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E-DIP – A PROPOSAL FOR WEB-BASED COLLABORATION IN THE EARLY STAGES OF PRODUCT DESIGN

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1 Introduction

The major 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 at these stages of the product development process. A number of Web-based collaborative systems have been recently developed to assist the product design process. However, following a general trend in the development of computational tools for design, such systems focus on the late stages of this process. This paper introduces e-DIP, a prototype for a low cost Web-based collaborative system intended to support the early activities of product design (Informational Design and Conceptual Design). This is a project under development at the Federal University of Santa Catarina in close cooperation with the University of São Paulo in São Carlos, both renowned universities in Brazil.

2 The Design Process

Models of the Design Process have been developed since the early 1960's. In engineering design, this development seems to have converged into a Phase Model consisting of four phases [1]. In Pahl and Beitz [2] these design phases are: Clarification of the Task, Conceptual Design, Embodiment (or Preliminary) Design and Detail Design. Fonseca [3] proposes a systematic approach to the development of Product Specifications. The author coined the term 'Informational Design' to highlight the importance of this process to the final quality of the product. Forcellini [4] presents a classical approach to Conceptual Design. These approaches have been successfully employed in the product design projects developed at our institution. Figure 1 illustrates the Four-Phase Model of the Design Process while Figure 2 summarizes the activities carried out during the Informational and the Conceptual Design.

The subtle differences between the terms that refer to the wishes and demands of clients, employed in Figure 2 (Informational Design), are elucidated below:

- **Need** – A requirement, as stated by the client, usually in a non-technical way.
- **User Requirement** – A need expressed in a standard (technical) form.
- **Design Requirement** – A measurable/tangible attribute of the product under development.
- **Design Specification** – A design requirement together with: its target value; a way of accessing it; things to be avoided; and any other pertinent remarks.

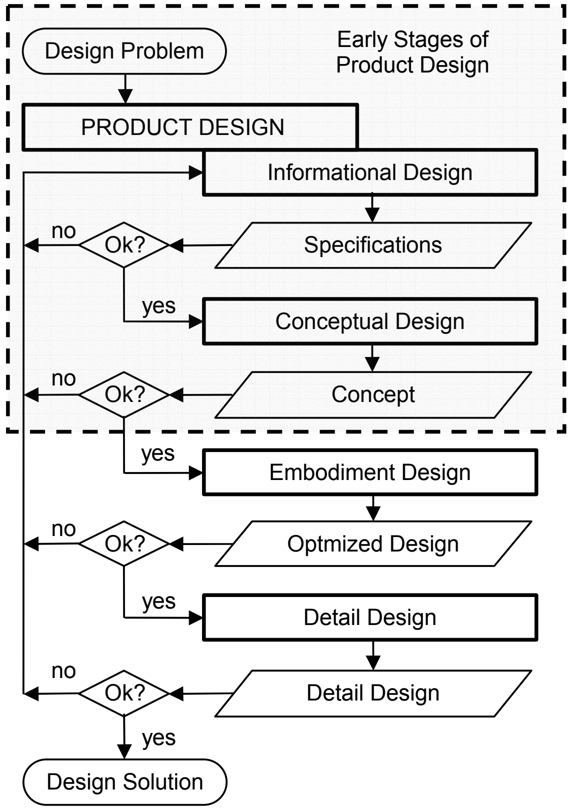

Figure 1. Four-phases model of product design.

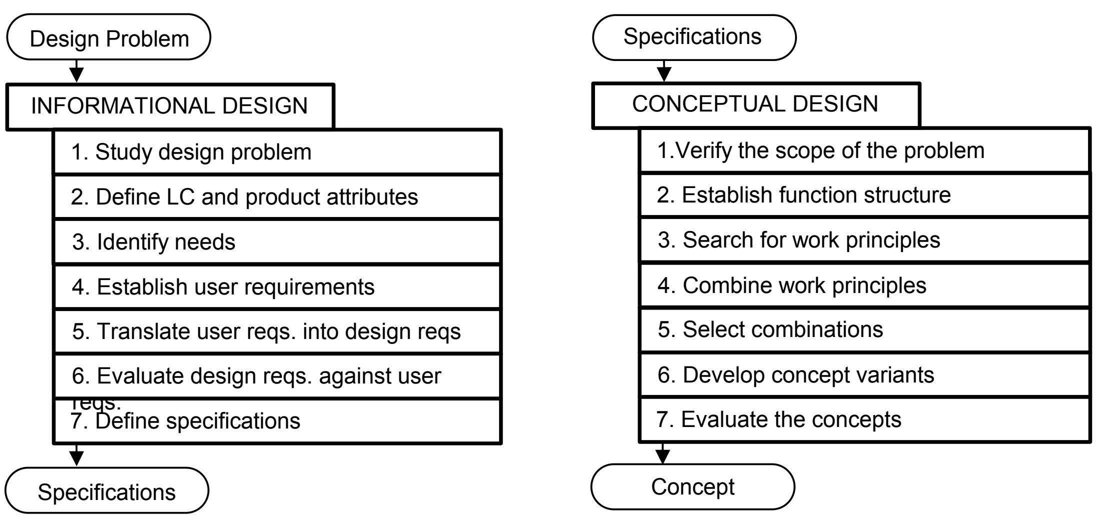

Figure 2. Informational and Conceptual Design.

3 The Internet and the Web

The Internet is a computer network made up of thousands of networks worldwide. No one knows exactly how many computers are connected to the Internet. No one is in charge of the Internet. There are organizations which develop technical aspects of this network and set standards for creating applications on it, but no governing body is in control. The Internet backbone, through which Internet traffic flows, is usually owned by private companies. All computers on the Internet communicate with one another using the Transmission Control Protocol/Internet Protocol suite, abbreviated to TCP/IP. An Internet user has access to a wide variety of services: electronic mail, file transfer, vast information resources, interest group membership, interactive collaboration, multimedia displays, real-time broadcasting, shopping opportunities, breaking news, and much more [5].

The World Wide Web (WWW or simply Web for short) is a system of Internet servers that supports hypertext to access several Internet protocols on a single interface. It was developed in 1989 by Tim Berners-Lee of the European Particle Physics Lab (CERN) in Switzerland. The initial purpose of the Web was to use networked hypertext to facilitate communication among its members, who were located in several countries. Word was soon spread beyond CERN, and a rapid growth in the number of both developers and users ensued. In addition to hypertext, the Web began to incorporate graphics, video, and sound. The use of the Web has reached global proportions and has become a defining aspect of human culture in an amazingly short period of time [6].

Almost every protocol (set of rules that allow for intermachine communication on the Internet) type available on the Internet is accessible on the Web. The following is a sample of major protocols accessible on the Web:

- **E-mail (Simple Mail Transport Protocol or SMTP):** distribution of electronic messages and attached files.
- **Telnet (Telnet Protocol):** allows access to remote computers and the execution of commands there.
- **FTP (File Transfer Protocol):** transference of files between servers and their clients.
- **Usenet (Network News Transfer Protocol or NNTP):** news distribution.
- **HTTP (HyperText Transfer Protocol – the protocol of the Web):** transmission of hypertext documents over networks.

Many other protocols are available on the Web. To name just one example, the Voice over Internet Protocol (VoIP) allows users to place a telephone call over the Web [6].

The Web provides a single interface for accessing all these protocols. This creates a convenient and user-friendly environment. In the past, it was necessary to be conversant in these protocols within separate, command-level environments. The Web gathers these protocols together into a single system. Because of this feature, and due to the Web's ability to work with multimedia and advanced programming languages, the Web is by far the most popular component of the Internet [6].

According to Zahng *et al*. [7], the Web is currently being viewed as the most advanced information system deployed on the Internet. It provides designers with the means to combine multimedia information and to publish information relevant to the different stages of the design process, from conceptualization and prototyping to product realization and virtual manufacturing. This has motivated the adoption of the Web as a collaborative design platform. It is now playing increasingly important roles in developing collaborative product development systems.

A number of CAD software vendors have recently released Web-based versions of their software products, e.g. AutoDesk's AutoCAD2000i and Auto-CAD2002 with eTransmit and i-drop technologies to support Web-based collaboration, PTC's Pro/Engineer based on Groove Networks Technology to support cross-firewall and real-time collaboration, and EDS' Product Lifecycle Management (PLM) solutions to enable all participants in product lifecycle to work in concert. Some researchers have developed Web-based tools or systems based on standalone applications [7].

4 Collaborative Design

In a general sense, there is collaboration when a group of people join together voluntarily to accomplish a certain task. For Chiu [8], collaboration implies a durable relationship and a strong commitment to a common goal. Kvan [9] states that collaborative success can be said to be achieved when we have accomplished something in a group which could not be accomplished by an individual.

In the strict context of product design, collaboration aims at the sharing of knowledge, expertise, resources and responsibilities among members of the design team and the people involved with the product under development.

According to Kristjansson *et al.* [10], good collaboration in the development process is important due to a number of reasons; to name a few, late identification of problems within the development process are costly and time consuming, participation of all relevant stakeholders can boost innovation and therefore increase the likelihood of product success, and it can change the nature of organizational boundaries in a way which improves cooperative relationships. Good collaboration can improve manufacturability and product quality, lower the cost of designs, improve time-to-market, generate greater buy-in and reduce late costly change orders; it helps incorporate ideas into design early on in the process and so gets the product right the first time and on time to market.

Time and space are two dimensions frequently used to study collaboration and the technologies employed to support it – see Figure 3. Collaboration between the functional departments of the company, between the elements of its supply chains, and between the people involved with the many stages of the Life Cycle of its products are important aspects to be considered when developing a collaborative system – see Figure 4.

		TIME	
		Same	Different
PLACE	Same	Synchronous Collocated	Asynchronous Collocated
	Different	Synchronous Distributed	Asynchronous Distributed

Figure 3. Dimensions of collaboration.

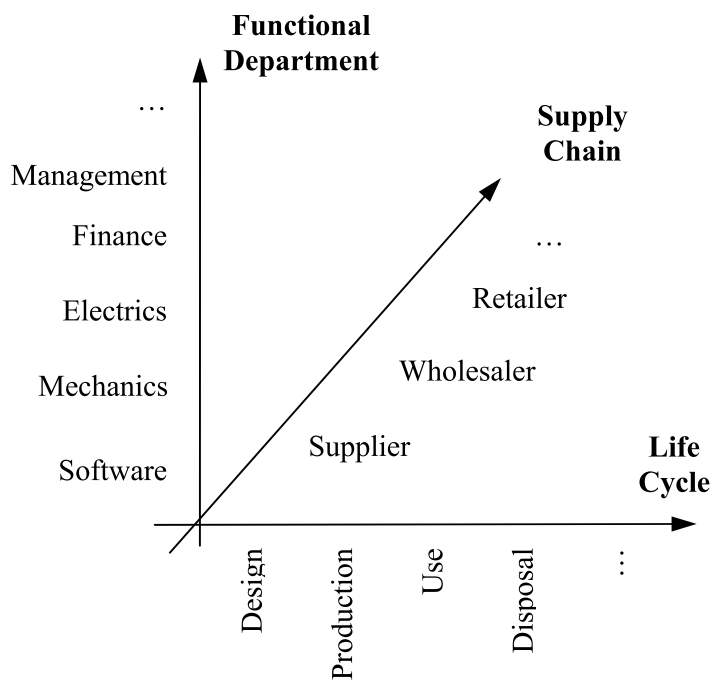

Figure 4. Three collaboration aspects.

The term Collaborative Design usually relates to the use of computer networks to support the collective activities of the members of a product design team. According to Wang *et al.* [11], Collaborative Design can be physically enabled by the Internet and the Web. Powered by technologies, such as Java, search engines, HTML, and XML, the Web provides a familiar interface that gives us a common 'look and feel' to information exchange. As the use of Internet spreads, the paradigm of design activity changes drastically.

5 Review of collaborative systems for the Early Stages of Design

Wang *et al.* [11] provides 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 are highlighted among the emerging technologies that have been proposed to implement collaborative design systems. PACT [12] and SHARE [13] are two frequently referenced collaborative environments devoted to the general product design. In the following, four projects that focus Conceptual Design are briefly reviewed.

5.1 Product Conceptualization Tool (PCT)

Developed by Roy and Kodkani [14] at the Knowledge Based Engineering Laboratory (Syracuse University, NY, USA), the system 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.

5.2 Distributed Design Assistant (DiDEAS)

Developed by Schueller [15] 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.

5.3 Virtual (Conceptual Design) Office

A general Web-based collaborative framework developed by Huang and Mak [16] 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.

5.4 ProDefine

More recently developed by Huang *et al.* [17] 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 deployed and configured according to a typical three-tiered architecture for Web and Internet applications.

6 E-DIP distinguishing characteristics

E-DIP differs from, and tries to improve, the systems discussed in the review in the last section with respect to the following distinguishing characteristics.

6.1 Better Support for Informational Design

Better support is given to the development of the Product Specifications: the earliest activities of the design process. This is indeed the scope of e-DIP in this first phase of implementation. Function analyses, concept generation, and concept evaluation (activities more related to the Conceptual Design itself) are to be implemented later in the project.

6.2 Exploitation of 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) is sought. Many of these valuable design resources, in the form of Web hyperlinks or documents, are being gathered and analyzed. They must be associated with each activity of the early stages of product design in a very clear way. Their use in the context of such activities must also be clarified.

6.3 Pragmatic Use of Communication Tools Already Available on the Web

A more pragmatic use of communication tools already available on the Web is also sought. There are several tools available on the Web to support collaboration such as conferencing tools, and whiteboards. These could be utilized in alliance with customized tools developed for the Web, which specifically tackle issues related to product development [14].

6.4 Support for the Managerial Aspects of Product Design

In e-DIP, support is given not only to the technical aspect of the design process. It is clear that collaborative product development needs to be treated more critically than at present. Attention has to be given to managerial and other factors that influence the outcome of the collaborative process [18].

6.5 Support not only for Distributed Collaboration

Contrary to the systems discussed in the last section which focus specifically on distributed design, e-DIP is an environment to support collaboration in the early stages of product design, no matter whether it occurs in a collocated or distributed way (local), or whether it occurs in a synchronous or asynchronous way (time).

7 E-DIP requirements

High speed, reliability, maintainability, accessibility (user-friendly interface) are among the many requirements which determine the effectiveness of a system on the Web. Next, some important requirements, related to e-DIP performance as a Web-based system, are presented.

7.1 Ability to 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, as shown in Figure 5.

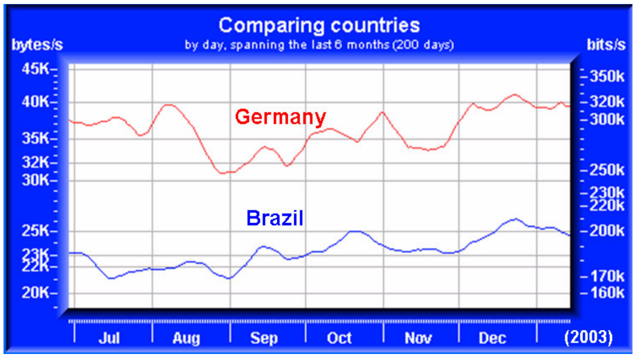

Figure 5. Average speed of the Internet – from http://www.numion.com/YourSpeed/.

7.2 Use of Low Cost Hardware Components

In order to be actually accessible to small and medium-sized enterprises, a collaborative system should make use of low cost hardware components. The intention is to take advantage of the already existing resources of the company: personal computers and low cost peripherals. Web-cams, headphones, tablets and scanners are among the hardware components to be tested in the collaborative design experiments – see Figure 6.

Figure 6. Low cost hardware components.

7.3 Platform Independence

The system should run equally well regardless of the operational system (MS Windows or Linux, for instance) and the Web browser (MS Explorer or Mozilla Firexox, for instance) being used.

7.4 Safety

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.

7.5 Modularity

Complementary modules of applications, knowledge-bases and communication channels should compose the collaborative system. Modularity assures easy maintenance and future expansions of the system.

8 E-DIP Elements

Figure 7 illustrates the general framework based on which e-DIP is being developed.

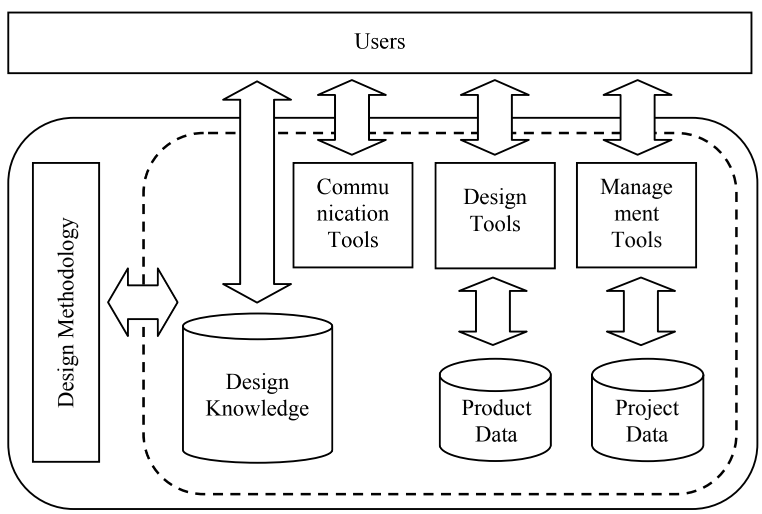

Figure 7. E-DIP framework.

8.1 Design Tools

These are self-developed applications that implement specific design methods to be used by the members of the design team both in a synchronous or asynchronous and in a collocated or distributed way. The methods prescribed by Fonseca [3] for Informational Design are being implemented at this first stage of the project. In addition, e-DIP tests the synergetic use of

TRIZ and QFD. TRIZ is supposed to help the designers to solve the contradictions between design requirements detected at the roof of the House of Quality (first matrix of QFD).

8.2 Communication Tools

These allow multimedia communication between the members of the design team: chats, conferences, collaborative writing or sketching, and so forth. These tools are not to be developed in the project. The intention is to work with already available communication tools, such as ICQ (by ICQ) or the Yahoo! Messenger (by Yahoo!), opened within e-DIP. Exchange of all sorts of design related documents (questionnaires, sketches, reports, and so on) should also be support by e-DIP.

8.3 Management Tools

These tools (also not to be developed here) should support the collaborative coordination of the design activities. A Web-based calendar and a blog are the first two management tools to be attached to e-DIP. The blog serves as a 'design notebook', where the designers can keep track of ideas developed and decisions made during the product development, as Ullman [19] recommends. The calendar WebCalendar (by k5n.us) and the blog Serendipity (by s9y) are two open-source tools under analysis.

8.4 Design Knowledge

The Design Knowledge database supports the members of the design team with specific technical knowledge that are necessary for the carrying out of the design tasks. An important component of this database is a collection of hyperlinks to useful design knowledge sources already available on the Web: patent databases, consumer review portals, search mechanisms for norms and codes, on-line product catalogs, manufacturer catalogs, sites about the design methods, magazines, among many others.

8.5 Product Data

This database stores the information necessary to model or represent the product during its design process. It is usually accessed and edited by the design tools.

8.6 Project Data

This database stores the data that belong to the design process, but do not refer directly to the product under development. Usually accessed and edited by the management tools.

8.7 Design Methodology

The design methodology acts as a background for the development of the above described elements. The design tools and knowledge are related to the individual steps of the design methodology.

9 E-DIP users

For the purpose of its implementation, the following classes of users – illustrated in Figure 8 – are defined for e-DIP.

9.1 System Manager

In charge of the development and maintenance of the system. Is acquainted with Design Methodology and Information Technology.

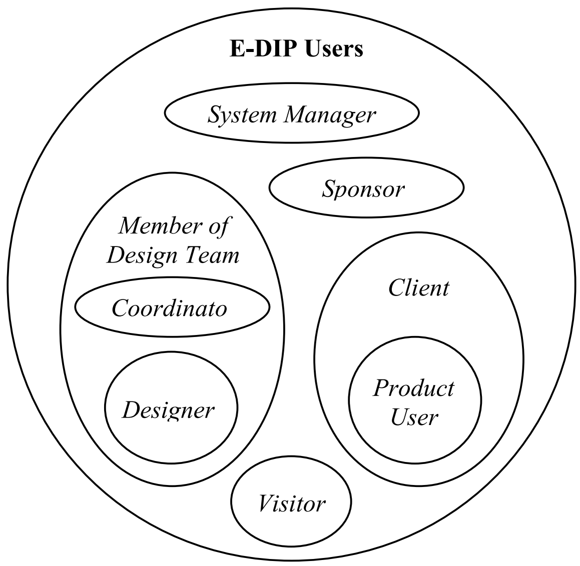

Figure 8. Classes of e-DIP users.

9.2 Sponsor

Orders and finances a product design project. Is in charge of the approval (or rejection) of its deliverables.

9.3 Member of Design Team

Effective member of a design team. May come from any department of the company (technical or non-technical), or even from outside the company (suppliers, for instance).

9.4 Designer

Joins a design team as a product designer. He/she often comes from a technical department of the company.

9.5 Coordinator

Leader of a particular product design project. Designates the other members of the design team.

9.6 Client

Anyone concerned with the product under development during the phases of its Life-Cycle (design, production, assembly, packaging, storage, transport, sales, purchase, use, function, maintenance, recycling, or disposal). Main source of requirements for the product.

9.7 Product User

Makes use of the product under development. Regarded as the most important client of the design.

9.8 Visitor

Accesses e-DIP to know its characteristics and functionalities. Is not allowed to visualize the private data of any particular product design. Only a demonstrative design example (a school desk) is available for him/her to access.

Table 1 presents the roles of the users of e-DIP in an abridged form. This knowledge is important to the development of the access control policy for the system. The access control policy assures the users the access to the tools and information necessary for the proper carrying out of their duties. It also prevents some private design information from being accessed by a non-authorized person.

Table 1. Roles of e-DIP users.

USER	ROLES
System Manager	- Includes new projects. - Develops and aggregate new tools.
Sponsor	- Orders new projects. - Approves (or reject) the deliverables of the design process.
Member of Design Team	- Makes use of the tools and the knowledge provided by the system. - Suggests new links. - Includes new clients.
Designer	- *Same as a Member of a Design Team.*
Coordinator	- *Same as a Member of a Design Team.* - Includes new members in his/her design team.
Client	- Includes wishes and demands (interacting with the Members of the Design Team through the communication tools).
Product User	- *Same as a Client.*
Visitor	- Is shown a demonstrative design example.

10 Technologies

E-DIP runs on an Apache Web server, running on a Linux platform. Apache is today a very popular Web server (half of the Internet servers use Apache) and runs safely and reliably on Linux. The system uses PHP and MySQL (data server) for the server side processing. This architecture known as LAMP, which stands for "Linux-Apache-MySQL-PHP", is depicted in Figure 9. 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.

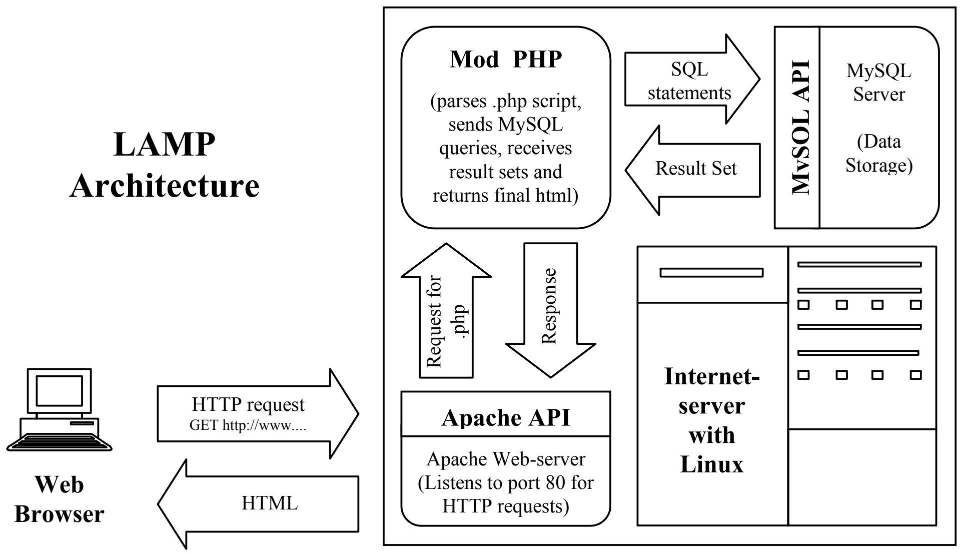

Figure 9. LAMP Architecture

11 Conclusions

The Web and its related technologies present great potential to promote collaboration between the members of product design teams. More intensive collaboration in the early stages of design should result in better, less expensive and more competitive products launched into the market. This is a hypothesis to be tested with e-DIP – a Web-based collaborative system developed to support the early stages of the design process. Enhanced support for the development of product specifications, better use of knowledge already available on the Web, and a more pragmatic use of communication tools are among the distinguishing characteristics of e-DIP, when compared to the previously developed Collaborative Conceptual Design Systems. A Prototype of e-DIP shall be developed by March this year, in order to be used and evaluated by the graduate students attending the Product Design discipline in the Mechanical Engineering Course at our institution.

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