GEPP-net: a system to support collaboration in the early stages of the design process

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Abstract: This paper introduces the GEPP-net: a Web-based system to support collaborative work in the early stages of design process. The system brings together technical, managerial and communication tools regarding a well established product design methodology. The paper reviews four previously developed similar systems. Insufficient support for the activities of understanding the customer needs and the development of design specifications were detected as key deficiencies in these systems. The paper describes the requirements and general architecture for the GEPP-net, as well as its fundamental functionality, and discusses three cases where the system was applied in order to evaluate its performance and potential. Besides a good interface design and an appropriate structure, the system presents as a main advantage the fact that design tools and knowledge are presented in the context of a design methodology that works as a backdrop and structure for them.
Keywords: collaborative design, product design, conceptual design, informational design.

1. Introduction

The great influence of the early stages of the design process in the success of a product is today emphasized both in academia and industry. Final cost, quality and time-to-market are to a high degree determined during these stages of the product development process, where there is usually a variety of possible design solutions, frequently coupled with bad information quality: very fuzzy and frequently incomplete. According to WANG et al. (2002), the concept generated at the early stages of product development affects the basic shape generation and material selection of the product concerned. In the subsequent phase of detailed design, it becomes extremely difficult or even impossible to compensate for or to correct the shortcomings of a poor design concept developed in the early stages of the design process.

A number of web-based systems have been recently developed to assist the collaborative work in the product design process. As stated by WANG et al. (2002), the potential of the web for designers to combine multimedia to publish information relevant to the spectrum of the design process, from concept generation and prototyping to product realization and virtual manufacturing, motivated the adoption of the web as a design collaboration tool. It is now playing an increasingly important role in developing collaborative product development systems. However, following a general trend in the development of computational tools for design, such systems focus on the late stages of this process, when layouts, geometries and tolerances (low level of abstraction) are defined for the products and for their components.

This paper introduces the GEPP-net (GOMES FERREIRA, 2006): a web-based system to support the collaborative work in the early stages of the product design process: identification of customers needs, establishment of product specification and conceptual design, as described by ULRICH & EPPINGER (1995). FONSECA (2000) coined the term ‘informational design’ to refer to these two first stages that deal with the customers needs and the product specification. The system gathers together four general classes of computational tools to support the distributed (space and time) work of the members of the design team: specific design tools, communication tools, project management tools, and knowledge management tools (Figure 1). A well established design methodology guides the design team during the use of the system. This system was developed at the Federal University of Santa Catarina (GEPP research group) in close cooperation with the University of São Paulo in São Carlos (NUMA/GEI2 research group).

In the following section we make a short review of four previous related systems developed in the domain of collaborative conceptual design. The two next sections describe the requirements and a general architecture for web-based systems to support the collaborative work in the early stages of the design process. After that, the GEPP-net system is presented, focusing its fundamental functionality and the programming technologies used to develop it. Three design cases are then discussed in order to evaluate the performance of the system and its potential to support the early stages of the design process. In the last section, the GEPP-net system is compared with the four collaborative systems presented in the second section, and some future improvements planned for the system are proposed.

2. Previous similar systems

WANG et al. (2000) provided a comprehensive review of research projects and applications in the domain of collaborative conceptual design, based on internet and web technologies. Agents and the web were highlighted among the technologies to implement collaborative design systems. PACT (CUTKOSKY et al., 1993) and SHARE (TOYE et al., 1994) are two frequently referenced systems devoted to support collaboration in the general product design process. In the following, four projects that focus the conceptual design are briefly reviewed.

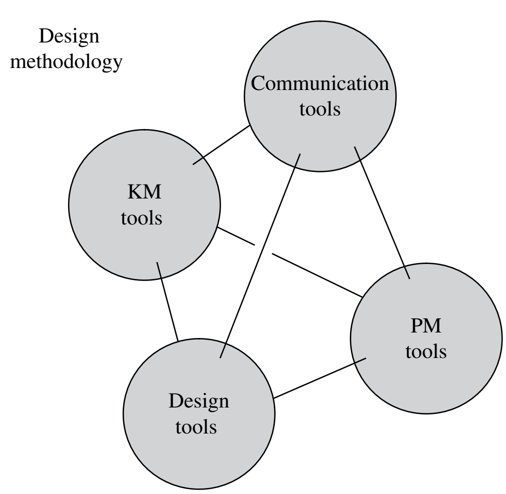

Figure 1. GEPP-net elements.

2.1. PCT

Developed by ROY & KODKANI (2000), at the knowledge based engineering laboratory (Syracuse University, NY, USA), the product conceptualization tool (PCT) uses enabling web technology to support geographically dispersed designers, to develop and select the product concept, through a collaborative effort. PCT allows designers to represent their concepts and also aids them to search for existing ideas on similar products - providing a link to existing patent databases on the web. The issue of selection of the best concept is tackled by adopting the gallery method, through a module, which computes ratings for individual drawings for a pre-discussed set of criteria.

2.2. DiDEAS

Developed by SCHUELLER (2002), at the Stellenbosch University (South Africa), this is a three-segment system to support a distributed team of designers. The segment 'design methodology' places a methodology that guides designers through the conceptual design at their disposal and offers tools for concept generation and evaluation. The segment 'communication and information transfer' coordinates the communication between the distributed designers and provides a platform for the exchange of design-related data, such as customer requirements, ideas, sketches, comments and decisions. Both segments make use of the third segment: a support service for various input devices.

2.3. Virtual office and prodefine

A general web-based collaborative framework developed by HUANG & MAK (1999), at the University of Hong Kong is here instantiated for the conceptual design. The start-up home-page (virtual office) provides access to three web-based conceptual design tools (virtual consultants): functional analyzer, morphological concept generator, and morphological concept assessor. These tools correspond to the three major stages of conceptual design, according to the authors.

More recently, developed by HUANG et al. (2003), at the University of Hong Kong, this system attempts to support early product definition. The system offers four main front-end components (customer and project explorer, requirement analysis explorer, concept generation explorer, and concept evaluation explorer) and two back-end databases (concept base and solution base). These components are employed and configured according to a typical three-tiered architecture for web and Internet applications.

3. System requirements

The software development process comprises a group of activities with the objective of producing a system to assist the requirements specified by the users. The satisfaction of such requirements is the basic condition for the success of the computational system. Once badly specified, it will disappoint their users and will cause extra work to the development team that will have to modify the system in order to be adapted to their users' needs. The specification of the requirements also serves as a reference for the evaluation of the developed system. The so called 'requirements document' holds all the functional and non-functional (usability, reliability, efficiency, maintainability, portability, among others) requirements of the system, including the capabilities of the product, the available resources, the benefits and the acceptance criteria. This document is also used to establish a formal agreement between the development team and the users about what is intended with the system to be developed.

This section presents the main quality (non-functional) and functional requirements that guided the development of the GEPP-net collaborative system. Such requirements were obtained in part from our own experience (and the experience of our research colleagues) as product designers and in part from an analysis of the previous collaborative systems presented above. Also, many of the functional requirements derive naturally from the steps of the design methodology adopted by the system.

3.1. Non-functional requirements

High speed, reliability, maintainability and accessibility (user-friendly interface) are among the many requirements which determine the effectiveness of a system on the web. Table 1 identifies some important non-functional requirements that have guided the development of the GEPP-net system.

3.2. Functional requirements

Table 2, on the other hand, presents the main functional requirements for the system. Such requirements concern the functions that the system will have to perform, and thereby its architecture tools.

4. System architecture

Based on the requirements presented in the last section, the architecture for GEPP-net was developed. Figure 2 depicts this architecture in an abridged way. One should note that such architecture serves not only for the development of our system, but also for the development of any Web-system to support the collaborative work in the early stages of the design process.

Figure 2 shows a three layered architecture, typical of systems developed for the web. The first layer (interface

Table 1. Non-functional requirements for the system.

The system should…	Description
… give better support to the informational design	Better support should be given to the processes of customer needs analysis and design specification elaboration in the informational phase of the design process.
… make use of low cost hardware components	In order to be accessible to small and medium sized enterprises, the system should make use of low cost hardware components. It should take advantage of already existing resources in the company: personal computers and low cost peripherals.
… cope with bandwidth limitations	It is important to be aware of the bandwidth limitations that companies will have to cope with when using the collaborative system on the Internet. The bandwidth issue becomes even more problematic in developing countries, such as Brazil.
… exploit the knowledge already available on the web	A better exploitation of some useful knowledge already available on the web (patents, consumer reviews, norms and codes, product catalogs, magazines, among others) should be sought. Several of these valuable design resources, in the form of web hyperlinks or documents, should be gathered, analyzed, and associated with the activities and methods of the design process in a clear way.
… make pragmatic use of tools and resources already available on the web	A pragmatic use of tools and resources already available on the web is sought in the system. This is particularly valid with respect to the communication and project management tools that compose the system.
… be independent of platform, operational system and browser	The system should run equally well regardless of the platform (PC or Mac), operational system or web browser used.
… give support to managerial aspects of the design process.	Support should be given not only to the technical aspects of the design process, but also to its managerial (coordination) aspects.
… have a modular structure	Complementary modules of applications, knowledge-bases and communication channels should compose the system. Modularity assures easy maintenance and future expansions of the system.
… be safe and reliable	New product design usually deals with secret information, susceptible to industrial espionage. Hackers and non-authorized users should be kept away from the knowledge bases of the system. The system should also be perceived as reliable by its users, i.e., present a low rate of failures and interruptions during its operation.

Table 2. Functional requirements for the system.

Area	The system should…
Design methodology	... present a product design methodology to guide the activities of the members of the design team.
Design methods	... make computational tools available in order to implement the most important design methods used in the early stages of the design process in a collaborative way.
Communication and document exchange	… allow and stimulate the multimedia communication (both synchronous and asynchronous) between the members of the design team: text, voice and video.
	… allow the exchange of design related documents (questionnaires, sketches, reports, and so on) as electronic files.
Knowledge management	… allow the storage of links to websites that present important data, information and knowledge that can be used in the design process: patents, norms and codes, industrial catalogs, among many others.
	… allow the storage of electronic files that contain important information about the product design process: scientific and technical papers, academic theses and dissertations, technical reports, design handbooks, function and part diagrams, sketches, flowcharts, and so on.
Project management	... support the collaborative coordination of the design activities. The system should strive to support the nine project management knowledge areas: integration, scope, time, cost, quality, human resources, communication, risk, and procurement.

layer) represents the web browser employed by the users to access the system on the client side. On the second layer (middle layer), we can find the tools and applications of the system: (specific) design tools, project management tools, knowledge management tools, and communication tools. These tools make use of the data, information, and knowledge - related both to the design activities and to the product under development - that are stored on the databases from the third layer of the architecture (data layer).

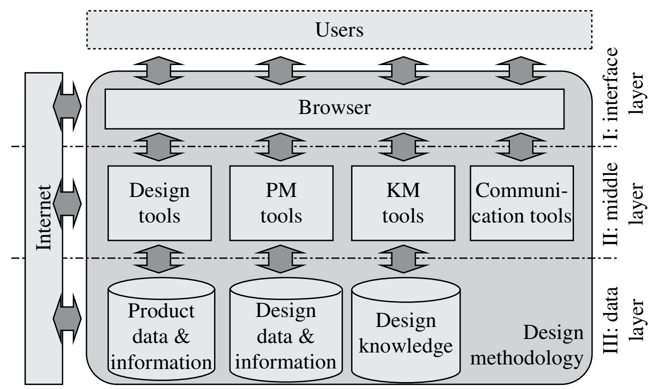

Figure 2. GEPP-net architecture.

5. The GEPP-net system

Based on the requirements and on the architecture delineated in the two previous sections, it was possible for us to develop the GEPP-net collaborative system, with the specific design tools necessary to identify the costumer needs and to establish the target-specification for the product (informational design). The designs tools that are necessary to accomplish the conceptual design are today under development by GUERRA (2005). This section presents the interface of the GEPP-net system and also the programming technologies used to develop it.

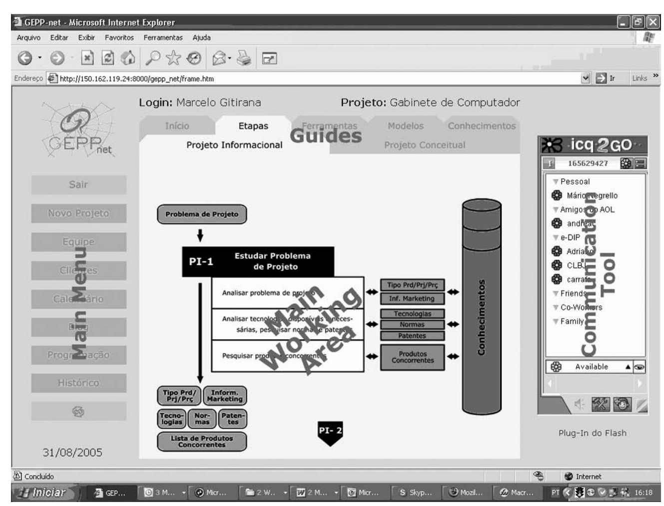

Figure 3. Interface of GEPP-net system.

5.1. System interface

Figure 3 shows the interface of the GEPP-net, opened in the Internet Explorer browser from Microsoft Company. On the left area of the screen, below the logo of the system, we can find the main menu. Its first button (up to down) allows the user to quit the system, while the second allows him/her to leave a project without quitting the system. The two following buttons, respectively, give access to a list with all the members of the design team, and to a list with all the clients of the design process. The buttons that follow give the users access to the following computational tools: a calendar to arrange and view the appointments for the project; a blog with information and discussions related to the project; a Gantt diagram to plan the design activities; and a historic record with all the actions carried out by the members of the design team. The last button of the main menu allows the user to refresh the screen and update its information, without causing an interruption in the section of the communication tool used by the system.

On the central area of the screen, we can find the main working area of the GEPP-net system. Figure 3 presents this main working area for the first activity of the informational design phase: ‘to study the design problem’. The code and the title of the referred activity are written inside a black box. Just below the black box come the tasks that belong to the activity: ‘to analyze the design problem’, ‘to analyze the available and necessary technologies, and to search for norms and patents’, and ‘to search for competing products’. In the right side of each task, there are red boxes that represent and give access to the tools that the design team uses in order to execute the tasks of the design process. The House of Quality is one example of design tools provided by the system, as Figure 4 illustrates. Such tools make use of the information and knowledge stored in the databases of the system, represented by a blue cylinder in the right side of the main working area. Each design activity receives, as an input, some information about the product under development to be processed, and in return provides, as an output, some other information, that will be used as an input for the next design activity. This input and output information is represented by the green round-edged boxes in the main working area. Black arrows on the top and on the bottom of the main working area allow the designers to navigate between the consecutive activities.

Above the main working area there is a set of guides. The first one gives the users access to the homepage of the system, with some important and current information about the project in use. The second guide allows the users to navigate through the activities of the design process, as shown in Figure 3. The third guide presents the users with all the design tools provided by the system in just one page, which makes it easier for experienced designers to use the

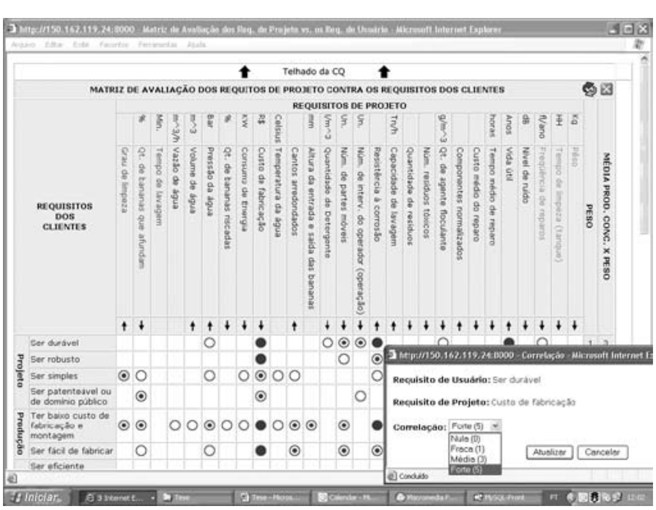

Figure 4. Main matrix of The House of Quality.

system. In the same way, the fourth guide shows the users all input and output information about the product under development. This page also allows the users to manage their completion status. Finally, the last guide gives access to one portal with links to homepages and another with electronic documents, both with important information and knowledge for the early stages of the design process. Above this set of guides, the users can see who is using the system, and which design he/she is working on. In the right area of the screen, the user can access the ICQ2GO communication tool (instant message).

5.2. Technologies

GEPP-net system runs on an apache web server on a Linux platform. Apache is today a very popular web server and runs safely and reliably on Linux. The system uses PHP and MySQL (data server) for the server side processing. Ease of learning and synergy were decisive criteria for the choice of these two technologies. This whole architecture, known as LAMP - which stands for “Linux-Apache-MySQL-PHP” - is shown in Figure 5. It combines four technologies distributed under GLP (General Public License) and enjoys the support of a large group of devoted open-source developers. For the client side processing, HTML and JavaScript are employed.

6. Evaluation of the system

In order to evaluate its functionalities and its potential to support the early stages of the design process, the GEPP-net system was used in some product design cases, during and after its development. Three significant design cases are discussed in this section. The criticisms and suggestions provided during such cases are being used to optimize the system, and its general architecture.

6.1. Banana washer basins

CARRAFA (2007), and his design team were one of the first to use GEPP-net. They had a request, from the farmers of the district of Luiz Alves (Santa Catarina, Brazil), to improve a system, already in use, to wash just-harvested green bananas. These farmers had a significant loss of production, because the bananas that ripened during the cold seasons of the year sank in the washing basins, due to their higher density. When these fruits stay submersed for more than fifteen minutes in the basins with water and aluminum sulfate (to flocculate the dirt), they have their peel ‘chemically burned’. With the support of the system, the team designed a device that allows the bananas to keep floating with the help of water jets that come from the bottom of the basins.

Since the system was still under development when this project was carried out, and the design team was composed of a low number of members, the aim here was to evaluate the

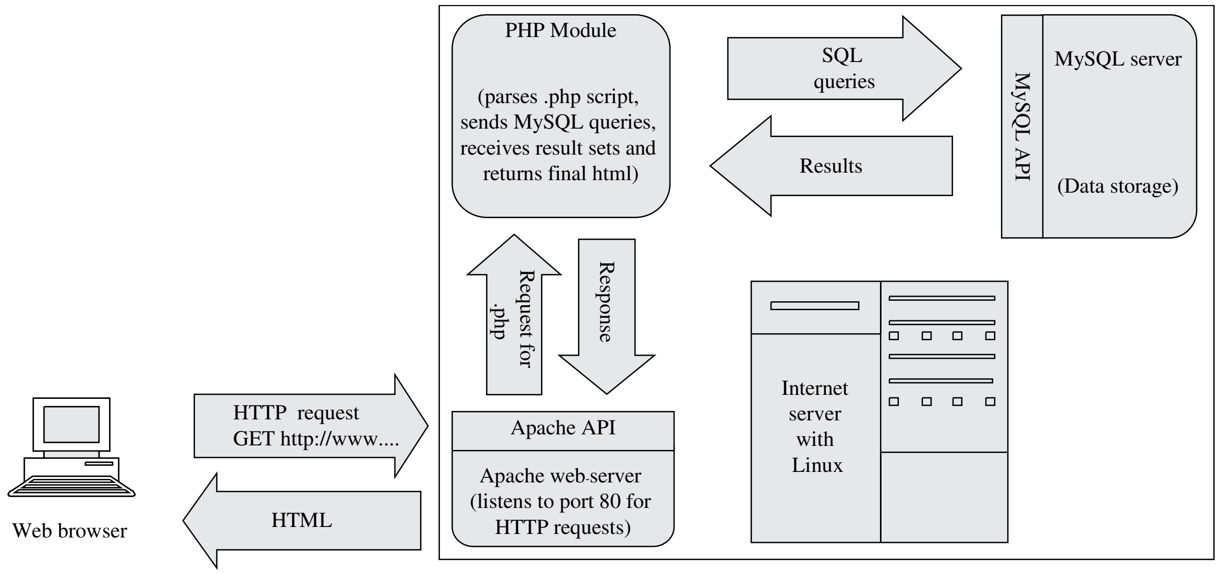

Figure 5. Lamp architecture.

functionalities of the specific design tools: questionnaires, Mudge Diagram, House of Quality, and so on.

6.2. Drug packager

The system was also used by MOECKEL et al. (2005), in the collaborative development of a small size solid drug packager. This was a request from the pharmacy of the University Hospital of UFSC. The pharmacy employees used a low productivity (4 to 5 units per minute) thermal sealer to pack unitary doses of solid drugs (pills and tablets) to be delivered to the patients. A few other high productivity drug packagers existed on the market, but with a higher productivity than that necessary and a much higher cost than the purchasing power of the University Hospital of UFSC, and also of the great majority of Brazilian public and private hospitals.

The design team was composed of five members who lived and worked in three different cities (each at least 120 km from the other) and had only two short presential meetings per week. Thus, they needed some informational and communication technologies to support their design (team) activities on the other days of the week. The GEPP-net was one of such technologies used by the team.

Taking advantage of the geographic distribution of the members of the design team, this project was intended to evaluate not only the functional aspects of the specific design tools, but also, and with a greater emphasis, the support provided by GEPP-net to the non-presential (distributed) collaborative work. To evaluate its didactic potential was also an aim of this use of the system, in other words, to evaluate the suitability of using the system to teach engineering design, and associated design methods, in a collaborative environment.

Regarded, in general, as satisfactory by the design team, the good interface design and appropriate structure of the system were highlighted. The system offers not only the design tools, but also a context where such tools are to be used: the design methodology. Little used were, however, the project management and the knowledge management tools provided by the system, probably because such tools were not fully developed thus far. The team also mentioned the absence of a help file and general instructions for its tools as a negative characteristic of the system.

6.3. Computer case

Lastly, the GEPP-net was used in the design of an innovative computer (desktop) case. This computer case should be especially suitable for students with a good knowledge in informatics who usually open their machines for maintenance and component installations. This was a fictitious product design that aimed at the evaluation of the full developed system by a team of doctorate students from our research group, and also from TU-Braunschweig in Germany. Some activities were conducted in an asynchronous way, with the help of the blog of the system and e-mails, while others were conducted in a synchronous way, with the help of a VOIP system.

Once again, the system was regarded as satisfactory by the evaluation team, its good interface design, and the dynamicity that it imposes on design process being highlighted. At this time, the team was able to use all classes of tools available in the system (Figure 1) with, at least, acceptable results.

7. Comparative analysis

Table 3 presents a comparative analysis of the performance of GEPP-net in relation to the four collaborative systems presented above - the quality and functional requirements as criteria. In this analysis, our system stood out from the others with respect to the more comprehensive support given to the informational design stage, and also with respect to the tools to support the project management and knowledge management activities. In spite of not offering tools for voice (nor video) communication, the system was idealized to be used together with other specific communication tools that provide, with great efficiency, such facilities: voice messengers and VOIP applications, for instance.

8. Conclusions

This paper introduced the GEPP-net system, together with a set of requirements and a general architecture that allows the development of web-based systems to support the collaborative work in the early stages of the product design process.

Appropriate structure and good interface design were two characteristics of GEPP-net frequently pointed out by its users. Another notable characteristic is that the system presents the design tools and knowledge not in loose way, but in the context of a well established design methodology, that works as a backdrop and a structure for the above mentioned tools and knowledge.

Through its project management and knowledge management tools, the system evidenced the importance of addressing not only the technical aspects of the product design process, but also and, at the same time, its managerial aspects. The product design process, and product development process in a broader perspective, must be regarded as a business process in the organization.

The system was also successful to demonstrate to the users the importance, and all the associated difficulties, of collaborative work. This is especially true for a distributed design team that has to take advantage of technological resources in order to accomplish their group activities. Teamwork is here regarded as a basic condition for the

Table 3. Comparison between systems to support collaboration.

	GEPP-net	PCT	DiDEAS	Virtual office	Pro-define
Design tools					
Customer needs analysis	●	○	○	○	○
Specification determination	●	×	○	○	×
Functional analyses	× [a]	×	●	○	○
Solution principles search	× [a]	○	●	●	●
Concept development	× [a]	●	●	○	○
Concept selection	× [a]	●	●	●	●
Project management tools					
Calendar	●	×	×	×	×
Gantt	●	×	×	×	×
Historic record	●	×	×	×	×
Other	○	×	×	×	×
Knowledge management tools					
Links on the web	●	×	×	×	×
Documents repository	●	×	× [b]	×	×
Lessons learned	× [a]	×	×	×	×
Best practices	× [a]	×	×	×	×
Other	× [a]	×	×	×	×
Communication tools					
Bulletin board	●	×	●	×	×
Instant messenger	● [b]	● [b]	●	×	×
Forums	●	×	×	×	×
Voice and video	×	● [b]	●	×	×
Documents interchange	● [b]	● [b]	●	×	×
Other	×	×	○	×	×

● = fully satisfied; ○ = partially satisfied; × = not satisfied; a = under development; and b = implemented with external tools (ICQ2GO, BSCW,...).

implementation of a simultaneous engineering environment in a company.

Besides its expansion in order to encompass the activities of the conceptual design process, today we are working to make it possible to use each design tool of the system independently, that is, without necessarily having to follow all the steps of the proposed design methodology. With respect to the knowledge management tools, we are developing new tools with the aim of storing elaborated forms of knowledge, such as best practices, lessons learned, and decisions taken during the product design process. Lastly, we are also improving some security and reliability aspects of the system, and providing it with a help file and general instructions for its tools and activities.

9. References

CARRAFA M. R. **Desenvolvimento de um sistema para processamento pós-colheita de bananas destinadas à exportação.** 2007. Dissertação (Mestrado em Departamento de Engenharia Mecânica) Universidade Federal de Santa Catarina, Florianópolis, 2007.

CUTKOSKY M. R. et al. PACT: an experiment in integrating concurrent engineering systems. **IEEE Computer**, v. 25, n. 1, p. 28-37, 1993.

FONSECA, A. J. H. **Sistematização do processo de obtenção das especificações de projeto de produtos industriais e sua implementação computacional.** 2000. 180 f.. Tese (Doutorado em Engenharia Mecânica), Departamento de Engenharia Mecânica, Universidade Federal de Santa Catarina, Florianópolis, 2000.

GOMES FERREIRA, M. G. **Requisitos e arquitetura para sistemas de apoio à colaboração nas fases iniciais do processo de projeto.** 2006. 230 f.. Tese (Doutorado em Engenharia Mecânica), Departamento de Engenharia Mecânica, Universidade Federal de Santa Catarina, Florianópolis, 2006.

GUERRA C**. Definição e desenvolvimento de ferramentas colaborativas para a fase de projeto conceitual de produto.** 2005. 33 f.. 2005. Projeto de Dissertação (Mestrado em Engenharia Mecânica) Universidade Federal de Santa Catarina, Florianópolis, 2005.

HUANG, G. Q.; LEE, S. W.; MAK, K. L. Collaborative product definition on the Internet: a case study. **Journal of materials processing technology**, v. 139, n. 1-3, p. 51-7, 2003.

HUANG, G. Q.; MAK, K. L. Web-based collaborative conceptual design. **Journal of engineering design**, v. 10, n. 2, p. 183-94, 1999.

MOECKEL A. et al. **Embaladora de medicamentos em dose unitária para farmácias hospitalares.** Florianópolis: Federal University of Santa Catarina; 2005.

ROY, U.; KODKANI, S. S. Collaborative product conceptualization tool using web technology. **Computers in industry**, v. 41, n. 2, p. 195-209, 2000.

SCHUELLER, A. **Aspects of distributed conceptual design support.** 2002. 276 f.. Thesis (Doctor of Philosophy), Department of Mechanical Engineering, Stellenbosch University, Stellenbosch (South Africa), 2002.

TOYE G. et al. SHARE: a methodology and environment for collaborative product development. **International journal of intelligent and cooperative information systems**, v. 3, n. 2, p. 129-54, 1994.

ULRICH K. T.; EPPINGER S. D. **Product design and development.** New York: McGraw-Hill; 1995.

WANG, L. et al. Collaborative conceptual design: state of the art and future trends. **Computer-Aided Design**, v. 34, n. 13, p. 981-96, 2002.