An Adaptive Virtual Reality Architecture for Shopping Malls

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INTRODUCTION

Firms and organizations are increasingly exploiting electronic channels to reach their customers and create new business opportunities. To this end, electronic shops have been developed, either offering products from a single firm or encompassing multiple individual electronic stores, comprising thus electronic shopping malls. Besides development activities, electronic shopping has attracted the attention of researchers, who have studied various perspectives, including user attitude, critical success factors, security, technical aspects etc (e.g. Fang, 2003; 1997; Liaoa 200; Wang, 2003).

Two of the main concerns for e-commerce are personalization and enhancement of user experience. Personalization addresses the ability to offer content tailored to the preferences of each user (Anupam, 2001) or user group (Wang, 2003). Preferences may either be explicitly declared by the user, or derived by the system through inspecting user interaction; if the system dynamically reacts to changes of visitor behavior, it is termed as *adaptive*. Personalization allows customers to focus on the items they are interested in, and enables electronic shops to make targeted suggestions and send promotions to customers (Lekakos, 2005).

Enhancement of user experience is another major issue in e-commerce, given that two-dimensional images and texts on the screen are not sufficient to provide information on aspects such as physical dimensions, textures and manipulation feedback of products (Park, 2004). Major e-commerce categories that could benefit from giving a more accurate and/or complete view of the products include real estate brokers who could present detailed models of properties, furniture stores that could allow their customers to view how certain pieces would fit in the target place (Hughes, 2002) and clothing shops that could provide a virtual fitting room with customizable avatars (Compucloz, 2003). Multimedia presentations can also be used as a means for “information acceleration” for promoting “really new” products (Urban et al., 1997). Enhancement of user experience may finally compensate for the loss of the pleasure associated with a visit to a shopping mall (Laskaridis, 2001).

Nowadays, the technological potential of Internet systems provides adequate means for building online multimedia applications that can help e-commerce sites attract e-shoppers. Applications can be built to adapt to the user’s profile and provide the user with a suitable set of information in the most efficient way. Virtual reality (VR) technologies are also now mature enough to be used for the wide public, offering vivid and highly interactive environments, allowing users to view synthetic worlds within which they can visualize and manipulate artifacts. This article aims to specify a system that exploits capabilities offered by adaptation and VR technologies to offer e-shoppers personalized and enhanced experiences, while addressing challenges related to the cost, complexity and effort of building and maintaining such a system.

BACKGROUND

E-commerce sites nowadays expose variable degrees of sophistication, functionality and complexity. Most e-commerce sites offer lists of available products, usually organized in categories. For each product, a brief description, the price and possibly an image are made available to e-customers; more information items may be included depending on the e-commerce domain (e.g. customer reviews for books and music). A basic e-commerce site offers the same content to all its visitors.

The first step towards offering services tailored to the user needs, is the categorization of users into groups and serving each group with specifically selected content (Menasce, 1999; Arlitt, 2001; Heer, 2001). Personalization provides a finer granularity for tailored content delivery, because the content formulation procedure takes into account the preferences and behavior of individual users, rather than aggregate data from user groups. Preferences may be declared through *static profiling* (Datta, 2001) where users declare their preferences through profile definition pages; dynamic profiles extend their static counterparts by incorporating information collected from user activities during the interaction sessions.

On the other hand, 3D objects and VR can greatly enhance user experience within an electronic shop. Since 3D environments are inherently more complex as compared to 2D interfaces, the issue of navigation within such an environment is important. In (Chittaro, 2000) the use of animated products as a navigation aid for e-commerce is discussed. (Hughes, 2002) examines the integration of ideal viewing parameters with navigation, to assist the navigation procedure. (Park, 2004) presents a prototype augmented reality system, enabling users to “put and feel a product” in order to find the match in the real environment.

Although adaptation and VR technologies seem promising for e-commerce, their adoption is currently hindered due to a number of challenges, mainly related to the technologies themselves. The first major challenge is *content creation*: For each item in the VR-mall, the respective representations have to be created. The virtual space for the mall has also to be designed, and stands and shelves on which items will be placed must be inserted. Finally, interaction methods for each item need to be designed, which may vary from item to item depending on type of the digital representations (e.g. 3D models may be rotated, videos may be played, paused and continued, photographs may be only viewed), and the nature and semantics of the item (e.g. for a 3D model of a camera interaction may be provided to illustrate change of lenses, while a 3D model of a vase can be only rotated). This is a cumbersome, time consuming and costly process (Lepouras et al. 2001).

A second major challenge is the overall system complexity, stemming from the diversity of its components, structures and interactions (European Center for VR, 2004). The system must include provisions for user profile modeling (both static and dynamic parts), selection of the items that best fit the current user profile, dynamic creation of virtual worlds (VR-worlds) in which the selected items must be placed, coupled with proper interaction methods.

A final challenge is the overall size of the VR-mall description. VR-worlds tend to be of large size, and thus their download time can be considerable. Constructing thus a single world representing the whole VR-mall will result to long waiting times, which may lead users to navigate away from the VR-mall. A more prominent approach would be the formulation of smaller VR-worlds, each one containing a subset of the VR-mall merchandise. These worlds may be interconnected using gates, teleports, or any other suitable means (when a user reaches an interconnection item, they are transferred to another VR-world, constructed and downloaded at that time; thus waiting times are broken down into small portions). The proposed architecture adopts this approach, which additionally provides the opportunity to populate each VR-world with the merchandise that best fits the user interests, as this can be determined by the user activities observed so far. The details of this process are analyzed in the next section.

THE VR-MALL ARCHITECTURE

The proposed architecture provides a generic framework for building an adaptive VR-mall, undertaking the tasks related to user profiling and monitoring, selection of the items best suited to the user profile, association of the relevant interaction methods and dynamic formulation of the VR-worlds. In this sense, the tasks that need to be performed by the VR-mall maintainers are limited to the provision of the content, i.e. the digital representations of the items merchandised through the VR-mall. The proposed architecture is depicted in Figure 1.

DEFINING THE VR-MALL CONTENT

In the proposed system, creation and maintenance of the adaptive VR-mall is undertaken by two stakeholder groups, namely content creators and domain experts, who perform their tasks using specially crafted *content management tools*. Content creators provide the digital forms of the VR-mall merchandise in the appropriate form (pictures, 3D models, sounds, videos etc). Content creators additionally design the space elements that are used within the VR mall; these include rooms, halls, corridors, shelves, display cases and stands that will be used to formulate the VR-mall. Space elements generally contain *merchandise placeholders*, which are replaced by appropriate merchandise items or navigation aids when an instance of the VR-mall is created. For example, shelves may contain placeholders indicating where products will be placed, whereas a corridor may include a placeholder, which will be replaced by a sign listing the merchandise categories that may be found along the corridor. All resources can be provided in multiple *levels of detail*; high levels of detail are used for e-shoppers with broadband connections and when e-shoppers explicitly request highly detailed images of items. Low levels of detail are used to reduce download times, because the size of the digital representation in low level of detail is significantly smaller.

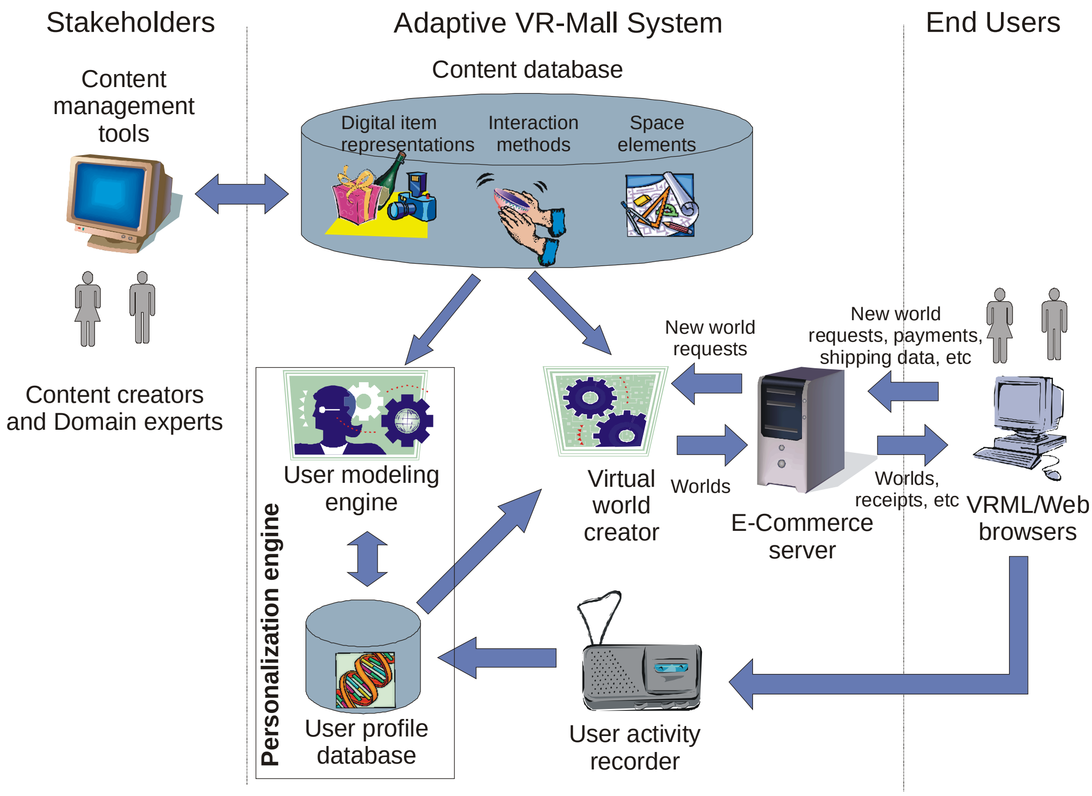


Figure 1 – System architecture

To enable the selection of the most suitable items to be presented to each user, the adaptive VR-mall system needs to possess certain information regarding each item, such as the item category (e.g. furniture, electric appliance, holiday pack), target age group, shopping season and so forth. This information is provided in the form of *property-value* pairs by *domain experts*, i.e. VR-mall stakeholders who have significant expertise on the merchandise. This information is stored alongside the digital representations of the merchandise and is exploited by the VR-world generator in the process of selecting the items that are considered to best match the interests of the current e-shopper.

PERSONALIZATION AND ADAPTATION

Central to the proposed architecture is the *VR-mall personalization engine*, comprising of the *user profiles database*, and the *user-modeling engine*. The user profiles database stores information regarding the profiles of individual users, and associations between user profiles and specific items or specific item properties. This information is utilized in the process of VR-mall creation, so as to include in the mall the merchandise that most closely matches the interests of the current e-shopper. For each e-shopper, the user profiles database hosts both *static* and *dynamic* information. Static information reflects characteristics that remain constant, at least in the context of the current visit, e.g. preferred language, connection speed, age and so on. This information is either entered by the user (e.g. a response to a “Language selection” prompt) or deduced by the system (e.g. the connection speed is estimated by measuring the download time for an image of known size). Dynamic information pertains to the interaction of the user with the virtual environment and is collected by the *user activity recorder*. This information describes certain actions that the e-shopper has performed in the VR-mall, including moving close to an item and moving away from it, start and end of item manipulation, resetting activities (probably due to disorientation problems), acquiring and loosing visibility for items, requesting specific resources or resource types and so forth. This information is collected within the user browser, and communicated to the user activity recorder periodically. When the user activity recorder receives a group of event information, it firstly arranges to combine "activity beginning-activity end" records, so as to compute the duration of each activity. For example, a record indicating that the user started interacting with a 3D model of a camera at 12:40:28 is coupled with the record stating that this interaction ended at 12:41:50 to compute that the interaction duration was 1:22. For events that are instantaneous by nature (e.g. request for an image of a product), only the count of these events is computed. The combined information is inserted into the user profiles database, and the user-modeling engine is invoked to update the profile of the user.

The user-modeling engine is a separate architectural module that undertakes the task of examining the user activities observed within the virtual environment, and deducing the preferences of the user towards certain items or item categories. Upon invocation, the user modeling engine extracts from the user profiles database the records that describe activities of the current user and processes them as follows:

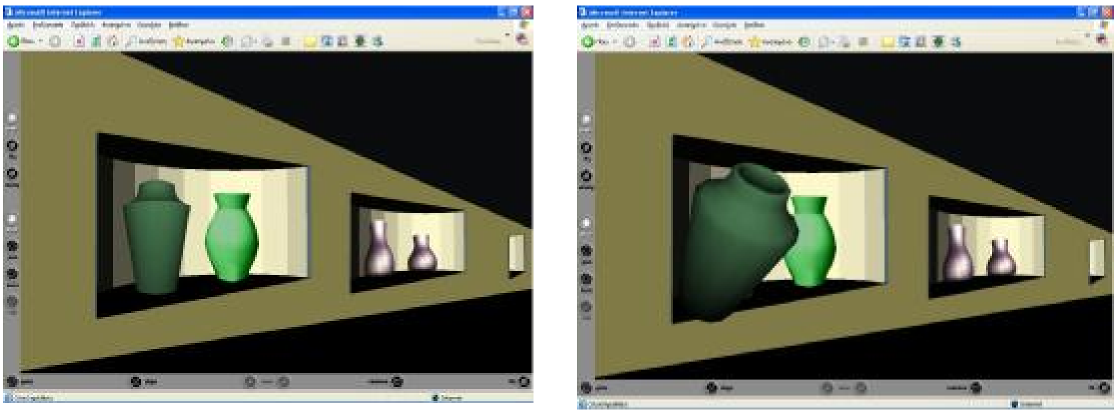
1. items that have attracted the e-shopper's attention for a long time are assigned a high grade (6-10)
2. items that have attracted the e-shopper's attention for a medium time period are assigned a medium grade (1-5)
3. Items having become visible but have attracted the e-shopper's attention for little time (or not at all) are assigned negative grades (–1 to –5)
4. If for some item some resources have been explicitly requested (e.g. 3D models, detailed text, images), an extra amount is added to the item's interest grade (1 to 3, depending on the time the extra resource was viewed).
5. Items that have not come into visibility are not assigned any grade, as the user may ignore altogether that the items were present in the VR-world.

In order to compute the final grade for each item, the time that the related activity took place is considered: the item grade is multiplied by a factor between 1.0 (for recent activities) and 0.1 (for activities that occurred a long time ago), effectively assigning a greater importance to recent activities and allowing for modeling of *changing user interests* (Kilfoil, 2003).

The last phase of the user profile update procedure is the mapping of the grades computed in the previous step to preferences towards item categories, or –more generally– *item properties*. To this end, the semantic information associated with the items (in the form of *property-value* pairs) is firstly extracted from the digital items representation repository. For each property-value pair retrieved, the grades of all items associated with it are summed up to form the score of the specific property-value pair. This information is finally inserted into the user profile database. Similar algorithms are used to deduce user preferences towards specific media types and interaction methods.

GENERATING VIRTUAL WORLDS

When a user reaches a "VR-world interconnection" point (gate, teleport, etc), a request is issued to the VR-world generator, which will create the next "portion" of the VR-mall to be sent to the user. This request will contain the user identity and –possibly– expressly stated user preferences (e.g. "I want a high quality environment" or "I am interested in velvet textiles"). The VR-world generator additionally retrieves from the user profile database the preferences and information for the specific user (either statically stated or deduced by the VR-mall personalization engine). Afterwards, the VR-world generator accesses the content database to extract the items that will be placed in the new VR-world. The initial list of the items to be placed in the new VR-world is formulated in either of the two following ways: (a) the user selects to visit an "e-mall department" (e.g. furniture, clothing etc), in which case the items belonging to the selected department are chosen or (b) the user requests to see "matching items" to some designated merchandize (items within the shopping cart or some explicitly specified), in which case the items having common properties with the designated merchandise are chosen. Once the list is initially populated, it is sorted in descending order of the sum of scores corresponding to the property-value pairs within each item. It is worth noting that the VR-world generator has an upper limit, regarding the number of items that will be placed in a VR-world, and another upper limit, pertaining to the download size; if either limit is exceeded, items are removed from the list until the restrictions are met. When the item list has been determined, a proper space element is selected from the content database (one with enough placeholders for the selected items and matching the user preferences), and the items are positioned at the placeholder locations, arranging for "similar" items to be placed in clusters (Lepouras, 2004). At this point, the VR-world has been fully created and can be sent to the user.



(a) (b)

Figure 2 – The VR-Mall environment. (a) Moving along an isle with vases (b) examining a specific vase

Figure 2 presents two screenshots from the VR-mall; the first one illustrates movement along an isle, while in the second screenshot an object has been “grabbed” and is examined.

FUTURE TRENDS

New technologies offer to e-commerce sites the possibility of creating enhanced and highly personalized user experiences, increasing the site potential to attract more e-shoppers. One issue that has to be settled in this context is the *time to adapt*, i.e. how much time elapses from the instant that some user behavior is observed to the instant that the system changes the user environment. In the proposed architecture, the environment will change only when a new VR-world is made. Some users may find this reaction delayed; most users, however, have been found to react negatively to constant changes in their environment (e.g. items disappear to be replaced ones considered to be more interesting to the user [Schneidermann, 1997]). A viable approach to a more timely reaction would be use of *navigation clues* that will direct users to an interconnection point (where change of environment *is* expected); navigation clues may appear when the system decides that the user’s environment should be changed. In order to support either form of a more timely reaction, certain portions of adaptability mechanisms have to be executed at client side, eliminating the requirement for creation and transmission of new content. The use of more sophisticated methods for item selection, with possible integration of AI techniques is also an interesting research direction. Finally, the possibility of allowing multiple users to simultaneously enter a VR-mall and interact with each other while shopping will be investigated.

CONCLUSION

The architecture proposed in this article allows e-commerce sites to benefit from the advantages of adaptive and VR technologies, and simultaneously addresses a number of challenges usually associated with such systems. The proposed system incorporates modules that undertake user monitoring, deduction of preferences, selection of the most prominent items and dynamic formulation of the VR-world, limiting the tasks that the e-commerce site stakeholders need to perform to content provision and the semantic tagging, which are performed via specifically crafted content management tools. Effectively, this architecture limits the cost and effort associated with the creation and operation of an adaptive VR-mall, opening up the potential to more e-commerce sites to offer their customers vivid, life-like and personalized experiences.

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TERMS AND DEFINITIONS

Adaptive VR-mall system: An e-commerce site that offers an immersive or semi-immersive environment for e-shoppers to navigate in, and tailors the content delivered taking into account the individual e-shopper preferences and interests.

Personalisation engine: A system component that exploits information regarding user activities to derive user preferences and interests, and tailor the content to be delivered according to these.

Digital item representations: Multimedia content related to the merchandise of the VR-mall, coupled with semantic information that describes and categorises each item.

Interaction methods: The ways that an e-shopper can manipulate items within the VR-mall. The interaction methods may vary, depending on the type of the item representation (video, 3D model, photograph), the item semantics and the preferences or expertise of the user.

Space elements: Halls, corridors, shelves and other items representing physical shopping mall components, which are used together with the multimedia representation of the merchandise to formulate the VR-mall worlds.

Virtual world creator: A system component that uses space elements and digital item representations to dynamically create a virtual environment, which is sent to the user.

Activity recorder: Software that monitors important user activities within the virtual environment and records this information into a database for later perusal.