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A web-services oriented workflow management system for integrated digital production engineering

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ABSTRACT

Digital production engineering is a complex procedure, since distributed engineering teams, using heterogeneous IT tools, should be able to collaborate in order to design and implement a production system. This work presents the concept and its implementation of a workflow system for collaborative computer-aided production engineering. The workflow system supports the execution of production engineering activities in the Extended Enterprise (EE) and is built on the basis of web services and the BPEL (Business Process Execution Language). It also manages the electromechanical data exchange, using XML that conforms to the AutomationML format. An application of the tool, developed for an assembly engineering project in the automotive industry, is being presented.

1. Introduction

Shorter product and production lifecycles, an increased number of product variants and the unrestrained global competition have led many industrial companies to improve their development process from product designing up to its production. Production engineering involves the design, control and continuous improvement of manufacturing systems in order for customers to be provided with high-quality products, in a timely and cost efficient manner. This work focuses in particular on the initial design and engineering of a production system. In this context, a production engineering project includes the mapping of the manufacturing system's variables such as the number and type of machines, the layout, the process parameters and the control logic to product parameters such as the bill of materials and the product's geometry in order to meet performance requirements such as production cost and rate, quality and flexibility [1]. The production engineering projects are usually multidisciplinary and inter-organizational in nature. The current situation, in digital production engineering, is characterized by a large number of different IT tools, based both on PCs and on workstation applications. Integrated production engineering could be operated within the entire network of collaborating enterprises, defined as the Extended Enterprise (EE), with a long term agreement involving suppliers up to end-use customers. Typical examples of production engineering projects in the automotive and aerospace industries cover the entire process from rough product geometry to the ramp-up and start of production.

Internet may provide the infrastructure by which information can become simultaneously available to all those involved in production engineering, such as designers, planners, production managers, and so forth. However, there are problems with the efficient integration of the production engineering activities in the EE:

- The generation and the execution of a production engineering project may both take a long time and involve several organizations, with different roles and competencies, dispersed in different geographical locations.
- Monitoring and improving the production engineering project plans may be complex, difficult to automate and manage changes.
- The commercial Computer-aided Manufacturing/Engineering (CAM/CAE) systems, used by process designers and planners, may vary. The internet-based manufacturing needs to overcome this heterogeneous software environment.
- Data inconsistency and data redundancy.

These problems can be tackled by distributed, adaptable, open and intelligent process planning systems within a collaborative environment.

1.1. Collaborative production engineering

In the field of production engineering, the literature presents different approaches in terms of functionalities, communication protocols, programming languages and data models. The following

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review focuses on systems that use technologies, such as web-services and workflow definition/management.

Siller et al. [2] proposed a workflow model defined in the BPMN (Business Process Modeling Notation) and implemented it within a commercial PLM (Product Lifecycle Management) system for a collaborative process planning environment. They demonstrated the way that the workflow approach could be successfully applied for the integration of PLM by CAPP and CAD/CAM tools. However, the workflow is not extended to include equipment automation aspects, which add additional requirements to the interoperability ones within the extended enterprise and in their approach, there is not any service oriented architecture framework, integrated into the workflow engine, to support collaborative data storage/retrieval and communication issues. Kuk et al. [3] focus on the use of a service-oriented-architecture (SOA), namely web services, intelligent software agents and a workflow engine to support integrated engineering activities. The pilot case execution has indicated a significant man-hours saving, due to the coordination of engineering activities and automation. Nevertheless, their approach was to use a proprietary implementation to bind the workflow with the SOA architecture and not some standard approach, such as the BPEL (Business Process Execution Language). Other approaches that demonstrate the use of an agent based framework for the integration of heterogeneous software tools, even non-engineering application fields, can be found in the literature (e.g. [4,5]). In Butala and Ueda [6] the implementation of a multi-agent system in production engineering is discussed, aiming at an emergent behavior and an adequate structural and organizational model in the real-world system. Communication protocols can be autonomously generated, refined or adapted by the agents. This approach uses basic concepts of machine learning for integrated conflict management and open adaptive communication. By this, a highly complex communication structure emerges during the runtime. Jagdev and Wortmann [7] discussed the complexity of product data and models being integrated into the planning phase of the production facilities. The main issue is that the production partners are globally distributed, resulting in sub-models that are not possible to be integrated into a complete model. Therefore, a consistent digital representation of the production facility is improbable today. The authors have proposed an XML and a web-services based approach for managing the production engineering; however, it is applied to a rather simplistic scenario without being able to support the usage of heterogeneous tools in the process, thus requiring further enhancements in order for the complexity of the production engineering process to be managed. Kiefer et al. [8] present a framework for digital validation of production and they employ AutomationML for data interface reduction, because it wraps and integrates already standardized sub-standards for the different data types. However, it is mentioned that AutomationML is not fully supported by a typical production engineering software and it should be further disseminated as a standard of a different production planning software.

The production engineering projects are typically multidisciplinary and inter-organizational. Although the backbone of engineering activities is typically a PLM, the current situation in digital production engineering is characterized by a large number of different IT tools, based both on PCs and main frame applications [9]. There are tools in support of mechanical design operations, process design and simulation, electrical engineering, OLP (Offline Robots Programming) as well as PLC coding and automation.

In a geographically dispersed production engineering environment, web-based tools for collaboration are highly relevant but they are not a panacea. They should be complemented by a framework that would enable the integration and coordination of engineering activities (product development, process planning, and commissioning) and the exchange of data among entities (Original Equipment Manufacturers – OEM, product designers, engineering service providers, system main integrator). In the case of an EE, different tier engineers collaborate within the common communication infrastructure, provided by the OEM. The engineering tasks are usually accomplished in the OEM, the main integrator for the complete system, and probably any additional engineering service providers. During a production engineering project, the main objective is that a sequence of the manufacturing and assembly processes be established and used in order for the raw materials to be converted from their initial form into the final products. In terms of the underlined data, involved in this activity, the objective is to link product, process, and resource data with each other by defining the type of component (product) that is to be manufactured with the use of production steps (process) on specific manufacturing equipment (resource).

The aim of this paper is to describe a web-based workflow management approach and the corresponding tool that has been developed in order to support the coordination and integration of production engineering activities using different digital tools. The design and development of the proposed approach tries to cover holistically all the problems during collaborative production engineering.

2. System architecture and implementation

The work presented in this paper, focuses on typical production engineering scenarios, where an OEM communicates with geographical dispersed engineering teams in order to define the equipment (e.g. robots, grippers, PLC devices, weld stations, and slide-in carts) required for production. Furthermore, it is common that the engineering enterprise selected, requires that its engineering activities be planned in a collaborative way, in order for the engineers' knowledge and the relevant engineering tools to be incorporated with efficiency and robustness. Additionally, the system must be able to deal with unexpected changes in the project throughout its lifetime. The dynamic nature of the evolving engineering environment entails robust but manageable configuration of the workflow. In order for these objectives to be achieved, it is required that all collaborative activities and data flows including geometrical product description, parts list, engineering bill of materials, manufacturing process plans and engineering software tools be identified, and that they should be integrated into a workflow management infrastructure that would allow all the collaboration and coordination. In this context, 'collaboration' refers to the activity of people, teams and organizations working together in production engineering projects using digital tools, while 'coordination' refers to the process of managing and synchronizing these engineering activities.

In this paper the workflow of the engineering process is defined using BPEL. The tasks of the process, sequencing and control, both within and between the tasks, users/resources that will be involved as well as the information within and between the tasks are defined. The instantiation of a workflow is implemented with the use of a BPEL engine and it is supported by a set of web-services. For users such as engineers, designers and managers a graphical user interface, customized to provide access to the tasks of the workflow is generated. For the implementation of our approach we use the AutomationML (Automation Markup Language) open standard [10] which is an XML data format for the exchange of plant engineering information. It is used for interconnecting the heterogeneous engineering tools, such as mechanical plant engineering, electrical design, HMI development, PLC and robot control. The main objective of AutomationML is to increase the interoperability among different engineering tools [11]. Should there be a need to support cooperating partners, who