Integration of Software Tools with Heterogeneous Data Structures in Production Plant Lifecycles

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Abstract: Today, most technical disciplines involved in the lifecycle of production plants process their tasks with software tools that establish their own data stocks. Thus, the corresponding information networks are characterized by heterogeneous data structures leading to drawbacks considering information retrieval, identification of interdisciplinary dependencies and creation of generalized design solutions. Information integration aims to solve these problems by providing unified access to distributed heterogeneous sources. This article first describes the information network in production plant lifecycles and discusses the required elements for the process of information integration. This is followed by an outline of current research and technology in the fields of neutral formats and engineering ontologies. The developed concepts for information integration in production plant lifecycles are presented based on this, and demonstrated with a model plant for bottling, commissioning, and recycling.

Keywords: Information integration, Industrial production systems, Lifecycles, Semantic networks

1. INTRODUCTION

The lifecycle of production plants from the definition of a product to efficient production involves many technical and organizational tasks that need to be solved by production companies and their suppliers. The accomplishment of technical tasks requires input information. For instance, mechanical designers usually work on the basis of requirement specifications, technical standards, guidelines, past projects, design catalogs and part databases. Moreover, the mechanical designer has to consider the requirements and information associated with other technical disciplines. For example electrical and fluid devices have to be integrated into the mechanical design, the results of mechanical calculations have to be taken into account for the dimensioning of critical parts – and the experience of assembly and service technicians should be considered to obtain an assembly and service friendly design. Regarding the whole lifecycle of production plants, a complex network of information flow evolves since a piece of information generated in one discipline is used in multiple other disciplines. This may either refer to direct use, such as the import of 3D-CAD models for simulation, or indirect use meaning that a piece of information affects decisions made outside the original discipline.

The process of information integration aims to provide each participant in the plant lifecycle with as much information as necessary. However, this requires a general understanding of the production plant lifecycle and the corresponding flow of information. Therefore, the following section describes the stages of the production plant lifecycle.

2. LIFECYCLE OF PRODUCTION PLANTS

2.1 Planning of Assembly and Production Processes

The execution of assembly and production processes should yield products that fulfill defined requirements with an adequate allocation of resources (Cutting-Decelle et al. 2007). To manufacture a product with desired properties, an appropriate selection of manufacturing processes is required, whereby each process step can be allocated to one of a set of potential resources. The planners choose a suitable process and a set of resources considering prospective demand, existing resources and reference data from previous projects.

2.2 Production Plant Design

The design of machinery usually involves mechanical, fluid and electrical design as well as the development of control programs and human machine interfaces. None of these disciplines can work independently, but a successful integration is based on the exchange of interdisciplinary relevant information. Choosing a motor, for example, requires the mechanical engineer to consider performance data, power transmission and geometrical dimensions, while the electrical engineer ensures that a suitable power supply and a suitable control infrastructure are available. Further, a draft mechanical design of the machinery including required sensors and actors is the basis for choosing the appropriate automation devices. The control logic is programmed on the basis of the output information from the electrical design with regards to the initially defined processes and functions.

2.3 Virtual and Real Start-up

Virtual start-up is used to validate the compatibility of design information generated using different engineering disciplines by quickly and systematically iterating through many potential plant operation scenarios (VDI 2009). The virtual start-up process generates feedback information for plant design and operation. Examples include optimized PLC programs, additional sensors for collision avoidance and change orders for mechanical design. Since many complications can be identified and eliminated in this way before the actual plant has been assembled, the time for real start-up can be significantly reduced.

The actual design of the plant with all of the details is generally not specified before assembly and real start-up. For example, electrical and pneumatic routing as well as exact positions of sensors and actors are often based on decisions and optimization that are made on the shop floor. However, the information obtained from adjustments and optimization on the shop floor is usually not systematically saved. However, this information could rationalize similar assembly and start-up tasks by contextual provision of information and would yield an up-to-date information basis to be used for change and adjustment designs.

2.4 Production and Service

Up-to-date digital models are further valuable after completion of the start-up process. On their basis plant, operation can be continuously optimized without costly test runs performed in the actual plant. Moreover, up-to-date digital models help service technicians to identify errors in the plant operation, for planning complex service tasks in advance or for task-related supply of information. Feedback from service technicians improves future design and planning tasks since error prone parts, for example, can be avoided.

3. REQUIREMENTS FOR INFORMATION INTEGRATION

Up until now, the information network in the lifecycle of production plants is characterized by a heterogeneous software tool landscape (Brecher et al. 2008). Heterogeneous information networks imply several drawbacks for the stakeholders. Firstly, information has to be gathered manually, which is time-consuming and error-prone. A service technician, for example, may need to browse through instruction manuals, electrical diagrams, technical drawings and control programs to identify a defective device, disassemble and repair it. Secondly, heterogeneous information networks impede the observation of interdisciplinary dependencies, i.e. a piece of information generated in one discipline potentially affecting decisions in other disciplines is not systematically transferred to these. Thirdly, heterogeneity restricts the possibilities to generalize interdisciplinary design solutions, i.e. there is no library that considers interdisciplinary dependencies.

Information integration aims to solve these problems by providing unified access to distributed heterogeneous sources giving its users the illusion of a centralized, homogeneous information system (Genesereth et al. 1997). Information integration requires a common conceptual schema for semantic interoperability (Guarino 1998), interfaces to integrated software tools, methods for inter-domain object identification (Naumann et al. 2006) as well as efficient database and communication systems.

A common conceptual schema can be provided by neutral formats (Turk 2001). Examples are STEP (cf. Pratt 2005), AutomationML (cf. Drath et al. 2008) and PLM XML (cf. Siemens PLM Software 2007), which are further described in the following section. Moreover, ontology languages such as the Web Ontology Language (OWL) (McGuinness & van Harmelen 2004) provide the capabilities of defining conceptual models for semantic interoperability.

4. RESEARCH AND TECHNOLOGY REVIEW

4.1 Neutral Formats for the Exchange of Lifecycle Data

Neutral formats can be classified with regards to their application. The JT format (Siemens PLM Software 2008) and 3D XML (Dassault Systèmes 2010), for instance, are neutral formats that focus on 3D visualization. Considering information integration in the whole lifecycle of production plants neutral data formats for the exchange of lifecycle data are of special interest. Three examples of such formats, STEP, AutomationML and PLM XML, are discussed in the following paragraphs.

STEP (Standard for the Exchange of Product Model Data) is an international standard for the exchange of product data (ISO 10303) and comprises several parts and so-called Application Protocols (AP). The part series of STEP contains definitional resources, implementation methods and basic building blocks (Ball et al. 2008). Examples are the reference manual for the employed information modeling language EXPRESS (part 11), the definition of geometric and topological representations (part 42) and the description of kinematic behavior (part 105). The application protocols address different products (e.g. AP214 for the automotive mechanical design process), domains (e.g. AP 212 for electrical design and installations) and lifecycle stages (e.g. AP 239 for lifecycle support). Note that while initial parts of STEP focused on design and manufacturing, expansions now cover whole lifecycles (Pratt 2005). Though the STEP standard saves the industry substantial resources (Cutting-Decelle et al. 2007), it is associated with several drawbacks. Firstly, the transfer of data from proprietary formats to STEP is not loss-free, i.e. features and constraints may be lost or misunderstood so that exchanged models are difficult to modify (Pratt 2005). Secondly, the interoperability of the different application protocols of STEP is not yet proven (Ball et al. 2008). Thirdly, the information modeling language EXPRESS, as an essential part of STEP, also has some drawbacks. Since additional constraints are difficult to add (Ball et al. 2008), the semantic expressiveness of EXPRESS is impaired. Finally, difficulties in the