Development of Intelligent Assistance System to Support Eco-efficient Planning

Sarfraz Ul Haque Minhas and Ulrich Berger
Chair of Automation Technology, Brandenburg University of Technology Cottbus, Cottbus, Germany

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Abstract: The automotive industry is facing challenges due to high mass customization and consequent decentralization of manufacturing systems. Currently, the evaluation and optimization of eco-efficiency of production processes is complicated due to time consuming LCA simulations and inexperience of production planners to make respective decisions. This paper addresses this issue by developing ontology based intelligent assistance system to support planner in environmental assessment of manufacturing of customized production in decentralized manufacturing networks as well as decision making in production planning.

1 INTRODUCTION

The manufacturing industry particularly the automotive industry is facing challenges to remain competitive. The increasing product customization and continuously reducing time to market on the automotive landscape has compelled manufacturers to speed up their innovation process as well as frequent restructuring of value chains. Additionally, the shifting of manufacturing facilities from high wage locations to low wage locations, high outsourcing and frequent collaboration with external partners has resulted in distribution of manufacturing facilities. It can be realised by that fact that currently 75% of the vehicle production and 50% of automotive research and development is carried out by suppliers (Christensen, 2009). Furthermore, the lack of skilled people to manage change and enable customized production in manufacturing facilities has put the complete innovation process at risk. The decision concerning selection of optimal production schemes for customized products is quite complicated as it requires optimization of manufacturing processes not only based on conventional key performance indicators such as cost, time, quality, flexibility but also on potential environmental impact. Unlike the conventional key performance indicators, the knowledge concerning environmental impact as well as assessment is not well versed and intrepretable for machines and users to be taken as decision support system. In addition to this fact, reducing number of skilled workers, inexperienced planners to take decisions based on eco-efficiency and the time consuming environmental simulations demand leveraging of exploiting concepts and innovative methods related to knowledge management. Focussing on the scope of this paper, it must be added that the increasing number of activities in a decentralized production environment results in increasing environmental impact in terms of several emissions and ecological wastes. The new environmental directives and regulations needs new metrics, advanced assessment methods and efficient environmental assessment tools have limited the potential environment assessment in conducting holistic, reliable, quick and precise assessment. Furthermore, the addition or removal of certain environmental terms according to the new directives and changing assessment methods and unfamiliarity with the potential impact of combinations of materials, process and resources on the environmental impact of the production processes has made manufacturers to ignore this factor in production planning and optimization. Consequently, the production planning in distributed environment is not cost efficient any more. A strong need has been felt for an efficient environmental information system to support decisions on environmental impact of the potential production schemes. In the absence of such system, the planner must be experienced enough to conduct precise and

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efficient assessment. The probability of availability of such experts is very low as the knowledge about environmental terms, regulations, assessment methods as well as the simulation tools is expanding along with the expansion of manufacturing domain with new materials, processes and resources such as machines. Therefore, the planner cannot conduct assessment without the knowledge assistance system or tool and therefore be be facilitated with information or knowledge assistance system to get the desired information from the knowledge assistance system upon request. This approach will enhance productivity in planning.

2 KNOWLEDGE MANAGEMENT IN DECENTRALIZED PRODUCTION NETWORK

Production planning and scheduling refers to activities that deal with selection and sequence of production processes as well as the optimal assignment of tasks to manufacturing resources over a specific time. Several methodologies have been introduced in the literature to enable computer aided process planning namely feature based planning (Cai, 2007; Mokhtar et al., 2007; Berger et al., 2008), artificial intelligence i. e. neural networks and genetic algorithms) based planning (Joo, 2005; Monostori et al., 2000; Venkatesan et al., 2009; Zhang et al. 1997) and knowledge based approaches (Wu et al., 2010; Tsai et al., 2010). In a highly individualized customer demand scenario i. e. one-of-a-kind production, incremental process planning has been proposed for extension or modification of primitive plan incrementally according to the new product features (Tu et al., 2000). Likewise, agent based approach is used to enable manufacturing organizations dynamically and cost effectively integrate, optimize, configure, simulate and restructure their manufacturing system as well as supply networks (Zhang et al., 2006). It must be added that the scope of optimization in planning is mainly limited to the traditional key performance indicators such as cost, time and quality. Mass customization production scenario has however made manufacturers focus on flexibility in optimizing processes. The sebsequent decentralization of manufacturing systems demand planning decisions based on environmental impact of the intended activity or process besides decisions made on conventional key performance indicators. From the literature, several approches and methodolgies have been proposed convering several distinct areas of planning but no significant contribution has been made sofar that help accessing and supporting decision making based on key performance indicators. The knowledge management framework for supporting manufacturing system design is proposed by Efthymiou et al., 2011a. The proposed framework encompasses four constituent components of the knowledge management system. The extended work to this framework is described in work presented by Efthymiou et al., 2011b, in which the ontology for the manufacturing system is defined. The extended work emphasizes structuring of knowledge to support evaluation of manufacturing facilities and activities based on cost, time, quality and flexibility. There is no contribution made sofar in the scientific literature that addresses the issues related to eco-efficient evaluation as well as decisions support system for optimal selection of production processes for customized products. Moreover, commercially available PLM tools as well as lifecycle assessment tools are incapable of facilitating planners with the environmental knowledge that support them in decision making. Therefore, an intelligent assistance system must be devised as an add-on to existing planning tools that facilitate planners in make decisions on eco-efficiency of manufacturing.

3 DEVELOPMENT OF INTELLIGENT ASSISTANCE SYSTEM

In this regard, the concept for intelligent assistance system is described by Minhas et al., 2012. The production scheme for manufacturing customized products is retrieved from the commerical planning tools in XML format. It contains information about the whole production scheme for manufacturing any customized product. The scheme consists of several nodes each specifying the product information, the process technological information and the resource information corresponding to the process technology. The ontology based knowledge repository is enriched with the already existing simulated environmental impact results of the potential production schemes. The information concerning the input (process node specifications) and output information (simulated environmental impact results) for the simulated case are stored either manually in the knowledge repository by experts or exchange through the xml file from the

conventional LCA tool such as SimaPro.

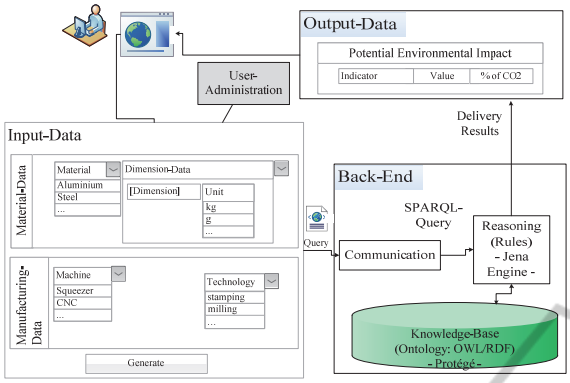

Figure 1: Architecture for web-based reasoner.

There are two possibilities for the user to query the knowledge repository of the intelligent assistance system. One way is to query in complete natural language format. It triggers huge complexity in processing the natural language sentence and extracting the context of the query. The second way is (see Figure 1) to restrict the degree of freedom of user's in specifying search. This is done with the web-based configurator developed in PHP. The SPARQL query is generated as a result of the configurator input. It is communicated to the server through web-service which then navigates the required information concerning the potential environmental impact of any desired process node. The knowledge repository is regarded as multiple instances of domain ontological concepts. This ontology is represented in specific platform independent open source language to maintain consistency while navigating information as well as the information exchange. This knowledge repository is made capable of making conclusions against the queries due to its inherent reasoning capabilities. The reasoning part of the knowledge repository is enriched with production and inference rules associated with the material and process environment of decentralized manufacturing.

The outcome of the navigation is the environmental impact results by matching the same case stored in the knowledge repository or inferred from similar cases. The application is capable of running on the web-based system and a web service has been created to query the knowledge repository. The planner before making environmental assessment sends request to the server; the server generates the required output in reponse to the SPARQL query which navigates the information into the ontology based knowledge repository.

The concepts for manufacturing domain relevant to the environmental impact are modelled in an open source ontology editor named as Protégé. At the process level, material specifications, operation and relevant resource information formulate the basic concepts for manufacturing domain (see Figure 2) in RDF format. Furthermore, semantic web rules are defined to incorporate reasoning capabilities in the intelligent assistance system. These rules are programmed using JENA Engine.

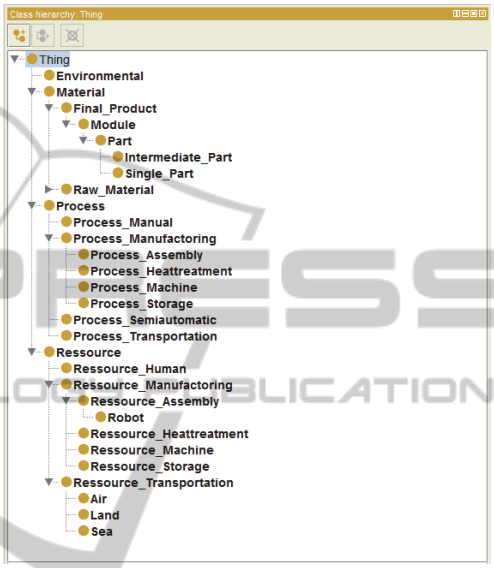

Figure 2: Fundamental Ontology Concepts.

The user can send the request for the search of environmental impact or emissions of certain combination of materials. The web service based on JAVA will generate a query which will navigate inside ontology for retrieval of the information using JENA inference engine.

4 SUMMARY

The knowledge management concepts can be exploited in each of the planning area in the automotive production networks to achieve quick and reliable multi-objective decision making. The artificial intelligent approaches and knowledge bases implemented using ontologies with reasoning capabilities, will be helpful in reusing, inferring from as well as for making quick optimization. In this paper, these concepts are being exploited considering optimization of production processes based on environmental impact assessments. The addition of environmental impact factor as one of the key performance indicator needs to be evaluated first using commercially available software tools.

The representation of knowledge about material, process and resource and its consequent impact of environment using ontologies together with reasoning capabilities will help the inexperienced planners as well the experienced ones to get knowhow concerning emissions that is anticipated to be assessed as well as the environmental impact of combination of potential product, process and resource. The intelligent assistance tool runs on web based system to facilitate geographically distributed planners in building, updating, sharing knowledge. Moreover, this knowledge helps in conducting assessements regarding eco-efficiency in manufacturing of customized products.

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