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A SEMANTIC WEB SERVICE AND SIMULATION FRAMEWORK TO INTELLIGENT DISTRIBUTED MANUFACTURING

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ABSTRACT

To cope with today's fluctuating markets, a virtual enterprise (VE) concept can be employed to achieve the cooperation among independently operating enterprises. The success of VE depends on reliable interoperation among trading partners. This paper proposes a framework based on semantic web of manufacturing and simulation services to enable business and engineering collaborations between VE partners, particularly a design house and manufacturing suppliers.

INTRODUCTION

The VE concept signifies the need for methods to rapidly and cost-effectively develop products, production facilities and supporting software including design, process planning, shop floor control, enterprise resource planning, and supply chain management is becoming urgent. However, the success of VE requires reliable and large-scale interoperation among trading partners via a semantic web of trading partners' services whose properties, capabilities, and interfaces are encoded in an unambiguous as well as computer-understandable form.

To this end, we first give an overview of distributed manufacturing in the web service framework, including detailed activity and information flow diagrams. Second, we propose an ontological definition of resource models and process-capability models using an ontology definition language. Third, we propose a method based on stochastic discrete-event simulation, whose model is automatically generated from the resource and process models, to evaluate highly nonlinear process plans.

DISTRIBUTED PLANNING AND MANUFACTURING

This section describes two functional views of the manufacturing web service. The first view shows a Unified Modeling Language (UML) sequence diagram describing the activity flows between the design house and the VE manufacturing partners (see Figure 1) (Kulvatunyou et al. 2005). The second view illustrates a proposed manufacturing information workflow for the manufacturing web-service scenario (see Figure 2).

The UML sequence diagram convention is used to represent the high-level views of the activity flows within collaborative planning and manufacturing. There are four basic steps in the collaboration: (1) service discovery, (2) partner-filtering, (3) plan construction, and (4) contracting. In the *service discovery* step, the design house discovers the manufacturers that match the necessary service category (e.g., machine shop) from a web service registry and retrieves the manufacturing capability profiles. The *partner-filtering* step then selects the manufacturers whose manufacturing capabilities match the process requirements. The result of this step is a roster of potential manufacturers. In the *plan construction* step, the design house sends out Request For Quotes (RFQ) and receives back quotes from the manufacturers on the roster. Figure 1 shows the case where collaboration succeeds without design and process plan revision. After the revision, the collaboration process may loop back to the discovery step or the filtering step depending on the degree of changes in the revision. After the distributed process plan is completely constructed, the design house can start business processes to subcontract each of the selected partners.

The evolution of the proposed collaboration process in the information-centric view is illustrated in Figure 2. The designer designs the part and then prepares the process-centric data, so called a Resource-Independent Process Plan (RIPP). The RIPP is represented in a two-level process-plan graph (see

Figure 3a). When the RIPP is completed, the design house searches the manufacturing web-service registry for one or more relevant manufacturers that can perform the operation specified in each node. The search returns meta-data for manufacturing web services, which consist of manufacturer names, pointers (e.g., URL) to the manufacturing capability profiles, and the service invocation address. Once manufacturers are identified for all of the operations specified in the RIPP, the RIPP is transformed into a manufacturer-dependent process plan (MDPP, see Figure 3b). The process plan for each manufacturer, which is represented as a node in the MDPP, is conveyed to the related manufacturer with a RFQ. The manufacturer then maps its own resources to the conveyed process plan, which results in a Resource-Dependent Process Plan (RDPP). In order to win the RFQ issued from the design house, the manufacturer minimizes the manufacturing cost and time subject to the constraints of detailed surface finishes, tolerances, etc. Each manufacturer returns detailed quotes and/or a list of the problems that occur when mapping resources. Once the design house has received and evaluated manufacturers' quotes, a Distributed Process Plan (DPP, see Figure 3c) is generated, in which a single manufacturer is selected for each node in the manufacturer-dependent process plan. In the evaluation stage, the design house selects the best plan based on the quotes; otherwise, it re-plans the part if there is no feasible plan.

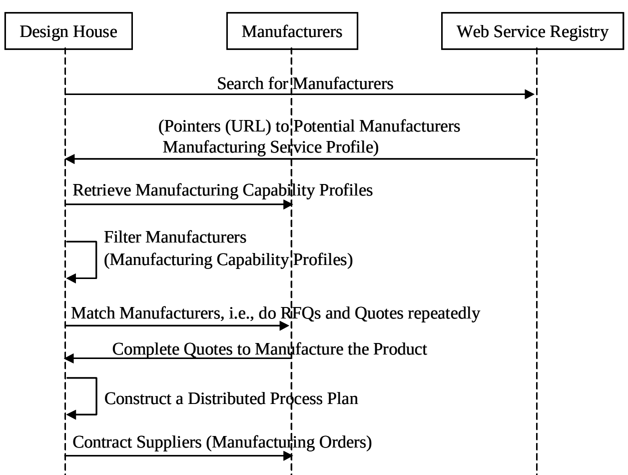

Fig. 1 Activity flows in the collaboration

SIMULATION-BASED EVALUATION

In this framework, stochastic discrete-event simulation technique is proposed to evaluate highly nonlinear process plans. The design house can evaluate the alternative quotes via simulation, considering production and material transportation costs and their variances as well. Similarly, manufacturers, when creating quotes based on a current shop status, can estimate accurate manufacturing cost and lead time via simulation.

CONCLUSION

The manufacturing web services have been implemented using the Darpa Agent Markup Language (currently called Web Ontology Language (OWL)) (McGuinness and Harmelen 2003). The descriptive logics nature allows the manufacturing services to be effectively discovered and filtered. Simulation models will be dynamically generated from the resource and process models according to Son et al. 2002. Not does only this allow ease of entry to the web of manufacturing services, the simulation models also represent real-time snap shot of the resources and production conditions. This paper complements the other paper by Woo et. al 2003 which provides a framework for the design house to evaluate and generate the Distributed Process Plan (DPP).

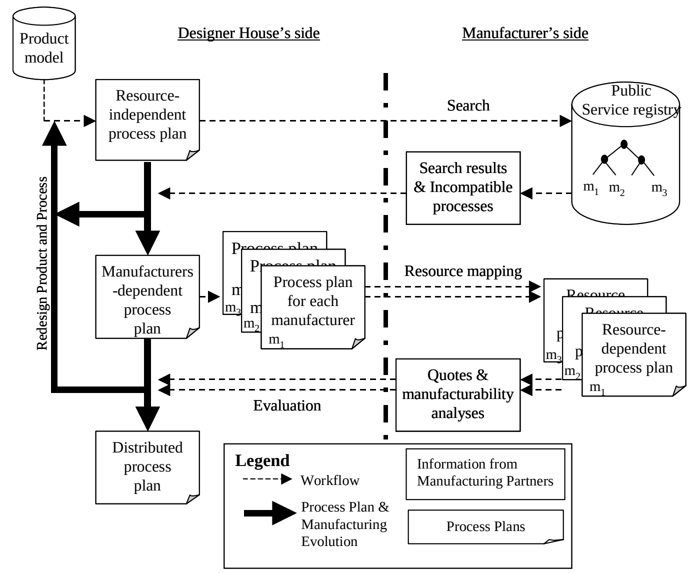

Fig. 2 Process information workflow for collaborative planning and manufacturing

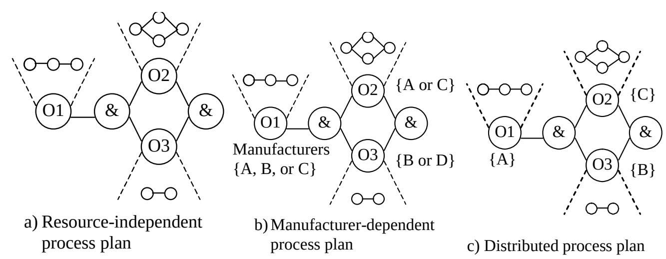

Fig. 3 Process plan evolution illustration

DISCLAIMER

Certain commercial software products are identified in this paper. These products were used only for demonstration purposes. This use does not imply approval or endorsement by NIST, nor does it imply these products are necessarily the best available for the purpose.

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