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Product lifecycle management in knowledge intensive collaborative environments: An application to automotive industry

Filipe Ferreira[b,*], José Faria[a,b], Américo Azevedo[a,b], Ana Luisa Marques[a,b]

[a] Faculty of Engineering, University of Porto, 4200-465 Porto, Portugal
[b] Centre for Enterprise Systems Engineering, INESC TEC, 4200-465 Porto, Portugal

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ABSTRACT

Today, manufacturing is moving towards customer-driven and knowledge-based proactive production. Shorter product life cycles lead to increased complexity in areas such as product and process design, factory deployment and production operations. To handle this complexity, new knowledge-based methods and technologies are needed to model, simulate, optimize and monitor manufacturing systems. Product lifecycle management research tends to focus on situations that are responsive to formal analysis and modelling. However, in several domains such as knowledge intensive collaborative environments, it's not possible to model processes using formal notations. Knowledge based and collaborative process management involves a combination of structured and non-structured processes. Structured processes management can be reduced to a set of fully-defined rules leading to high efficiency but also low flexibility, whereas the management of non-structured processes is not prone to a full formalization. A combination of both structured and unstructured management approaches is required in order to achieve a successful trade-off between efficiency, flexibility and controllability. We call a process as semi-structured when it contains both structured and non-structured sub-processes leading to a flexible and efficient hybrid approach. Large enterprise information systems, impose structured and predictable workflows, while knowledge based collaborative processes are unpredictable to some extent, involving high amount of human-decision. Moreover, large enterprise information systems are not able to manage the daily ad hoc communication inherent to the knowledge-based process itself. This paper introduces a set of concepts, methods and tools of an innovative Hybrid Process Management approach validated by a real world business case in the automotive industry.

1. Introduction

Today, manufacturing management is being re-shaped by a shift from the mass production paradigm to a new on demand, personalised, customer-driven and knowledge-based proactive production paradigm. Shorter product life cycles, an increased number of product varieties, high performance processes and flexible machines and production systems result in an increased complexity in all domains from product design, process development, factory and production planning to factory operation. To face these challenges, companies are moving to intensive use of manufacturing knowledge in early phases of engineering and manufacturing activities in order to increase the efficiency of manufacturing systems. New value-added products, reassured and trusted planning of processes and adaption of factory structure are now critical factors for business success, which leads to the need of a continuous exchange of knowledge as well as improvements on the communication between the operation and the design and planning domains.

The current challenge in knowledge intensive collaborative environments is the integration of the product, process and factory worlds, in order to reduce the planning time and give reality to the synchronisation and alignment of products, processes and factories life cycles with the production operations (Tolio et al., 2010). Furthermore several critical aspects like the increasing complexity of product and production systems and the synchronised communication between the factory level domains (product design, process development, factory and production planning and factory operation) are other major challenges in the management of knowledge intensive collaborative environments. Reference models supporting planners and interdisciplinary teams can be used to overcome these challenges (Constantinescu, Hummel, & Westkämper, 2006;

* Corresponding author.
E-mail address: filipe.d.ferreira@inesctec.pt (F. Ferreira).

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Westkämper & Hummel, 2006; Ferreira, Marques, Faria, & Azevedo, 2016).

This is not a matter of technology, but how to fit the available technologies in the best way to capture the knowledge, to embed context into the knowledge, to use/re-use the knowledge in an intelligent way and to share the knowledge among all manufacturing stakeholders and to involve and motivate people during the entire product, process and factory lifecycle phases.

Currently, enterprise information systems, such as Product Lifecycle Management (PLM) platforms, are often large applications encompassing multiple functionalities that are expensive, difficult to use and hard to maintain (Moody, Gruen, Muller, Tang, & Moran, 2006). It is also observed that in many cases existing information and communication technologies tools are not prone to manage effectively daily activities due to their lack of flexibility regarding dynamic (Kammer, Bolcer, Taylor, Hitomi, & Bergman, 2000) and changeable environments and processes (Lu, Sadiq, & Governatori, 2009; Mangan & Sadiq, 2002). Large enterprise information systems impose structured and predictable workflows, whereas "real world" processes, in particular, those related with concept and design of new products and services are hardly predictable once they involve several human based decisions and collaboration (Hill, Yates, Jones, & Kogan, 2006; Lu et al., 2009). Moreover, many times, large enterprise information systems are not able to manage communication and information together with the knowledge-based process itself (Mangan & Sadiq, 2002).

Indeed, in the context of related engineer project activities, team members are forced to use office productivity tools such as spreadsheets and text editors as well as shared folders and internal email and phone to manage processes in largely unpredictable work environments (Hill et al., 2006) (Jørgensen, 2001). This is leading to a major shift in the Enterprise Information Systems (EIS) paradigm and to the development of cross linked and easy to use in order to support the product designers, process planners, and shop floor managers in their daily activities with a special focus on supporting collaboration in flexible work environments. Tools must be smooth, smart and fault tolerant in the interaction with the knowledge workers, and provide the integration of the shop floor level with engineering along the whole product life cycle (Hill et al., 2006; Brocke et al., 2010).

This paper presents a complete solution to support product lifecycle management in flexible work environments in the scope of industrial equipment engineering, planning, manufacturing, maintenance, improvement and decommission, including integrated work, information and communication management. The rest of the paper is organized as follows: section two presents the main phases considered in the research methodology. Then, in section three we highlight the theoretical issues related to this research work. In section four, we briefly describe the considered business case and we explore the main processes, starting with the diagnosis, followed by a short reference to the designed solution. The next section present the implementations issues as well as the validation process. Finally, overall conclusions are mentioned in Section 7.

2. Research methodology

The work presented in this paper has followed a research methodology that encompasses four main phases, as described hereafter:

(i) Background and Literature Review, where topics such as process lifecycle management and knowledge intensive collaborative environments, i.e., flexible work systems are explored.
(ii) Business Case Presentation and Analysis, where the current practices of process and product concept, modelling, implementation, utilization, improvement and decommission, followed by a wide range of industrial equipment manufacturers were analysed and mapped using accurate techniques for business process analysis. Several workshops were conducted, in order to collect qualitative and quantitative data and relevant information, taking into account the expertise of all team members and experts. After analysing the as-is situation, current industrial challenges and issues and consequent improvement opportunities were identified, the to-be business processes were designed and validated by the industrial partners, leading to the design, specification and development of new suitable and accurate supporting methods and tools. Industrialists, technology providers and researchers did participate in this task, bringing their multi-disciplinary expertise to the project.
(iii) Solution Design and Implementation: where a complete solution, founded on collaborative platforms was specified and designed taking into account issues, challenges and potential improvements identified in previous phases. This includes the functional and technical specification. Having specified the complete solution, a comprehensive software package was developed using the most advanced technologies aligned to stakeholder's needs and constraints such as security, maintainability, usability and sustainability. Integration with legacy systems and openness to current advanced mobile technologies and cyber physical systems were considered and an open API towards full interoperability was developed as well.
(iv) Validation, where the solution was tested and validated by the end users in their daily work. In order to guarantee its sustainability, criteria for the solution evaluation were established and measured, paving the way for a successful exploitation and pointing out the strong points as well as aspects to be improved.

The next Sections are directly related to the four stages of the methodology.

3. Foundations and research topics

3.1. Semi-structured processes

Workflow management research tends to focus on situations that are prone to formal analysis and modelling. However, in several business areas, there are domains, such as knowledge intensive work environments and collaborative engineering environments (Moody et al., 2006; Faria, Silva, & Marques, 2010; Faria & Nóvoa, 2015), in which it is not possible to fully structure and model processes using formal notations (Kammer et al., 2000; Hill et al., 2006). The flow of so called semi-structured processes is not known a priori, and many times, only the main phases and baselines may be specified a priori (Lu et al., 2009; Mangan & Sadiq, 2002). Efforts have been made to classify this kind of processes based on formal approaches, but the results achieved so far are limited (Paola Soto Rojas, Barros, de Azevedo, & Batocchio, 2012).

The characteristics of a structured process include (Adams, Hofstede, Edmond, & Van Der Aalst, 2006):

- The scope is totally defined and all the activities are known;
- It is possible to identify the initial state, a goal state, and all potential transitions;
- Activities and Transitions are computationally practicable.