Collaborative Working Environment for Innovation in Manufacturing Industry

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Abstract
The paper addresses the problems of collaboration of teams in manufacturing industry in the scope of innovation processes. The problems of involving different teams and specifically shop-floor teams in product/process innovation are analysed. The objective is to develop a new platform based on software collaborative services supporting different innovation processes where different teams – product and process design, maintenance, shop-floor teams but also customers etc. - around the complex assembly and manufacturing lines have to be involved. The work presented includes a design of new tools and core collaborative services for development of such a platform, aiming at supporting different collaboration patterns. Several potential applications of the platform are described.

Keywords
Innovation, Manufacturing and services, Knowledge management for collaborative innovation, Collaborative services, Collaborative Reference Architecture, Extended Enterprise

1. Introduction

The modern approaches for products/processes innovation in manufacturing industry require involvement of many different teams in Extended Enterprise (EE) context. The increasing trend of globalised manufacturing environments and a radical increase in number of product variants in modern manufacturing industry (e.g. Build-to-order) requires new forms of collaboration among teams involved along product/process innovation life cycle (e.g. design, planning, production scheduling, manufacturing, after sales services etc.), as well as seamless knowledge and experience sharing among these teams, often distributed geographically and in time. This is especially a challenge for manufacturing industry in many leading industrial countries facing massive migration of manufacturing facilities towards Eastern European and Asian countries.

The objective of the work presented in the paper is to develop a new Collaborative Working Environments (CWE) to support collaboration among teams in manufacturing industry enabling more effective innovation processes addressing design/improvement/reengineering of assembly and manufacturing systems (AMS). The platform is primarily intended to support collaborative work on innovation within organised teams in industry in EE context, but it will be extendible to support collaboration between teams in industry and ad-hoc groups and wider communities e.g. RTD, customers etc.

The paper is organised in the following way: Section 2 comprises a brief overview of the state-of-the art on collaborative work and CWE in manufacturing industry (stressing specific needs regarding collaboration in industry), Section 3 explains the rational and objectives of the work presented, Section 4 elaborates in detail the proposed approach for development of the new platform, and provides description of the selected architecture of the new collaboration platform, of the core collaborative services, information middleware, knowledge management approach, and of the implementation strategy. Section 5 presents some potential applications of the proposed platform, while in Section 6 conclusions and future work are briefly discussed.
2. Relation to Existing Theories and Work

The collaborative work in manufacturing industry amongst e.g. shop-floor teams and teams in other areas, often geographically dislocated, requires solving several fundamental problems concerning distribution of work, synchronisation and persistence of workspaces, accommodation of different collaboration patterns, knowledge activation etc. The problem is the teams in modern and highly flexible manufacturing industry require often different collaboration patterns (e.g. a combination of synchronous and asynchronous collaboration during innovation processes [Stokic, 2006]). For example, collaboration for decision-making purposes within innovation and concurrent engineering processes has to integrate effective information sharing and activity synchronization [Miao & Haake, 1998].

The collaboration amongst teams in industry is still frequently managed using insufficiently systematic methodologies, or following non-human centred manufacturing concepts applied in classical mass manufacturing. This specifically may constrain productivity, collective creativity and collaborative work on innovation.

The application of CWE in manufacturing industry, specifically for collaborative innovation and engineering, has been subject of many research activities. Different algorithms for e.g. collaborative computer-aided design [Li et al., 2006] and various ICT tools to support collaborative work [Drira et al., 2001; Churchill et al., 2001] were proposed. Besides generic tools for collaboration (e-mails, “blogs and wikis”), widely applied in different communities, specific solutions for manufacturing industry have been also developed. However, collaboration among teams with different technical backgrounds and with different collaboration patterns (e.g. shop-floor teams and design teams, organised teams and ad-hoc communities etc.) has not been sufficiently explored, and ICT solutions supporting such collaboration are generally missing. The existing tools do not support dynamically changing collaboration patterns, which is one of the key requirements for effective innovation processes in manufacturing industry.

Based on the analysis of the requirements of users in industry in two European projects [AIM, 2005; InAmI, 2005], and the analysis of state-of-the-art, the main gaps are identified.

3. Objectives and Rational

**Objective:** The objective is to develop generic and widely applicable, modular collaborative platform to support work on innovation as presented in Figure 1. The platform will provide various Collaborative Application Services (CAS) to support innovation in industry, especially those enabling the teams in shop-floor to be involved in innovation processes, e.g. for process improvements of AMS, or improvements of product manufacturability etc. The targeted platform will be open for various services to support innovation and to involvement of different actors (AMS designers and service providers, maintenance providers, shop-floor foremen/operators, control vendors, designers of products manufactured/assembled at AMS, end-customers).

CAS use the Information Middleware (IM) which provides information on products/process/production units needed for collaborative work.
Rational: Innovation processes in manufacturing industry have been analyzed within the above mentioned European projects. The baseline innovation processes in manufacturing industry are identified. The innovation in manufacturing industry can be fostered either (a) by requiring innovative solutions of identified products/processes problems and improvement potentials, or, (b) by directly and continuously collecting ideas from all involved actors in an extended enterprise (independently of the identified problems). Both classical incremental and systemic innovation in industry have been studied. For both approaches, collaborative application services are needed to support the collection of ideas (both synchronous and asynchronous) and a collaborative work around the gathered ideas. The analysis has shown that the required application services to support innovation processes have common ‘collaborative’ actions which may be supported by a common approach.

Therefore, in order to provide such application services, as required by users in manufacturing industry, it is intended to provide a new “upper layer” middleware consisting of core collaborative services, covering the common collaboration approach, which can be mutually combined and which will additionally use existing technologies to satisfy the needs of end-users. Since the services will have to be dynamically updated and have to be integrated with other collaborative services, there is a clear need to provide a platform which will allow for effective generation/update of such services. The objective is to develop means/tools to efficiently generate different application services for collaboration among groups in an EE.

The main innovation of the work presented is provision of a new platform including a set of core collaborative services, combined with existing technologies (e.g. semantic-based knowledge management, decision-making tools etc.) to provide application services for collaborative working environments in manufacturing industry. By this, several existing technologies will be ‘upgraded’ by adding collaborative aspects (i.e. by making them being more ‘cooperative’).

Such an approach is fully in line with the findings of the Expert Group on CWE (see [Expert group Report, 2006]).
4. Research Approach

**Design tools:** The main tools are intended to support development of CAS which can be easily integrated in different environments and with the existing applications (e.g. systems for innovation, concurrent engineering tools, CAD/CAM systems etc.). The tools include:

**Service Generator (SG):**
- Tool set to support:
  - creation, editing and composition of CAS (creates the application service by defining its basic structure, composing core collaborative services and other applications)
  - identification of knowledge flow in CAS (provides a list of available information/knowledge objects and set of available tools for the management of knowledge on problems addressed and allows a designer to select the knowledge objects and knowledge management tools needed for the collaborative work of teams)
- Set of CCS

**Knowledge Management (KM) tools** as a basis for collaborative services (e.g. tools to support decision-making, sharing of knowledge within an EE, ontology, tools for personalised and team oriented knowledge presentation etc.).

**Repository** combining knowledge gathered along different production-cycle phases over EE (both AMS vendor and users) allowing sharing of knowledge in a distributed CWE using IM.

**Architecture:** The architecture fits with the (currently) proposed Reference Architecture [Ralli, 2005]. It includes three layers.

The **orchestration layer** provides the capabilities to build CAS (orchestration instead choreography). This layer allows combining CCS and other applications in order to meet specific needs regarding e.g. temporal aspect, workflow, business process addressed etc. The architecture includes the orchestration instead choreography, since orchestration describes a process flow between services controlled by a single party (see Peltz, 2003) which more corresponds to the cultures/approaches accepted by the manufacturing industry. The ‘uniforming’ sub-layer assures harmonisation and management of CCS. For the current implementation of the platform an off-line approach in which the combining of CCS requires some additional activities by system operator/ICT provider/user, is selected, supported by SG.

**CCS layer** includes generic set of services as presented in Table 1. These CCS will be combined with different communication services (e.g. chats, e-mails, video conferences etc.).

The work on CCS is based on the state-of-the-art research regarding collaboration patterns and collaborative work in general. For example, the development of the CCS for traceability of collaborative work strongly takes into account research on traceability of project development and knowledge modelling (Bekhti & Matta, 2002). The current research on ontology issues is also of a high relevance for the development of both CCS and orchestration layer (Wache et al., 2001). The special attention is given to security and Intellectual Property Right issues, being one of the most critical aspects of collaborative work on EE in manufacturing industry (Tang & Molas-Gallart, 2004).
<table>
<thead>
<tr>
<th>CCS</th>
<th>Input/request</th>
<th>Output</th>
<th>Main functionality</th>
<th>Specific requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource discovery</td>
<td>Request for expertise</td>
<td>Appropriate and available expert(s)</td>
<td>Searching for expertise</td>
<td>Mobile users</td>
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<td></td>
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<td>Check availability</td>
<td>Already defined groups</td>
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<td>Open group (other machine vendors)</td>
</tr>
<tr>
<td>Collaboration Traceability</td>
<td>Request for tracing of the group</td>
<td>Info on the requested states of groups and collaboration information to react on certain events, (warnings)</td>
<td>Tracing of collaboration: - continuous - event driven, (event identification)</td>
<td>Specific requirements regarding security, companies specific rules</td>
</tr>
<tr>
<td>Product/process knowledge provision</td>
<td>Request for a specific knowledge for the actor/group</td>
<td>Knowledge provided to the actor/group</td>
<td>Selection from the set of the basic KM functionalities the one which is most appropriate to provide the requested knowledge</td>
<td>Documents Stored user knowledge</td>
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<td>Data bases with stored data from process</td>
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<td>Direct access to processes.</td>
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<tr>
<td>Ideas management</td>
<td>Problem defined, request for ideas</td>
<td>Ideas collected</td>
<td>Presents problems, collects ideas from different actors, provides similar ideas, evaluate ideas</td>
<td>Different representation of problems and ideas for different expertise of actors</td>
</tr>
<tr>
<td>Decision support</td>
<td>Problem defined, ideas evaluated</td>
<td>Decision support</td>
<td>Supports weighting of criteria for decision, supports traceability of decisions (see service above)</td>
<td>Hierarchy in decision making according to enterprise rules</td>
</tr>
<tr>
<td>Team composition</td>
<td>Request for optimal team</td>
<td>Optimal team</td>
<td>Proposes team based on identified expertise</td>
<td>Enterprise rules etc.</td>
</tr>
<tr>
<td>Selection of communication services</td>
<td>Communication needs</td>
<td>Selected communication</td>
<td>Provides basic communication functionality. Selects most appropriate for the specific actor, collaboration pattern etc.</td>
<td>Voice, Text, Drawings, imagines, Videos, Virtual environment (e-mail Chats)</td>
</tr>
</tbody>
</table>

Table 1: CCS for work on innovation in manufacturing industry

The key issue is that the design tools and the CCS support different patterns for collaboration among the teams: asynchronous, synchronous, multi-synchronous etc. CCS for team composition and resource discovery allows for an easy switching from one pattern to another (e.g. from synchronous work to asynchronous work etc.), which is specifically important for the shop-floor teams.

**CAS:** include different (existing) tools for KM to support knowledge sharing. **Product/process knowledge provision** CCS has a task to select the appropriate tool to provide knowledge (e.g. for searching on documents related to problems etc.). The CCS for **Ideas Management**
provides ‘similar’ ideas to the one provided by an actor/group by applying CBR and RBR tools. The existing tools are used, but they are upgraded by adding collaborative aspects: for each actor the knowledge on his/her collaboration within different groups is used in defining searching criteria and/or weighting of different similarity criteria. A new approach for distributed set-up and maintenance of ontology is applied [Kuczynski et al., 2005].

**IM** includes interfaces to AMS and other systems to collect information on AMS, products and processes. Different solutions for IM are under testing starting from different customised company–specific solutions and web based solutions (such as Siemens’ ePS platform), agent solution, up to generic solution - so-called Generic Data Server providing data flow between the lower and higher control levels of an AMS [InAml, 2005].

**Platform Implementation:** Service oriented architecture is implemented, allowing for full flexibility and effective instantiation for different innovation processes.

The platform is built as an internet-browser based (GUI) application, a Wiki based application for CCS and a centralized application server to achieve more sophisticated functions based on Enterprise JavaBeans. BPEL is used for the orchestration [Trickovic, 2006].

To gather information from systems around AMS, PLCs and other legacy systems, modules designed as WebServices (supporting machine-to-machine interoperability, using SOAP, XML and other Web-related standards) are used.

5. Findings

The tools for development of the CAS and (part of) the architecture are and will be applied in several manufacturing EE to support collaborative work on innovation [AIM 2005; InAml, 2005]:

The services for ideas management and knowledge provision have been tested within a large multinational company, manufacturing cans, for process improvements. The services are used to collect ideas from different actors and over geographically distributed subsidiaries (in Germany and Poland) to solve complex process problems. The services provide information on problems identified, in different forms, depending on the expertise of actors, and gather ideas from shop-floor workers and process designers and support collaborative work on evaluation of these ideas. The services provide ‘similar’ ideas in order to support ideas gathering and evaluation. The services are mainly tested in asynchronous collaboration, and their extensions to synchronous applications are ongoing. The challenging task is how to motivate shop floor workers to provide their ideas and collaborate on innovative solutions for process improvements. The objective is to support cross regional teams building within different subsidiaries including international teams, where one of the key problem is appropriate (multilanguage) ontology. Once introduced in the two plants, it is expected to bring improvement in productivity and reduction in waste for about 5-7 %, but once introduced in at least 8 plants world wide, the benefits (due to exchange of ideas on common problems) may bring improvements of over 12 %. The expectations are based on the measurement of productivity and wastes before and after introducing the services at a critical part of the manufacturing line.

Another application addresses CAS for problem solving within of complex assembly lines (for small motors at the automotive industry supplier), supporting collaboration among AMS designers with: operators/foreman at the shop-floor, maintenance service and control system providers, in order to identify the problems/possible improvements and support design of new/reengineered lines. The currently used IM (based on the Siemens’ ePS) is ‘upgraded’ with CCS. It is intended to also use the platform to support collaborative elaboration of the proposed changes in the design of AMS and for gathering ideas.
6. Conclusions

The paper presents the RTD approach in development of a new collaborative platform to support work on innovation of AMS which includes collaboration of different teams in manufacturing industry. The key innovative aspects are:

1. A combination of innovative collaborative services with ‘classical’ tools – upgrading of classical tools to become more ‘cooperative’
2. New collaborative platform fitting with the Collaboration Reference Architecture, being one of the first implementation of this architecture in manufacturing industry
3. A set of new design tools and CCS for an efficient development of CAS to support innovation
4. Solutions which support different collaboration patterns and different technical background of the collaborating people
5. IM for collaboration in EE environment
6. Approach to select KM solutions to support collaborative innovation processes.

Many RTD problems still have to be solved such as: collaboration among organised and ad-hoc teams, representation and handling of uncertainties within collaborative decision making, security and IPR issues specific for manufacturing industry (e.g. different accesses to virtual resources in creating new ideas among organized teams and wider community are critical for acceptance of new collaborative environments in industry), automatic orchestration of CCS etc. The assumption is that the proposed platform could be extended to support collaboration among organized teams in manufacturing industry and wider communities on innovation of different products.

Acknowledgement

The work presented is partly carried out in the scope of the past RTD project: AIM and the current RTD project: InAmI supported by the Commission of European Community, under Information Society Technology Programme under the contracts FP5- IST-2001-52222 and FP6-2004-IST-NMP-2-16788.

References


