Towards a user-aware virtual museum

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***Abstract*—The exploration of cultural heritage through well-designed virtual worlds has met an increase in popularity within the last decade. More and more well-known museums around the globe have started to spend funds in order to build systems with which users can virtually navigate through the museums' exhibits. Technological breakthroughs in graphics design and the use of multimedia content have helped these systems become more attractive and easier to use. However, the vast majority of these systems are solely there to represent content in an appealing way, with users just having the submissive role of requesting information. In this paper, we want to make one step further and present a user-aware system for virtual museums. Users in the proposed system are active users who can express their opinions in many different ways, enabling us to extract user preferences on cultural content. We follow a group-based logic in order to capture the underlying differences in user preferences between the groups. We believe that these findings are beneficial for providing a better user experience and, also, for the museum's administrators who can easily assess user interest about the museum by analyzing their evaluations.**

***Index Terms*—virtual museum, user preferences, user groups**

I. Introduction

In 1994, the Museum of Computer Art (MOCA[1]), a physical gallery located in Brooklyn NY, launched the first and foremost online museum to disseminate its cultural treasure via the Internet. Since then, and especially within the last ten years, there was an increasing popularity in developing such interactive environments from many well-known museums around the world.

Multimedia techniques have been widely used for enhancing users' experience and attracting more visitors to museums, as well as for providing new means for presenting their content and consequently exhibit related information. Technological advances in 3D graphics design (e.g. Virtual Reality, Augmented Reality) have been adopted to facilitate the presentation of cultural artifacts in museums' collections [11] [12] [13] [14].

In addition, the emergence of the World Wide Web has played a significant role in the dissemination of cultural heritage by making it available to a global level. As a result, museums gain worldwide publicity, while at the same time they attract potential 'real' visitors, as research has indicated that 70% of the people who have visited a museum's web-site would be more likely to also visit the 'real' museum [15].

[1]Museum of Computer Art: http://moca.virtual.museum/

Considering the changes that have been made in the development process of these systems, one may conclude that there has always been an adaptation to the available technology for achieving two objectives: (1) cultural heritage dissemination, (2) increase of user experience. We believe that many of the existing virtual museums have offered adequate solutions to the aforementioned problems. However, in the vast majority of these systems the user is only requesting information with this leading to a restrictive and submissive role.

In this paper, a user-aware virtual museum environment named **Virtual Wing** is proposed where users, apart from 'consuming' content, can express their opinions on it. By providing such an option, we give users an active role which helps them retain their interest, deal with potential boredom and develop the feeling that their actions have an impact. In particular the Virtual Wing creates and presents a complete virtual representation of a museum, providing rich multimedia descriptions for its content. Moreover, it models both associations and common features between artifacts and entities that may be abstract or reside outside the museum (e.g. eras and archaeological sites, respectively) through specialized filtering and group-presentation capabilities. Visitors are free to explore the virtual museum's world having constant assistance during their navigation. Furthermore, the Virtual Wing provides user interfaces tailored to the needs of different user groups.

Apart from the functionalities of content presentation, Virtual Wing also contains a user monitoring component which is responsible for capturing user feedback and extracting user preferences. Its main characteristics can be summarized in the following points:

- **Users in groups:** Each user belongs to a predefined group which represents particular classes of people (e.g. adults, children, experts). This way, we can extract different statistics for the different groups of users which can be used as useful indicators of their preferences. In addition, the extraction of the groups' interests can help us enhance the quality of the services offered to each group.
- **Feedback on content:** We enable users to rate and comment on content, offering them ways to express their opinions on the exhibits they view. Analysis on these user evaluations can lead to assessments on the exhibits' popularity which are a useful output for the museum administrators.
- **General point of view:** We are also interested in users'

opinions about the system itself. To get such kind of feedback, a number of general questions are given to the users at the end of a tour. Their answers are processed by museum administrators for the purpose of future improvements in the system.

The rest of the paper is structured as follows. Section II briefly overviews existing systems. In Section III there is a brief discussion about the architecture of the proposed system while in Sections IV and V both our group-based logic and the user monitoring subsystem are presented. Section VI outlines some beneficial uses of the monitoring system, and finally, in Section VII the paper is concluded. It should be noted that the proposed system is being developed for the Archaeological Museum in the Greek city of Volos.

II. Related Work

In the last few years, there have been several projects related to information technologies, dealing with the preservation of cultural heritage and the restoration and learning resources. Some examples in the field of digital and virtual museography include: Euromuse.net [2] (EU) and DigiCULT[3] (EU). In addition, the project 'Virtual Museums' [1] was sponsored by the Greek General Secretariat of Research and Technology and has focused on the development of a Virtual Environment that would enable museums' visitors to view and manipulate 3D exhibits. Ten museums located in Athens have been integrated within the context of a virtual environment and participated in the project by providing 2D and/or 3D content to be digitized and presented within this context. The number of participating museums as well as the diversity of their content required a generalized strategy which catered for different museum presentation needs and allowed for future expansion.

The creation of a virtual educational museum which unifies cultural information from various EU countries in a common framework was also envisioned in the NEOTHEMI[4] (the new Network Of Thematic Museums and Institutes) EU collaborative project [2]. In NEOTHEMI physically-distant cultural content, such as objects, texts and artifacts, coming from ten different European countries but belonging to a number of common themes is made available to the general public via the Internet. The virtual museum uses VRML to present the cultural content to users in a realistic and engaging way, allowing them to freely wander through the museum's thematic pavilions. The results of a dedicated online survey conducted on users who are either teachers or students revealed that they are relatively positive on using Virtual Museums for accessing geographically distributed cultural content via the Internet, provided that certain technical difficulties are compromised (e.g. speed of access) [3].

The 3D-MURALE project [4] is developing and using multimedia tools to measure, reconstruct and visualize archaeological ruins in virtual reality, using as a test case the ancient city of Sagalassos in Turkey. A conventional text based database is being developed for the storage and retrieval of text, 2D image and VRML image information on archaeological content such as buildings, artifacts, parts of artifacts, drawings, documents, and research papers. The project makes this content available by remote Internet access for other archaeological researchers and members of the public. Moreover, ARCHEOGUIDE [5] is a system providing information access at cultural heritage sites through the use of augmented reality, 3D visualization, mobile computing, and multi-modal interaction techniques.

The ARCO system, discussed in [6], allows museum curators to build, manage, archive and present virtual museum exhibitions based on the integration of 3D models of artifacts accompanied by multimedia and metadata information. The main purpose of the system is to offer an entertaining, informative and enjoyable experience to virtual museum visitors. In [7] authors propose a complete environment that enables easy and low-cost authoring of virtual museum representations as well as navigation, based on a game engine. Their aim is to enable museum curators to design and set up the museum's virtual world by adding visual and auditory content as well as metadata relating to the museum's items, with as little effort and technical knowledge as possible.

In [8] an interactive guide system for kids in museums is presented. The system uses a sensing board which can rapidly recognize types and locations of multiple objects, and creates an immersive environment by giving users visual and auditory feedback to their manipulations on the board. The purpose of the system is to attract users' interests in a real exhibition, by allowing them to interact with the corresponding virtual exhibition on the board, and providing them with relevant information.

Lately, Google has launched the Google Art Project[5] which is an online compilation of high-resolution images of artworks from galleries worldwide, as well as a virtual tour of the galleries in which they are housed. The project includes works in the Tate Gallery, London, the Metropolitan Museum of Art, New York City and the Uffizi, Florence. Seventeen galleries and museums were included in the launch of the project. The $1,061$ high-resolution images (by 486 different artists) are shown in 385 virtual gallery rooms, with $6,000$ Street View-style panoramas.

Recently, there has been rising research interest on the presentation of personalized museum-related content to users of various backgrounds in the context of virtual museums [7] [9]. In [7] authors propose a method for providing personalized views to online museum visitors in the context of virtual theme-related tours. The proposed visualization technique is based on agent technology and graph theory and allows some freedom to users who interact with the system in order to make decisions on what to see next. In [9] emphasis is put on the provision of personalized museum tours to both online (e.g. infokiosk) and on-site (PDA) visitors. This work,

[2]Euromuse.net: http://www.euromuse.net/

[3]DigiCULT: http://www.digicult.info/pages/index.php

[4]NEOTHEMI: http://www.neothemi.net

[5]Google Art Project: http://www.googleartproject.com/

which was conducted as part of the CHIP[6] (Cultural Heritage Information Presentation) project, allows users to: browse online collections, plan a personalized museum tour based on their interests and be recommended with artifacts of their interest.

Research has shown that virtual museum visitors: (i) are particularly interested in visual content (images), (ii) want to be able to find connections and differentiations between items, and (iii) need to follow their own path while browsing the museum's exhibitions [10]. Moreover, the opinion and interests of museums' visitors should be exploited in today's virtual (as well as potentially 'real') museum content presentation. Different users have different needs, so museum content presentation should be adjusted in order to best suit them. Therefore, we propose a tailored user monitoring system whose logic can be seen as a pattern for building related components in virtual museums in general.

III. Virtual Wing Architecture

In this section we describe the architecture of the Virtual Wing. Figure 1 provides a quick review of this system's architecture by subdividing it in subsystems. The following analysis is going to be based on this division. It should be noted that the Virtual Wing was purely based on the development of dynamic web pages using only PHP and Javascript scripts which retrieve content from a MySQL database.

- **User Settings:** The 'Select Language' view allows users to choose between the available languages (currently Greek, English and French). This functionality can be easily extended with more languages. On the other hand, the view 'Select Audience' has three different types of audiences, namely: visitors, children and experts. Depending on the selected audience type, the content and the aesthetics presented in the following screens are adjusted to meet the demands of each user's category. Finally, if there is no information registered for the selected audience type, the system presents the content that refers to the general audience type (i.e. visitors).
- **Room Selection:** Users can select a virtual room in which they want to navigate to. In that screen all the available rooms of the virtual museum are presented. From this state users have the ability to transfer to a new page that shows the plan of the room with the enclosed showcases.
- **Plan of Room:** That screen presents the plan of the room that was previously selected by the user. The plan of the room covers the center of the screen and shows the positions of the showcases that are placed in the actual room. By creating a panoramic view of a room we manage to present a complete representation of the respective actual museum's room. Below the presented plan of the room, there is a number of filters, such as: Material, Class, Era, Site, and Rating. Users can select between these filters so as to highlight the showcases that respond to their needs. Finally, there is a 'Reset' button that allows users to return to the previous state so as to make a different filtering of the available showcases.
- **Showcase Navigation:** When users are on the screen which presents the plan of the room, they can click on a specific showcase. Then, a popup menu appears ('Preview Showcase') enabling users to have a quick review of the presented showcase. This popup contains some basic information and a representative picture of the showcase so that users can decide whether they want to view more detailed information about it as well as browse the items it contains ('Go to Showcase').
- **Showcase:** This view describes a specific showcase. Users can see a representative image of the showcase and read a related textual description. On the left side of the screen there is a number of multimedia which enable the user to learn more about the showcase in a more exciting way. This set of multimedia consists of images, audio and videos. On the right side of the screen there is a scrolling list that contains the items of a specified showcase. When users click on the preview of a given item, a new page appears, providing more detailed information about the item ('Item').
- **Item:** This screen contains an extended description of a specific item and it has almost the same layout as the 'Showcase' screen. In this screen there are two new options (compared to the previous one) for the user: 'Rate Item' and 'Comment on Item'. Users can express their level of likeness by assigning a grade (1 to 5) or by making comments (more than one times). Users' comments will be visible to the other visitors after being approved by the museum administrators. Also, in this screen there is one more button, that leads to the 'Excavation Site' screen (see next paragraph). Finally, on the right side of the screen there is a menu with information relevant to the specific item (length, width, height, diameter, girth, class, material, era, and excavation site).
- **Excavation Site:** This part of the system contains information about the excavation site where the respective item was found. The view of this page is similar to the 'Showcase' screen, except the fact that there is no any information on the right side of the screen.
- **Standard Options:** It is a standard panel of the virtual museum that exists in all screens except the first one. It contains the following buttons: Go Back, Go to the Start, User Manual, End of the tour.

IV. Group-based logic

Time and time again experience has taught that systems that treat the majority of their users as one group would have various problems at satisfying their preferences as well as their interests. Each person has a unique personality and therefore items or information that might interest one may have significantly less value to another. Therefore, a good practice is to divide the system's users into groups and provide each user with information and items that interested his peers. The 'Virtual Wing' chose to make use of this idea by separating

[6]CHIP: http://www.chip-project.org/

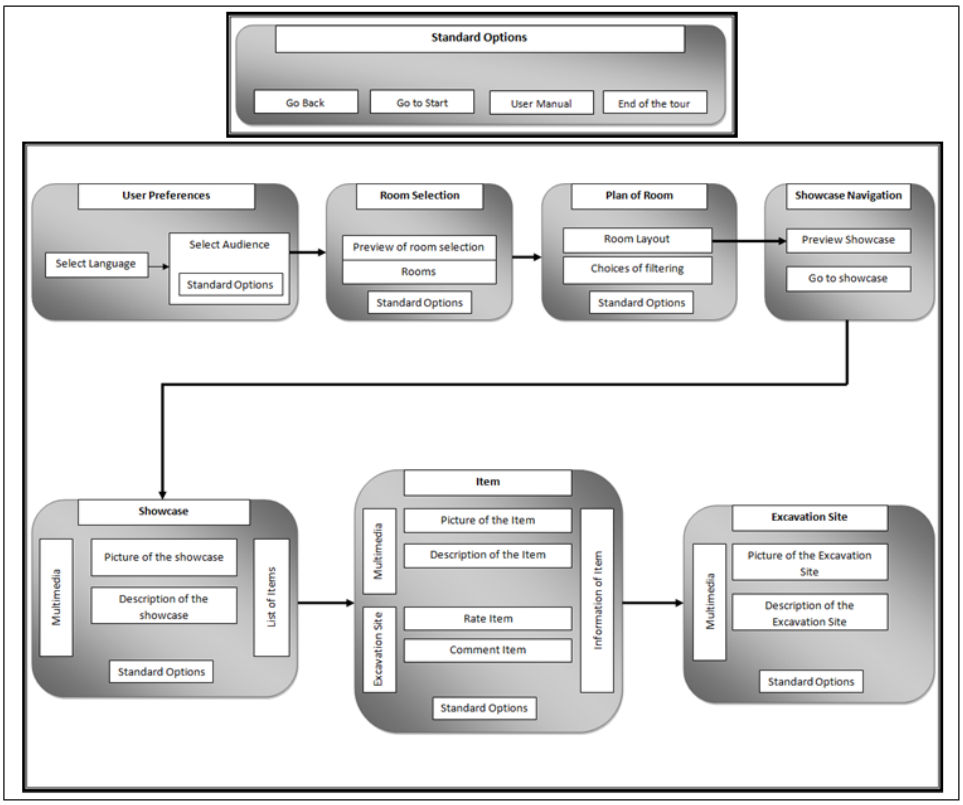

Fig. 1. Virtual Wing Architecture

its users into groups. Since there is no information about the people making use of the system initially, a grouping based on implicitly collected data of one's preferences is not possible. Thus, the next best alternative was to split our users based on age and knowledge background, ending up in three distinct groups: children, visitors and experts.

Visitor's grouping has been used in the past to serve the needs of museums. In a previous work [16], visitors would be divided into two categories, frequent and infrequent. This was done in order to provide the former with more material about the exhibits as well as more time, while avoiding to overwhelm the latter with information they did not want. This grouping was intended purely on maximizing the reward/effort ratio of the museum, with reward being the satisfaction of the museum's visitors. In another work [17], groups were recognized and created based on the individuals' age or interest in art. This was done to compare the accuracy of recommendations made to each group of users.

In the related works it was proven that grouping users would indeed facilitate people into finding their interests when they themselves would not know about them yet. Although grouping was not adopted by the museums that participated in the research, the results pointed out the importance of dividing users into groups. Nonetheless, there was no grouping based on the combined characteristics of age and expertise; a gap that Virtual Wing comes to fill in.

A. *Children Category*

It is common knowledge that museums are visited by a wide range of individuals of diverse culture and age. However, a child is most probable to visit a museum than an adult, since many schools often organize tours in order for the students to learn more information about history. Students often consider such excursions to be uninteresting and thus simply go quickly through the museum's exhibits. This is due to the fact that most museums adopt a strict and austere appearance inside the museum and in the multimedia provided during the tour. However, museums that have adopted a more child-friendly character with decoration and multimedia received much higher ratings from children. Therefore, the existence of the distinctive group 'children' aims at providing a more child-friendly interface and multimedia content, raising the satisfaction levels of children and making them more interested in the tour and the exhibits provided. As a result, children learn from a child-friendly tour in contrast to a non-child-friendly one, which they prefer to finish as quickly as possible.

B. *Visitors Category*

Visitors are also a very distinct category from the rest. Usually, regardless whether they are tourists or indigenous, they do not have an in depth knowledge of the exhibits and/or history of the eras to which the exhibits belong. Therefore, general information on the various eras of the country as well as the most important heirlooms and sites are usually the most

popular subjects sought by this particular category.

C. Experts Category

Scientists of the field are expected to have a much deeper understanding of the country's culture and historical eras. Therefore, visitors that belong to this distinct category are rarely interested in general information and are mostly interested in exhibits and information of a more specific nature. Therefore, a person belonging to this category will not be presented with general information, but rather with exhibits that are quiet rare, excavation sites, or exhibits that where recently discovered, in the most popular section.

Figures 2 and 3 depict the differences in content presentation and aesthetics when the same item is shown to a child and an expert. As it is clearly depicted in the two figures, information is more detailed in case of experts (e.g. related bibliographic references are included) while the exhibits are presented in a more focused way since experts have the appropriate background to appreciate more their values. On the author hand, archaeological content provided to children is adjusted to their knowledge and comprehension capabilities. Moreover, children's display is characterized by more vivid colors and larger size fonts that make the overall presentation more interesting and comprehensive.

V. User monitoring

Although there are some static features provided to each group of users, some elements, such as the most popular content for each group, are dynamically adjusted to the users' preferences. To this end, the activity of each group of users is monitored in four separate ways during their navigation to the museum, providing the system with enough data to adjust the presentation to each group of users, as well as providing the museum with statistical data to further expand and improve its services. These four mechanisms are namely: questionnaires, ratings, page-hits and comments.

A. Questionnaires

This form of explicit information gathering has been deployed on numerous occasions to measure the users' satisfaction level, as well as provide the museum managers with feedback to further improve the quality of services. Therefore, the Virtual Wing, at the end of each navigation session, urges users to provide feedback which is taken into consideration for changes and statistics about the respective group they belong in. This way, the opinions of one group doesn't affect those of the others and improvement is more targeted, comparing to how it would have been in a more unified context.

B. Ratings

A scaled rating system of 1-5 is in place in the Virtual Wing which provides the system with the necessary feedback be it positive or not about the exhibits of the museum (see Figure 4).

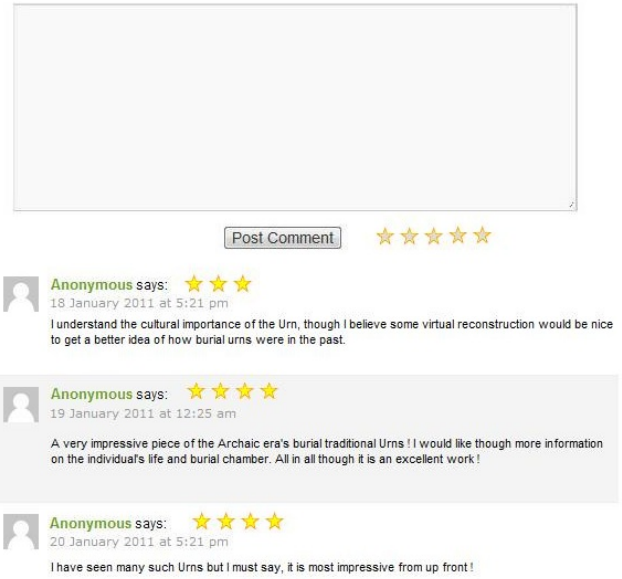

Fig. 4. User Feedback screen

C. Comments

Users are also given the capability of leaving comments on each of the items. Comments are an indication of an item drawing the attention of an individual and therefore it is a crucial part at creating the most popular list of items (see Figure 4).

D. Page Hits

Page hits is the system's implicit way of collecting data from a user's experience in the museum. Each user is represented by a sequence of nodes (pages) he/she has visited. This sequence is used either to add page hits to a specific set of items visited during the user's navigation, or together with the rest of the collections of nodes to search for popular paths in the system's graph.

As it was previously described, ratings, comments and page hits are used to calculate the most popular content for each users' group. In order to create the list of items for each group of users, the feedback data is divided into three subgroups consisting of the feedback given by each group. Then, 20% of the available data is kept from each kind of feedback with priority given to the date it was provided. At this point, we have the most recent 20% of all comments, ratings, and page hits, regardless of the objects to which they may belong. Then we apply the following formula:

$$PS_i = (RA_i - RA) \times a + (\frac{PH_i}{PH} - \frac{PH}{n \times PH}) \times b + (\frac{C_i}{C} - \frac{C}{n \times C}) \times c$$

where PS_i is the popularity score of i-th item, RA is the average rating of all items, RA_i is the average rating of the i-th item, PH is the number of page hits of all the items while PH_i is the number of page hits of the i-th item, C

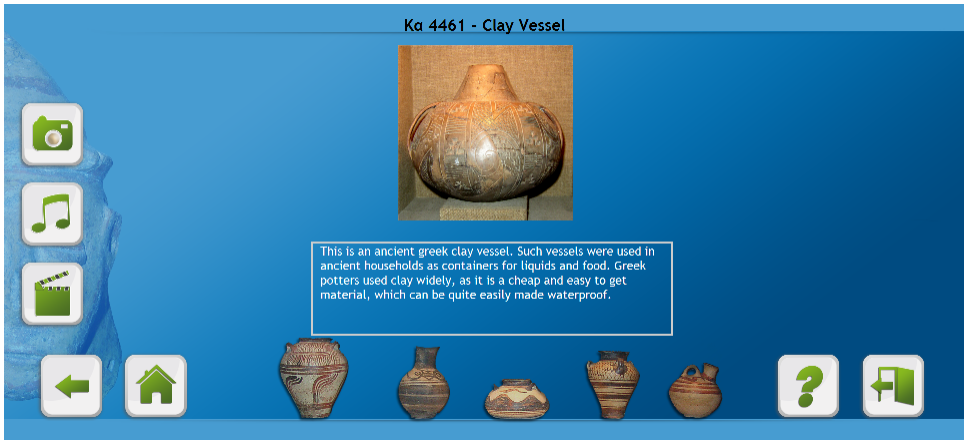

Fig. 2. A clay vessel artifact presented to a child

Fig. 3. A clay vessel artifact presented to an archaeologist

is the overall number of comments, C_i is the number of comments on the i-th item and, finally, n is the total number of items. Also, a, b and c are the relative weights we assign respectively to ratings, page hits and comments. The above constants comply by the following formula:

$$a + b + c = 1, c > a > b$$

We give greater weight to comments and then ratings since experience has shown that users tend to rate more frequently than comment since it requires significantly less time and effort. Therefore, commenting is considered evidence of stronger interest than rating.

The above formula assigns a score to each item, based on how many comments and page hits it has received, as well as its overall rating. The formula was created taking into consideration all three types of feedback in order to avoid cold-start problems and grey sheep phenomena, which are encountered when a new item is added, as well as avoid overfitting of the group's model. The former is achieved mainly by the fact that we use 20% of the latest data and not the entire population, allowing new exhibits that only recently caught the attention of the visitors to be included in the list. On top of that, an initial build of momentum is more easily achieved due to the inclusion of page hits as an interest indicator. It is commonly known that a user may view many items but will not rate or comment in most cases. Additionally, all measurements have been normalized to further avoid the problem of overfitting and instead of using all of the data, only the latest 20% according to the submission date are used. This method enables us to effectively detect trends and rising interest from a particular group for certain items.

VI. User monitoring exploitation

Both the group-based logic of operations as well as the monitoring of the users' activities in the system can be used in a number of ways to improve users' experience in the

museum. Two ideas are presented below. The first one is used to further improve the virtual tour provided to visitors, while the second is used to improve the museum administrators' job of collecting data from visitors.

A. Group Routes Gallery

In the Virtual Wing, each item can be represented by a node in a graph. The total number of items is represented by the graph of our system, effectively containing all the content available to the virtual museum's visitors. Each time a user visits an item, the system creates a new record in a dedicated database containing: his id, the respective user's group's id, the visited item's id, as well as a date-time object representing the time of visit. The overall behavior of the user can therefore be represented by a set of nodes and arches that connect the visited nodes.

For each group of users then an arch colored edition of the system's graph is created. Each arch may have a variety of colors with each color being represented by a user's id that has hopped from one node to the next. When all the colors of the users are inserted into the group-specific editions of the system's graph, a number of paths are extracted from each graph containing the arches which include 'closely related' (in terms of color) arches and their respective adjacent nodes. The score of color relation is calculated using the entropy between the colors of an arch with source node A and destination node B with all the arches adjacent to nodes A and B. If the entropy is below a threshold set by the administrators of the system, then the respective connected nodes are considered part of a popular path frequently visited by the group's users. Each path is expanded until no more nodes can be added. If more than one immediately connected nodes has arches whose color relation score surpass the threshold set, then a number of clones of the path are created with each path containing one of the arches and nodes. Finally, when all paths are created, they are stored in the database for each of the groups. With this method, when users enter a node which is part of at least one of the paths, they are recommended with all the popular paths/tours that contain this node.

B. Automated Comments Classifier

At the current version of the Virtual Wing, all comments left by users in the virtual museum's guestbook and items' views are used as an indicator of their interest, as well as a variable for the most-popular function. Nonetheless, no sentiment polarity is considered, unless comments are combined by rates. A distinction between positive and negative comments could go a long way improving the most-popular algorithm's accuracy, as well as providing the system administrators with more structured feedback instead of the unstructured natural language feedback that comments belong to. Of course, a sentiment polarity could be defined for each comment through manual annotation, but this procedure requires a significant amount of time and effort and is additionally subject to the administrator's subjective nature and current state.

To this end, an automatic way of classifying comments could be sentiment analysis, also known as opinion mining [18]. Using the available mechanisms, comments could be easily classified into positive or negative with a degree to each polarity. Although the field has many problems in terms of training and accuracy, in this particular application neither of them is an issue. Comments that are followed by rates and are already available to the system can be used as training data for the sentiment classifier. This way, the issue of training the adopted model is resolved due to the nature of the application, which allows rating and commenting at the same time. Accuracy is normally an issue when many objective facts are given since sentiments rely on subjective statements. This is particularly evident in forums or blogs, where many posts are short-sentenced and have almost no clear subjective nature, since they are devoid of adjectives or adverbs. Once again though, comments on items usually have many subjective statements since they rely on personal experience. Therefore, due to the ease of integration and use in the particular application, along with the obvious advantages, we are examining sentiment analysis techniques that can classify comments into categories of sentiment polarities. This approach could significantly assist the museum's administrators as it would provide them with additional structured data either for use in statistics or improvement of recommendations.

VII. Conclusions

A user-aware virtual museum which has been developed for the Archaeological Museum of Volos is proposed in this paper. In contrary to existed related systems, we offer an active role to our users which are not just content 'consumers' but they also contribute to the system by providing valuable feedback. Users can show their preferences on the exhibits by rates, express their viewpoints by posting comments on them, and provide their general opinions about the system itself through questionnaires. The analysis of all this provided information may lead to useful outcomes for museum administrators in terms of content popularity and the system's services. Therefore, we believe that with the proposed system, virtual museums can take one step ahead in the ultimate objective of providing better user experience.

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