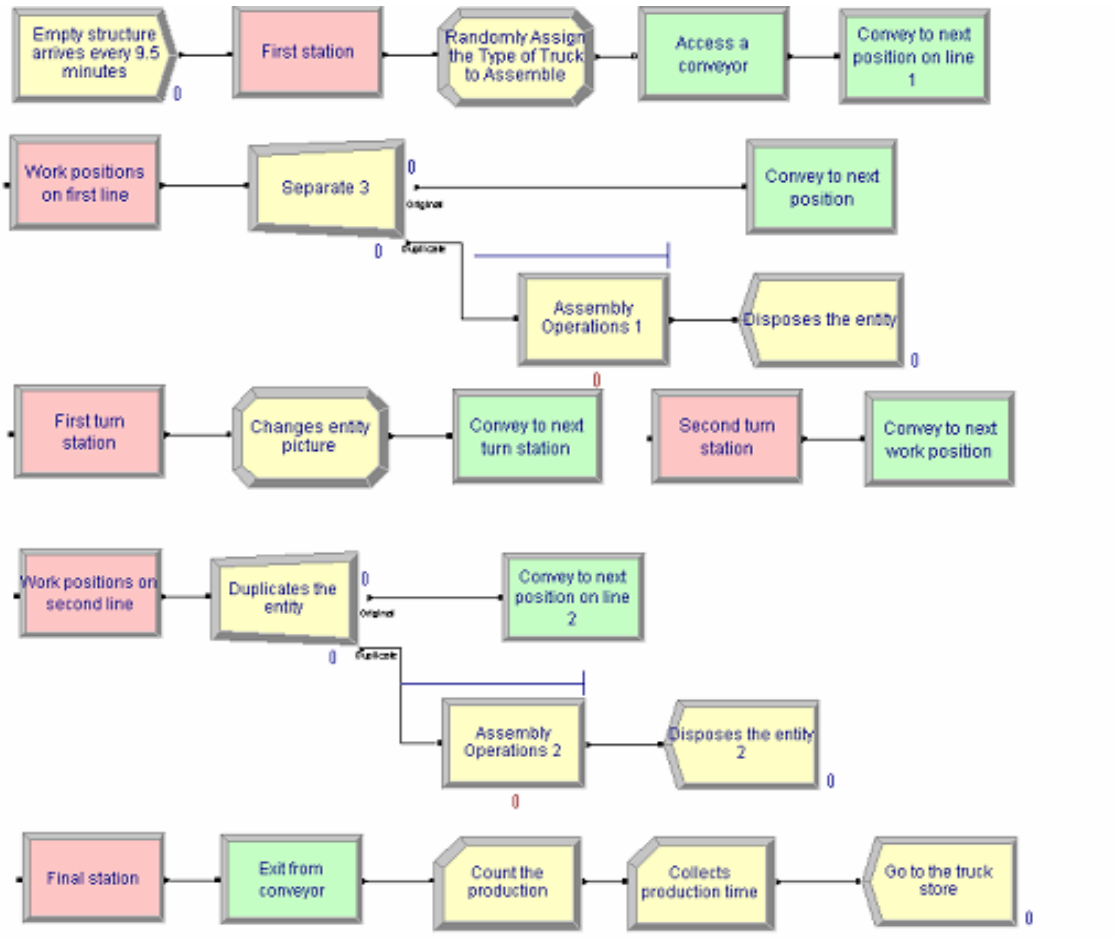

Figure 1: A simulation model of a truck assembly line

5. Standardization

Our ultimate objective in this machine shop project is to promote the establishment of a standard data interface for manufacturing simulators. The machine shop information model is recently transferred to the Core Manufacturing Simulation Data (CMSD) Product Development Group (PDG) of the Simulation Interoperability Standards Organization (SISO) (SISO 2005). The CMSD PDG formed in 2004 for developing manufacturing data standards. The resulting standard created by this group will be an Institute of Electrical and Electronics Engineers (IEEE) standard. NIST is actively involved in the group's administrative and technical activities. SISO focuses on facilitating simulation interoperability and component reuse across the Department of Defense, other government, and non-government applications. SISO originated over ten years ago with a small conference held 1989, called, "Interactive Networked Simulation for Training." In November 2003, the IEEE Computer Society Standards Activities Board voted unanimously to grant the SISO standards activities committee status as a recognized IEEE Sponsor Committee. The ultimate result is a single body for creating and promoting interoperability standards in the modeling and simulation community.

6. Conclusion and Future Work

Manufacturing simulation systems normally provide interfaces for data import and export using proprietary formats. Dependent data interfaces limit simulation applications in the manufacturing industry. This paper describes a mechanism for transferring data between a traditional database and XML files, which represent a machine shop data model developed at NIST. The data transfer mechanism is based on Document Object Model, XML Path Language, and Open Database Connectivity database engines. The paper also described implementation activities performed at NIST including the development of machine shop database model, custom-built software programs, prototype implementation, and standardization process. The machine shop information model was recently transferred to CMSD PDG of the SISO for standardization. The standard is for the modeling and simulation community in the manufacturing industry.

7. Disclaimer

Mention of commercial products or services in this paper does not imply approval or endorsement of any commercial product by NIST. The work described was funded by the United States Government and is not subject to copyright.

8. References

Appleton Company, Inc. 1985. “Integrated information support system: Information Modeling Manual: IDEF1-Extended (IDEF1X),” ICAM Project Priority 6201, Subcontract #013-078846, USAF Prime Contract #F33615-80-C-5155, Wright-Patterson Air Force Base, OH.

Carlisle, M., and J. E. Fowler. 2001. “Systems Integration for Manufacturing Applications Biennial Report,” Fiscal Years, NISTIR 6721. National Institute of Standards and Technology, Gaithersburg, MD.

ISO 10303-11. 1994(E). “Industrial Automation Systems and Integration-Product Data Representation and Exchange - Part 11: The EXPRESS language Reference Manual.”

Lee, Y. T., and Y. Luo. 2003. “A Database Design for the Machine Shop Information Model,” NISTIR 7077, National Institute of Standards and Technology, Gaithersburg, MD.

Lesker Company. 2005. Kurt J. Lesker Company [online]. Available via <www.lesker.com/newweb/index.cfm> [accessed June 3, 2005].

McLean, C.; A. Jones; Y. T. Lee and F. Riddick. 2002. “An Architecture for a Generic Data-Driven Machine Shop Simulation,” Proceedings of the Winter Simulation Conference, San Diego, CA.

McLean, C.; Y. T. Lee; G. Shao and F. Riddick. 2005. "Shop Data Model and Interface Specification," NISTIR 7198. National Institute of Standards and Technology, Gaithersburg, MD.

MSDN. 2005. ODBC Overview [online] <msdn.microsoft.com/library/default.asp?url=/library/en-us/odbc/htm/odbcintroduction_to_odbc.asp> [accessed June 3, 2005].

Rockwell Automation. 2005. Rrockwell Software [online]. <www.software.rockwell.com/index.cfm> [accessed June 3, 2005].

SISO (Simulation Interoperability Standards Organization). 2005. Welcome to SISO [online]. <www.sisostds.org> [accessed June 3, 2005].

URL Resource Center. 2005. Unified Modeling Language [online]. Available via <www.rational.com/uml> [accessed June 3, 2005].

W3C World Wide Web. 2005. XML [online]. Available via <www.w3c.org> [accessed June 3, 2005].