Tools for Designing Collaborative Working Environments in Manufacturing Industry

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Abstract. The objective of the work presented is to enable different equipment manufacturers, especially SMEs, to provide new services to extend their products. Although a number of ICT solutions for product extension are available, they do not allow for an efficient collaboration within extended enterprise, taking into account different, dynamically changing collaboration patterns and different technical backgrounds of the actors to be involved. The research work presented is aimed at pushing the use of advanced service oriented architectures for Collaborative Working Environments (CWE) in industrial practice. The new CWE solution will include so-called core collaborative services, addressing application independent functionality to support collaboration and covering the common collaboration actions. The objective is to develop means/tools to efficiently engineer application services for product extensions. The tools which will either automatically update application services and/or allow users, non-IT experts, to generate/update application services by themselves, are investigated. The applications in specific industrial environments are presented.

Keywords. Collaborative working environments, product extension, extended enterprise, service design tools, core collaborative services, knowledge sharing.

1 Introduction

The main business objective of the work presented in this paper is to provide a comprehensive solution to extend products of manufacturing companies acting at the global market. The objective is to enable different equipment manufacturers, especially SMEs, to provide new services and new business models, e.g. selling services (instead of selling classical equipment as e.g. control systems), by renting the equipment and guaranteeing its optimal use, which in turn will ask for innovative monitoring of product usage conditions and functions. So companies

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will not sell (only) the classical products, but also the knowledge on how to optimally select and use the products. Such an approach, i.e. provision of effective customer support for the equipment operating world wide, is of a vital importance for survival on the global market. An effective provision of such application services requires means for efficient collaboration of different actors within a supply chain on one side and customers on the other side, within an extended enterprise (EE) context. Although a number of ICT solutions for product extension are available, they do not allow for an efficient collaboration within EE, taking into account different, dynamically changing collaboration patterns and different technical backgrounds of the actors to be involved.

The research work presented is aimed at pushing the use of advanced service oriented architectures for Collaborative Working Environments (CWE) in real industrial practice. Such a CWE solution has to enable cost-effective product extension independently of geographical locations of customers and manufacturers.

The paper is structured as follows. In Section 2 a brief overview of the State-of-the-art of CWE in manufacturing industry is provided. Section 3 explains the concept of the proposed CWE platform. Section 4 is dedicated to the tools for design of CWE in manufacturing industry. Section 5 briefly presents applications of the results in specific industrial environments. Conclusions indicate the key innovations of the research work presented in this paper and outline future work.

2 State-of-the-art

The collaborative work in manufacturing industry requires solving several fundamental problems. Collaboration amongst teams in an enterprise often geographically dislocated, is currently burdened with a number of problems concerning distribution of work, synchronisation and persistence of workspaces, knowledge activation etc. The teams in modern and highly flexible manufacturing industry often require different collaboration patterns (e.g. a combination of synchronous and asynchronous collaboration) [6]. For example, a collaboration for product problem solving has to integrate effective information sharing and activity synchronization [4].

Based on the analysis of the requirements of users in manufacturing industry in the two European projects [8, 2], and on the analysis of state-of-the-art (SotA) the main gaps between the requirements and SotA are identified. This led to the definition of the key RTD challenges which have to be addressed in order to satisfy the requirements of industry regarding CWEs for product extensions.

The analysis of users′ requirements clearly indicate that different so-called collaborative application services (see the next Section) are needed which will satisfy the (basic) requirements to support (a) different collaboration patterns with special emphasis on temporal aspect: synchronous, asynchronous, multi-synchronous patterns, (b) distributed work in EE environment, which includes identification of appropriate expertise, team forming, checking availability of experts etc. with special challenges regarding collaboration among organized teams and wider community, (c) effective (on-line) provision of knowledge on product/equipment and on actors involved, (d) effective knowledge management

(KM), (e) dynamic changes in collaborative work conditions, and (f) decision making in CWE.

Many of the addressed problems are common for collaboration work in multiple different domains. However, there are several specific issues related to CWE in manufacturing industry which impose the needs for RTD activities specifically focused upon manufacturing industry. Such issues are:

- high difference in working environments of the collaborative teams (e.g. shop-floor, logistics area, office area for design teams, etc.)
- different technical backgrounds of teams collaborating on common problems (e.g. shop-floor workers with practical experience but (often) low ICT backgrounds, designers with technical expertise etc.)
- specific security requirements
- strong focusing on organized groups but evident needs to include in collaboration more ad-hoc groups.

3 Proposed CWE

The objective is to develop a generic and widely applicable, modular collaborative platform to support product extensions. The platform will provide various Collaborative Application Services (CAS) to support product extensions, e.g. support in solving problems related to product use (including support in diagnostics etc.), maintenance service, product/equipment reconfiguration etc. The targeted platform will be open for various services to support different products/equipment and involvement of different actors (product designers and service providers, maintenance providers, shop-floor operators, end-customers).

Under CAS are understood the services which involve collaboration of different actors, teams and artefacts within an EE, and which are focused on specific application areas [7]. These services use the information middleware which connects machines/equipment with the platform and provides information on products/processes/production units (equipment) needed for collaborative work within specific application area.

The analysis has shown that the required application services to support product extension have common 'collaborative' actions which may be supported by a common approach. Therefore, the new CWE solution will include so-called core collaborative services, addressing application independent functionality to support collaboration and covering these common collaboration actions (such as resource discovery, collaboration traceability, knowledge provision etc.). The core collaborative services (CCS) will be combined with application specific software solutions and semantic-based knowledge management tools (SBKM) allowing for effective collaborative work and knowledge sharing among different actors.

Since the application services will have to be dynamically updated, due to frequent changes in collaboration needs and conditions, 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 engineer CAS supporting different collaboration patterns and users' backgrounds. The challenge is to provide tools for design of CAS which will either automatically update CAS (e.g. make changes in collaboration support based on tracing of the collaboration work) and/or allow users, non-IT experts, to generate/update application services by themselves.

4 Main Collaboration Design tools

The main design tools have to support development of CAS which can be easily integrated in different environments (i.e. at different information middleware, with different legacy systems) and which can be easily integrated with the existing application solutions (e.g. existing systems for equipment maintenance, diagnostics CAD/CAM etc.). Several groups of tools are investigated as indicated in Figure 1.

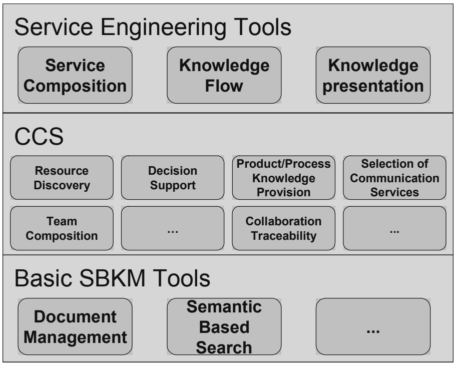

Figure 1. Design tools

4.1. Service engineering tools

Three tools are investigated and developed, addressing several RTD problems:

Service Creation and Edition of CAS: The tool allows users to create a new application service, or edit/modify an existing application service. The functionality is available to expert users, and might require programming skills and it certainly requires high-level access rights, as it implies access to sensitive information of the company (e.g. list of all users and respective rights). The tool will allow users to define issues such as: the purpose of CAS; text and structure for the help system to be used in CAS; users who are allowed to use CAS; collaboration patterns which are supported by CAS; CCS and additional functionality that are necessary to implement CAS, the history of all actions related to creating and editing of CAS.

Identification of Knowledge Flow for CAS: The tool will help the service developer in defining which information is needed for the service, a selection of SBKM tools and auxiliary functionality and their potential use in the services. It provides a list of information/knowledge needed for the CAS, together with sources from which this information can be collected.

This tool supports the knowledge flow identification for the application services, also helping the BPEL (Business Process Execution Language) process definition by providing BPEL partner links details[2]. The tool has the functionality for presentation of the existing knowledge objects in the system, filtered by the target user group's rights and the desired collaboration pattern, allowing the user to select which one is relevant for the composite application service and for presentation of the available SBKM tools/functionality and other relevant tools (again, filtered by user rights and collaboration pattern) so that the user can select the ones needed for the CAS

An oriented graph of the dependencies between entities which are manipulated by this tool helps to define the correct order of the operations. An oriented arrow from A to B means that A influences B, i.e. a fixed A reduces the possible B's to a subset of the original set.

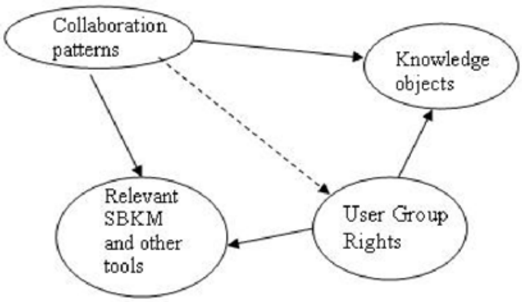

Figure 2. Concepts dependencies

The tool gets information from the Service Creation tool what the supported collaboration patterns will be for CAS, as well as the target user group. Knowing those is the starting point for the definition process. For instance, as can be seen in Figure 2, the expected collaboration patterns restrict the possible range of available Knowledge objects. The visibility of a knowledge object is defined as follows:

Visibility (Object) = v (collaboration pattern, user rights)

That means that whether a Knowledge object will be available in a service depends both on the desired collaboration pattern (for instance, some objects could be available only in asynchronous mode) and on the rights of the users in the group cleared for using the service.

The relevance of a SBKM tool is defined in an analogous way:

Relevance (Tool) = r(collaboration pattern, user rights)

e.g. Particular cases of tool relevances: for instance, communication tools like email are not highly relevant if the spatial collaboration pattern is local.

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[2] The CCS are available as atomic Web Services which can then be composed/orchestrated in order to obtain composite CASs. An orchestration of CCS could be done by BPEL tools. Thus, the BPEL partner links will point to CCS which will be used by the composite service.

Even if a tool would be helpful, if the users' collaboration is conducted after a pattern which does not allow for the use of said tool, its relative relevance is minimal in that case. The User rights themselves could be treated differently at different levels: (a) transparently, at OS level – influenced by collaboration pattern (for instance, permission to read/write in a synchronous collaboration mode). This influence is symbolized in Figure 2 by the dotted arrow linking collaboration patterns with user rights, (b) visibly, at ICP level: user rights defined upon the user's SME affiliation, expertise level , etc.

Definition of Knowledge Presentation and GUI for CAS: This module helps ascertain which information will be provided to different actors in the scope of the application service. In order to do this, different actors will see different GUIs which present only the information they need or have access to. This module has the functionality to define the information which will be presented in the GUI for the CAS; given a user or group of users and the available GUIs, the designer may define which GUI can be used by which user. The presentation of the available GUIs will be made taking into account an ontology of existing GUIs. A rough sketch of the ontology is defined in terms of classes: (1) GUI, (2) User Group, (3) Information/Knowledge Object, and slots (properties of classes): User rights, User device type, Collaboration pattern (some objects may not be visible with some collaboration patterns, or have restricted visibility), visibility, or viewing rights (an object is visible-to a user group which has the proper rights for that; a GUI formatted for a desktop computer monitor is not visible-to a user group which uses PDAs) . The user's device type could be merged as a special case into user rights.

4.2. Core Collaborative Services

The key layer includes CCS – generic set of services supporting collaboration among teams in an EE. The key issue is that the design tools and the CCS support different patterns for collaboration among the teams [5]. Table 1 provides an overview of the key CCS.

4.3. Semantic based Knowledge Management Tools

Different (existing) tools for KM are combined within CAS to support knowledge sharing among teams. The CCS for Product/process knowledge provision has a task to select the appropriate tool to provide knowledge (e.g. for searching on documents related to problems etc.). This CCS provides e.g. 'similar' problems to the one to be solved by an actor/group by applying Case Based Reasoning and Rule Based Reasoning tools [8]. 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 for Case Based Reasoning. The problem of ontology is addressed by applying new approach for distributed set-up and maintenance of ontology [3].

Table 1. CCS for work on innovation in manufacturing industry

CCS	**Input/request**	**Output**	**Main functionality**	**Specific requirements**
Resource discovery	Request for expertise	Appropriate and available expert(s)	Searching for expertise Check availability	Mobile users Defined groups Open group
Collaboration Traceability	Request for tracing of the group	Info. on the requested states of groups	Tracing of collaboration: - continuous - event driven, (event identification)	Specific requirements regarding security, companies specific rules
Product/pro-cess knowledge provision	Request for a specific knowledge for the actor/group	Knowledge provided to the actor /group	Selection from the set of the basic KM functionalities the most appropriate one	Documents Stored user knowledge Data bases
Decision support	Problem defined, ideas evaluated	Decision support	Supports weighting of criteria for decision, and decisions traceability	Hierarchy in decision making according to enterprise rules
Team composition	Request for optimal team	Optimal team	Proposes team based on ident. expertise	Enterprise rules
Selection of communicatio n services	Communicatio n needs	Selected commu-nication	Selects most appro-priate for the specific actor, pattern etc.	Voice, Text, Drawings, imagines, Videos, (e-mail Chats)

5 Application

One application addresses CAS for problem solving within complex assembly lines (for small motors at the automotive industry supplier), supporting collaboration among product (line) 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 information middleware (based on the Siemens' ePS) is 'upgraded' with CCS.

Another application is the company that designs, manufactures and trades air conditioning equipment. The company needs effective solutions for maintenance and after-sales services since such CAS have a strong impact on the brand image. In one CAS oriented to the support of acclimatisation units, three different entities in distinct geographical locations interact simultaneously to solve a problem in the machine. The second CAS is oriented to product design and reconfiguration.

6 Conclusions

The main innovation of the work presented is the provision of a new CWE platform including a set of CCS, combined with existing technologies to provide application services for product extensions in manufacturing industry. The proposed approach is fully in line with the findings of the Expert Group on CWE [1]. The group has identified needs to develop collaboration services which can be layered in three blocks: generic services that define basic components (i.e. CCS); domain-specific services (e.g. for manufacturing industry) and context-specific services. Any layer of this architecture has to be supported by services and tools for collaboration design. Exactly these are the objectives of the work presented:

- to develop a set of CCS to allow building of CAS for product extensions

1. to develop a set of tools for design of CAS in manufacturing industry.

The solution will be general enough to be used for different products and scalable to support future products, and thus usable by a wide spectrum of companies and their customers. The future work will be focused upon automatic design/update of CAS by the developed design tools.

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