A Collaborative Framework for Conceptual Design

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ABSTRACT

Currently almost all complex products, including physical products as well as information-based products are developed through the interaction of many participants that work on different elements of project. This creates a need for increased adoption of information technology and computer-based communication tools to manage the entire process of product development. This work proposes a framework of a collaborative system to support conceptual design. This should provide a team environment in which to discuss, exchange knowledge and information, negotiate, and develop joint projects through intelligent interfaces in order to have more flexibility to design more efficiently and effectively.

KEYWORDS: conceptual design, collaboration, collaborative systems.

The development of industrial products has always been, in some way, an activity that requires the collective involvement of individuals and companies. Currently, almost all complex products, including physical products such as appliances and airplanes, information-based products such as software, as well as business processes and planning are defined through the interaction of many, sometimes hundreds, of participants working on different elements of a project (Klein et al., 2003). This suggests that there is a need to increasingly adopt information technology and computer-based communication as tools for managing the entire process of product development.

The difficulties encountered in administrating group activities have been a challenge for researchers in information and communication systems. Moreover, these technologies have drastically changed the relationship between consumers and producers in many industries, and with important implications for the development of new products (Nambisan, 2002).

The process of product development is mainly based on knowledge and communication. This work, which is part of a broader project of developing collaborative systems, proposes a framework of a collaborative system to support conceptual design. This environment should provide the participants of a project group an opportunity to discuss, exchange knowledge and information, negotiate, and develop joint projects through intelligent interfaces in order to provide more flexibility to design more efficiently and effectively.

Conceptual Design

Several researchers have produced methods and procedures to describe the process of developing new products, among them we point to Wheelright and Clark (1992), Ulrich and Eppiger (1995), and Ullman (1997). Generally this process can be divided into three main phases: The first phase is to define the product characteristics and requirements. The second phase, called conceptual design, is where the solutions that meet the specifications are proposed. The third stage is where the project is detailed and evaluated in relation to the designs' function, manufacturing, quality, etc.

Decisions made during the early phases of the project, especially in the conceptual phase have a significant influence on factors like the cost, reliability, safety and environmental impact of a product (Hsu & Woon, 1998). The conceptual design phase is, by nature, creative and dynamic; it is also very difficult to execute, especially in a group setting.

The impact of the initial deliberations is quite high, and decreases sharply in the later stages, yet the tools available to

aid product development are scarce in the early stages, and increase as the project moves toward production, as shown in (Fig. 1). The greatest opportunities appear to propose suitable alternative design appear in the initial stage (Wang et al., 2002).

The use of computer-supported collaborative systems in conceptual design is particularly complex in relation to other stages due to the uncertainties that characterize the beginning of a project and the process of transforming abstract ideas, such as consumer needs, into concrete product solutions. Furthermore, there are inherent difficulties related to the development of group work environments, described by (Hupfer et al., 2005), such as determining levels of sharing and relevance of information, search ease, content tracking and group member updating.

Conceptual design involves four main steps of development: research, creation, representation and evaluation. For each one there are many methods and techniques that assist the design process that are widely used according to the type of product being developed. Some of them are shown in figure 2 (Fig. 2).

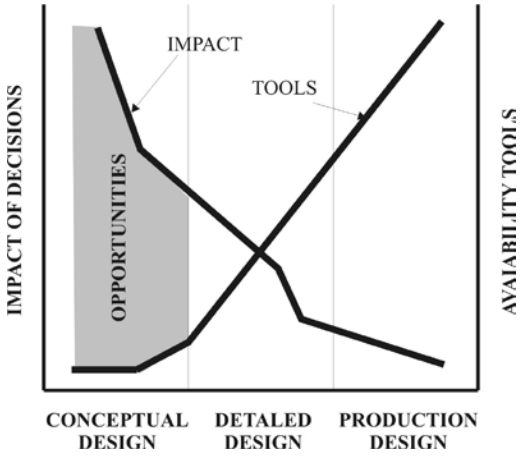


Figure 1. Opportunities in the early stages of design. Source: Wang et al. (2002, p. 982)

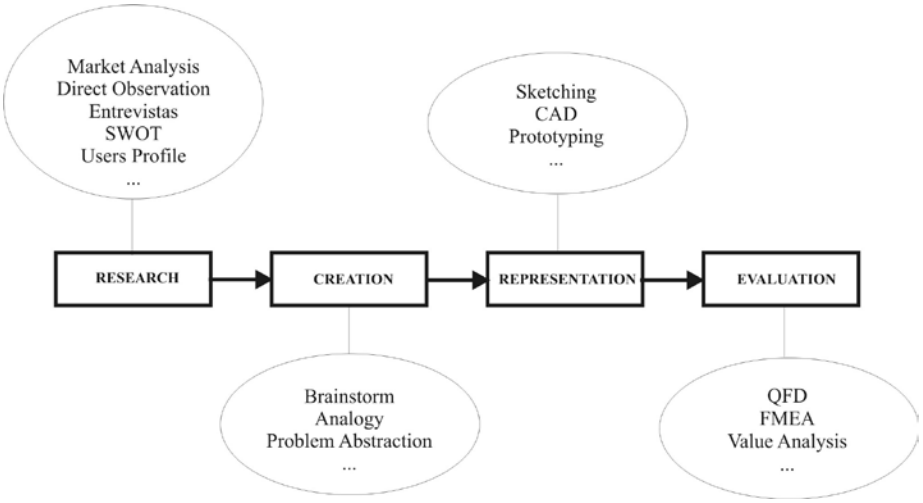
Collaboration

Collaboration can be thought of as joint problem solving. It means working with others with shared goals in an attempt to find solutions that are satisfying to all concerned (Kavan, 2000). Another general definition of collaboration is given by Winkler, "Collaboration is broadly defined as the interaction between two or more people and may cover a variety of behaviors, including communication, information exchange, coordination, cooperation, problem solving and negotiation" (Winkler, 2010).

This work deals with the collaborative process applied to the development of industrial products. In this context cooperation is directly associated with the use of computers as a support for group work. This allows members of a project team to accomplish tasks at different times and in different places. This situation, which is not new to industry, had been studied even before computational tools were developed and available to the public as supports for different levels of interaction between people and machines.

As a result, the purpose of a collaborative system to support conceptual design is to create a development environment that eliminates or automates many non-creative team activities, and provide tools that promote creativity and efficient communication between the members involved in a project (Booch & Brown, 2002). In an approach found more commonly in agent systems, coordination is essential to reach the global goal, and to ensure the quality of the project.

The collaborative project combines the notion of time and space with synchronous and asynchronous forms of interaction. Booch and Brown presented a categorization of the main resources for a collaborative system for design (2002). Apart from being applied to software development, it is possible to apply this classification to product design processes. This system categorization is divided into three groups: coordination, collaboration and community building, as shown in figure 3 (Fig. 3).



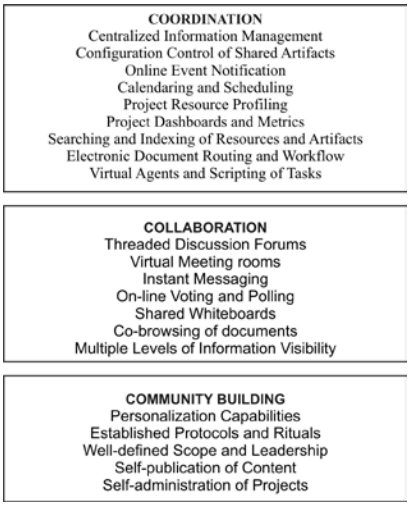


Figure 2. Conceptual Design Tools and Techniques. / Figure 3. A categorization of collaborative system resources. Source: Booch & Brown (2002, p. 21).

It may be noted that although there are many tools, a few can create an effective collaborative environment for projects where interaction between team members converges naturally to establish a solution. Many of them are devoted to the management and control of all information and means of communication available to participants.

In product design, collaboration takes on some peculiarities because of the use of computer-aided design (CAD) systems as a primary means of support and development. The use of such programs by group members may occur at different times, or may not be available to all participants. Two approaches are dominant in the implementation of collaborative environments for product development, agent-oriented and Internet- or Web-based (Hao et al., 2006).

From a computational point of view, agents or intelligent agents, or more specifically Artificial Intelligence can generally be described as computer systems (hardware or software) that have the following characteristics: autonomy, social ability, reactivity and pro-activity. Moreover, they are implemented using concepts that are usually applied to humans, such as knowledge, intention, obligation and emotion (Wooldridge & Jennings, 2005). Thus, collaborative systems using multi-agent mix automated software components with human decision making, giving support to all participants, both human and computer as well as offering a framework for combining different sources and types information and knowledge (Lander, 1997).

Web-based systems are already widely used in areas such as e-commerce, B2B, customer and supplier management, among others. In product development they complement, in a way, systems based on agents to share computing resources and enable collaboration among distributed teams (Hao et al., 2006).

Currently there are several commercial systems available to support the various stages of product development, from conception to an eventual exit from the market. Most of them are suitable for the design phases that establish the requirements and specifications of the product or the process of detailing and manufacturing. As mentioned earlier, few applications exist for the stage of generation and evaluation of design solutions. The purpose of this study is not to analyze in detail the systems available on the market. However, works such as that done by Hsu and Woon (1998) and Wang and colleagues (2002) provide a broad survey of these technological developments.

A Collaborative Framework for Conceptual Design

Collaborative product development is hampered by at least two important factors, as pointed out by Bock (2009):

Partial product descriptions developed independently by different designers cannot be reliably and consistently refined and combined. Significant effort is needed to create a complete description, because separate contributions rarely fit together and are often overlapping. This prevents teams of designers from contributing to the same product independently, and from building on existing products.

Engineers and product design tools have only loose alignment on how to interpret different languages and terminologies. Engineers and tools interpret the same product description in different ways. This results in significant cost overruns due to rework when discrepancies are discovered, often after implementation and testing are already underway.

This leads different sectors of a company to have different views and concepts about specific features or, potentially, an entire product. Furthermore, design factors have different levels of importance for those involved in the lifecycle of the product.

One way to tackle these problems is to invest efforts in the initial stage of the project that establishes product requirements, a well-structured language to define the criteria and standards for project evaluation that has consistent ways of describing the design factors associated with the creative stage, such as aesthetic form and social and psychological behaviors. In light of this it is appears possible to make the collaboration process more efficient in order to coordinate the interventions of members to provide appropriate design solutions.

Among the possible approaches to describe the design process, the use of ontology seems to be a conceivable alternative to define a language capable of meeting the specific needs of project activities while simultaneously creating a concise method of communication.

Ontology has been used in design in several ways. Studies have described the sharing and reusing of product design information to help reduce costs and development times, and facilitate the design of product families, or in creating complete or partial product descriptions that possess the necessary precision to verify consistency in the combination and interpretation of models (Bock, 2009; Moon, Kumara & Simpson, 2005).

Given this, we propose a collaborative web-based system containing synchronous and asynchronous tools to aid conceptual design by increasing coordination, collaboration and dissemination of information as shown in figure 3 (Fig. 3). This system should allow access to resources for each stage of conceptual design as shown in figure 2, also including the phase that establishes product requirements (Fig. 2).

One strategy to meet these requirements is to use a basic open-source collaborative system to incorporate the required collaborative and design tools. This system structure, presented in figure 4, should be flexible enough to be integrated with other systems such as databases and general project applications (Fig. 4). Thus, it is possible to combine tools normally used at each stage of conceptual design and create new collaborative applications to complement those already available in the system.

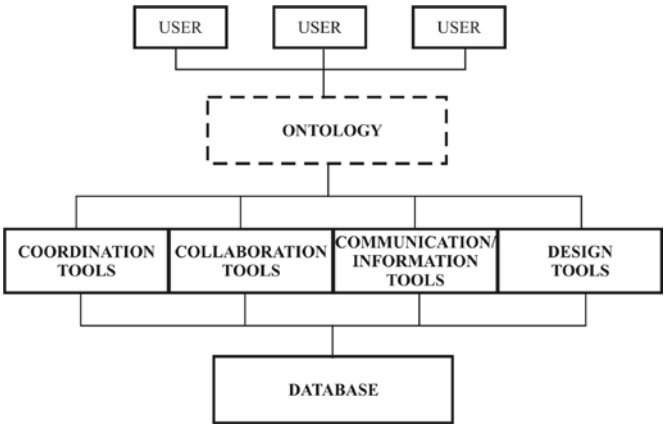


Figure 4. Collaborative system structure

Conclusions

Starting from the assumptions made at the beginning of this work considers that: (1) The conceptual stage of product development is particularly important in defining the product and its entire lifecycle; (2) this step is characterized by difficulties in turning initial abstract ideas into a concrete product solution; (3) the concepts and views of members of a project team are distinct in relation to the properties and characteristics of a product, and this inhibits the process of collaboration; (4) the existing systems available on the market are generally focused on the subsequent stages of design and are more dedicated to managing and exchanging information than to creative collaboration; (5) it is essential to create a common language for team members to describe and unify the concepts and ideas about the product.

The web-based system presented, which is supported by ontological alignment, will allow the creation of a collaborative environment suitable for this stage of the project. The next step becomes the computational implementation of the system.

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