Even Better Than Reality: The Development of a 3-D Online Store that Adapts to Every User and Every Platform

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Abstract

This paper describes the development of an e-commerce Web site based on a virtual world that replicates a real store in order to offer a more familiar interface to the user, but overcoming the problems of reality offering a customized presentation of items to each consumer. An ethnographic study of a real store was made first in order to gather the requirements of store, and to identify the main processes that it involves. Early designs of the interface were evaluated by means of paper prototypes. Then, technology was assessed and a decision was made to carry on the development using VRML97 and Java. The system architecture is based on a client/server model, where the server manages the description of the items, the 3D models that are rendered in the interface, the recorded information of registered users and the adaptation rules. For the adaptation of the system to the each possible target platform, different levels of detail are used for each 3D model, and for the adaptation to the user, the system serves different 3D worlds according to the user's preferences while taking into account the policies defined by the store manager, as reflected in a set of adaptation rules. In addition, a rule editor was implemented so that the store manager can add, modify or remove the adaptation rules that direct the presentation of the 3D online store.

1 Introduction

Even though the Web was initially conceived as a hypertextual space where scientists could exchange information, the quick spread of Internet all over the world and the rise of new technologies related to it have multiply the number of applications. One of the applications that have grasped much attention in last years is electronic commerce, or e-commerce. Most stores that are present on the Web are based on the metaphor of the paper catalogue, which means that the user looks at the photos and reads the description of different items following an ordered set of pages looking for those goods that are interesting for her or him. However, computer technology makes it possible to provide value-added functionalities that would be impossible in a paper format, such as automatic item search, or catalogue customization based on preferences of the user and her or his shopping log. Furthermore, these online shops make use of other metaphors in an attempt to make Internet shopping a much more natural and intuitive task, such as the shopping cart.

Another application of the Web is the distribution and online exploration of three-dimensional virtual worlds, an application that raised quite interest in the first years, leading to the proposal of

VRML language in 1995, two years later the first Web-oriented standard for the specification of 3D worlds. However, that language and its expectations were too ahead of that time, as in those years 3D graphics accelerators were not a commodity yet, and the network bandwidth available to most users was not enough to allow a downloading fast enough for virtual worlds and their resources, such as images and sounds. Ten years later, almost every new PC shipped is equipped with specialized 3D hardware, and it will be fitted in most mobile devices soon. Besides, Internet providers now offer a much faster access in all networks. This ubiquity of 3D technology makes us consider its use in e-commerce applications. In fact, there are currently many manufacturers that publish 3D models of their products on their Web sites. But it is also possible to go further, leave aside the metaphor of the paper catalogue and to offer to the user/customer a virtual environment that reproduces a real store, making Internet shopping an even much more familiar task.

This paper describes the analysis, development and evaluation of a Web site for e-commerce whose user interface is a virtual world that replicates a real store, whose shelves show the products as 3D models of them. This project has been carried out focusing on two main aims: adaptation to the users' choices and preferences (López-Jaquero *et al.*, 2004), and adaptation to the 3D performance of the computer platform that the user employs to access the online store. Both aims are part of our main concerns at the LoUISE research group. The first aim will assure that the Web site offers one of the cited advantages of e-commerce, which means that the user's preferred products will be presented in a foremost position, based on her or his choices and shopping log. This adaptation takes also into account the interests of the store manager, who can decide to bring to the foremost places some products. The second aim will assure that the user will experience 3D graphics as good as possible, bearing in mind that, in spite of the 3D technology widespread, not every terminal will perform the same regarding 3D graphics rendering. This is not just only because there are many old computers still in use, but also because there are emerging devices that, as for example mobile phones, do not offer the same performance rates as PCs.

The development process (López-Jaquero *et al.*, 2004) (Molina *et al.*, 2003) has been carry out not only in a structured way, but also involving the user in it, using the techniques from the fields of Human-Computer Interaction and Software Engineering that have been considered the more appropriate to each stage of the software life cycle. In the following sections, every stage of the site development process will be described, including the implementation of an adaptation rule editor.

2 Domain of the Problem

As a first task of the development process, an ethnographic study of a shopping mall was fulfilled to gather the information of the domain of the problem which was considered necessary to carry out the creation of the system. This study, which is detailed in next section, served as a basis for the definition of the high-level requirements of the 3D store.

2.1 Ethnographic Study

Ethnography provides interesting ways to gain insight into existing processes, focusing the attention on the task and actions performed by different people. This method is not new, since it has been profusely used by anthropologists, including methods such as interviews, passive observation or active participation in the studied environment (Shneiderman, 1998). As ethnographer, the user-interface designer observes the interfaces in use for the purpose of

improving them in the final system, trying not to misinterpret observations or overlook important information, in order to increase the trustworthiness and credibility of the system.

2.1.1 Ethnographic Study of a Real Store

The ethnographic study of a real store included the observation of the behaviour of customers when shopping, and interviews with different employees of the store. As it was observed and later confirmed by those employees, the reason that leads a customer to buy a product is her or his interest on it, which derives from necessity or simply fondness. For example, a customer that is fond of computers may decide to visit the computer accessories section in a first place, and if a product grasps her or his attention, she or he may decide to buy the product even though its purchase was not in mind before finding it.

The interviews to different employees also revealed some of the reasons that guides the allocation of products the store. One of these reasons is the interest of the store manager to sell certain products, which are located in places such as the corners of shelves or the central part of pathways, since these places are the most seen by customers, which are then attracted by the products located in them. Sometimes, these products are sales, which the shop sells at less than the normal price. Sometimes, the reason is that there are too many items in stock.

Marketing studies also guides the allocation of products in the store, as the employees recognized in the interviews. These studies analyze the behaviour and preferences of customers depending of several factors, such as age, genre, purchasing power, country, etc. As the employees recognized, the studies show that is better to place near related consumer products, as there is much chance that when a customer buys a product, she or he will buy a related one. For example, if the customer looks for a TV set, she or he will find other related products near the TV sets, e.g. a DVD-ROM, that the customer may think of buying too.

2.2 Requirements of a Store

Based on the observations made during the ethnographic study, a list of requirements was produced, characteristics that a store should exhibit. There requirements are:

- *The customer is free to enter in the shop, no ID is required*
- *The customer is free to walk around in the shop*
- *The customer is free to look and examine the products*
- *The customer is free to purchase products or leave the shop without buying*
- *The products must be well organized, grouping related items*
- *The information of the products must be clear and specific*
- *The interests and preferences of customers must be taken into account*

3 Analysis and Design

The information gathered in the previous study is used in this new stage of the development process, where the computing system is analyzed by identifying several scenarios of use. These scenarios where described using storyboards, which were found very useful to create sketches of the system and envision the interaction between the user and the machine. The early ideas drawn in the storyboards resulted from brainstorming sessions, and its validation required the creation of prototypes. Then, several paper prototypes were created. The evaluation of them by a group of

selected users was also found extremely useful, as several changes in the design of the interface were introduced taking into account the comments of these users. As a result, the number of iterations through the development process is minimized by avoiding most of interface errors that we would have been made if, otherwise, we had directly proceeded with the detailed design.

Following the analysis stage of this structured development, at the design stage was chosen VRML97, Java and JDBC as the key technologies, and a client/server architecture was chosen for the system. The user adaptation and platform destination adaptation techniques were specified, and the first three-dimensional models were created. The following sections describe in detail these steps taken in the analysis and design stages.

3.1 Scenarios

The scenarios are textual descriptions of the interaction between the user and the computing system. Several scenarios were described for the Web3D shopping mall under development, and the corresponding cases of use identified. The following list shows the main scenarios that were taken into account:

- *The user enters into the shop*
- *The user navigates around the 3D world*
- *The user perform the purchase of a product*
- *The user becomes a registered one*

3.2 Storyboards

Storyboards were thought very appropriate to envision the system, using drawings and sketches to represent how interaction would be between the user and the computing system, showing details of the user interface, including the interaction techniques and the interaction objects. As an example, figure 1 shows a cut of the storyboard that represents the user navigating around the 3D virtual space of online store, using a PC. As it is shown in the figure, at some point, the user finds a product that is of her or his interest and selects it to obtain further information of it, having also the possibility to add it to the shopping cart.

Figure 1: Cut from the storyboard

3.3 Paper Prototypes

The use of paper prototypes for validating early ideas was chosen due to its low cost in time and resources. Each prototype was prepared drawing screen snapshots on different sheets of papers, according to the scenarios listed in a previous section. The resulting paper prototype was meant to be used by real users, interacting with the sheets of papers as if they were the graphical output of the system to be implemented.

The evaluation of the paper prototypes was carried out with two different groups of people. The first group of people had a tight relationship with computers, being most of them programmers, software engineers and user-interface designers. The second group of people was formed by Internet users without further computer knowledge. The main objective of the experiment was to identify which aspects of our user interface were considered as bad ideas by the users, and which of them could be improved. In opposition to the storyboard, which reflected the ideas of the development team, this tool tries to gather the users' opinions. As an example, figure 2 shows some sheets of the paper prototype where the user decides to buy a product (a fridge) and, once the purchase is completed, the system asks the user to fill a form in order to record her or his preferences for future use.

Figure 2: Some sheets of the paper prototype

From the results of the experiment, the design of the user interface seems to be approved by the first group of user, those with deeper knowledge in the development of computing systems, being quite satisfied with the prototype even though it was just a paper one. On the contrary, the other group of people, the Internet users, were also satisfied with the proposed interface, but suggested some changes for it, such as reducing the number of different interface windows, as they made them feel disoriented. Taking into account that suggestion, the initial design was changed keeping always visible a view of the 3D online store and a 2D dialog panel. This panel would change its representation depending on the state of the shopping task.

A new paper prototype was made then, which was also validated by both groups of people. This new prototype consisted of an intro sheet, where the user could identify as registered user and specify the performance of its 3D hardware. The second sheet shows the rendered 3D store from the point of view of the user, allowing her of his to examine different products, whose characteristics are listed in the 2D dialog panel, and to add those products to the shopping cart. The next sheet represent the check out process, with the 2D panel listing the selected items and the total amount, but keeping the view of the 3D store to the right, as suggested by the second group of users. The final screen allows the user to fill a questionnaire that will be used to record her or his interests and preferences.

3.4 Utilized technologies

One of the main requirements of the online store was to replicate the real world by means of a three-dimensional virtual world, in an attempt to make much more natural the interaction with the computer, as the natural environment of people is the three-dimensional space that they inhabit (IBM RealPlaces). For this purpose, the VRML language (Web3D Consortium) was chosen as it was conceived for the description of Web-oriented virtual worlds, distributed all over the Internet, and rendered by PCs. The first version of VRML, 1.0, was presented in 1995, but only allowed to

describe static worlds. The second version was taken as a basis of the ISO standard, known as VRML97, which introduced important improvements such as interactivity, sound or animation.

Each VRML file describes a hierarchy of nodes that, most of them, represent the objects of the scene. Some nodes are named sensors, they do not describe geometry or appearance to be rendered in the viewport, but make it possible for the user to interact with the scene. The user's actions are transformed into events by those sensors, and then routed to other nodes, most cases Script nodes, which encapsulate the behaviour of objects. Besides, the user can define her or his own types of nodes by means of a prototyping mechanism. Prototypes are a key mechanism in our system architecture, as the 3D models of products were created as parameterized prototypes that are served to the client platform. Thus, each prototype is made of a hierarchy of existent VRML nodes that represent the set of pieces of the 3D model, and the set of parameters allow us to customize its characteristics, such as size, appearance or level of detail.

As for programming of the online store, Java language was chosen. The characteristics of Java include abstraction, encapsulation, modularity, inheritance, polymorphism and security. But, most important for our purposes, it also allows the execution of the same program in different platforms, using its virtual machine technology (Naughton & Schildt, 2001). This is the main reason that makes Java so interesting for Internet programming, since users with different computing platforms and configurations can download the same pieces of Java code and execute them in their local machines. The only requisite is to have the Java Runtime Environment installed, which is freely available from Sun website and other mirror sites all around the world.

Java allows the programmer to create two basic types of programs: applications and applets. Applications are executed directly in the local machine, while applets are pieces of code that are executed in an Internet browser, and for that purpose special programming interfaces are used to embed an applet in a Web page. In our 3D online store, an applet was used in the client side to control the dialogue between the user and the machine. Besides, the applet control the 3D virtual world rendered in the VRML browser through the External Authoring Interface (EAI) defined in the VRML specification. Nowadays, Java is the only language that implements the EAI interface, and that was another reason in favour of selecting Java for our project.

Finally, JDBC was used to access the database that is managed by the server. JDBC provides a common interface to access different types of databases from Java applications. The list of supported database systems includes Oracle, MS SQL Server, MySQL, and Access. From the 3D model prototypes kept in the database, the server will dynamically generate a virtual world retrieving the models by means of the JDBC interface.

3.5 Adaptation in a 3D Online Store

One of the most important advantages of a virtual environment as a container for a e-shop is the wide range of possibilities that it exhibits from the point of view of adaptation (López-Jaquero *et al.*, 2003). User interfaces adaptation is usually broadly classified into adaptivity and adaptability (Benyon, 1993). While adaptability is the ability of a user interfaces to provide the required facilities to the user in order to customise or personalize the user interface, adaptivity is the ability of a user interface to adapt by itself to the different changes in the context of use of an application (user characteristics, environment conditions and hardware/software platform).

Both kinds of adaptation imply handling a set of models to represent both the context of use and the user itself. In our system a user model was built to reflect what and how our 3D online store should adapt to the user within a certain session. The 3D online store adaptation engine includes not only adaptation to the context of use, but also to the marketing strategy of the store. To pursue the goal of adaptation, the possible adaptations the system is able to apply have been expressed by means of rules. A rule is composed of a set of preconditions, which need to be met for the rule to be applied, and a set of consequents, which describe the actions the engine will carry out to perform the adaptation.

The first time the customer (user) access to the e-shop he is asked to fill a small questionnaire about his interests and preferences. The data collected in this questionnaire includes, for instance: the favourite type of products or the preferred colour schemas. The number of times the user has visited the 3D online store, the total amount of expenses each user has made or the number of units of each product type sold to each user are some of the statistics gathered from user interaction logs.

The 3D environment that represents the online store is customised according to the data collected, from both the questionnaire and the user's interaction traces. In this way, the adaptation engine will position the virtual items available in the store following the guidelines inferred from the user preferences and store marketing strategy. The favourite products for the current customer will be positioned closer to the user initial position. The system positions closer to the user also those items that the store would like to sell first.

With the advent of mobile devices and the increase of the availability of information the user's interaction with applications is carried out, not only by using desktop PCs, but also by using a wide range of devices, each one with different capabilities. In our 3D online store, one especially important issue regarding this heterogeneity of interacting platforms is the different capabilities that target devices have to render 3D models. To tackle with this problem, the adaptation engine sends different models to the client platform depending on its 3D rendering capabilities. Level Of Detail (LOD) technique has been included to achieve this objective. The platforms with higher rendering capabilities will receive more detailed models than the ones with lower rendering capabilities. This technique avoids stressing the target platform further that its capabilities, allowing a smooth navigation through the e-shop for each platform considered.

3.6 3D Models

For each level of detail different 3D models were created. A threshold was defined to limit the maximum number of polygons that each model could have. This threshold was chosen according to the graphics card 3D rendering power of the target platform. To guess the maximum number of polygons that each 3D model could have for each level of detail we took into account the polygons per second that some of the most common graphics cards of the target platforms families considered support. Three types of graphics cards were considered (Table 1). We supposed that 20 the images per second (fps) would be enough to produce a smooth navigation, because the minimum frequency to perceive movement in a group of images is 10 images per second. Therefore, a speed between 10 and 20 fps is acceptable. As long as our 3D environment is not composed of a single object, that figure still did not reflect how many polygons at most should have each 3D model. Being conservative, we thought that the e-shop would never have more than 2500 objects simultaneously in the scene. Thus, the maximum number of polygons for each platform was computed taking into account the graphics card performance, the frames per second

required in order to provide a smooth navigation, and finally, the number of objects expected per scene.

Table 1: Types of Graphics Cards

	Polygons/Image	Polygons/Image	Polygons/Model
High performance graphics cards	40 millions	2 millions	800
Medium performance graphics cards	20 millions	1 million	400
Poor performance graphics cards	10 millions	500.000	200

Once the 3D models were created, an application to reduce the number of polygons in a 3D model (VizUp) was used to be able to create different versions of each model for each level of detail (Figure 3). For each level of detail, a VRML97 prototype was created with some input parameters (translation, rotation, scale and colour) to be able to integrate every model in the whole scene by setting those parameters.

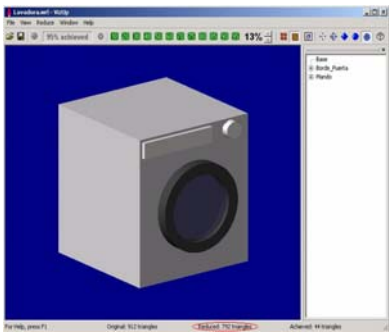

Figure 3: Washing-machine 3D Model (low detail).

3.7 A Client-Server Architecture

The design of the system architecture was made following client-server paradigm. The client side includes the Web browser with the embedded VRLM navigation plug-in (*Cosmo Player*), that the user uses to access the 3D online store, and a Java applet to control the 3D user interface and manage database access. The server side includes a Java servlet to send the user interface to the client, and a database where all the information about the products and clients is stored.

The user interface is split into two panels: in left panel a 3D user interface shows our 3D online store, and the right panel is used to input/output information from/to the user (shopping cart, purchases, registration, etc) (see figure 4b). This layout is the one that the users liked the most when the paper prototype was assessed.

The server side attends the requests from the client. To better reply these requests, the server side has been divided into different agents (adaptation agent, purchase agent and user agent), as figure 4a shows.

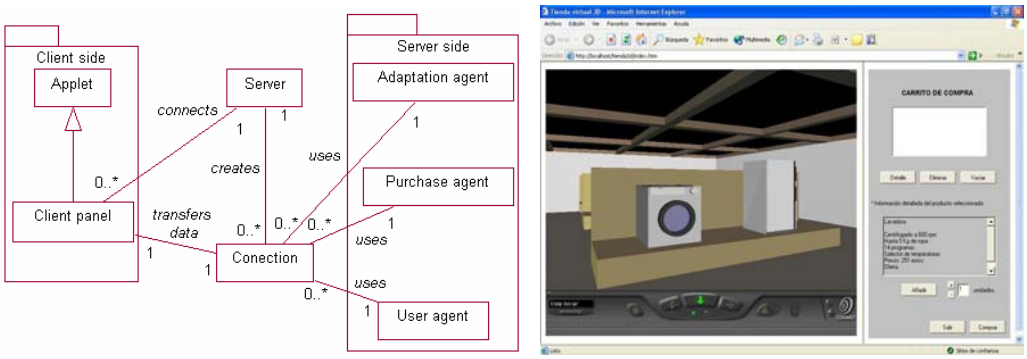

Figure 4: (a) System architecture design. (b) 3D online store user interface.

4 Evaluation

Finally, an evaluation process for the final software prototype was conducted. For this evaluation we asked the same users that made the paper prototype assessment to perform some tasks in our 3D online store. Then, they were asked to fill a form to try to get their opinion about the prototype. One interesting issue we assessed was how the user thought that a 3D user interface performs in comparison with a 2D version of the same user interface.

After a statistical analysis of the answers in the forms we found that the users felt comfortable interacting with the system, because of the similarities the system have with the way those tasks are made in the real world. However, as we expected, the users also found the 3D version a little bit harder to use that the 2D version. We think this is because of two main reasons: (1) a mouse was used to navigate through the 3D user interface, although it is a 2D device, and (2) the users are more used to 2D user interfaces when interacting with computers, so switching to a 3D version requires some training.

5 Conclusions

One of the main aims of this work has been providing a more natural interaction to the user, to try to take advantage of the experience the user has in the real world to perform the same task he makes through the user interface. But virtual stores do not just imitate the real world, but they can improve the way tasks as preformed in the real world by providing personalized user interfaces that help the user to perform the tasks and improve his experience. To achieve our objectives, an ethnographic study was conducted to get the initial requirements for a real store and extrapolate those requirements to the virtual one. By studying these requirements, a storyboard and some paper prototypes were created to assess the initial design with the final users. Our 3D online store is able to overcome the real store by providing adapted versions of the e-shop for each user by means of a user model, and a set of rules to exploit it. The user interface is also able to adapt to different platforms by applying LOD techniques to adequate the 3D models used to the rendering power of the target platform.

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References

Benyon D., & Murray D. (1993). Developing adaptive systems to fit individual aptitudes. *Proceedings of the 1st International Conference on Intelligent User Interfaces* (pp. 115-121). ACM Press.

Chittaro, L., & Ranon, R. (2002). Dynamic Generation of Personalized VRML Content: a General Approach and its Application to 3D E-Commerce. *Proceedings of the seventh international conference on 3D Web technology* (pp. 145-154). ACM Press. ISBN: 1-58113-468-1.

IBM. RealPlaces Design Guide. http://www-3.ibm.com/ibm/easy/eou_ext.nsf/Publish/580

López-Jaquero, V., Montero, F., Fernández-Caballero, A., & Lozano, M.D. (2004). Towards Adaptive User Interfaces Generation: One Step Closer to People. In Camp. O, Joaquim, F, Hammoudi, S. and Piattini, M. (Eds.) *Enterprise Information Systems V* (pp. 226-232). Dordrecht: Kluwert Academia Publishers. ISBN: 1-4020-1726-X.

López-Jaquero, V., Montero, F., Molina, J.P., González, P., & Fernández-Caballero, A. (2004). A Seamless Development Process of Adaptive User Interfaces Explicitly Based on Usability Properties. *Proceedings of Design, Specification and Verification of Interactive Systems 2004, DSV-IS 2004.*

López-Jaquero, V., Montero, F., Molina, J.P., Fernández-Caballero, A., & González, P. (2003). Model-Based Design of Adaptive User Interfaces through Connectors. In Jorge, J.A., Nunes, N.J., Cunha, J.F. (Eds.) *DSV-IS 2003: Issues in Designing New-generation Interactive Systems Proceedings of the Tenth Workshop on the Design, Specification and Verification of Interactive Systems* (pp. 245-257). Springer Verlag.

Molina, J.P., & González, P. (2004). Model-based design and new user interfaces: current practices and opportunities. In Trætteberg, H., Molina, P.J., Nunes, N.J. (Eds) *Proceedings of the First International Workshop on Making model-based user interface design practical: usable and open methods and tools*, IUI/CADUI 2004. CEUR-Workshop Proceedings, ISSN 1613-0073. Vol. 103. online http://CEUR-WS.org/Vol-103.

Molina, J.P., González, P., Lozano, M.D., Montero, F., & López-Jaquero, V. (2003). Bridging the gap: developing 2D and 3D user interfaces with the IDEAS methodology. In Jorge, J.A., Nunes, N.J., Cunha, J.F. (Eds.) *DSV-IS 2003: Issues in Designing New-generation Interactive Systems Proceedings of the Tenth Workshop on the Design, Specification and Verification of Interactive Systems* (pp. 303-315). Springer Verlag.

Naughton, P., & Schildt, H. (2001). Java 2: Manual of Reference. McGraw-Hill.

Shneiderman, B. (1998). Designing the user Interface: strategies for effective Human-Computer Interaction. Addison-Wesley.

Web3D Consortium. http://www.web3D.org/