2012 EL Project Title and Number: Manufacturing Services Network Models

Program Title: Systems Integration for Manufacturing and Construction Applications

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Date Prepared: September 2, 2011

Summary: Production network agility is a measure of the network's ability to respond quickly to customer needs and market changes while still controlling costs and quality. Agility is impacted by production network creation process, which identifies those manufacturers with the skills, equipment, and capacities needed to perform the required manufacturing services. These processes often represent an impediment to agility because of the time it takes to identify the manufacturers. Efforts to reduce that time through automation are hampered by the different approaches the manufacturers use to describe their manufacturing services. A key barrier to achieving automation, therefore, is the absence of a standard method to represent manufacturing service descriptions. That method must produce digital descriptions, called manufacturing service models, which are computer interpretable and take into account the different views of network partners. This project will develop the measurement science that enables such a method to be developed. Once in place, this method will allow creation of standard models and descriptions of manufacturing services that support automated production network creation and increase production network agility.

Objective: To develop and validate a method to build and maintain standard production network models of manufacturing services for realistically complex, multi-stakeholder manufacturing environments, by 2014.

What is the new technical idea? Agile production networks in the 21st century need to respond quickly to customer demands with higher product availability while minimizing inventories[1]. Ability to create such agile production networks is dependent on ready access to effective descriptions of available manufacturing services, plant equipment, and systems. Presently, however, the ability to create agile production networks is restricted by the limited and heterogeneous descriptions of the manufacturing services, which are based on subjective views of varied stakeholder groups.

A key barrier is the absence of a method to develop manufacturing service models that take into account different views of stakeholders, allowing evolution and eventual convergence of these service models to a standard model. The new technical idea is a novel manufacturing knowledge-based methodology to develop production network models of manufacturing services.

The novel methodology comprises two essential capabilities: (1) Ontology Learning and (2) Ontology Mapping and Evolution[2]. Ontology Learning identifies, from existing manufacturing sources, such as manufacturing manuals, databases, and catalogues, new manufacturing concepts (such as a new type of process or equipment) that may be of relevance but are not yet included in the service model. Ontology Mapping and Evolution manages changes to the manufacturing service model so that mapping requirements from manufacturing applications (e.g., production network planning, and optimization) and manufacturing service suppliers are addressed as the model evolves.

The two capabilities, Ontology Learning and Ontology Mapping and Evolution, have been developed to address problems with little concern of application domain knowledge. The research challenge is to find means for effective use of manufacturing knowledge to address issues for realistic manufacturing problems. First, the Ontology Learning methods will need to be specialized for the manufacturing domain to extract information from existing manufacturing sources. Second, the Ontology Mapping and Evolution methods capacity need to be potentially expanded for large manufacturing problems. Third, the Ontology Learning and Ontology Mapping and Evolution methods need to work together, to reconcile probabilistic results from Ontology Learning method and formal constraints of the Ontology Evolution method.

A promising path to introduce manufacturing knowledge effectively within the proposed methodology is offered by design patterns (i.e., reusable model components). Such patterns increase efficiency of evolution of new ontologies, which is essential as manufacturing ontologies change and converge towards a standard. Our previous work in ontology engineering, and semantic integration is a foundation for the novel methodology based on design patterns.

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[1] Implementing 21st Century Smart Manufacturing, Workshop Summary Report, June 24, 2011.

[2] These are names of general knowledge processing techniques; ontology, however, in this document refers to models of manufacturing services.

What is the research plan? The intended users of the novel methodology are technical experts who work at SDOs to develop service models required by manufacturing software applications. These users need to consider requirements and proprietary models from a large, multi-stakeholder community. This, in turn, requires identification of conflicts and alignments, reconciliation, and support for eventual convergence of manufacturing service models. These requirements for the novel methodology guide the research tasks in three major phases: (1) Design of the Methodology; (2) Development of the Methodology Capabilities; and (3) Validation of Methodology.

During the Design of the Methodology phase, we will devise a process to develop and maintain models of manufacturing services across manufacturing sectors. To assure such broad applicability, the method will use design patterns for their composition into complex manufacturing models. For example, service models that use manufacturing process models of varied detail will refine same design pattern by using standard refinement operators for greater efficiency and reuse. So, a manufacturing service at a highest level of specification may use a design pattern that contains descriptions of manufacturing resources, manufacturing performance, manufacturing services, and supporting services. Machining Service, in turn, may refine the pattern's manufacturing performance property to include accuracy, surface finish, production volume, etc. The methodology will support these operations

- selection of standard manufacturing service model patterns;
- identification of proprietary model components mapping requirements;
- identification of potential conceptual mappings between the standard and proprietary models;
- confirmation and adoption of proposed ontology mappings;
- identification of additional concepts missing from the standard model; and
- evolution of the model by introducing the newly suggested concepts within the model.

During the Development of the Methodology Capabilities phase, we will perform research to advance the manufacturing knowledge-based methodology and toolset.

- First, we will develop principles and rules that govern construction and evolution of design patterns within manufacturing service models across the manufacturing sectors. We will perform analysis of multiple service models and their components, such as the Manufacturing Service Description Language[3], to identify plausible modeling patterns. In parallel, we will analyze and include applicable general principles for well-behaved models discovered in other application domains, such as OntoClean[4] within our methodology.
- Second, we will analyze the Ontology Mapping methods for application on large manufacturing service modeling scenarios. The tasks include finding alignments and selecting a matching algorithm to identify mappings between standard and proprietary concepts. When using informally structured textual sources, the tasks include source schema extraction, textual annotations with a manufacturing lexicon and thesaurus, and mappings between the textual source and service models. A Manufacturing Ontology Mapping Toolset

[3] Manufacturing Service Description Language (MSDL) ontology in collaborative development with Prof. Farhad Ameri of Texas State University.
[4] Guarino, N. and Welty, C.: Evaluating Ontological Decisions with OntoClean. Communications of the ACM,2002.

will be developed to generalize examples of ontology-based models into statistic, linguistic, and logical templates supportive of identifying mappings between manufacturing concepts.
- Third, we will analyze and extend Ontology Learning method performance for manufacturing specialization and scalability. The relevant aspects of the task include identification of relevant manufacturing corpuses; construction and utilization of manufacturing lexicon and thesaurus; and selection of natural language and resource processing approaches. A Manufacturing Ontology Learning Toolset will build on the templates and patterns developed in Ontology Mapping area to identify relevant manufacturing concepts, relationships, and structures.
- Fourth, we will prototype a platform that will integrate the developed Ontology Evolution capabilities with the Ontology Mapping and Learning capabilities.

During the Validation of Methodology phase, we will assure that the new methodology meets requirements to develop and maintain production network models of manufacturing services. The validation approach will allow

- description of service examples using a standard model,
- interpretation of the proprietary model in terms of the service example descriptions,
- determination of the 'true' mapping between the two models, and
- use of the ‘true’ mappings to evaluate performance of the Methodology Toolset.

As an outcome of applying the methodology, standard service models will be developed for implementation by software vendors in a variety of manufacturing applications to analyze, plan, and optimize production networks. Ultimately, such use of the standard manufacturing service models could provide a largest possible access to manufacturing service providers. In this way, the ability to create agile production networks that quickly respond to customer demands with highest product availability will be advanced.

Major Accomplishments:

Recent Results: The following are results from the previous 12 months:

- Manufacturing Service Description Language[3] (MSDL) analyzed for Supplier Discovery problem, based on a DoD part.
- Paper titled “An Experimental Evaluation Platform for State-of-the-Art Manufacturing Supplier Discovery Methods” by Shin, J., Ivezic, N, Kim, J., Ameri, F., McArthur, C., DeFlitch, S, Scacchitti T. Submitted to Electronic Commerce Research and Applications.

Standards and Codes:

Standards to facilitate production network efficiency and agility do not exist. We will begin discussions with industry partners to establish requirements and initiate development of the needed standards in the area of manufacturing service modeling for agile production networks. In particular, we will approach Smart Manufacturing Leadership Coalition to refine ideas of agile production networks, manufacturing services modeling, and proposed measures such as to “Drive toward modeling 90% of plant assets (equipment, systems) in 75% of plant operations across manufacturing enterprise.” [1].