Personalization of Content in Virtual Exhibitions

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Abstract. Presentation of content is an important aspect of today's virtual reality applications, especially in domains such as virtual exhibitions. The large amount and variety of exhibits in such applications raise a need for adaptation and personalization of the environment. This paper presents a content personalization framework for Virtual Exhibitions, which is based on a semantic description of content and on information implicitly collected about the users through their interaction. The proposed framework uses stereotypes to initialize user models, adapts user profiles dynamically and clusters users into interest groups. A 3D virtual museum has been implemented as a case study, and an evaluation has been conducted.

Keywords: Virtual Reality, Virtual Museums, User Modeling, Personalization

1 Introduction

This advent of Virtual Reality in recent years has enabled the development of novel interactive and immersive applications that emphasize on the presentation of content and satisfying user experience. Examples of such applications are 3D Virtual Exhibitions, i.e. interactive 3D environments containing a large collection of media objects. While the graphical representation of the exhibits is an important aspect of Virtual Exhibitions, the large amount and variety of these elements presents another challenge to the designers of such environments, namely to adapt the presentation of a collection according to user interests, i.e. content personalization.

A number of Virtual Exhibition applications are currently available and run standalone [1], or over the Internet [2,3,4], representing real or fictional museums and exhibitions. It can be noted that most of today's exhibition environments emphasize on the content and aim to the deeper understanding of entities and concepts through user navigation and interaction in 3D. Most of these applications contain, nevertheless, static collections arranged in predefined positions, and the design of the virtual space and its contents is based entirely on the author's categorization. Therefore, the user's role is limited to a passive observer and the presentation of large collections may fall into the obstacle of navigational difficulties in 3D environments [5], which eventually leads to the reduction of user interest and to the disability to explore and search for the desired content [6].

The problem of presenting and categorizing large quantities of content has been effectively addressed in Web [7,8,9,10] and multimedia applications [11], where user modeling has been used to personalize content presentation based on the users' own interests. The authors claim that virtual environments could also benefit from user modeling and adaptation techniques that make assumptions about user interests and intentions concerning the application, and construct the virtual space accordingly. Such a personalized space may reduce the navigational burden while it still retains the metaphor of being immersed in a 3D environment. Although the concept of personalizing content is not new, there have been few approaches towards user modeling in 3D environments. In analogy to the theory of content adaptation on the Web [12], content personalization in 3D could be supported by a) a process of recognizing user interaction patterns in the 3D environment [13], b) a mechanism that makes assumptions about user preferences based on these interactions, and c) respective modifications of the environment that reflect user needs and increase her satisfaction.

As a first step towards this theory, Chittaro and Ranon have proposed AWE3D [14], an architecture for presenting personalized 3D content on the Web. In this approach, the system monitors and records user interactions with the environment and applies a rule set on the recorded interactions in order to modify the user model, and personalizes the environment based on assumptions concerning user preferences. They present a 3D E-Commerce application as a case study. The work of dos Santos and Osorio [15] also focuses on content adaptation in 3D environments. They use a rule based approach with certainty factors to modify the content and structure of the environment according to user interests. A distance learning environment has been created as a prototype. Both approaches adopt a rule based mechanism to generate and update the user models, and the responsibility of defining and validating these rules lies entirely on the designer. Any modification of the content will require respective changes in the rules.

Celentano and Pittarello [13] propose an approach to facilitate adaptive interaction with the virtual environment, which is based on the following: a structured design of the 3D interaction space, the distinction between a basic virtual world layer and an interaction layer, and the recording of the environment's usage by the user in order to find interaction patterns. The aim is to facilitate the system's usage by monitoring user behavior and predicting future needs for interaction purposes. When the system recognizes the initial state of an interaction pattern, it executes the final state without letting the user engage in the intermediate ones.

The authors propose a novel approach towards adaptive virtual environments, in which objects are dynamically distributed among rooms and users may experience personalized presentations based on their previous interaction with the system. The proposed framework is supported by a semantic graph, defined by the designer, which describes the nature of the exhibits by hierarchically categorizing the content, and drives the user modeling process. Additionally, the authors support the claim that users' experience in a virtual exhibition is enhanced through communication and collaboration with other users in a shared environment [16]. In this context, the proposed framework supports dynamic clustering of user groups based on the similarity of user models, which may lead to the formation of e-societies with similar interests. The authors have implemented a science fiction virtual museum as a case study of the proposed framework and have performed a user evaluation of the application. Evaluation results indicate the impact of the user modeling process in adapting the presentation of content to the user preferences and a significant degree of user satisfaction from the system in general.

The rest of the paper is structured as follows: section 2 presents the proposed framework for content personalization in virtual exhibitions, while section 3 presents a science fiction virtual museum as a case study and section 4 presents an evaluation of the implemented system. Finally, section 5 draws the conclusions and states the future work.

2 A Framework for Content Personalization

The proposed framework for designing and implementing virtual exhibitions with content personalization is based on four methods that enhance a static 3D environment with dynamic characteristics: user model generation, content selection and presentation, user model update and clustering. In the next paragraph a full user interaction session with an application designed under this framework is presented.

When a new user enters the environment for the first time, a user model is assigned to her based on stereotypes [17] that correspond to her selection of an avatar, i.e. her graphical representation in the 3D environment. While the user is browsing the environment, her navigation and interaction with content are monitored and the recorded behavior is utilized to make assumptions about her interests and preferences, which are then incorporated into the user's profile. At any time, the user can ask to be transported to a personalized environment, which reflects her assumed preferences and recommends new content that might be of her interest. The user can also join communities with similar preferences, visit other personalized environments, and exchange opinions about the content. User interest groups are proposed by the environment through an automated clustering process.

From the designer's point of view, the framework can be employed to construct new dynamic virtual exhibitions without having to define explicit rules for content personalization and adaptation. The designer has to provide the 3D content, i.e. the rooms and objects of the environment, the semantic graph, i.e. an ontological description of the content, and the user stereotypes that contain templates of initial user preferences concerning the content. A presentation process then creates the exhibition rooms and distributes the exhibits dynamically based on the above data. The personalized environments also depend on the interaction history of the respective users. Furthermore, exhibitions generated using the proposed framework can be easily adapted or enhanced by altering or inserting new 3D content and making appropriate changes in the semantic graph and the user stereotypes.

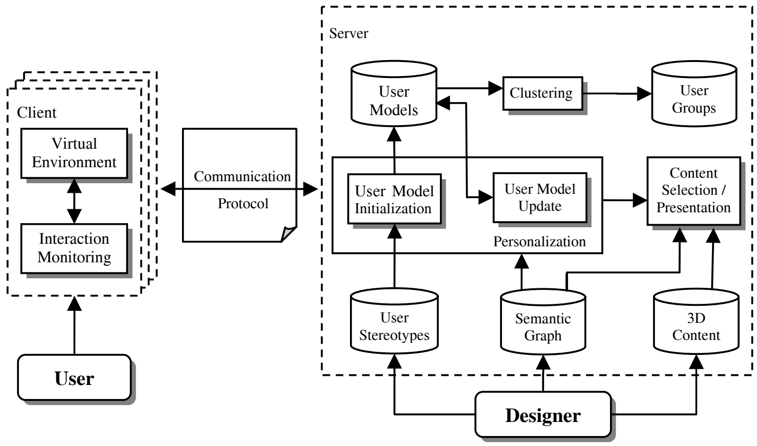

Fig.1. The proposed architecture

The proposed framework is based on a thin client/server architecture (Fig.1), in which the users interact with the environment on the client side and user modeling takes place on the server side. This architecture follows the paradigm of decentralized user modeling architectures [18], and allows clustering of users into groups with similar preferences, whilst it is also necessary for the support of multi-user environments and for immediate adaptation and expansion of exhibition data by the designer.

The rest of this section describes the proposed framework and the related architectural components in detail.

2.1 The Semantic Graph

A vast number of applications that utilize user modeling methodologies try to address the user's need for quick and efficient access to a subset of information that meets her interests and preferences, without having to search through a larger set of objects. A widely used term in the literature for describing these applications is recommender systems [7,10,11,17,19,20,21]. A distinctive characteristic of these systems compared to information retrieval and filtering systems and to search engines is the output of individualized information based on a priori knowledge about the content and assumptions about user preferences.

A thematically uniform set of objects can be grouped together and categorized based on a number of criteria; relations can be determined between objects and categories or between categories themselves, e.g. relations of affinity and inheritance. For example, in an art exhibition, exhibits can be grouped with respect to their creators, the epoch or the style. These categories can be generalized into broader categories or specialized into subcategories. A categorical hierarchy of this type forms a tree with nodes being the categories and edges being the relations between them. The entirety of the categories can thus be represented as a forest (a set of distinct trees). Nodes at higher levels in each tree imply categories with broader meaning and relations between nodes can be viewed as inheritance relations. Nodes of different trees can be connected implying a semantic *union* relation. Because of the union relations this categorization scheme is used as a graph instead of a forest in the context of determining related categories. The actual objects are attached to the categorization trees using connection(s) with one or more lowest-level category nodes (the leafs of the categorization trees) via an instance relation. Thus, the resulting structured hierarchical semantic taxonomy forms a directional graph, the Semantic Graph (SG), in which nodes (distributed into levels) stand for objects and concepts, edges represent the relations between them [19,22,23] and the levels represent the degree of generalization.

Nodes are divided in two categories, the *object nodes*, which represent the actual elements of the environment, and the *categorization nodes*, which represent object categories. The latter are distributed hierarchically based on generalization relations; a broader term lies at a higher level than a more specialized one.

Figure 2 presents a sample part of a semantic graph that is used for categorizing cars. The dashed line is a union relation that connects two categories belonging to different trees. In the example the node Type is divided into two subcategories, the nodes Professional and Racing that are also divided into two subcategories each. The EVO 5 has been used as a WRC racing car and it was manufactured by Mitsubishi, thus it can be connected with the nodes WRC and Mitsubishi. The union relation connects the respective nodes to imply the association between Ferrari manufacturer and F1.

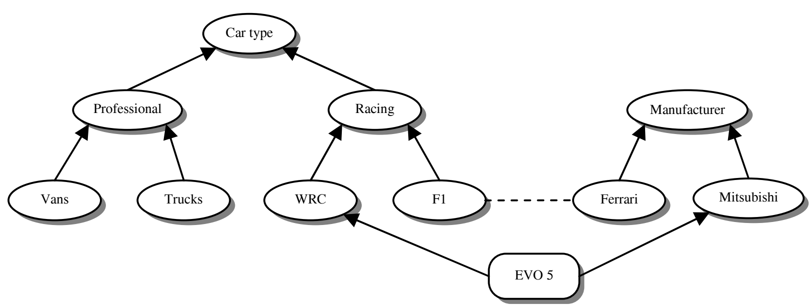

Fig. 2: A part of a semantic graph for categorizing cars

Let A be the node at the lower end of a categorization edge and B the node at the upper end. All edges (which represent the aforementioned relations) have a numerical weight in the range of (0, 1], which is the degree of membership of the object or concept that node A represents to the set that the node B portrays. The use of the degree of membership is analogous to the respective term from the Fuzzy Set Theory [23]. For example, the Terminator II movie can be said to be a well known sci-fi movie of the 90's, so the degree of membership of this movie in the Sci-fi and 90's categories is significant. In the case of union edges, the weights represent the degree of association between the connected nodes. The choice of weights can be made by using expert knowledge or by using machine learning techniques. The degrees of membership and the degrees of association are used during the execution of the personalization-recommendation algorithm.

In the proposed framework, the SG is the core element, because it drives most computational procedures:

- modeling user preferences in the environment,
- providing recommendations to users,
- clustering users with similar preferences to groups, and
- dynamically distributing the content into separate rooms and determining the connections between them.

The authors argue that the SG facilitates access to the exhibition's content repository, by reflecting a natural content interpretation, effectively serving the users' informational needs and preferences.

2.2 Dynamic Content Generation and Rendering

The hierarchical structure of the SG is used for the creation of the virtual exhibition's spatial structure. Each categorization node can be represented by a set of conceptually relevant rooms that are connected via doors, following the graph's edges and the relations of kinship between semantic nodes. This approach provides a multidimensional navigation paradigm, in which rooms are connected based on their semantic similarity. A user can navigate inside the exhibition environment and browse the content by following paths that correspond to any of the concepts that can characterize it. E.g. a room with objects from Steven Spielberg movies is connected with the room of US directors (at a higher level). By dynamically structuring the environment, the effort of designing and creating every room in the exhibition is reduced to a minimum.

The designer provides a number of template rooms that are used by the client application to construct the actual exhibition rooms. The system requires a default template room and, optionally, any number of thematic rooms related to existing categories of the semantic graph. Each template room is a 3D model of a section of the exhibition environment, in which two types of objects are inserted: *doors* and *exhibit containers*. When the client application has to construct a thematic exhibition room it searches for a predefined template that matches the respective category. In the case that no such template exists, the default room is used. Then, the system dynamically links the room with related ones using the existing doors, each labelled by the name of the room it leads to. Finally, the exhibits are dynamically placed in the containers defined by the designer. A default exhibition is constructed by creating an entrance room that is connected to all the general (top-level) category rooms of the semantic graph.

The collection of objects that will populate each room is generated by traversing the graph from the respective categorization node to the set of object nodes. The number of objects can be significantly large, especially when browsing the content of higher-level nodes. In that case, objects are distributed into a set of interconnected rooms.

2.3 Personalization

All available objects in the proposed framework are categorized by the SG in a semantic taxonomy. When and if a user is interested in a certain object, it can be assumed that she is also interested in one or more categories to which the object belongs (she likes the movie series Star Wars because she likes sci-fi movies). If this belief is reinforced during the interaction with the system, a recommendation set with members originating from this particular category would probably be a preferable choice. The *user model* is an instance of the SG, with all nodes being given a numerical value (positive or negative), which represents the degree of interest that the user is assumed to have for the term or object that the node portrays. The process of calculating these degrees of interest is analytically explained in the next paragraphs.

User Stereotypes. As stated in [24], the explicit creation of a user profile may annoy users that are unwilling to state their interests and lead to user models that do not actually reflect the user preferences. Therefore, an indirect method for generating an initial user model has been utilized, in which a set of stereotypes [17] is used to initialize the model of a new user. At registration time, the user selects an avatar from a provided library, and the system creates an initial user model and thus makes an assumption about her preferences and interests based on her selection. Each avatar is related with assumptions about the user, which are lexical values of properties defined by the designer. A possible set of properties can be age, sex, education or anything that is considered to characterize the users and the respective values can be young, old, female, male, high, low etc. The stereotypes are rules that relate each value of each property with estimated degrees of interest for a set of nodes in the SG.

The degree of interest in the categorization nodes is calculated as follows. Initially all the categorization nodes have a zero value. For each value of each property, the degree of interest declared in a stereotype (if any) is added to the respective categorization node. This initial user model is used for the formation of a recommendation set (which will be explained in the following paragraphs) prior to the user interaction with the 3D environment. This approach deals with the new user problem [20], with a reduced accuracy nevertheless. This is an initial estimation, however, and as the user interacts with the system, information is accumulated in the user model, updating it and thereby increasing its accuracy.

The aforementioned methodology is based on researches [25,26] that state the possible relation between the choice of an avatar by the user and the users' intrinsic characteristics and personality trades. Expert knowledge and/or user segmentation researches can be used to create the set of stereotypes.

Data Acquisition and User Model Updating. The algorithm that updates the user model based on her interactions uses a forward propagation mechanism. Initially, it collects the summing degree of interest for each object node of the SG that the user has interacted with. This is the result of a monitoring process that takes place on the client side. A variety of acquisition methods can be used, such as measuring the time spent by the user observing an object, taking into account the type of interaction, and providing a rating system that lets users express their preferences. The framework supports various types of acquisition methods and interpretations. At the end of this step, all object nodes have a degree of interest ranging from negative values (dislike for the particular object) to positive values (positive interest).

For algorithmic uniformity, each union relation in the SG is substituted with a dummy node (union node) placed at one level higher than the maximum level of the categorization nodes it connects. These nodes are connected to the union node with dummy relations that have weights equal to w, where w^2 equals to the degree of association of the union relation. For the rest of the paper we refer to both categorization and union nodes with the term *semantic nodes*.

Let SN be a semantic node and $DI(SN)_t$ the degree of interest in node SN at time instance t. Let $CSN = \{CSN_1, CSN_2, \ldots, CSN_N\}$ be the set of children nodes of node SN, with $DI(CSN_i)_t$, $i \in [1,N]$ being the respective degrees of interest. Let also W_i be the weight of the edge that connects CSN_i to SN. Then, the degree of interest at time instance t+1 for node SN is calculated by:

$$DI(SN)_{t+1} = \sum_{i=1}^{N} (DI(CSN_i)_t \cdot W_i) + DI(SN)_t$$

Calculations begin at level 0 (the object nodes level) and they proceed level by level until the maximum level of the SG. Object nodes maintain the values from the initial step. The resulting degrees of interest comprise the updated user model.

Adaptation of the Environment. For the creation of a personalized room, a set of objects is chosen to be recommended to the user by populating the room with them. This task is realized using a backward propagation mechanism based on the user model. This mechanism is computationally equivalent to the forward propagation mechanism described before, having only the opposite direction. Thus, instead of the CSN, the $ASN = \{ASN_1, ASN_2, \ldots, ASN_K\}$ set is used which represents the set of ancestor nodes of node SN and N is replaced by K. During the backward propagation procedure an estimated degree of interest is assigned to the object nodes. The choice of objects that will be part of the user's personalized room depends on the ratings of the respective object nodes. Consequently, the simplest approach is to choose the M top rated nodes of level zero (the level with the object nodes), where M is the capacity of the room, whilst variations of the proposed room can be produced by employing methods, such as to insert a few random elements to increase the diversity, or to avoid selecting objects that the user has already interacted with.

Besides the selection of the recommendation set, a personal room should also have connections to other rooms of the virtual environment, allowing the user to further explore the exhibition. The set of rooms that are connected to the personalized room should also reflect the user's preferences. As mentioned earlier, every categorization node is represented as a set of rooms. So, to connect the personal room with the rest of the environment, L doors, where L is the door capacity of the personal room, are dynamically created. These doors are connected to a single room of each room set from the L top rated categorization nodes of the user's model.

2.4 Clustering: Formation of user communities

In internet based applications, added grouping capabilities can promote the formulation of e-communities, thus increasing the sense of immersion in the virtual environment, enhancing communication opportunities, and satisfying the need for social interaction and awareness. To create a group of users with similar interests and preferences in the proposed framework, the user models must be compared. By assigning a unique index to every node of the SG, a user model can be taken as a numerical vector with each item being the degree of interest in the corresponding node. The dissimilarity between a pair of vectors can be computed using multidimensional Euclidean distance, and thus a group can be created based on distances smaller than a given threshold. This technique can provide satisfactory results in finding users with similar interests and presenting the respective personalized rooms to promote user communication. The user can choose a personalized room from a subset of recommended rooms, the owners of which have been clustered by the system, based on their interests.

3 Case Study: A Science Fiction Museum

In order to assess the proposed framework, a Virtual Museum concerning science-fiction movies, has been developed. It lets users navigate in thematically different rooms (e.g. containing characters, vehicles etc.), enter a personalized room with various exhibits that the user might enjoy, according to her interests, or enter online exhibitions of users with similar interests. The exhibition's content (3D models) has been created using external modeling tools and imported to the environment, while an authoring tool has been implemented to facilitate the process of construction, manipulation and maintenance of the SG and the system's database management. The authoring tool can be used by the designer of the virtual exhibition, effectively reducing the effort of creating all the needed elements. The Virtual Museum contains 87 exhibits with a SG consisting of 34 nodes distributed over 3 levels.

As the users navigate inside the virtual museum, they look at exhibits that fall inside their field of view. In order to perceive an exhibit, a user must be oriented towards it and be within a predefined distance. Furthermore, the users have the option of manipulating an exhibit, i.e. rotating it in order to gain a full perspective. Presentation of additional information concerning the exhibit is achieved through description pages in a provided panel. The users are also able to provide feedback about an exhibit by rating it and entering their personal message/comment. At the same time, users can view comments written by others, chat with them, observe their actions in the virtual space (via their avatars) and enter their personalized room.

The initial assumptions concerning user preferences are based on stereotypes related to the avatar gallery, and consequent interaction in the exhibition's space provides the appropriate degrees of interest for the profile update. Three types of interaction are monitored (ordered by the degree of influence upon the rating of an object, ascending):

- *viewing time*: the time spent looking at an exhibit. It is considered that the more time the user looks at an exhibit, bounded by an upper limit, the more interested she is in it.
- *manipulation of an exhibit*: interaction with an exhibit has a stronger impact than viewing time, as the user expresses her preferences more explicitly.
- *commenting and rating exhibits*: users can write comments that others can read and rate the exhibits accordingly. There are three available rating values: positive, negative and indifferent, which can reveal the user's opinion directly.

User interactions produce degrees of interest that are used by the server to assembly the personalized room and to distribute its contents dynamically upon user request. Users have the added ability to be instantly transported to any exhibition room (including the personalized room), in order to access rapidly a desired category/exhibit room.

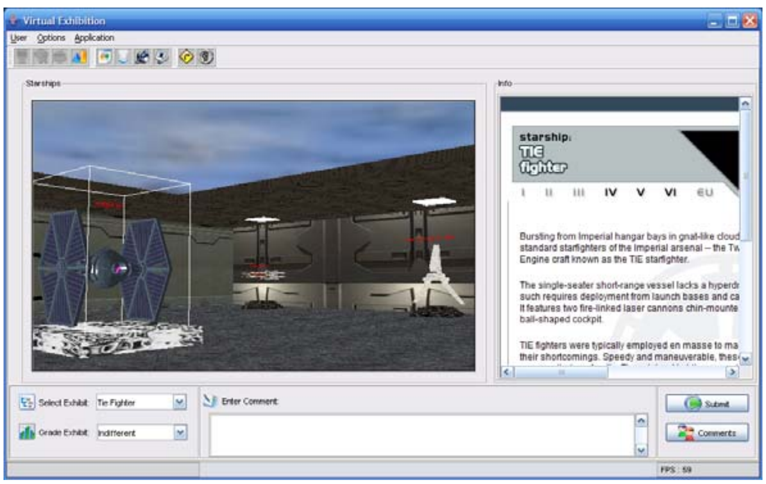

Fig. 3. A screenshot of the case study

The museum's 3D content is modeled in VRML and is loaded/rendered by the client application, which is implemented in Java, using the Java3D API. At the server side, the exhibition and user data were stored into an SQL Server 2000 database and their retrieval/manipulation is coordinated by the server application, implemented in Delphi programming language. The client-server communication is achieved with the use of TCP/IP sockets. Figure 3 presents a screenshot of the virtual museum application.

4 User Evaluation

In order to provide insight on the effectiveness of the proposed user modeling framework, a user evaluation has been conducted, using the aforementioned implemented system. A group of 20 users participated in the evaluation process, all of which were undergraduate students in the Computer Science department of the University of Piraeus. The users had to interact with the system and then fill out a questionnaire that was given to them. The degree of familiarity with 3D environments was almost uniformly distributed, with 11 participants stating that they had a fairly good experience in such environments, while 9 of them had almost never used a 3D application.

In the first step of the experiment process the user had to choose an avatar from the provided library, register into the system and state her opinion about the degree of representation by the avatar. After logging into the system, the user had to complete the main process of the evaluation, which included navigating in the personalized room, interacting with the recommended objects and finally navigating through the rest of the exhibition for a short period of time, interacting with other objects of interest. Every object in the personalized room had to be marked in the questionnaire as known or unknown to the user and to be rated in a scale of -3 (total dissatisfaction) to 3 (total satisfaction). This evaluation process was repeated three times, while the system was adapting her user model, based on the user interaction with objects. At the end of the evaluation, the participant was asked to rate her experience with the system, and write down comments.

Following discussions with the participants and analysis of their written comments indicated that the quality of the rendered graphics and models is an important factor in object rating and therefore it affects total user experience, i.e. a visually appealing, high-resolution model is more interesting than a low-resolution model with poor quality textures. Additionally, the quality of navigation (smooth movement, collision detection etc.) and the interaction capabilities of the objects significantly influenced user opinion. Several users stated that if the aforementioned factors were improved, the total system rating, which was formulated in a scale of 0 to 5 at an average of 3,65, would probably be higher. Overall, the experience gained during the conducted user evaluation, indicates that intrinsic characteristics of dynamic 3D exhibitions have an important impact on user satisfaction about the set of the recommended objects.

The analysis of the questionnaire showed that 66,85 % of the recommended object ratings were positive, 18,82 % were negative and 14,33 % were neutral, whereas the average positive rating was 2,12 and the average negative was -1,85. Although these are preliminary results, it can be inferred that the contents of the personalized room have matched user preferences to a satisfying degree. Additionally, user satisfaction by the object recommendations has improved from the first round of the evaluation to the last by an average factor of 10,47%. This improvement, although small, was considered satisfactory by the authors, as the duration of the interaction periods was small and object recommendations are implicitly influenced by the initial collection of objects contained in the personalized room, during early user interactions with these objects.

5 Conclusions and Future Work

This paper presented a user-oriented framework for designing and implementing virtual exhibition environments. Implicit generation and adjustment of user models allows applications that are based on this framework to dynamically adapt content presentation to user interests and preferences, based on user stereotypes and prior interaction of users with exhibits. A semantic graph is used as a basis for both content categorization and user modeling. This semantic representation of content enhances presentation capabilities and simplifies the alteration and/or extension of existing environments. Additionally, it is possible to detect similarities among user models, leading to the formulation of user interest communities. A case study i.e. a virtual museum application has been implemented, in order to gain insight about the effectiveness of this approach. A user evaluation of this case study produced favorable feedback towards the application of this framework in virtual exhibitions and virtual content presentation systems in general.

In the future, the authors are planning to fine grain the proposed framework, through the development of more complex case studies, in order to better evaluate the user modeling process. Another objective for the research team would be to provide an open-ended platform for virtual reality content presentations thus promoting researcher, developer and designer cooperation in the field. Finally, an ongoing extension of this work is to enrich the framework by allowing users to customize their personal space, thus providing stronger feedback on the quality of their user model.

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