Developing Adaptable Hypermedia

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ABSTRACT
In this paper we discuss the design and implementation of hypermedia able to adapt to different types of usage. Our work is based on a method whose main elements are: a strong user involvement, the identification of different types of users, and the application of task models to support the design and development of hypermedia. Different task models are associated with different types of users. We show examples of the approach proposed taken from a case study where museum information is considered.

KEYWORDS: Task Models, Model-based Design, Hypermedia, Adaptable User Interfaces, Museum Applications.

INTRODUCTION
Model-based approaches aim to find declarative models that allow designers and developers to concentrate on relevant aspects of their work without being immediately immersed in implementation details. They have mainly been developed in academic environments. There has been a limited use of such approaches in developing real applications. The advent of the WWW has stimulated a diffuse interest in developing and using hypermedia and consequently a strong need for structured frameworks to support design of usable hypermedia [10]. Often such hypermedia have to support accesses to the same information from different types of users.

Consequently, we found it interesting to develop a work aiming to:

- investigate how a model-based approach can support the design of hypermedia that can be used by different types of users;
- apply the criteria identified to the development of a real application that has a wide variety of users.

For this purpose we needed a method for supporting the design and implementation of easy-to-use and adaptable hypermedia to overcome the main limitations that can often be found in current approaches:

- *design completely based on ad hoc solutions and the intuition of the designer*, this can be successful in a few cases but generally designers will have to solve problems without having methods supporting elements to provide effective solutions, moreover they may propose inconsistent design where in similar situations different solutions are provided thus confusing the end user;
- *system-oriented models used in the design of the hypermedia*, these approaches are oriented to the systematic structure of the data and the software architecture. They are useful to solve technical and implementation problems but they only provide a limited contribution to introduce user-oriented elements, thus allowing designers to obtain implementations which are engineered from the implementation point of view but still with inadequate usability.

We believe that to overcome these limitations it is fundamental to have a strong user involvement. However, users are not designers. They can supply very useful information to designers who should then use it in developing the presentation and the navigation of the hypermedia. Design is a complex activity which needs to be supported by principles which incorporate the designer's skill and experience and are able to support the management of the increasing complexity of the information contained in a hypermedia in order to obtain applications usable for the end user. To this end we have developed a structured method which is based on the following elements:

- *User involvement*; right from the early phases of the design cycle in order to obtain task models which are meaningful by incorporating the intentions of the users when approaching the application.
- *Task models for the various use types foreseen*; a wide variety of users can access a hypermedia with different purposes, thus it is important to have different task models for different types of user.
- *Rules for structuring a hypermedia according to the task model*; once non-prescriptive and flexible descriptions of the possible tasks and their performance

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are obtained, they can give useful information in the various phases of the hypermedia design.

Task models allow designers to address the specification of functional and interaction aspects within an integrated framework. Interest in their use [6, 9, 11, 12] for designing interactive applications is becoming greater and greater. Our contribution with respect to other approaches to task modelling is that we provide a richer set of temporal operators able to support precise descriptions of concurrent, interactive, and interrupting tasks. Besides, previous works have mainly focused on the design of the user interface, in some cases including its underlying software. We have found a lack of proposals that introduce user and task related aspects in structuring hypermedia, which have specific navigation and presentation styles. Hypermedia are characterised by supporting access to a large amount of information organised into numerous nodes that are linked to each other and with the possibility to display to the user only one node at any time.

A proposal for applying a comprehension model in the design of hypermedia manuals can be found in [7]. In [4] a museum application is analysed and evaluated by using the HDM model for hypermedia [5] structures. This model has been influenced above all by models for the design of data bases, so it is useful to identify inconsistencies in the structure of the data and the related presentation and navigation. However we believe that task models can provide further information to design usable hypermedia. For this purpose task models have to be developed with the involvement of users so that they incorporate the user requirements for navigation and presentation design. An interesting approach in this direction is the Object-Actions Interface model [10] which provides a helpful guide to web site designers in decomposing a complex information problem and fashioning a comprehensible and effective web site. We have a similar purpose but we provide a more formal approach, considering a wide set of temporal relationships and aiming at obtaining more structured task models and systematic indications.

When a hypermedia is used by users with different goals and levels of knowledge another important aspect is to support adaptation: different users may be interested in different parts of the information contained and they may want to use different links for navigation. Systems that allow one to modify some parameters of the system and then adapt their behaviour accordingly are called *adaptable*. We believe that *to design adaptable hypermedia we need to take into account that different types of users have different task models associated with them*. This means that if task-based design is followed then the hypermedia should be able to adapt itself to this diversity of possible tasks depending on the user type.

In the paper we discuss task-based design of adaptable hypermedia and how we have applied it to a case study: the design of hypermedia containing information on the Museum of Marble in Carrara (Italy). We highlight aspects that may be useful for other designers or researchers working on similar problems.

THE METHOD USED

The method we used starts with an informal task analysis where we have a strong user involvement by conducting interviews, questionnaires and we analyse which tasks are supported by similar applications and how. The purpose is to identify the tasks that the new application has to support and the current problems in their performance in order to understand how to improve it. Once we have identified an informal list of tasks to support and further requirements to satisfy, we begin building a task model that describes how the tasks should be performed in an optimal way.

We use the ConcurTaskTrees notation [8] to describe the task model. It is an automatic tool-supported notation (http://giove.cnuce.cnr.it/ctte.html) for specifying task models in a hierarchical way with a rich set of operators allowing designers to give a compact specification of many possible types of temporal relationships thus allowing them to describe flexible, non prescriptive task models.

In building the task model we have to take into account the data which we have available to support the tasks.

The development of the task model is the result of an interdisciplinary discussion involving many actors: designers, developers, managers, application domain experts, end users, etc. Once we have obtained task models for the classes of users identified we use them to drive the design of the hypermedia because they contain many useful suggestions for a user-oriented design. The task model can give information about how to structure the multimedia presentation and the links supporting the navigation. The resulting hypermedia contains the available data and its structure can be described by models for hypermedia [5].

This initial hypermedia design can be evaluated by metrics for hypermedia and presentation design, which have been demonstrated to incorporate valid indications for obtaining more usable applications. The evaluation based on metrics is not considered in this paper.

We performed some empirical evaluation of the hypermedia with the purpose to validate the usability of the hypermedia obtained by a task-based design. Empirical testing can be expensive as it can take a lot of time before meaningful results are produced. However the use of our method, which includes many user requirements by using task models developed with a strong user involvement, allows designers to reduce the amount of user testing. This type of evaluation is always important. Sometimes it does not change the overall structure of the hypermedia but it always helps to improve small aspects of the design. We can thus obtain the final hypermedia and the related task model.

INFORMAL TASK ANALYSIS

We have applied our method to the design and development of a hypermedia for accessing and navigating information related to the Museum of Marble. This museum is located in Carrara (in Italy). This area is characterised by a huge concentration of white marble quarries. This material has been used for artistic works since the Roman period. The museum is interdisciplinary as it contains modern sculptures made from white marble or other materials, pieces of industrial archaeology which were used to quarry the marble in the past, a gallery of marbles (samples of many types of marbles and granites), technical applications of marble in architecture, artisanship, and so on. The town (Carrara) can be considered as a natural extension of the museum as many works of art (sculptures, monuments, marble icons, etc.) are located in it.

In our case study during the development of task models for our application we decided first to interview experts in the field and possible end users. We soon recognised that we had to design slightly different task models for different types of users because people with different backgrounds interact with the same information for different purposes and in different ways. We decided to give the users the possibility to change dynamically, during the application session, their profile, so that they can carry on the navigation in the museum information receiving information presented differently.

This work considers three types of users: tourists, students in artistic heritage, and experts. They differ mainly in terms of the knowledge of the information contained in the application and in the preferred style of navigation. When there is a classification of possible users it is always possible to find a few cases that do not fit exactly into any of them. However we find this grouping suitable for most users. In the next sections we describe the requirements highlighted by interviews and meeting that we had with possible end users, application domain experts, and employers of the museum considered.

The main requirements for the different types of users identified are:

- Tourists are characterised by a low average knowledge of the topics considered. Usually they prefer to have guided tours through the rooms of the museum and the town with pictures and information about the works of art. However linear pre-defined tours alone would be too restrictive so some degree of navigational freedom is important. Tourists want general information on the artistic works, and this information has to be presented clearly and in a limited amount because it has to be interpreted easily. Thus a work can be presented by an image, the title, a short description, the name of the author, the material and technique used for its creation, and when it was made.
- The students in the artistic field who visit a museum already have some basic knowledge. They prefer to have information on a wider variety of topics with respect to the tourists. The presentation of some images and related texts often stimulates a request for more detailed information. In this case providing pre-defined tours is not the right answer. Instead, we let such students choose from different types of information which may concern not only the works of art but may also involve a wider spectrum of topics, so that students can improve their knowledge. They also appreciate the availability of a technical glossary explaining specific terms. Examples of information that they may be interested in are: the life of an artist and so the artist's works including in depth information on the topic of the work, its relationships with other works, the state of conservation, etc.
- Expert users generally know exactly what information they want and should thus be allowed, right from the beginning of the session, to make increasingly precise requests, for example specifying directly the name of the artist of interest or the historical period or title of the work (see Figure 1). In this case the information required may concern:

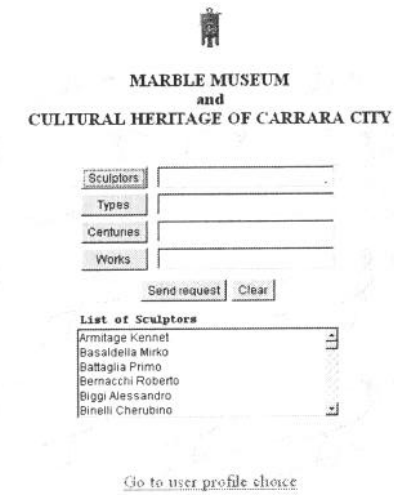

Figure 1: Initial choice of information for expert users.

an artist - initially a critique may be useful (not a simple biography as an expert is presumed to know this already), from which it should be possible to get information on the artist's work and texts or Internet sites which discuss them, plus a short summary;

artists who lived in the same period and/or area;

works of art - the work presentation should yield information concerning the artist who created it and also allow receiving in-depth descriptions;

a specific historical period that gives the expert user the chance to get detailed information such as how to reach the works characterising it.

TASK MODELS

Task models describe how to perform the possible activities to reach the users' goals without violating temporal or semantic constraints. They should not be prescriptive and thus it is important that they provide, as in our approach, the possibility to describe a rich set of temporal relationships so that parallel tasks, alternative ways to reach goals, and dynamic enabling and disabling of tasks can be described.

A task model records the results of the discussion among the different actors involved in the design. The specification should be used by the designer in order to remove ambiguities, to evaluate design options, and to check the completeness of the design. Task models can be used to support the development of hypermedia. They are also useful to support the modifiability of the related hypermedia because when new tasks have to be supported or users require the possibility to perform existing tasks in different ways then they give immediate indications about what part of the application has to be modified and how it relates with the other parts.

ConcurTaskTrees is the notation that we have developed to specify task models. It is a graphical notation where it is possible to describe tasks at different levels of abstractions. We have a distinction of categories of tasks depending on the allocation of their performance (to the user, to the application, to their interaction otherwise we have abstract tasks that are not univocally allocated for the performance). In the task specification different icons indicate the category of the task. Besides, we have a set of operators describing the possible temporal relationships that we introduce by considering the example in Fig. 2 although we will not describe all the details of the specification.

This figure describes the first levels of the task model for the tourist. At the first level we have a distinction between the activities which can be performed during the session (*AccessWorksOfArt* task) until they are disabled ([> operator) by the *CloseSession* task. Iterative tasks are indicated by the * operator. At the beginning there is an optional task (*AccessGenInfo*), optional tasks have their name in between squared brackets. Its subtasks allow users to access various information: general information concerning the museum (fares, opening time, how to get), the possibility to change the language, the possibility to activate some music. Then the user can explicitly starts the session (*StartSession* task). Once this task is terminated it enables (>> operator) the task performed by the application to present the possible user profiles. There is another optional task that allows the user to have more information about the user profiles available (*AccessInfoProfile* task). When the selection of the user profile is performed, in the case of the tourist profile, s/he can choose ([] operator) from four types of information: general information on the town, general information on the museum, activation of the interactive map of the museum, and activation of the interactive map of town. Depending on the selection it is possible to access different information ([]>> means sequential tasks where the former task provides some information to the latter task). If, for example the activation of the interactive map of the museum is selected (*SelMuseumMap* task), after its presentation (*ShowMusumMap*) the user can select a room and navigate in the related information (*AccessInfoRoom* task). This task is then decomposed into other activities (it is an abstract task as indicated by the cloud icon) that are not shown in the figure. It can be disabled by the task which allows the user to go to the museum map (*GoMuseumMap* task) again or by the task which allows the user to go to the initial choice (*GoTouristOpeningPage* task) of information for the tourist user or by the task which closes the session.

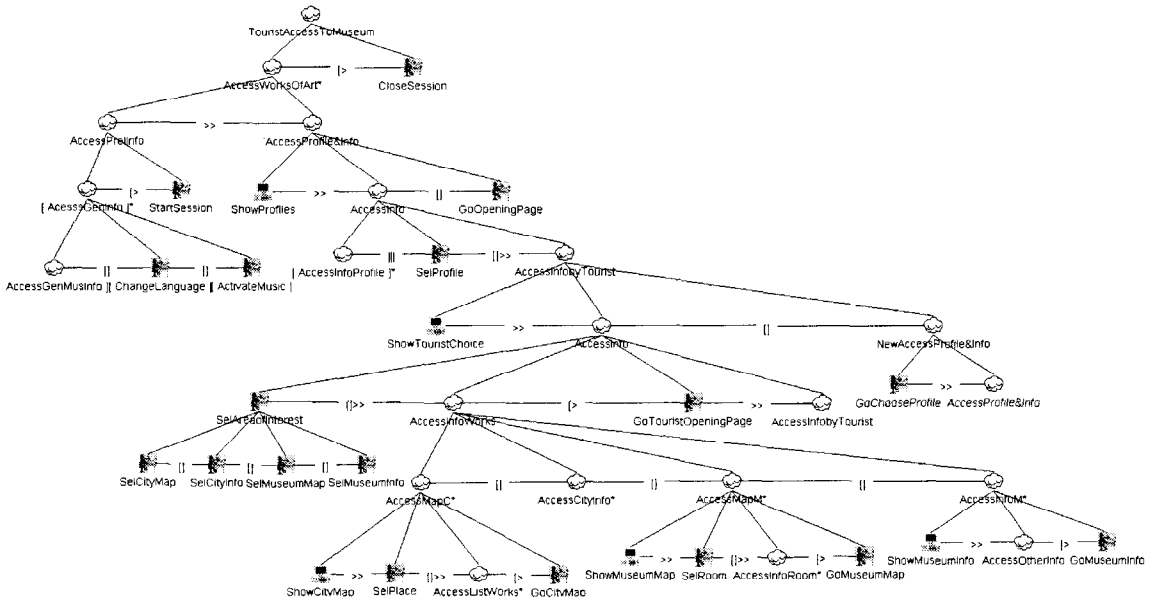

Figure 2: An example of task specification.

USING TASK MODELS TO DESIGN HYPERMEDIA

The task model can be used to support the design of the hypermedia structure underlying the user interface that will be used to communicate with the user. More specifically, the task model is useful for designing more user-oriented interactions because they will be structured according to the user's conceptual model of the possible activities. Thus it is important to avoid inconsistencies between what has been specified in the task model and what can really be done in the implementation. For example, if at the task level it is specified that after presenting one work it is possible to pass to the next work (according to a given order) at the hypermedia level we must have a link between the presentations of the two works, supporting their sequential access.

We have developed a method that allows designers to use the task model to identify the elements of a hypermedia and their relationships. To this end we have developed different types of rules:

- *Rules for designing the presentation*; depending on different aspects, such as the type of task, we have different requirements for choosing the media and the related interaction techniques in the user interfaces which should support the task performance.
- *Rules for designing the navigation*; they are mainly based on the analysis of the temporal relationships among tasks which should be supported and give indications about how to use the links in the hypermedia.
- *Rules to structure the information*; they indicate how to structure the data which is contained in the hypermedia.

Structuring the presentation

In designing the presentations supporting the various tasks we have to take into account many aspects:

Task type, we can decide the type of presentation according to the type of task, taking into account what information it has to communicate. For example if the task has to present a spatial relationship it is important to provide a graphical presentation which highlights the elements defining it.

Cognitive effort, there are different ways to reduce the cognitive effort required from the user. It is important to balance the use of different media, especially when they are used to support concurrent tasks, an example is when short information, complementary to that presented on the screen, is given by audio. Generally, it is possible to read a text and at the same time hear a sound or to speak, and to watch images simultaneously, whereas it is problematic to hear a long description and to read text at the same time. It is important to exploit the capabilities of our cognitive system to blend information which is perceived by different perception channels; however this blending needs to be helped, for example, by synchronising carefully information which is presented by different media at the same time;

Task frequency, it is also important to optimise the resources used within a certain media to support frequent tasks or frequent sequences of tasks, for example, if we know that the user often has to use a scrollbar and then to select a button, this control should be placed close to the scrollbar.

Contextual environment, we have to take into account the context in which the application is used, for example if it is a communal area then it may be noisy and so audio is not effective.

User knowledge; depending on the user's knowledge of the application domain we should present the information in a different way, if the user is a beginner then limited amount of information with clear fonts and colours have to be preferred.

Layout Optimisation, the performance of the same task sometimes requires different amount of information depending on the specific instances of objects involved (for example there are some work of art which require longer descriptions). This means that the structure of the presentation remains the same (the interaction techniques and the links are in the same part of the presentation) but either to avoid leaving large parts of the screen unused, some part of the layout is automatically resized or when there is a lot of information, it has to be split into multiple presentations sharing the same structure but with different information.

Structuring the navigation

The task model can also give useful information on how to design the dynamic behaviour of the user interface of the hypermedia document. For example, the structure of the task model can indicate the type of selections and possibilities available to the user at the beginning of the session (tasks on the left side of the task tree) or the tasks at the higher level of the task tree are usually those indicating how to start a search of some information whereas the tasks at the lower levels indicate how the accesses to the detailed units of information can be performed.

Depending on the temporal relationships among tasks we can decide when some interaction techniques should be available to the end user and when links supporting the hypermedia navigation should be included.

If a task disables another task then an anchor supporting the disabling task should be inserted. For example, in the task specification in Figure 3, we can note that the *AccessGenInfo* task is disabled by the *StartSession* task. In these cases when the information related to the first task is presented then a link allowing the performance of the second task and the disabling of the first one should be available for the end user.

If there is a sequential enabling relationship between two tasks then the presentation of information associated with the second task is automatically activated only after the

termination of the first task. For example, if the first task allows the user to start an application session (*StartSession* task) and the second task allows the system to show a set of already defined profiles (*ShowProfiles* task) and there is a sequential enabling relationship between them, this means that possible user profiles will be presented immediately after the accomplishment of the first task. This sequential constraint can be supported in other ways within the same presentation unit (for example greying out the interaction techniques associated with the disabled task or just making them insensible to user interactions).

When we have a choice operator the availability of the interaction techniques to support the performance of the choice depends on whether the choice is done by the user or the application. If the choice is performed by the application then only the information related to the task chosen will be presented. If the user performs the choice then at least the first actions of the possible tasks are enabled, for example, the selection of a link associated with each possible choice. Then depending on the user's choice, the information and the interaction techniques associated with the chosen task and, in some cases, those tasks which should be performed immediately after, will be made available while the information associated with the other choices will disappear completely. For example, the user can decide to get information about the town or about the museum. Each choice is supported by a specific link. Depending on the choice, only town-related or museum-related information will appear.

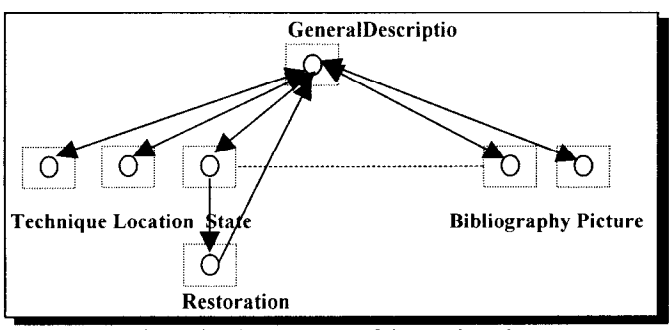

Figure 3: The structure of the work entity.

If two tasks are concurrent (the first action of one task can be performed before the last action of the other task) then the related presentation techniques can be available to the end user at the same time taking into account the criteria indicated in the section about structuring the presentation.

Structuring the information

By a top-down analysis of the task tree it is possible to determine the structure which has to be given to the multimedia data. The tasks at the high and intermediate levels are useful for starting the structuring of the data of a hypermedia. We use high level tasks to identify the entity types of the hypermedia. More specifically we consider the abstract tasks and the objects that they manipulate. The basic idea is to associate the entities of the hypermedia with the objects relevant for the high level tasks. How to structure the entities into components depends on the subtasks at the lower levels and the objects that they need to manipulate.

In structuring the hypermedia data we have to consider the requirements raised by the task models of all the user profiles so as to satisfy all of them.

In our current implementation we have as entities: Work, Sculptor, Town, Museum, Historical Period, Type of Work. Then each of them is decomposed into components. For example in Figure 3 we see that the components of the Work entity are: a general description, the techniques used, location, the state of conservation, possible restorations, bibliography, picture and so on.

EMPIRICAL TESTING

In order to check and optimise the design of the hypermedia obtained by a task-based approach we organised an empirical testing of the hypermedia.

The test was conducted by observing 30 users belonging to the three categories: 15 tourists, 9 artistic students, and 6 experts. The age was in between 24 and 50 years. None of them had seen the application beforehand but all of them had used a computer at least once. We tried to involve people with various levels of experience, particularly in terms of navigation in hypermedia.

The users received some written information depending on the category they belonged to which explained briefly what information the application allows users to access and what tasks can be performed. The tasks were identified in such a way to allow them to check most of the possibilities of the hypermedia.

We explicitly asked them to communicate all the observations or comments arising from the navigation.

In order to make the test more realistic we decided not providing any further information during the navigation.

The answers to the questions raised by the users were always very generic. For example, the user asked "how can I get the information required?", the answer was "observe carefully whether there is something which can provide useful information". To complete the test with all the users took about 9 hours, individual users varying between 15 and 20 minutes.

In the case of the tourists they often did not realise that the museum map was interactive and they selected the legend of the map rather than the rooms. The students (they were students in the art field) preferred to have single click versus double clicking for selecting items. They did not like to use the scrollbar when lists with many items were presented. They did not distinguish immediately whether the works of art were in the museum or placed in the town itself.

Generally the user interface was considered easy to use. However we received some suggestions for improving its

flexibility, such as some additional links which were not included in the prototype.

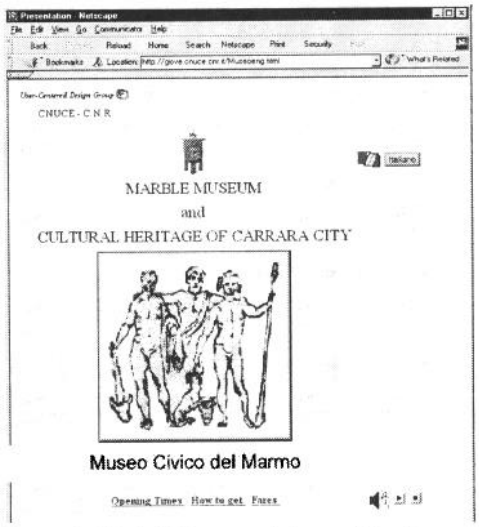

Figure 4: The initial page of the resulting hypermedia

Other suggestions were given to highlight information useful for possible tasks such as the entrance, the way out and the location of information office; to use more meaningful feedback when a street in the town was selected; to highlight the title of the work in the description of a work of art, and the legend of the museum indicating the various sections has been made selectable so as to activate general information on the section whereas when the section is selected on the map, then a video showing its content is activated.

Another modification performed was to make access to the description of the user profiles an optional task. In the initial version after selecting a profile the user received the description of such profile and then s/he could confirm the choice or go back to the profile selection. We realised that in this way we constrained users to access the profile description in every session they participated. We recognised that often users did not read such information either because the distinction of the different user types was immediate to understand or because they had already read it and did not need to read it again. Thus such task became optional that means when the profile selection is available the user can also select more info on such profiles but they can select a specific profile and then navigate in the hypermedia without accessing any more info as well.

The issues detected by empirical testing were specific and relatively minor. This means that our method, aiming at guaranteeing a design consistent with the task model, succeeded in providing a usable hypermedia. Indeed, since the task model was obtained with a strong user involvement it guaranteed to obtain a final design easy to interpret and understand even by end users without experience in interacting with software applications.

ADAPTABILITY SUPPORTED

In Figure 4 there is the initial page of the resulting hypermedia. It supports a few tasks which are independent from the user profile: the choice of the language and some general information on the museum that do not involve access to the information related to the works of art (opening time, how to get to the museum, fares).

Once the museum is selected the user is asked to choose one of the possible profiles. Users can ask information concerning the profiles available. Then they will be able to navigate in the hypermedia by the navigation styles associated with the user profile chosen.

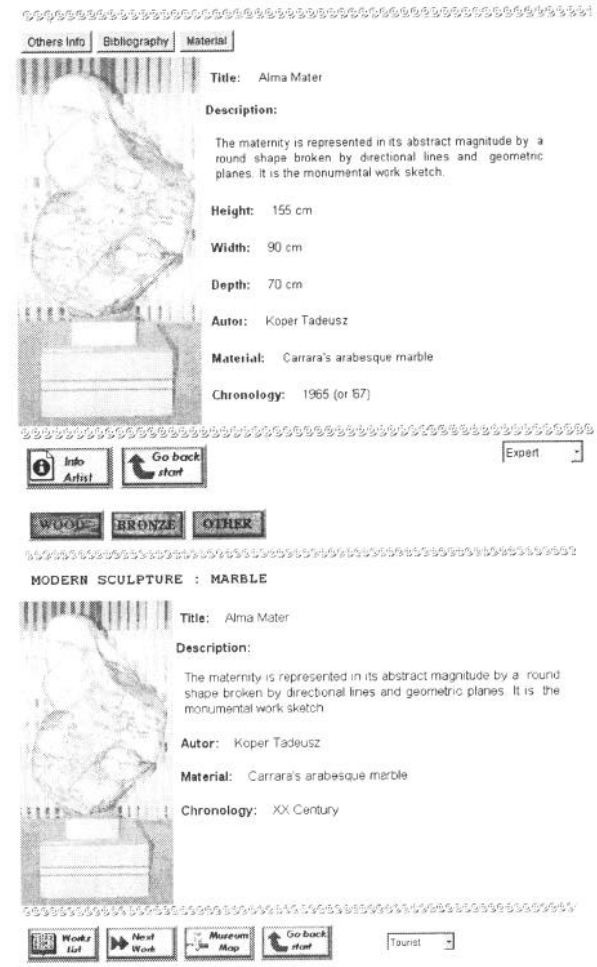

Figure 5: An example of different views of the same information

We developed three task models; one for each main type of user identified (expert, tourist, and student of art). They mainly differ for three aspects:

- *Initial access to the museum information*, the expert can specify directly very specific requests whereas the student can access only information by lists indicating the information available and tourists access information mainly by spatial representations of the museum and the town;
- *Presentation of the information related to the works of art*, which takes into account the basic knowledge of the

type of users and the different tasks that they are likely to wish to perform;

- *Navigation in the hypermedia*, which is more structured and pre-ordered for tourists whereas more navigational freedom has been given to expert users.

As we mentioned above, different views of the same information can be possible depending on the type of users. For example in the lower part of Figure 5, we can see the tourist view of information related to a sculpture. As you can see it is possible to be guided in the navigation. It is possible to go to the next work; in this case the next work means the next work in the Modern Sculpture Section of the museum. It is also possible to access the list of works made by this material, the works performed by using different materials (wood, bronze, and others) and the museum map which drives the visit of the tourist in the museum hypermedia.

In the case of an expert user (Figure 5 - upper part) the information can be accessed more immediately (for example, by just giving the name of the author), it is more detailed (for example, precise dimensions and precise date of creation are given), and further information on the material, the author, the biography or other information can be accessed. They can go immediately back to their initial page to provide a completely new different request.

Users can change the current user profile (tourist, student, and expert) interactively during the session and they have feedback of the current profile at the bottom right side of the presentations. Thus they can have different views on the information available and different navigation styles without having to start a new application session.

CONCLUSIONS

In this paper we have discussed a method which aims to support the designer in developing easy-to-use hypermedia along with its application to the development of a hypermedia containing museum information. The support is based on task models that should reflect the users' view of the activities to perform and are the result of an interdisciplinary discussion involving the relevant skills required in designing interactive applications. In this way the craft and the intuition of the designer are assisted so as to guarantee a design consistent with the task model.

We have considered that different types of users can perform different tasks while accessing to the same information and thus we have structured the resulting hypermedia so as to adapt its presentations and possible navigation to better support these different needs. We have shown an example of application of the proposed method to a hypermedia containing museum information.

Further work will be dedicated to improve both the dynamic adaptativity of the resulting hypermedia to different users and the current, limited, automatic tool support for task-based design.

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