Collaborative Design System for Supporting Dynamic Virtual Enterprises

Michele Germani[1], Marco Mandolini[1], Maura Mengoni[1], Margherita Peruzzini[1]

[1] Polytechnic University of Marche, Department of Mechanics, via Brecce Bianche, 60131 Ancona, Italy
{m.mengoni, m.germani, m.peruzzini}@univpm.it

Abstract. Collaborative design provides creative design solutions and improves product quality as well as enriches participants' knowledge. Nevertheless, design and supply chain integration in product development processes is not a trivial task. The complex scenario of the dynamic extended enterprise triggers research toward the development of an innovative co-design platform to support multidisciplinary workgroups. Starting from the definition of a new design process model, the proposed approach is based on the formalization of the distributed knowledge in terms of interaction rules and representational models.

Keywords: collaborative design, virtual teamwork, agile organizations

1 Introduction

Product development implies two main challenges: multidisciplinary team work and extended enterprise. As product design requires the integration of several specific domain solutions, multiple competences need to be involved in the design cycle, each performing their own task, converging on the same goal. Due to the different expertise, individual knowledge and background, communication problems can emerge. This means a continuous adaptation of the adopted design tools and methods for achieving the best solution in the estimated time. As a consequence, unforeseeable iterations increase, decision-making activities become more and more critical and time to market stretches. The creation of virtual teamwork extends product development, not only in terms of multisite enterprise, but mainly in methodological terms:

1. The typical cognitive design model is rearranged. Individual work is reduced while collective work is extended [1];
2. The whole design knowledge is dispersed along the product development chain. It is differently formalized according to the design stage and to the participants skill and adopted tools. It is mainly organized according to the project it is related to instead of the product structure;
3. Interaction styles and communication modes change according to synchronous and asynchronous collaboration. Supporting platforms should fit in with different collaborative dimensions needs.

In order to overcome all mentioned problems, supporting tools should stimulate collective creativity, facilitate communication, manage product models evolution, monitor the whole process and reconfigure it according to the unpredictable scenario that continuously changes during the project development. In this complex context, this paper proposes a knowledge-based approach that allows defining a process model able to manage all concurrent aspects in co-design. This model extends traditional processes by introducing more strategic decision-making activities involving design teams. It aims at overcoming the distinction between the leader company and its supply chain by managing collective acceptance and the legitimacy of rules and by using role-playing for collaboratively develops new projects. The developed model is then implemented by a web-based co-design platform that integrates different organizational structures, supports novel modes of interaction and creates a CAD-based environment for elaborating product models.

2 Research background: distributed knowledge management

Among all kinds of industrial cooperation, design and supply chain collaboration is one of the most complex. As time to market needs to be decreased and synchronous collaboration requires the involvement of multiple partners, face-to-face collaboration is progressively replaced by a computer mediated one [2].

Another important issue regards with knowledge management across design cycle, among teamwork members, inside different organizations. Byrne, Brandt and Port [3] definition of Virtual Enterprise (VE) points out three crucial aspects in virtual teamwork: 1) the importance of integrating different independent organizational structures, 2) the role of information management and 3) the concept of temporary, that is reconfigurable according to the different project tasks, product development stages and team members. VE problems can be faced by adopting a process view enabling the creation of inter-enterprises business collaboration while keeping autonomy of participating enterprises [4]. Supporting systems focus more on managing internal and external processes instead of investigate how the distributed knowledge can be formalized through the flow of activities and the mechanisms of collective problem solving. In the last years, several researches have been oriented to the management of dynamic workflows by developing advanced frameworks to support exception handling [5]. All proposed architectures remain at an academic level and requires strong implementation efforts for defining rules reconfiguring workflow models. Inter-organizations efficiency depends mainly on the strategic management of information and on the adopted methodologies to support networking. This statement is more evident by analyzing current limitations of available Communication Information Technologies. Current PLM implementations are strongly document-oriented, have a structured and not much customizable data model and suffer from inter-enterprise integration difficulties [6]. Open-source web-based platforms allow establishing communities of practice and harnessing the knowledge gained by individuals [7] by providing web portals to sharing documents and applications [8]. Main problems regard with: 1) the organization of data according to the specific project, to the specific stage of product development and partners

involved in, 2) the legitimacy of adopted rules and 3) the policy of data exchange authorizations.

The starting point to create integrated platforms to support virtual teamwork is the analysis of the distributed knowledge across the virtual teamwork and the definition of a new process model fitting in with the challenges of the extended enterprise [9]. As product design is heavily based on know-how gained from personal experience, the introduction of design teamwork makes complex knowledge capturing, formalization, storing, reuse, sharing and dissemination in distributed environments [10]. Enabling factors include: the use of common representational modalities and the integration of different design tools; the adoption of procedures shared by all participants; the management of responsibilities across the CPD; teamwork participants attitude, just-in-time expertise matching and timing of communication.

Both tacit and explicit knowledge can be related to the product and to the process. While product knowledge depends on the product model used to represent the different design aspects, the improvement of teamwork performance requires a robust analysis of process-related knowledge in order to formalize it across the distributed team context. Process information can be formalized within Workflow Management Systems (WfMS) using JECA (Justification, Event, Condition, Action) rules. They examine a set of conditions on the occurrence of events, and determine what actions need to be taken. Main implementation problems occur when the event has not been foreseen during the process analysis. In this case, Case Based Reasoning Algorithms (CBR) can be used to find a solution to unexpected events. They are able to search similar cases inside a proper database, to order them according to the similarity between the actual case and the historical ones and to adopt the right actions.

4 The approach: collaboration modes

The adopted approach can be summed-up into three steps:

1. Analysis of traditional product development processes and identification of the main drawbacks during collaboration;
2. Identification of new interaction modes in the extended enterprise and their integration into a process model that includes additional collective activities, new ways of participants engagement, different team working styles;
3. Implementation of the identified process model into a web-based co-design platform able to efficiently support virtual teamwork by providing an integrated tool to manage both process and product knowledge.

The investigation of inner and outer connections in the extended enterprise has been carried out within 21 companies (5 Large and 16 Small and Medium), involved in the CO-ENV project (www.coenv.it), funded by the Italian Minister of Economic Development. The project aims at developing innovative co-design supporting tools.

The study shows that although collaborative activities are often carried out, contacts with the design and supply chains are switched on and off only by the leader company. Suppliers just appear as external actors attending the leader company process without really influencing it. Data transfer is generally carried out by the support of shared workspaces (e.g. ftp server) and traditional communication means,

but only in one-way direction without exploiting the mutual opportunities to improve product and process knowledge. On the contrary, real team working requires a continuous stream of activities to achieve a coherent product design, as well as crosswise information management. The well known communication modes based on 1- to-1, 1-to-many and many-to-many patterns are not able to represent virtual teamwork (Fig. 1a). It is necessary to include the different identified relationships between the leader company and its design and supply chain. The network-based proposed model (Fig. 1b) considers the deployment of individual and collective work during interactions (Fig. 1c).

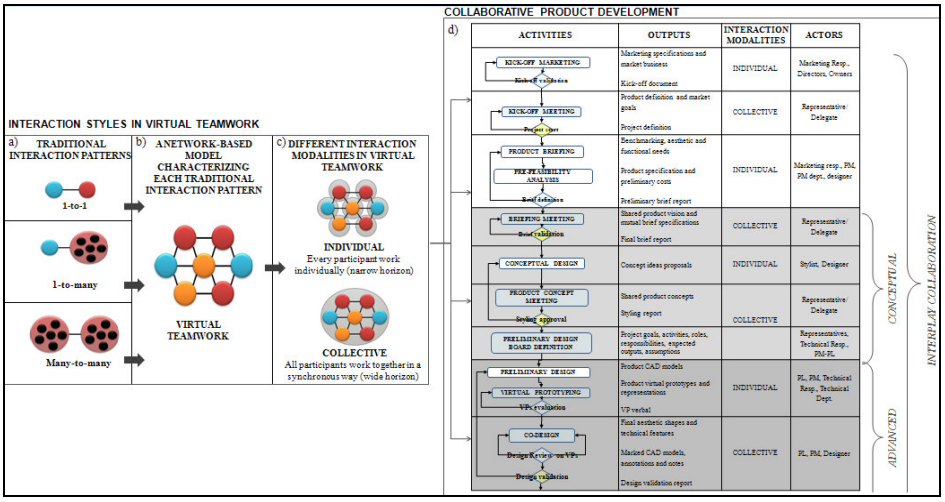

Fig. 1. The network-based model proposed to represent interaction styles in virtual teamwork created to support CPD

It is based on a network, where each node communicates with the other ones in both exclusive and mutual way, depending on the type of activity, on the design stage requirements and hence, on the adopted interaction pattern. In the network-based model, colours represent the 'specific gravity' of each actor carrying out individual and collective activities. When participants are separately working, their horizon is quite narrow and limited to those aspects they need to see in that particular moment to perform their own task (Fig. 1c at the top). In that case, traditional interaction modes fit in with collaboration needs. Otherwise, decision-making activities require knowledge sharing, individual work evaluation and specific solutions matching. A common space should be provided to activate the team network and make individual horizons in contact to extend the single viewpoints into the whole product perspective (Fig 1c, at the bottom). Figure 1d illustrates the proposed network model applied to conceptual design, advanced design and interplay collaboration stages. It highlights those activities whose interaction modality changes according to the design stage and the involved participants. The proposed representation aims at pointing out expected output, role-playing, interaction modes and collaborative dimensions. The lasts

change according to the process phase, the participating actors, the exchanged information, the ways of communication, the type of relationship (mutual or direct).

5 The co-design platform

In order to support the identified collaboration modes, a co-design platform has been developed. It supports product and process knowledge by creating 1) a structured repository of documents arranged according to the project they are related to, 2) project templates for supporting team members' communication and data exchange, 3) a collaboration area for collaboratively interacting on virtual prototypes enriched with attributes and annotations stored and retrieved from/to the databases and finally, 4) an activity-based workflow area for managing information flow across team members. The last is linked with an external module for dynamically configuring the implemented workflows according to the collaborative process targets (efficiency, timesaving, costs, etc.) and shared rules.

The platform architecture adopts a client-server approach and consists of three main modules through which data coherently flows (Fig.2).

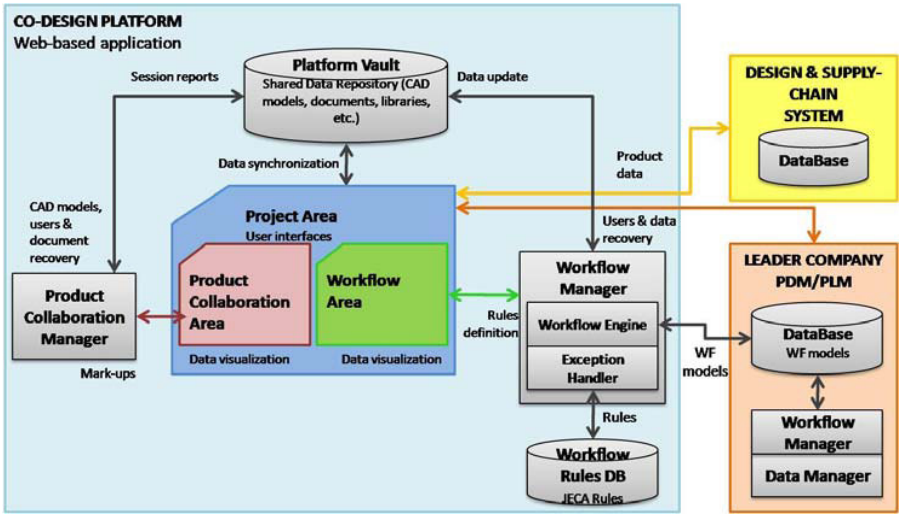

Fig. 2. The proposed co-design platform architecture

The project area represents the main interface for each participating actor. It is a project-based web platform supported by a collaborative portal server and a common vault. The project area consists of the collaborative and the workflows areas. All project have their own areas where similar and customized functionalities are implemented. The product collaboration manager allows collaborating on shared product models according to differentiated accesses for each team role. Both synchronous and asynchronous collaboration can be carried out. Data can be directly accessed through the collaboration area in the corresponding project space. Information is collected in and retrieved from the documents vault organized

according to the different projects carried out by different teams. This collaborative portal server enables the management of role-playing, the easy identification of project progress, of achieved results and of employed resources. Finally, the workflow manager allows both designing and instantiating CPD workflows enacting distributed design tasks and supporting their dynamic management according to the implemented knowledge-based rules stored into the JECA rules DB. The workflow manager is directly accessible by the workflow area in the relative project space. It consists of a workflow engine to implement the proposed collaborative model and of an exception handler to automatically support workflow problem-solving (e.g. desertion of a partner, dismissal, changes in executive jobs, times delays, costs variation, product's requirements changes).

The system framework has been implemented by integrating the different modules within a web-based collaborative portal server based on Microsoft Office Sharepoint Server 2007 to have comprehensive content management and enterprise search, to accelerate shared business processes, to control users and to facilitate information-sharing across boundaries for better business insight (Fig.3).

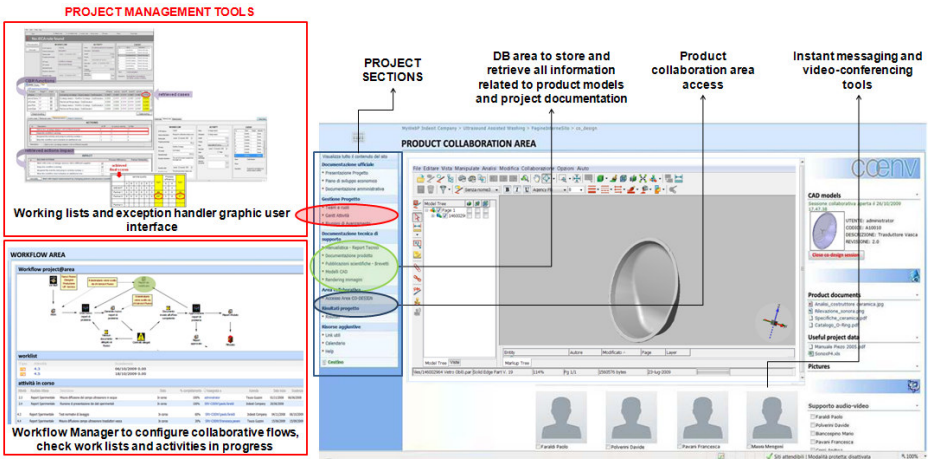

Fig. 3. Co-design platform implementation and product collaboration area user interface

The platform vault is a SQL Server database storing a list of websites (templates), each representing a project area. For each project, documents are collected and structured. The project page is structured by different sections: official project documents, technical information, obtained results, supporting adding resources, collaboration manager, project management tools. The last section provides the access to the workflow manager, to the exception handler, to the project plan, partners roles and responsibilities. The product collaboration area consists of a user interface that is directly visible from the project web-page, and of a project manager. The manager represents the real engine of the co-design tool. It integrates different commercial software packages: a collaborative CAD-based tool (AutoVue by Oracle), an instant messaging and communication tool (Skype), a video-conferencing area to support tele-presence and a DB area to automatically collect and retrieves information related

to the product model under investigation. The workflow area consists of a graphical user interface and of a workflow manager. The workflow manager consists of a workflow designer (softFlow) and a plug-in software for handling exceptions. The area can be accessed by the relative project area, as well as by the collaboration area. Some ad hoc applications have been also implemented to satisfy system requirements:

1. a set of dedicated website pages as templates has been created in order to support users in populating each project area according to the specific collaboration tasks.
2. a plug-in software has been developed to integrate the chosen WfMS (softFlow by Metisof) and the co-design platform. It enables the access to the WfMS from the project area and hence, to enact distributed design tasks;
3. a novel module to dynamic handle unpredictable events occurred during WfMS runtime.

In an operational way, once a new project is initiated in the CO-ENV platform by adopting a web page template, the leader company implements both the whole CPD and its sub-flows related to the collective activities carried out with the design and supply chain partners. To each teamwork member is assigned a role in the project and a set of activities in the specific workflows where he/she acts. At this point, each participant can control his/her own work list by directly accessing the project collaboration area. The system administrator can use the Exception Handler module to manage the unexpected events occurring during each collaborative workflow runtime. It enables firstly the identification and classification of the type of the occurring event, secondly the recognition of the best solution to the exception and thirdly, the reconfiguration of the related workflow to improve the whole process efficiency. All mentioned functions are carried out thanks to the information stored in the JECA rules DB and by the implemented CBR algorithms. They operate in case of no rules finding by searching similar historical cases to the occurred unexpected event. They order all retrieved cases by JECA rules according to a set of particular attributes, such as the activity actor, the workflow typology, the failure reason, etc. In order to compare each of them, a similarity multilevel structure has been identified (e.g. the organization chart can be used for determining the similarity level of the activity actor attribute). The search result is the most similar case to a previous one and the corresponding rule for problem-solving. The platform can itself instantiate the new reconfigured workflow or ask the administrator to modify the rule solution in order to better fit with the specific occurring event. In the second case, a new rule and event connection are created and automatically stored in the JECA rules DB. As a consequence the system knowledge increases.

6 Conclusions

Competitiveness highly depends on the ability of industrial companies to efficiently cooperate, communicate and collaborate in order to innovate processes and products and face everyday design challenges. This paper is a step forwards the implementation of a proper co-design platform for supporting virtual teamwork. A knowledge-based approach has been adopted to define the main modules features and relative functionalities. Experimentations are carrying out in four different projects

involving multiple partners of the COEVN consortium. All projects aim at developing new products. Preliminary results showed advantages in terms of team member engagement, reduced time to market, better control of project goals and expectations and decrease of design errors and iterations.
Future work will be focused on a better integration of all modules, on the objective measurement of the achieved experimental results, on the collection of more test cases to enrich JECA rules DB.

Acknowledgments
The research reported in this paper was supported by the Italian Ministry of Economic Development and the COENV R&D consortium

References

1. Bryan-Kinns N., Healey P.G.T. and Leach J., Exploring Mutual Engagement in Creative Collaborations, Proceedings of the International Conference on Creativity and Cognition, Washington, USA, ACM Press (2007)
2. Yang M.C., Jin Y., An Examination of Team Effectiveness in Distributed and Co-located Engineering Teams, International Journal of Engineering Education, Vol. 24, No. 2, pp. 400-408 (2008)
3. Byrne J. A., Brandt R., and Port O., The virtual corporation. The company of the future will be ultimate in adaptability, in Business Week, pp. 36–40 (1993)
4. Jiang P, Xinyu S., Qiu H., Gao L., Li P., A Web services and process-view combined approach for process management of collaborative product development, Computer in Industry, Vol. 60, pp. 416-427 (2009)
5. Mourão H., Antunes P. Supporting Effective Unexpected Exceptions Handling in Workflow Management Systems, Proceedings of the ACM symposium on Applied computing, Seoul – Korea, pp. 1242-1249 (2007)
6. Aziz H., Gao J., Maropoulos P. and Cheung W.M., Open standard, open source and peer-to-peer tools and methods for collaborative product development, Computer in Industry, Vol. 56, pp. 260-271 (2005)
7. Pollalis Y.A., Dimitriou N.K., Knowledge management in virtual enterprises: A systemic multimethodology towards the strategic use of information, International Journal of Information Management, Vol. 28, pp. 305-321 (2008)
8. He F., Han S., A method and tool for human-human interaction and instant collaboration in CSCW-based CAD, Computers in Industry, Vol.57, pp.740—751 (2006)
9. Krehmer H., Eckstein R., Lauer W., Roelofsen J., Stober C., Troll A., Weber N., Zapf J., Coping with multidisciplinary product development – a process model approach, Proceedings of ICED'09, 24-27 August 2009, Standford, CA, USA (2009)
10. Wallace K., Capturing, storing and retrieving design knowledge in a distributed environment, Proceedings of the Ninth International Conference on Computer Supported Work in Design, 24-26 May, Coventry University, UK (2005)