UAIS (2002) 1: 163–176 / Digital Object Identifier (DOI) 10.1007/s102090100016

Long papers

Design and evaluation of an adaptive virtual guide for Web applications

Luisa Marucci*, **Fabio Paternò**

CNUCE-C.N.R. Via V. Alfieri 1, 56010 Ghezzano, Pisa, Italy

Published online: 29 January 2002 –

Abstract. Most applications accessible through the Web suffer from a noticeable lack of support for adapting to the different information needs that different users may have regarding a certain topic. However, completely automatic adaptive support can still be confusing for users who may not understand the reasons for the dynamic change in the behaviour of an application. In this paper, we present a possible solution to provide adaptive support that does not disorient the user. The solution integrates a virtual January 18, assistant that is able to provide adaptive support in an adaptable application. We discuss an example of the application of this approach involving the support of Web visits to virtual museums. We then present the results of an empirical usability test of such an application.

Keywords: Adaptive user interfaces – Virtual guides – Web interactive agents

1 Introduction

The advent of the World Wide Web has introduced a new and powerful communication tool that allows people to easily access information related to any type of event, activity or interest. However, it was soon recognised that different people can be interested in receiving different information concerning the same topic, because they have different goals and different background knowledge. This raised the issue of furnishing different information with different presentation and interaction styles at the user interface level, and stimulated interest in user interfaces that are able to adapt to external factors (i.e. the user, the tasks to be supported, the available devices and the context of use).

Adaptation has been used in a number of application areas, including learning systems, online help systems, multimedia information retrieval systems and personalised views. Adaptation is traditionally classified [4, 18] into adaptivity, which characterises applications that are able to automatically modify their behaviour depending on the user interactions, and adaptability, which characterises applications that change their behaviour according to a small set of predefined options. Adaptable interfaces are easier to implement for developers and to understand for end users, whereas adaptive interfaces are more flexible, because they can react in a wider set of modalities depending on the user's interactions. This gives adaptive interfaces the possibility of supporting the needs of users in a more tailored way [1]. However, there are two main risks: (i) the tailored reaction may not match the user's interest, due to wrong deductions, or (ii) the user may not understand the reasons of the change of system behaviour and experience a sense of disorientation and frustration. Thus, a strong research interest has recently arisen in how to provide adaptive support that is under full user control.

An application area in which adaptive techniques can be particularly suitable is museums. Most museums have web sites that provide only some basic information without taking into account the different categories of users accessing them, and their possibly different interests. These web sites can benefit from the introduction of adaptivity because they address a wide range of user categories. One of their goals is to improve learning of interrelated concepts, and they usually contain a large amount of information with the consequent risk of disorientation for end users. However, most current user interfaces of museum applications are not adaptive at all, and provide

* *Correspondence to:* L. Marucci
(E-mail: luisa.marucci@guest.cnuce.cnr.it)

the same support for every user category and every type of user interaction.

A few research prototypes have been developed to use adaptive support in museum applications. One of the first proposals was AlFresco [19], an interactive system to access images and information regarding fourteenth century frescoes. The work focuses on issues related to how users can interact through the combined use of natural language and touch screens. Another example addresses the problem of how to find information that is interesting to the user [6]. This system allows users to express interest in a set of topics. Then, using a predefined network that correlates topics according to their semantic closeness, a mediating agent identifies further information that can be of interest to users, although they may not be explicitly aware of it at the beginning. Hyperaudio [16] provides audio comments on a palmtop computer. It takes into account the physical location of the user and the time the user spends at a location as a measure of interest in the pieces of work that are close to such a location. Guides [12] demonstrate the use of a narrative metaphor and of anthropomorphic agents to support browsing of a multimedia database on early American history through video storytelling. Hippie [11] is a prototype that aims to implement adaptive support for nomadic applications, where users can access both personal and public information from many locations and through various devices. GUIDE [2] is another tool with similar goals; more precisely, it is an adaptive hypermedia application supporting a physical visit to the Lancaster historical centre, implemented on a portable device that can exchange information with some servers through wireless local area networks. ILEX [3] is a system that dynamically generates text labels for exhibits in a museum jewellery gallery. In contrast to the approach presented in this paper, ILEX generates adaptive information by concatenating static and dynamic text in the same part of the user interface that contains the static information associated with an element of interest.

An interesting proposal for a pedagogical agent to support Web-based educational simulations is Adele [17]. Its purpose is to support student learning in the context of interactive learning environments. This is obtained through a task planner where all procedural tasks are represented using a standard hierarchical plan. This approach is particularly suitable in goal-oriented applications such as diagnosis exercises for medical students, whereas the present study addresses application domains where user goals are less structured, and the purpose is to dynamically provide additional information in order to enrich a virtual visit and help the user to better understand relationships among works of art.

This paper proposes an original solution based on the integration of both adaptable and adaptive support [15]. Adaptive support is provided by a virtual guide whose purpose is to enrich the visit by offering additional information on the works of art.

The paper introduces the logical dimensions that have been identified for the information provided by the virtual guide. It then discusses how to activate the virtual guide, and describes its underlying architecture and how such dimensions are applied to the case study under consideration. Finally, the paper discusses an evaluation of the system that was performed with 40 users, and provides some concluding remarks and directions for future work.

2 Design criteria

Adaptive techniques are flexible and are able to overcome some limitations of previous approaches, especially when they are supported by agents oriented to provide interactive support. However, completely automatic adaptive support can be rather confusing for end users, who may not understand the reasons for the dynamic changes occurring in the system's behaviour. Thus, when designing adaptive support, it is important to allow users to clearly understand several aspects of the system's operation:

- When the adaptive support can be activated.
- How the adaptive support provides information.
- Which criteria determine the generation of information provided by the adaptive support.

The work reported in this paper concerns the design of a virtual assistant in the application domain of museum systems. The main goal is to make the adaptive behaviour of the resulting environment easily understandable by users, as well as to enrich and facilitate navigation within the available information. To this end, users must have full control on the activation of adaptive navigation. Furthermore, users should be supported during their visit by a virtual guide using a number of techniques. More precisely, it should be possible to adapt the information to be delivered according to several logical dimensions [8], thus obtaining a behaviour similar to that of a real guide:

- *Introductory information.* This type of information is provided by the agent whenever a new topic or aspect of interest (e.g. a new artist or a new section) is accessed by the user.
- *Summary information.* This provides an overall perspective of the items that have been accessed in the current session. For example, if the user visits several works belonging to the same historical period, this can be interpreted as a strong interest in works belonging to that period, and, therefore, a summary of the most important aspects of that historical period can be provided.
- *Comparison information.* The purpose of this type of information is to compare the currently accessed topic with others that have been accessed previously, and identify common attributes such as, for example, dimensions and chronology.

- *Difference information.* This serves to bring into focus an aspect of the currently accessed topic that was not present in the previously accessed one; this information is useful for the user to better learn and remember the descriptions of the works of art.
- *Curiosity information.* Additional peculiar information can increase the visitor's involvement, highlighting those features of the work that can raise the user's interest.

The above logical dimensions characterising the information provided by a virtual guide aim to make the user's visit more interesting and pleasant. Previous work in this area has considered rhetorical structures [10], which can provide useful background but which need to be tailored to the specific application under consideration. Other work [9] has focused on an articulated set of comparisons (illustrative, clarificatory and direct). The approach adopted in this paper proposes a type of support similar to that provided by real museum guides, and uses similar techniques to involve visitors and make their visits more interesting. In order to identify the types of information suitable for the virtual guide, the behaviour of real guides in the museum has been observed, and guides have been interviewed in order to capture the communication goals they aim to achieve in their work. This analysis led to the conclusion that the above set of logical dimensions captures most such communication goals.

The described approach has been used in the design of a Web application whose user interface includes two main areas:

- A part of the main window is dedicated to the provision of adaptable information on works of art. At the beginning of an interactive session, the user selects a user profile or specifies a set of preferences. This information is used by the system to select the type of information to be presented and the way it will be accessed.
- The second part of the main window provides adaptive support through a virtual assistant that supplements the information presented with additional information belonging to the categories previously introduced.

This structure helps users in navigating through the information available, because they know that in one

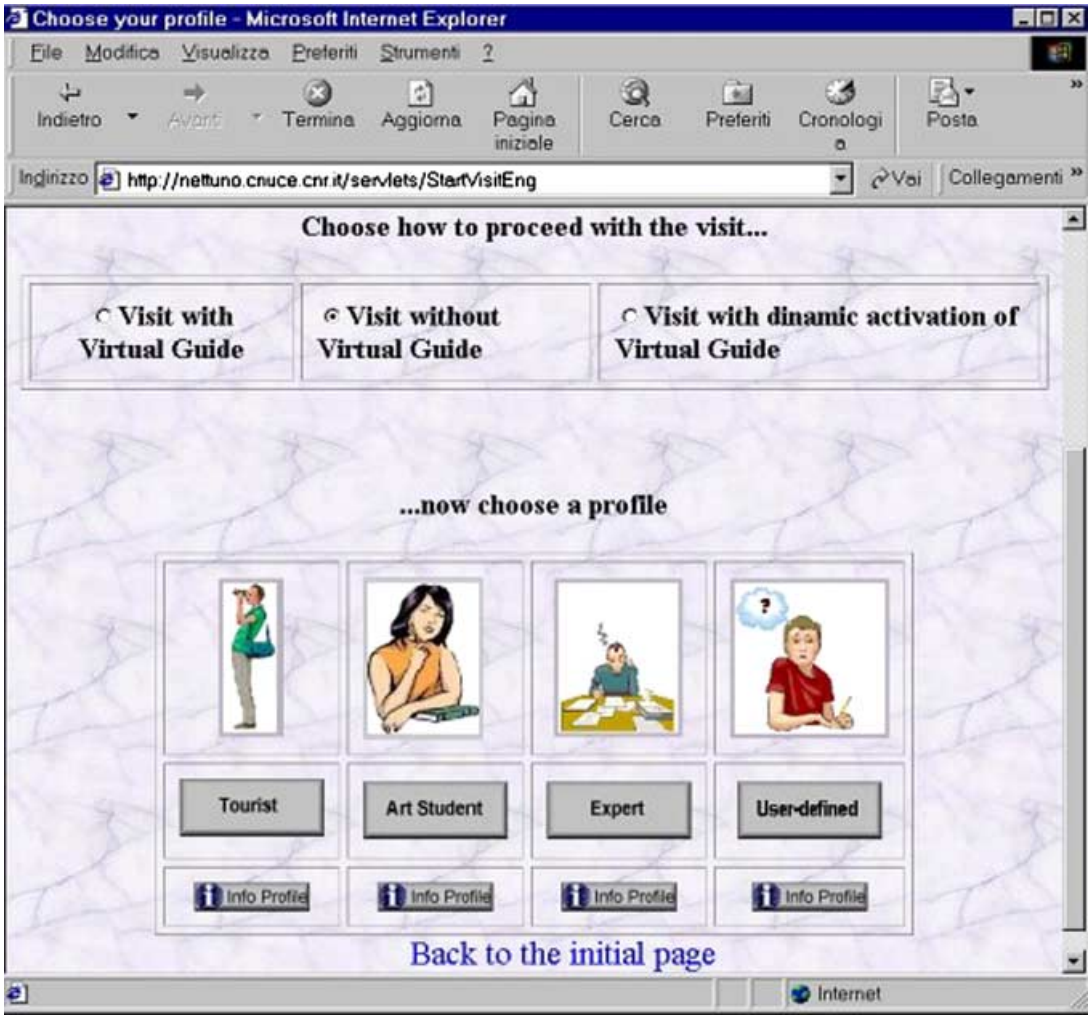

Fig. 1. User choice of possible stereotypes or preferences

part of the interface they will find the basic information, adapted according to the current user's profile, while the other part is dedicated to providing additional adaptive information. Adaptive support takes into account the current user model because different types of users can be interested in different types of additional information and in different ways of grouping information.

3 The virtual guide

Adaptive support was introduced into an already developed application, namely an adaptable virtual museum [14] that had been designed following a model-based approach [13]. It supports access to information related to hundreds of items situated in the Marble Museum of Carrara, Italy, notably sculptures and tools used to quarry marble, in various profiles (tourist, student and expert) or models derived from user preferences. At the beginning of a session, preferences can be explicitly indicated by the user among a set of predefined options that are displayed when the user-defined profile is selected (Fig. 1). These preferences can be updated during a session, taking into account the topics accessed by the user. According to the user model, the application provides different support regarding three main aspects:

- *Access to the available information.* This is supported through interactive maps in the case of tourists, and through lists of available elements in the case of students, while allowing for the possibility of flexible user-defined queries in the case of experts.
- *Presentation of the selected information.* The user profile determines the amount of information detail provided and the amount of visual aids used to highlight important aspects.
- *Modality of navigation.* In the case of the tourist profile, navigation is application-driven and guided, while in the other profiles, the ability to make sequences of unrelated queries allows the user more freedom in navigating through the hypermedia.

In order to give users full control over adaptive support, three activation options for adaptive support are offered by the system, following the initial choice of user profile. Users can choose to immediately activate the virtual guide, or to have it disabled, or to activate it on demand during navigation. In the last option, the user can activate the virtual guide whenever a work of art is presented.

When the agent associated with the virtual guide is activated, beside the presentation of a work of art there is a part of the main window dedicated to the comments of the virtual guide (Fig. 2). The additional information provided through the virtual guide aims to make the user's visit more interesting and pleasant.

Another goal is to provide additional dynamic information that helps users link the standard information associated with each work of art, in a manner similar to that employed by real museum guides when accompanying visitors. Thus, at any time, both standard information associated with the work of art selected and agent-based support are available. The latter provides additional in-

Fig. 2. The space dedicated to adaptive support

formation taking into account the user model and the history of interaction.

4 Application of the logical criteria for adaptive support

This section describes in more detail the information provided by the virtual guide, considering each of the logical dimensions introduced in Sect. 2.

4.1 Introductory information

Introductory information is generated when the user accesses a piece of information that is completely new during the current session. For example, when the user accesses the work of a new artist, the system is able to provide some information on that artist taking into account the current user model and the works previously accessed.

In the case where the user is a tourist, the information generated should also be useful for organising a future real visit. Thus, it should help users to remember the physical location of a new element, so that a mental model indicating where it is possible to find works of a specific artist, material or historical period can be created. Thus, the introduction of a new artist highlights how many works of that artist are contained in the museum and where they are located, specifying whether they are in a single or multiple rooms, and the name of these rooms. Another element considered when the tourist user profile is active, is access to a new museum room. In this case, the system generates an introduction to the main features of the works of art in that room.

When the user is a student, the system generates introductions based on definitions of specific types of art work (e.g. bas-relief, sculpture or plinth), thus helping users to associate work types with their definitions. Whenever a student accesses a new definition, the system provides related general concepts, indicates the materials used to make example works of that type, and the artists that have produced such art works and their historical periods.

In the case of an expert user profile, the introduction of a new artist has to take into account that the user is interested in a detailed search among the information contained in the museum. In this case, the user is assumed to already have a relevant background, so it is preferable to provide additional information (when available) concerning its chronology, artistic contexts, observations, critiques and historical notions.

4.2 Summary information

The purpose of this type of information is to highlight the most important aspects common to the works of art visited. The summary should help further assimilation of notions already presented to the user. Summaries are available after a certain number of accesses to the system, and depend on the current user model. Thus, for a tourist the summary will be related to the museum rooms visited, whereas in the case of expert and student users it will be related to the historical periods considered.

More specifically, in the case of the tourist, the system first checks – for each museum room – which and how many works of arts have been visited (Fig. 3), and in which order. Additional comparison comments and links to the list of works visited can accompany the summary.

Fig. 3. Example of summary information for a tourist user

Fig. 4. Example of comparison information

Thus, the movements in the museum are analysed whilst trying to identify the user's interests. The basic assumption is that tourist users of the virtual museum are interested in gathering information useful for a future visit, and in memorising the locations of rooms and works in the museum. In the case of student or expert users, the aim is to enrich one's personal research, thus the summary – providing information about historical periods – helps them to relate works of arts to the historical period.

Figure 4 shows an example case in which the user has visited five works of art, and the guide provides the summary information. From the analysis of the interaction history, the system identifies which and how many rooms have been visited. From the number of works accessed in each room, the system infers the level of knowledge of the user, and this parameter is used to define the amount of information to be provided in the comment (when more interest is shown, more information is provided by the guide). Since the currently active profile is the tourist's one, the summary is structured in terms of the visited rooms.

4.3 Comparison information

The purpose of the virtual assistant is to stimulate the user to spend more time on the application. This is achieved through presenting information more effectively and thus improving learning. Towards this end, adaptive comments are generated taking into account what the user has already seen and the current user model.

After having introduced a new topic presenting general information, the system links the new work of art with the previously visited ones, taking into account both the user model and the characteristics of the works previously accessed. There are different ways to connect a work of art to those seen previously. Comparison is a good tool for supporting learning, and can be easily memorised by the user. When new works are accessed, additional information is provided allowing users to relate the current work with those already seen. More specifically, aspects concerning the artist, historical period and material used are considered for each user profile.

Before comparing two artists, the system considers the works previously accessed and the current user model, in order to identify the topics that the user is familiar with. Based on this analysis, the system decides whether to apply the comparison, which aspects to consider in comparing the two artists and which parameters to use for the comparison. If the comparison between the two artists has already occurred in the current session, then it is not repeated. Regarding the aspects to consider in the comparison, the system has to identify the main features of the artist (e.g. techniques used and preferred material) by analysing the information contained in the application. Access to a new artist can occur along with access to a new, historical period, definition or other material. Thus, the additional comments have to consider all the aspects that hold in the specific situation.

When comparing works of art, the system is also able to discuss aspects that have associated quantitative information (e.g. relative sizes and chronology). Thus, these techniques generate comments such as "these two works have been made with the same material but in rather different historical periods".

All information concerning the introduction of a new subject or the comparisons between items is presented in the space reserved for the virtual assistant. Summary in-

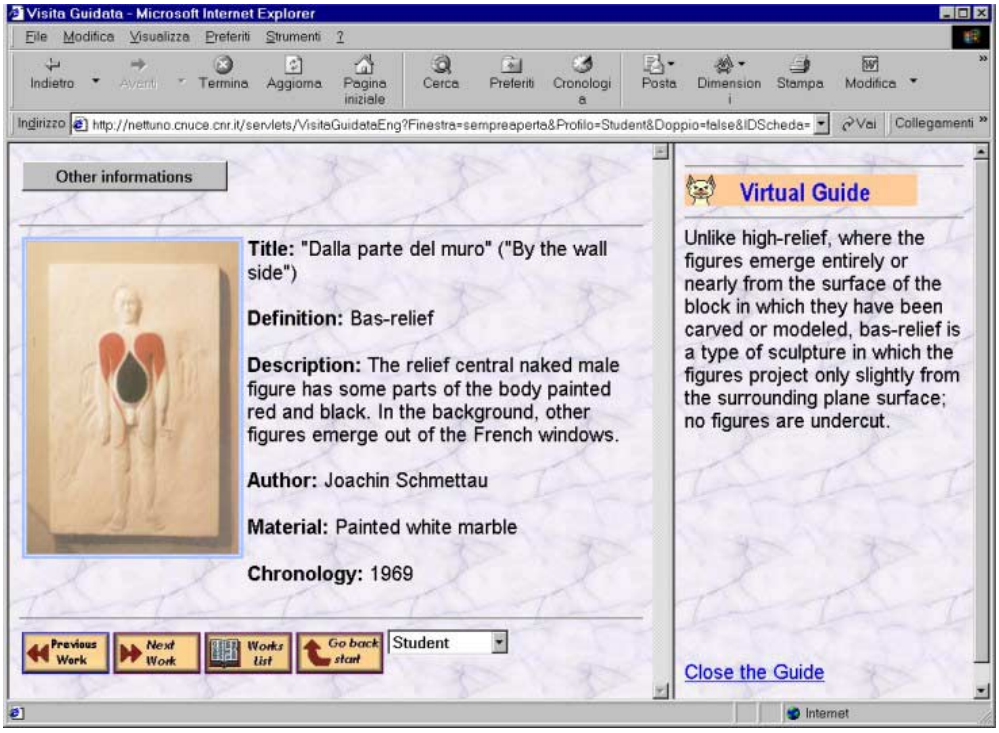

Fig. 5. Example of difference information

formation can also include comparison information. Figure 4 shows an example of comparison information. The current active profile is the tourist's one, and the user has moved from one section of the museum to another. Thus, the system provides some comparison information between the previous and the new section.

4.4 Difference information

Another type of information that can be furnished is difference information. It can be triggered for two types of reasons. After the user has already accessed some works of art, and is visiting a work that completely differs in some aspect from all those previously visited, this is reported by the virtual assistant. For example, this takes place if after a number of accesses the user requests information about a work of art made with a material that was not used for all the previously visited works. Otherwise, when there are works of art that differ in some aspects that some virtual visitors may not notice, then the difference is highlighted. For example, if after having accessed a high-relief, the user selects a bas-relief during the same session, the virtual guide highlights the difference between these two techniques in order to avoid misunderstandings that can result since the representations of the two are visually similar (Fig. 5).

4.5 Curiosity information

The purpose of curiosity information is to stimulate users' interest and attention. This type of information is generated whenever the work accessed exhibits some unique or peculiar aspect (Fig. 6). For example, if the current work of art was made with a material that has not been used for any other work included in the application, then the system highlights this feature. Uniqueness may concern the material, the artist (a unique work done by a certain artist) or the historical period, and relevant information is provided in all the user models. When available, anecdotal information is displayed.

5 The architecture of the system

The purpose of this section is to provide technical details on the architecture of the system, and on how the guide's comments are generated.

5.1 The components of the system

The architecture of the system is Web based. It is a client–server architecture that supports access by multiple users from different locations. The system is also able to store individual user access data across multiple sessions, so that the comments provided in a session also take into account the user's behaviour in previous sessions.

In Fig. 7 the basic architecture of our system is represented. Users interact with the Web interface. Their requests are sent to the database, stored in the interaction history and analysed by the agent. This agent has a set of rules that analyse the current request, the history of accesses and the current user model and, depending on this information, decides what information to generate in

Fig. 6. Example of curiosity information

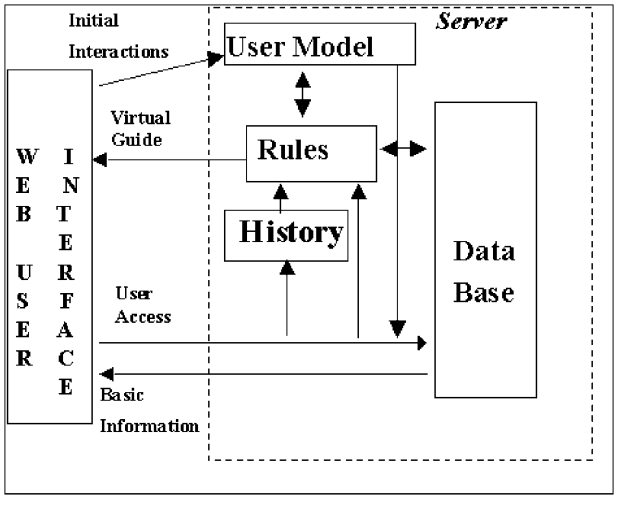

Fig. 7. The architecture of the system

addition to the basic information provided. Such information is generated using several techniques and it mainly consists of textual descriptions in natural language. In some cases there is information associated with a specific transition in the navigation (for example, moving from one room to another). In other cases, the comments are obtained by composing templates, that is, predefined structures that are filled with dynamic information depending on the user access history and the current user model.

5.2 How the text of the virtual guide is generated

In brief, the overall function of generating the virtual guide comments depends on four elements: (i) the current user profile (tourist, student, expert or user-defined); (ii) the user's preferences; (iii) the user's knowledge level; and (iv) the user's recent access history. The first three of these four elements define the user model. For each of the three profiles, the system considers distinct aspects regarding preferences, knowledge level and changes in the information access, as illustrated in Table 1 where more details are provided on each of these aspects.

For each type of information provided by the guide, it is important to clearly identify when its availability is triggered, how to retrieve the necessary information and how such information should be presented. In addition, the actual information provided also depends on the current user model. In order to avoid boring the user, replications of comments are avoided (e.g. within a session a certain comparison or curiosity is presented only once).

Table 2 summarises the basic events that are considered when triggering the adaptive display of information for the different user profiles. Introductory information is triggered when new aspects are considered. In the case of summary information, the basic assumption is that, depending on the level of knowledge, users need some summary. This may be less frequent with experts and more frequent with tourists. Likewise, the level of detail in the comparison depends on the user profile.

Difference information is triggered either when new information has been found during the visit or when specific changes occur in the sequence followed by the user, and clarifications are required. Finally, curiosity information is given to highlight the uniqueness of some work of art or to report observations made by other experts.

Table 1. Aspects considered relevant for the adaptive support of each user profile

	Tourist	Student	Expert
$f(preferences)$	Spatial path followed Visited rooms Accessed works per room Accessed artists Accessed materials Historical periods	Search performed Historical periods Accessed artists Accessed materials Accessed definitions	Keywords used Historical periods Accessed artists Accessed materials Work of art dimensions
$f(knowledge\ level)$	Generic historical period Work description Work material Authors	Specific historical period Work description Work material Authors Work definitions	Specific historical period Work description Work material Authors Work dimensions
$f(access_{k-1}, access_k)$	New room New artist New material New historical period	New definition New artist New material New historical period	New dimensions New artist New material New historical period

Table 2. Basic triggering events and aspects considered for the various types of information

	Tourist	Student	Expert
Introductory information	New room	New definition	New material
Summary information	Activated every five accesses (grouped by room)	Activated every ten accesses (grouped by definition)	Activated every 15 accesses (grouped by historical period)
Comparison information	Attributes considered: • Artist • Material • General chronology	Attributes considered: • Definition • Artist • Precise chronology	Attributes considered: • Dimensions • Artist • Precise chronology
Difference information	New material	New definition	Associated with specific transitions
Curiosity information	Unique artist	Unique definition	Specific observations made by other experts

5.3 Composition of comments in the virtual guide

Priorities among information types are managed by taking into account the user profile and the changes that have occurred during the most recent access. In particular, each user profile is associated with some type of information that is considered interesting for the corresponding users (for example, in the tourist profile more attention is paid to introductory information on the artist). In addition, there are rules whose purpose is to avoid redundancy. Most types of information are generated only if they have not been previously provided during a session. For example, introductory information on a certain topic is generated only if it has not already been provided, and a comparison between two works of art is generated only once. Once the text has been checked for redundancy, the system determines the sentences that should be concatenated in order to obtain a complete comment that is grammatically and logically correct.

Various methods can be followed to concatenate text in order to avoid repetitions. If the system has to generate the same types of information in different cases, but referred to different values, the resulting comment will have a structure (i.e. information order and words used) that is different from the previous one in order to avoid repetition.

To summarise, the main steps of the generation algorithm are:

- Analysis of user model to understand what types of information to generate.
- Removal of redundant information.
- Generating the types of information selected.
- Concatenation of information whilst avoiding redundancy.

The analysis of the user model first identifies the changes that have occurred during the most recent access, while taking into account the current user profile (following the scheme in Table 1). Thus, in the case of a tourist user, for example, the system analyses the changes related to the room, the artist, the material and the general chronology, as represented in Fig. 8.

Once the changes have been identified, the system determines what types of information to generate. In the ex-

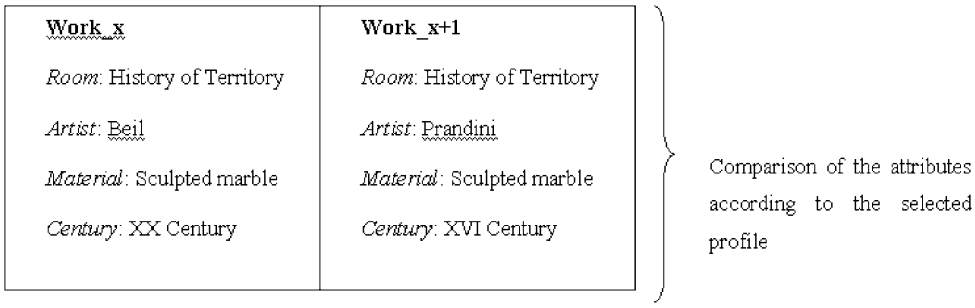

Fig. 8. An example of an access sequence

ample in Fig. 8, the artist and century have changed, but the material is the same. Thus the system can generate *introductory information* on the new artist, *comparison information* with the previous artist, *difference information* on the century and *curiosity information*.

At this point the system, taking into account the user model, can remove some types of information from those listed above, for example if no specific curiosity is available or if introductory information on the artist or difference information on the century has already been provided. After this step, the list of types of information that can be provided is ready. Supposing that such a list includes *introductory information* on the new artist, *comparison information* with the previous artist and *difference information* on the century, the system now has to concatenate the three types of information in order to obtain a complete comment. Different concatenation techniques are available. For example, with regard to the order of presentation, it is possible to mention the introductory information first, the comparison next, and the differences regarding the century last. Another solution is to first underline the differences concerning the historical period, and then to provide information regarding the artist. To avoid having comments that always follow the same structure, a concatenation function has been defined that takes into account the number of user accesses, in order to avoid providing the same comment structure in consecutive accesses. Likewise, different synonymous terms can be used in alternation to provide some variability in the language used.

5.4 An example interaction with the virtual guide

The previous section has shown how, during each user access to a work of art in the virtual museum, the electronic guide analyses the changes with respect to the previous work and the user model, and decides what types of information (among the five predefined ones) to generate and how to concatenate them. In particular, for each type of information, the related text is obtained by concatenating templates filled with information taken from the database. Finally, the concatenation of the various parts of text obtained in this manner provides the complete guide comment.

An example can help to clarify the process. Supposing that the user has selected the tourist profile and has accessed a new work of art, the guide first analyses which attributes have changed their values with respect the previously accessed work and which have remained the same. Since the current profile is that of a tourist, the following attributes are considered: artist, material and general historical period (see Table 2). Supposing that the material and the historical period are still the same, then only the artist has changed. The system defines the information to provide: if the artist has not been considered in the session (this is obtained through a history analysis), then introductory information for the artist is generated:

> "Aldo Buttini was born in 1898. He started to make sculptures a bit late after the end of the First World war." + "The township hosts" + number_of_artist_works(database analysis) + "works by the artist" + Artist_name + ". Such works are located in" + location(database analysis) "."

In addition, the system knows that the historical period and the material are the same as the previous work, and can therefore generate some comparison comment on such attributes:

> "*Another work made with*" + material(database analysis) + "from the same period of the previous work, the" + artist_century(database analysis) + "."

Finally, if the work is the only one in the museum by that artist, it is possible to add this type of curiosity information:

> "*This is the only work in the museum made by the artist*" + artist_name + " . . . "

The description above makes use of some functions (e.g. number_of_artist_works and location) that require access and analysis of the content of the database. At this point, all the possible types of information have been considered for this specific access, and it is possible to concatenate all of them and obtain the complete comment of the guide, for example:

"*Still another patinated bronze work from the same historical period as the previous one, the twentieth century. The township hosts three works by the artist Aldo Buttini, which are located in the Modern Sculpture room and in the city of Carrara.*"

6 Evaluation

6.1 Evaluation of adaptive systems

Little work has been performed so far into the evaluation of adaptive interfaces. In ILEX [3], an evaluation experiment was performed involving 30 people from Edinburgh University, each of them spending about 45 minutes in browsing the application and 45 minutes in filling in questionnaires. Ten participants used the static version of the system, and 20 used the version with adaptive support.

Even if the results of this experiment showed no particular learning benefits for users, there were some differences in the behaviours of the two groups, in terms of elements visited and pages accessed for each collection item, with about 50% fewer button clicks in the dynamic version.

In GUIDE [2], two evaluation phases were performed: (i) an inspection-based evaluation performed by four experts and (ii) an empirical test with 60 volunteers. The goal of the application was to provide flexible support during a visit (e.g. by enabling predefined itineraries in the application to be followed and free interaction with the map according to specific interests). Thus, in the evaluation, no specific task was assigned, and users were asked to use the application as long as it was found useful and pleasant in supporting the visit. The evaluation provided a number of suggestions for improvements. Most users appreciated the flexibility of the system, but some of them found that they had to make too many selections and choices to find the information of interest.

Another evaluation exercise was performed with PUSH [5], an adaptive hypermedia system used to help users find the most important information in a domain. In this case, the goal was to limit the amount of information provided and support users in finding the most relevant information quickly. Consequently, one of the most important parameters in the evaluation was the time spent in finding information. The time was measured by assigning specific tasks to accomplish, and then comparing the results obtained with and without adaptive support. The adaptive version slightly reduced the time required to accomplish tasks.

6.2 Evaluation of our systems

In the case of the system presented in this paper, the main goals of the evaluation were:

- To understand whether the virtual guide is able to make a visit more pleasant and instructive. To this end, navigation with and without the guide was compared to establish if there were differences in terms of navigation paths or in terms of learning of concepts during navigation.
- To understand if the types of information provided by the guide were considered interesting by the users, and if their presentation was effective or could be improved.

Forty users, aged 20–53 years (16 males and 24 females), took part in the evaluation. Most of them had previous experience in Web navigation, though about half of them had rarely accessed a museum web site before. Figure 9 shows details on the composition of the group of users participating in the evaluation. Users were asked to navigate for at least 30 minutes in the application (half

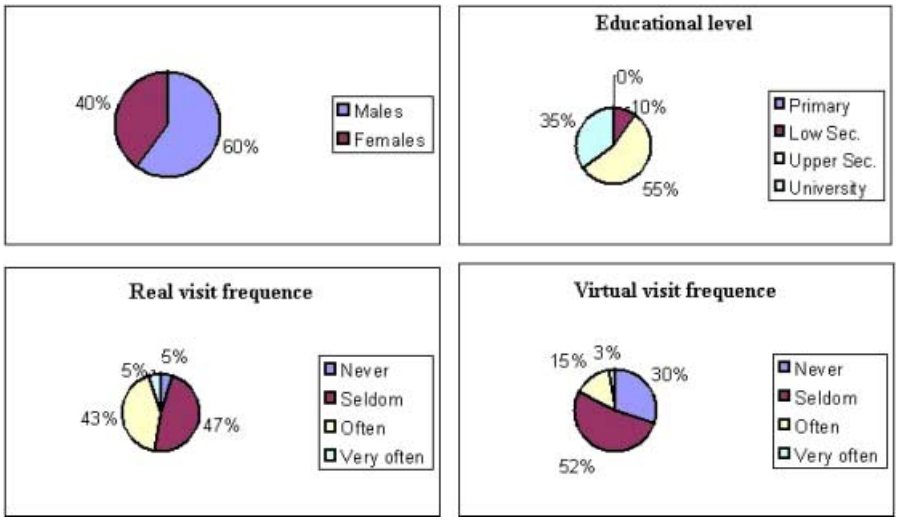

Fig. 9. Statistics on test users

the time with, and half the time without adaptive support, randomly ordered). It was explained to them that it was important for the purposes of the experiment that objective and unbiased comments and suggestions for improvements were provided.

After the session, users had to fill in a questionnaire. The questionnaire was composed of 29 questions, divided into the following three parts:

- Fifteen questions concerning the general usability of the interface, such as navigation and easy of access to the basic information associated with works of art.
- Five questions related to each of the five types of information provided by the virtual guide (each question was subdivided into three related subquestions).
- Nine questions related to the user (basic personal information, knowledge of the museum application domain and computer-related knowledge).

The purpose of the questions concerning the user interface was to identify the problems encountered by the users during navigation and access to information about the works of art. The questions related to the five types of information provided by the virtual guide that were aimed to evaluate the level of interest, usefulness and quality of the presentation. Finally, the questions related to the user were useful for better understanding the type of visitors, their familiarity with museum environments and with software application interfaces, as well as general personal information (e.g. age, gender and education).

During the visit, the users followed the think-aloud technique, allowing the evaluators to easily record particularly negative and positive reactions. During the session, the evaluators took note of the specific path followed by users and were careful not to influence user behaviour by making suggestions. No specific task was given to the user to accomplish.

At the beginning of the visit, the users had to decide which initial user profile to select (either one of the three predefined user profiles, or a user-defined one). Some of them did not clearly understand this option: some inexperienced users selected the expert profile hoping to find more useful information, and some experts chose the tourist profile. This occurred because these users did not check the profile description available, but just selected one of them on intuition. Another element that engendered some problems was the possibility of dynamically changing the profile during a session, because when users went back to the profile's starting point, they found different ways to start a query (e.g. the tourist profile calls for maps, whereas lists are presented to students and experts). The possibility of directly defining a profile was supported through three forms. However, this solution was not found to be particularly efficient by some users.

Figure 10 shows the users' rankings of the five information types of the virtual guide according to three criteria (i.e. interest, utility and presentation quality). The

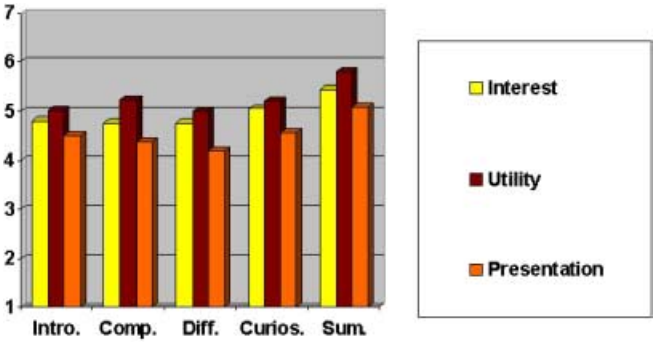

Fig. 10. Statistics on types of information

information type that users ranked most highly overall was summary information, including the list of works accessed. Interest was stimulated also by comparison, difference and curiosity information.

In the case of introductory information, sometimes users expected more extended introductions, thus suggesting the possibility of having introductions of varying lengths, depending on the user's interest. Overall, the evaluation of the introductory information was positive, and this type of information was found particularly useful in helping users to orient themselves within the path chosen. Users also sometimes found the comparison information too short, though still useful in relating a work of art to the next one. One user commented that: "*The comparison of some works of art made of marble was useful. I would also extend the comparison to other aspects such as techniques and the artists' motivations in choosing to work in a certain way*". Other interesting comments were: "*I think that for this type of information, as in the case of difference information, it would be important to provide a precise historic-critical context to facilitate comprehension of the works*" and "*They are interesting because they allow noticing elements that otherwise would be overlooked but sometimes are too vague and generic*". Difference information raised similar comments. Curiosity information was evaluated as useful in stimulating more attention to the particular work of art. When the information stated that the current work was the only one in the museum by a certain artist, this was sometimes found a bit repetitive, because it was generated repeatedly during the same visit. Thus, some users suggested that information on the life of the artist and on how they created the work should also be included.

Summary information most attracted users' attention. The summary with the associated list of works visited aimed to help users to organise and remember the path followed. Sometimes users tended to navigate in a random, disorderly way, and to forget the pages previously visited. Summary information was found useful for remembering the main information related to the works of art accessed (e.g. the artists, materials and historical periods) and planning how to go forward. In some cases, users wanted to access di-

rectly from the summary some work that was previously visited. One problem was that, when the numbers of accesses was high, it would have been important to avoid repetitions in the summary and highlight the most important aspects with respect to the user's interests.

Figure 11 presents the overall results of the evaluation of the guide, according to four criteria: usefulness, simplicity of use, amusement value and overall quality. Users were asked to score the guide on each criterion on a scale from one to seven. As the figure shows, the average score for all is near to five, with the exception of ease of use, which was more than six.

The following are some of the users' most significant comments on the interface:

"*The site is well thought out; few museum sites have been designed to offer the user such information. It's a good idea to create profiles for visitors, who thereby can access information well-suited to their levels. The virtual guide provides considerable support to visiting the site and understanding the art works.*"

"*It provides a very intuitive method for displaying large numbers of art works. The virtual guide is also very useful to recapitulate one's visit.*"

"*Generally, the site is rather easy to use and the interface is pleasant; the virtual guide is useful to avoid getting lost among the descriptions of the many works of art, and the ability to enable and disable it during the visit is also useful.*"

Regarding users who found the information received unsatisfactory, the most common request was for greater interactivity of the virtual guide, and, more generally, for the opportunity to receive more in-depth information on any topic at any moment. Most test users (85%) preferred the visit with the virtual guide, considering it more complete, stimulating and information-rich. The users said that they enjoyed the feeling of being "accompanied" by the guide, which provided the visit with a logical thread, allowed for better recall of the concepts encountered and caused less disorientation.

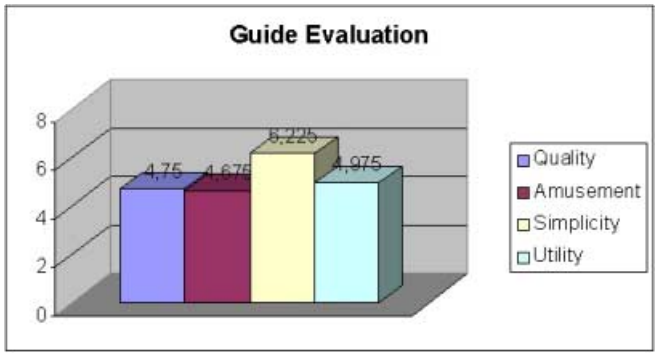

Fig. 11. Overall evaluation of the guide

7 Conclusions

This paper has described an approach to providing assistance to Web visits through integration of a virtual guide with adaptive behaviour within an already adaptable application. Such an approach produces a flexible environment, containing a virtual guide that is able to adapt its behaviour, as well as the information provided to different types of users, depending on their interactions and goals.

The adaptive support has been designed to be under the full control of the user, who can determine when to enable or disable it. This support follows a set of clearly comprehensible criteria, and the information supplied corresponds better to users' interests, thereby helping to make their visits more pleasant and increase their involvement.

A formal empirical evaluation involving 40 users has been carried out. The experiment has been useful in understanding the extent to which the usability of the application has been increased by this solution, and has provided suggestions for small improvements, such as the generation of comments with more precise and detailed information, and the representation of summary information that takes into account the number of accesses performed, in order to avoid long summaries.

The example provided is specific to the museum field, but the approach could also be applied to other application areas that share similar features. It is also planned to extend the application by using virtual reality techniques.

Acknowledgements. This work has been partly supported by the C.N.R. project on the Safeguard of Cultural Heritage.

References

1. Brusilovsky P (1996) Methods and techniques of adaptive hypermedia. J User Model User Adapt Interact 6:87–129
2. Cheverst K, Davies N, Mitchell K, Friday A, Efstratiou C (2000) Developing a context-aware electronic tourist guide: some issues and experiences. In Proceedings of ACM Conference on Human Factors, The Hague, The Netherlands, 1–6 April. ACM Press, New York, pp 17–24
3. Cox R, O'Donnel M, Oberland J (1999) Dynamic versus static hypermedia in museum education: an evaluation of ILEX, the intelligent labelling explorer. In Proceedings of the Ninth International Conference on Artificial Intelligence and Education, Le Mans, France, 19–23 July, pp 181–188
4. Fink J, Kobsa A, Nill A (1997) Adaptable and adaptive information access for all users including the disabled and the elderly. In Paris C, Tasso C (eds) Proceedings of the Sixth International Conference on User Modelling, Sardinia, Italy. Springer, Berlin Heidelberg New York, pp 171–173
5. Höök K (1997) Evaluating the utility and usability of an adaptive hypermedia system. In Proceedings of the International Conference on Intelligent User Interfaces, Orlando, Fla., 6–9 January, pp 179–186
6. Höök K (1999) Designing and evaluating intelligent user interfaces. In Proceedings of the International Conference on Intelligent User Interfaces, Redondo Beach, Calif., 5–8 January, pp 5–6
7. Kadobayashi R, Nishimoto K, Sumi Y, Mase K (1998) Personalizing museum exhibition by mediating agents (Lecture notes in artificial intelligence 1416). Springer, Berlin Heidelberg New York, pp 648–657

8. Marucci L, Paternò F, (2000) Logical dimensions for the information provided by a virtual guide. In Proceedings of the international conference on adaptive hypermedia and adaptive Web-based systems (Lecture notes in computer science 1892). Springer, Berlin Heidelberg New York, pp 359–362
9. Milosavljevic M (1997) Augmenting the user's knowledge via comparison. In Jameson A, Paris C, Tasso C (eds) Proceedings of the Sixth International Conference on User Modeling. Springer, Berlin Heidelberg New York, pp 119–130
10. Not E, Zancanaro M, (2000) The MacroNode approach: mediating between adaptive and dynamic hypermedia. In Proceedings of the international conference on adaptive hypermedia and adaptive Web-based systems (Lecture notes in computer science 1892). Springer, Berlin Heidelberg New York, pp 167–178
11. Oppermann R, Specht M (2000) A context-sensitive nomadic exhibition guide. In Proceedings on the Second International Symposium on Handheld and Ubiquitous Computing (Lecture notes in computer science 1892). Springer, Berlin Heidelberg New York, pp 127–142
12. Oren T, Salomon G, Kreitman K, Don A (1990) Guides: characterizing the interface. In Laurel B (ed) The art of human–computer interface design. Addison-Wesley, Reading, Mass.
13. Paternò F (1999) Model-based design and evaluation of interactive applications. Springer, Berlin Heidelberg New York
14. Paternò F, Mancini C (1999) Developing adaptable hypermedia. In Proceedings of the International Conference on Intelligent User Interfaces, Redondo Beach, Calif., 5–8 January, pp 163-170
15. Paternò F, Mancini C (2000) Effective levels of adaptation to different types of users in interactive museum systems. J Am Soc Inf Sci 51:5–13
16. Sarini M, Strapparava C (1998) Building a user model for a museum exploration and information-providing adaptive system. In Proceedings of the Second Workshop on Adaptive Hypertext and Hypermedia, Pittsburgh, Pa., 20–24 June, pp 63–68
17. Shaw E, Johnson WL, Ganeshan R (1999) Pedagogical agents on the Web. In Proceedings of the Third Annual Conference on Autonomous Agents, Seattle, Wash., 1–5 May, pp 283–290
18. Stephanidis C, Paramythis A, Sfyrakis M, Stergiou A, Maou N, Leventis A, Paparoulis G, Karagiannidis C (1998) Adaptable and adaptive user interfaces for disabled users in the AVANTI project (Lecture notes in computer science 1430). Springer, Berlin Heidelberg New York, pp 153–166
19. Stock O, The AlFresco Project Team (1993) AlFresco: enjoying the combination of NLP and hypermedia for information exploration. In Maybury MT (ed) Intelligent multimodal interfaces. AAAI Press, Menlo Park, Calif., pp 197–224