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Engineering the Design of Usable Hypermedia

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Abstract. This paper presents a systematic method for designing hypermedia that are easy to use for various types of users, along with its application to a specific case study. The design phase is supported by the use of task models. We have identified criteria that indicate how information in task models can be used to identify links, design presentations, and structure the data of the hypermedia considered. Different types of users imply different task models and thus different hypermedia designs. We then show how the design obtained was evaluated using both empirical testing and metrics for hypermedia navigation. We discuss the results obtained by these two evaluation methods and how they affected the original design.

Keywords: Systematic methods for hypermedia design, task models, usability evaluation of hypermedia, metrics

1. Introduction

The advent of the WWW has been one of the most important events in the last years. It has enabled many people not only to easily access hypermedia but also to easily design and develop them. A wide variety of tools, which allow people to rapidly implement hypermedia, are now available.

Hypermedia are characterised by supporting 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. They are becoming one of the most common types of software applications because they allow users to interactively access and navigate various types of information. Their design raises issues belonging to the intersection between software engineering and HCI (Taylor and Coutaz, 1994).

In many current approaches to the design, implementation and evaluation of hypermedia one of these two limitations can generally be found:

- *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 an 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 for solving technical and implementation problems but they only provide a limited contribution to introduce user-oriented elements, thus allowing designers and

developers to obtain implementations which are engineered from the implementation point of view but still with inadequate usability.

It is thus important to develop new methods which support designers in their work by highlighting relevant aspects to take into account and giving suggestions about possible solutions.

There is an increasing interest in using task models (Diaper 1989) for designing interactive applications. The purpose of task models is to describe the relationships among the various tasks identified. Tasks are activities which have to be performed to reach a goal. These can be logical activities such as *Booking a flight to Rome* or physical activities such as *Selecting the button on top left corner*.

Task models give an integrated view of both interaction and functional aspects whereas traditional software engineering approaches consider first functional aspects and then, once the functional structure is defined, they consider the possible user interactions thus obtaining often applications with low usability. Task models give useful support for both designers, providing a logical structure to address the design of interactive applications, and end users, supporting the development of user interfaces with interactions and presentations designed so as to better map their logical view of the activities to perform.

Model-based approaches to the design of interactive applications have mainly focused on the design of the user interface, in some cases including its underlying software. There is a lack of proposals that introduce user and task-related aspects in structuring hypermedia which have specific navigation and presentation styles with respect to other interactive software applications. More generally, there is a lack of model-based approach (Puerta, 1997) to the design of hypermedia. There are some exceptions: a proposal for applying a comprehension model in the design of hypermedia manuals can be found in (Narayanan and Hegarty, 1997) and in (Garzotto Mainetti, Paolini, 1995) a museum application is analysed and evaluated by using the HDM model for hypermedia structures. This model has been influenced above all by models for the design of data bases, so it helps to identify inconsistencies in the structure of the data and the related presentation and navigation. We believe that task models can provide complementary information for designing 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 (Shneiderman, 1997) 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 an approach more oriented to deriving systematic indications from structured and formal task models.

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, which allow one to modify some parameters of the system and then adapt their behaviour accordingly, are called *adaptable*. If the system adapts to the user automatically, on the basis of some assumptions, it is called *adaptive*. One solution to this problem is to use the data collected on a user which are contained in the user model to adapt the information and the links which have to be presented. By knowing the goals and the knowledge of

the user an adaptable hypermedia can support users during navigation by focusing on the information provided, providing comments on the visible links, or suggesting what links are the most relevant thus obtaining an adaptable navigation (Brusilovsky, 1996). In (Brusilovsky, Eklund, Schwarz, 1997) techniques to support adaptable navigation are highlighted and their application to the WWW context is discussed. For example, the technique of adaptable navigation proposed is interesting since it associates links with a comment informing the user about the current state of the nodes which can be reached. The annotation can be provided in textual form or in the form of visible elements, for example using different icons or colours or different types of fonts.

However 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. A first discussion of possible task-related adaptation is introduced in (Paternò and Mancini, 1999).

In this paper we provide an extended description of the method that we have used in designing and implementing a hypermedia containing museum information and the results obtained. More precisely the goals of this work are:

- *To investigate how task models can be used to design hypermedia*. In the work presented in this paper we want to understand how task models can give useful information for the specific area of hypermedia design. This means the design of structures connected by links supporting navigation, along with an overall architecture which can be defined in terms of nodes and components;

- *To develop a method for the design of hypermedia which provide different itineraries and presentations of information depending on the user type*, a usable hypermedia should be able to adapt to the needs and the tasks of different types of users;

- *To apply different usability evaluation methods to the hypermedia design*, in order to validate the design, to understand their further contribution with respect to task-based design, and to compare them. More specifically we decided to apply both a metrics-based evaluation and empirical testing. We use the task model to discuss the modifications suggested by the evaluation methods.

In the paper we introduce the method proposed and then we discuss it in more detail using a specific case study (the design of a hypermedia with museum information adaptable to different types of users). Section 3 is dedicated to the identification of the requirements for the distinct types of users identified. Then Section 4 is dedicated to the design of task models satisfying the requirements. These task models are used to drive the design of the hypermedia according to the criteria illustrated in Section 5. The next two Sections are dedicated to the analysis of two types of usability evaluation performed: metrics for hypermedia navigability and empirical testing. The hypermedia resulting from the application of the method proposed is briefly described in Section 8 before the concluding remarks.

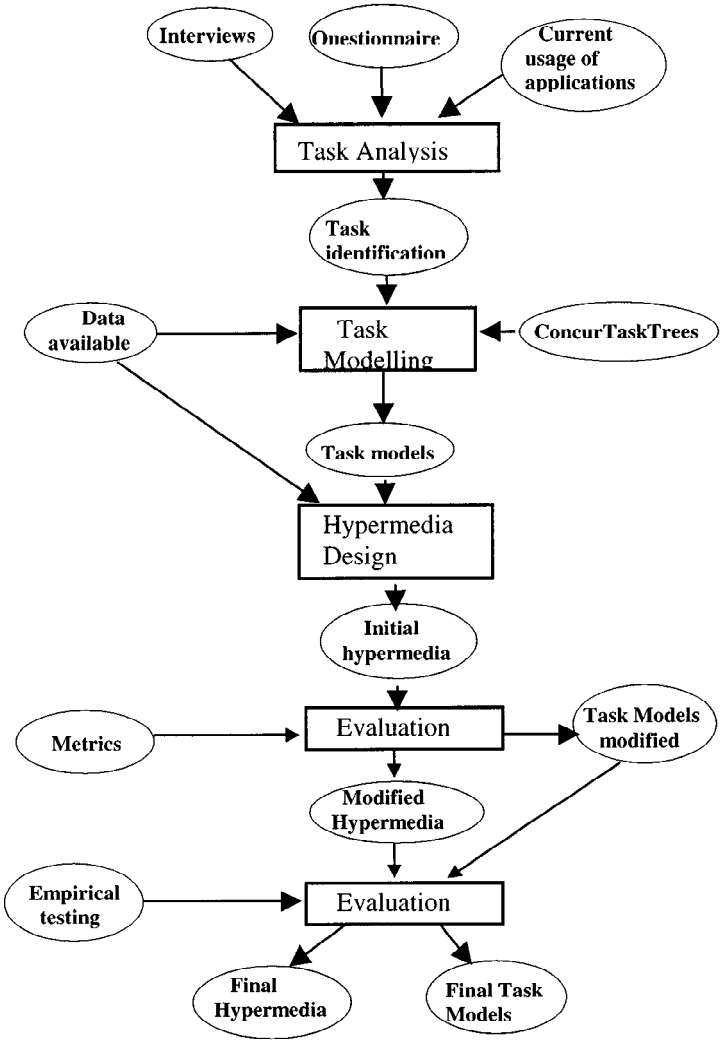

Figure 1. The proposed method.

2. The Method

The method we followed is described in more detail in Figure 1. Ovals represent input or results of activities which are described by rectangles. We start with an informal task analysis where we have considerable 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 build a model which describes how tasks can be performed.

We use the ConcurTaskTrees notation (Paternò, Mancini, Meniconi, 1997) to describe the task model. This 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 supporting compact specifications of many possible types of temporal relationships thus allowing designers 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 useful information about how to structure the multimedia presentation and the links supporting the navigation in such a way to better reflect the user's conceptual model of the possible activities. Thus it allows designers to obtain more usable hypermedia. This decreases the need for a usability evaluation which can still be performed but mainly to refine some limited aspects of the application.

The resulting hypermedia is constrained by the available data, sometimes it happens that some tasks cannot be supported because the related information is not available in electronic format. This initial hypermedia design can be evaluated by metrics for hypermedia (Yamada, Hong, Sugita, 1995) and presentation design (Sears, 1995) which have been proved to incorporate valid indications for obtaining more usable applications. These indications can improve the design of the initial hypermedia. The modifications in the structure of the hypermedia may require modifications in the modalities of the task performance.

Finally, we perform some empirical evaluations of the modified hypermedia. Empirical testing can be expensive as it can take a lot of time before meaningful results are produced. However 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 does not usually 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.

The method that we consider is an iterative method. The elements more innovative in it are the type of notation that we use for representing task models, the suggestions that we give to obtain a hypermedia user interface consistent with the information contained in the task model, the possibility to design user interfaces adaptable to different types of users whereas most of current user interfaces provide the same possibilities to all possible users, and the comparison of two types of usability evaluations, metrics for hypermedia navigation and empirical testing.

3. Requirements

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 the various types of users because people with different backgrounds interact with the same information for different purposes and in different ways. We decided to enable users to change their profile dynamically during the application session, so that they can carry on the navigation in the museum information receiving information presented in a different way.

If an application is used by different types of users often they differ mainly in terms of the knowledge of the information contained in the application and in the preferred style of navigation. For example in a museum application we can consider three types of users: tourists, (history of art) students, and experts. When there is a classification of possible users there are always a few cases which do not fit exactly into any of them. However we have found this grouping suitable for most users. In the next sections we describe the requirements highlighted by the interviews and meeting that we had with possible end users, application domain experts, and employees of the museum considered.

3.1. Requirements for Tourist Task Model

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. Access to the information should be provided with the support of spatial representations: the museum and town maps. This allows users to have immediate information about the locations of the works.

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 will 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.

Additional information about the museum and the town can be provided on request, such as the path to get to the museum from the closest railway station or airport, information (title, data, location) on further exhibitions, and historical information on the town and the museum.

3.2. Requirements for Student Task Models

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 than 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.

Thus access to the information available is more flexible than for tourists: it is possible to have the list of artists and historical periods, and then by selecting one of them to start the navigation in the hypermedia.

They also find technical glossaries useful. Such students may be interested in an artist's life and works including in depth information on the subject of the work, its relationships with other works, the state of conservation, related artists, the main cultural movements and artists in a specific period, etc. This information should be general (like an identity card) but it should also be possible to get more in depth information if required.

3.3. Requirements for Expert Task Model

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. In this case the information required may concern:

- An artist: an extended biography with the possibility to access a critique providing additional information. From here it should be possible to reach the following information: artist's work; lists of texts which discuss them, plus a short summary; and a list of Internet sites which concern the artist; information on the artists who lived in the same period and in the same area as the artist selected;

- A specific work which is presented from the point of view of the critique and not purely descriptively. From the work presentation it should be possible to reach information concerning the artist who created it and also to receive in depth descriptions;

- A specific historical period allowing the user to have some detailed information such as how to reach the most important works in this period.

Experts are also interested in having information on works presented so as to highlight specific relationships (for example a presentation grouping works developed in a certain period by using a specific technique and material).

3.4. General Comment on Requirements for Task Model

In many applications we can classify users depending on the basic knowledge of the application domain considered. However, there are also other aspects that differentiate different types of users. These aspects concern the tasks and the representations of the information more suitable to perform them. For example, in museum applications tourists often want to plan the possibility to physically visit a museum or some monuments and so they are more interested in having spatial representations from where they can identify the best itinerary that they should follow.

4. Task Modelling

Task models describe the possible ways to perform the activities to reach the users' goals which can be either desired modifications of the state of the application or attempts to get information from it. 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 supports multiple purposes:

- It records the results of the discussion among the various 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.
- Once a satisfying task model has been obtained it can be used to drive the development of the hypermedia so as to obtain an application that better reflects the user's view of the possible activities.
- It is also useful to support the modifiability of the related hypermedia because when new tasks have to be supported or users wish to perform existing tasks in different ways. This gives 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. Types of tasks are identified depending on the allocation of their performance (the user, the application, their interaction or abstract tasks which are not univocally allocated for the performance). Different icons in the specification represent the task allocation. There is a set of operators that describes the possible temporal relationships. These operators are considered in the examples in following sections. Our notation is more powerful than other approaches to task modelling because it supports a richer set of operators and more flexible situations can be described in a compact way.

Tasks were identified by conducting interviews, distributing questionnaires and analysing similar existing applications. The interviews were flexible because the interviewer tried to stimulate users to speak spontaneously about relevant topics rather than resorting to a rigid set of predefined questions. This information was then collated with a more structured research performed by distributing questionnaires to the visitors to the Museum of Marble and in the libraries of the town. The purpose was to collect the greatest amount of information both on their computer literacy and their preferences during the visit of the museum.

4.1. User-Independent Tasks

There are some tasks that are independent from the type of users. They do not concern access to information related to any work of art but they regard general information about the museum (fares, opening time, how to get there) and user preferences (such as language for the textual information or activating a music) and finally the selection of the type of user

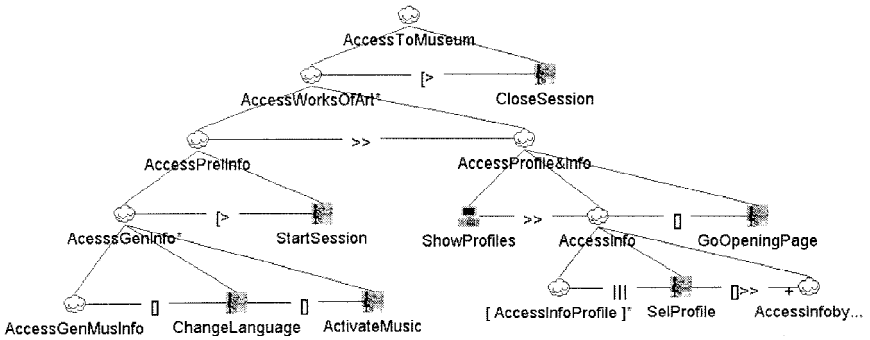

Figure 2. The task model of the initial part of the session.

that has to be supported for the current session (this choice can be dynamically modified during the session). These tasks are likely to be performed at the beginning of the session.

Figure 2 describes the first levels of the task model. At the first level there is 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. Then we have two sequential tasks (sequential tasks are separated by the >> operator) access to the general information (*AccessPrelInfo* task) and access to profile and museum information (*AccessProfile&Info* task). In the former there is the possibility to perform multiple times the subtasks (of *AccessGenInfo* task) concerning general museum information, change of language, and activation of the music. These subtasks can be disabled ([> operator) by starting the session (*StartSession* task). After that the application shows the possible user profiles (*ShowProfiles* task). Next there is the possibility of accessing information describing the basic assumptions for each user profile (*AccessInfoProfile* task) until the user performs the choice of the profile (*SelProfile* task). After this task we have different possibilities depending on the user profile chosen (the *AccessInfo* task is not unfolded, as indicated by the + symbol, because its unfolding depends on the user profile considered).

4.2. Task Model for the Tourist

When the user profile has been selected (*ShowProfile* task), in the case of the tourist profile, users 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 the town.

If, for example, the interactive map of the museum is selected (*SelMuseumMap* task) the user can select a room and then ([]>> is the operator indicating sequential tasks when the first task communicates information to the second task) navigate in the related information (*AccessInfoRoom* task). This task is further decomposed into other activities which are not shown in the figure. It can be disabled by the task which allows the user to go to the

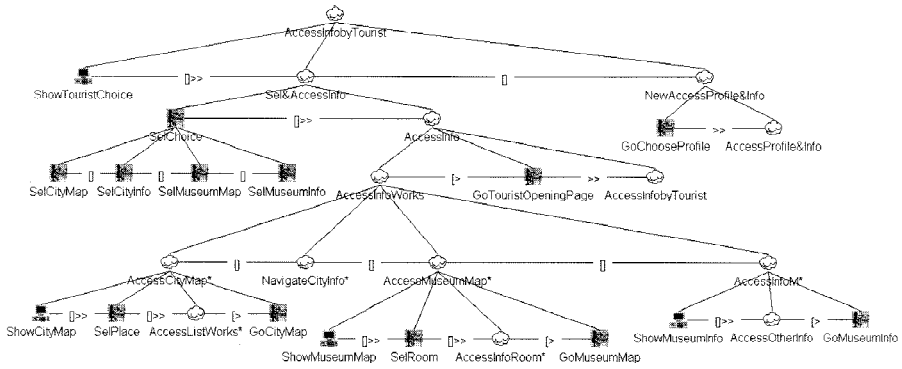

Figure 3. Main levels of the Tourist task model.

museum map (*GoMuseumMap* task) again or the task which allows the user to go to the initial choice (*GoSelInfo* task) of information or by the task which closes the session.

In the diagram in Figure 3 for sake of brevity the decomposition of some tasks (*AccessListWorks*, *AccessInfoRoom*, and *AccessOtherInfo*) has not been shown. *AccessCityInfo* is performed by a link to the city council web site where other informations related to the town are provided.

4.3. Task Model for the Student

We now consider the student profile. In this case relevant requirements are: receiving information on sculptors and works they performed; searching for works from the related historical period.

At the beginning, after selecting the profile, there are three interaction tasks (subtasks of *SelCategory* that is subtask of *SpecifyRequest*) which allow student users to visualise (*PresList* task) one of the available lists (sculptors, centuries, types of work of art).

Once the request has been sent (*SendbyButton* task) the access to the information (*AccessWorkInfo* task) can be performed in three ways described by the three task subtrees which refer respectively to the access to the information according to the choice performed (*AccessbyArtist*, *AccessbyCentury*, *AccessbyType*). They share the similar structure: show a further list of works satisfying the value selected (a name of artist, a century, a type of work) then the user can select one of them (*SelWork* task) and the application shows the basic information concerning it. After that there are two possible tasks (change current profile or access to further information concerning the selected work of art). In any case the user can either access the next work (*AccessNextWork* task) or go back to the list of work currently selected (*GoArtistList task*).

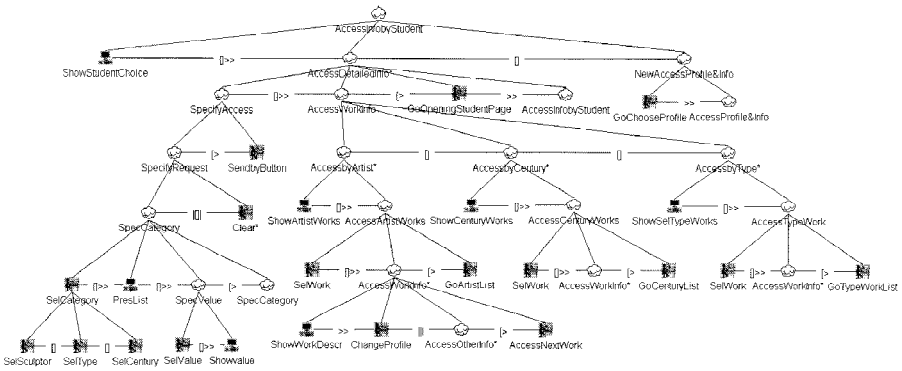

Figure 4. First levels of the Student Task Model.

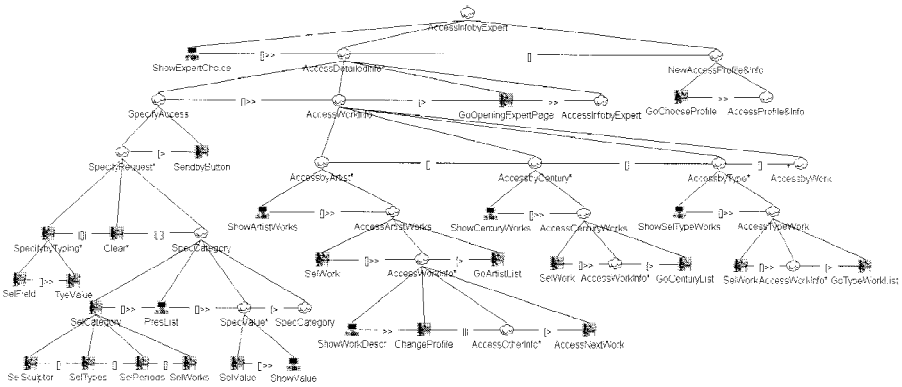

Figure 5. First levels of the Expert Task Model.

4.4. Task Model for the Expert

In the case of an expert the type of information requested are: information on the sculptors and works they performed; search of the works depending on the historical periods; sequential browsing of the works characterised by the same definition; search of works by title.

The task model requires at the beginning some interaction tasks (subtasks of *SpecifyRequest*) which allow users to insert parameters for their request or select them from a list: these parameters can be the name of a sculptor or an historical period or a type of definition or the title of a work or a combination of them. Differently from the student user type, in this case the expert user can also directly type the parameters of interest (*SpecifybyTyping* task) to drive the search of related information. Then for each of the possible alternatives there are different subtrees. The subtree concerning the handling of the information related

to a work (*AccessWorkInfo* task) is similar to the student case but with the possibility to receive further detailed information.

4.5. Comparison Among Task Models of Different Types of Users

If we analyse the three task models we can identify some parts that overlap or are rather similar. This kind of information is useful for user interface designers and software engineers for reuse of design and software. More precisely we can note that there is an initial part in the access to general information user-independent and information on the user profiles defined that is the same for all the task models. Besides it is possible to note that when a work of art is accessed then, although the information presented is different depending on the user current, in any case we need to support an access to the next work (according to some order such as next work done by a given artist or next work located in a museum room or in a street), to the list of the works currently under consideration (works done in a certain century, or by a certain artist or located in a certain placed), and to the initial page of the user profile currently active.

5. Task-Driven Design of Hypermedia

The task model can be used to drive the design of the hypermedia structure underlying the user interface which 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), then at the hypermedia level we must have a link between the two works.

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

- *Criteria for designing the presentation*; depending on 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.

- *Criteria for designing the navigation*; these 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.

- *Criteria to structure the information*; these indicate how to structure the data which is contained in the hypermedia.

5.1. 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, these controls should be placed close to each other.

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.

5.2. 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. Depending on the temporal relationships among tasks we can decide when some interaction techniques will be available to the end user.

If a task disables another task then an anchor supporting the disabling should be available when the presentation of the information related to the first task is presented.

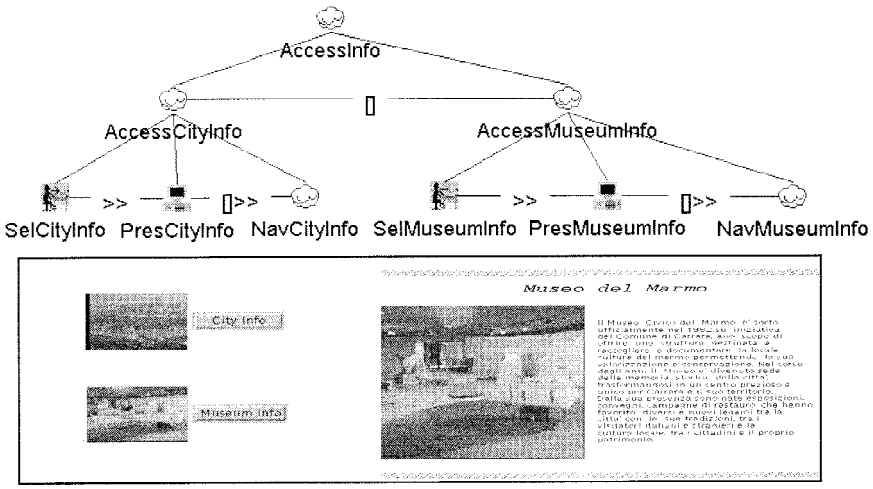

Figure 6. An example of choice in the task model and its corresponding implementation in the hypermedia.

If there is a sequential enabling relationship between two tasks then the presentation of information associated with the second task is automatically activated immediately after the termination of the first task. For example, if the first task allows the user to start an application session and the second task allows the system to show a set of already defined profiles 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.

When we have a choice operator the availability of the interaction techniques depends on whether the choice is made by the user or the application. If the choice is made by the application then only the information related to the task chosen will be presented. If the user makes the choice then at least the first action associated with the possible tasks are both available at the beginning. Then depending on the user's choice, the interaction techniques associated with the chosen task will be made available and the initial links will disappear. For example, in Figure 6 (above we have the task model and below the corresponding user interface), the user can decide to get information about the town or about the museum. Depending on the user choice, only town-related or museum-related information will appear and then the user can navigate in it.

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. Possible examples are: to show a video and manage the sound concurrently so that during the video presentation the user can enable or disable the sound or an expert user that is able to concurrently clear a request while specifying it when s/he realises that s/he made a mistake.

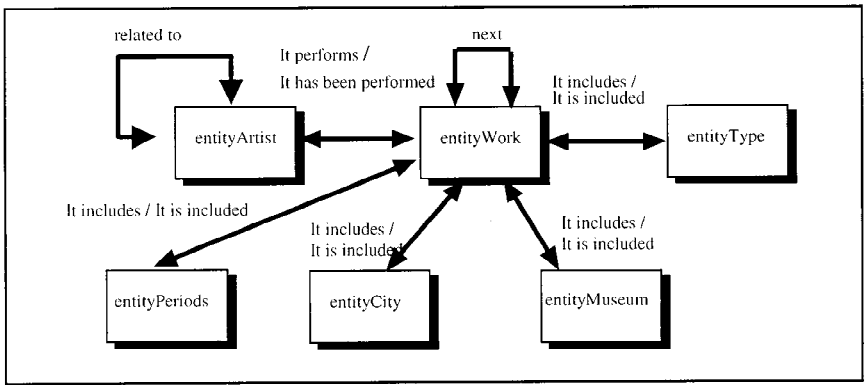

Figure 7. The final structure of the hypermedia information.

5.3. 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 follow two general rules:

- High level tasks are used 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. We can note in our case that the main objects which have to be handled are: the works (*AccessWork* task), the sculptors (*AccessArtist* task), the town (*AccessCityMap* and *AccessCityInfo* tasks), the museum (*AccessMuseumMap* and *AccessMuseumInfo* tasks), the historical period (*AccessPeriod* task), and the different types of works (*AccessType* tasks). Then each of them is decomposed into components.

Since there are different user types, each of them with their specific information needs, we have to identify the different views that different users have on them. This means that for each of them it is possible to provide only specific subsets of information depending on the type of user who requests the information. Entities are the main information objects that users want to access. In the museum application considered we found similar sets of entities from the analysis of the task model associated with each type of user.

Once the entities have been identified the problem is to determine the related components, nodes and links. This is done by considering the task model, and the subtasks of the high-

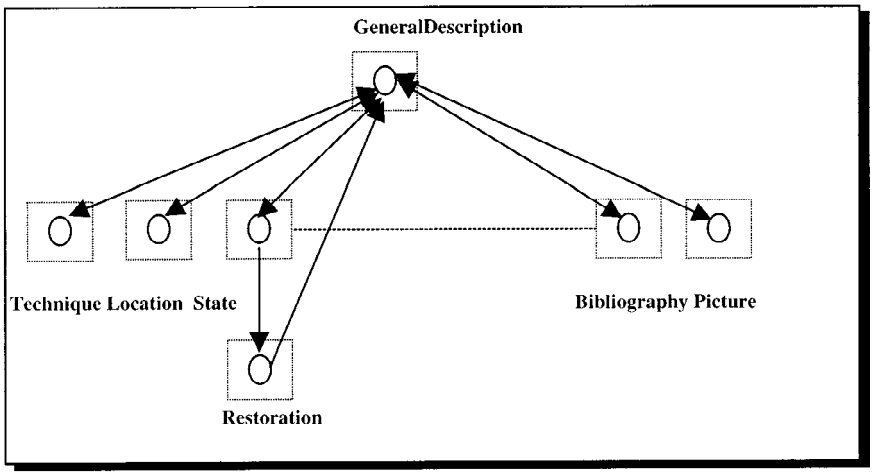

Figure 8. The structure of the work entity.

level tasks, which indicate the objects that they need to manipulate. For example Figure 8 shows 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.

Given the work entity there is a subset of components that are accessible from all types of users whereas some of them can be accessed only by student or expert users that can have more interest on more specialised aspects.

For the identification of the components we consider mainly application tasks which indicate the type of information that the application must present. In some cases this information is general and this means that we will need to create a component for each specific instance. For example, the *ShowInfoRoom* task means the presentation of a room so it will need multiple components, one for each room.

6. Metrics-Based Evaluation

Evaluation is a fundamental part in the user-centred design of systems because it allows us to establish whether the choices performed satisfy the need of the users and the system is suitable for the context where it will be used.

Metrics are used to provide some quantitative values to estimate some aspects of the design in order to provide some objective evaluations though in the end the designer can take decisions ignoring the indications provided by them. Metrics have been used in software engineering to consider either the structure of the code or some attributes (Fenton, Pfleeger, 1996). However, less attention has been paid on providing metrics for user interactions that is a relevant part to evaluate the quality of a software application. One of the few

works developed in this area was AIDE (Sears, 1995) whose purpose is to evaluate layouts considering the frequency with which each task should be performed. The MUSIC project was concerned with defining measures of software usability (Bevan, 1995), its results provide some measures that are related to user sessions and give an indication of how well users performed their tasks.

Similar problems characterise the hypermedia field where some metrics (Botafogo, Rivlin, Shneiderman, 1992) (Rivlin, Rotafogo and Shneiderman, 1994), have been developed to improve the initial design of the hypermedia structure. They can suggest how to add, modify or remove links and nodes in order to satisfy some properties. However these metrics address mainly structural aspects which do not include the user's perspective for the evaluation. A proposal to overcome this limitation has been put forward in (Yamada, Hong, Sugita, 1995), where three metrics to evaluate the ease of navigation are proposed:

- *Interface Shallowness* (Ish), which represents the heaviness of the cognitive load on users;
- *Downward Compactness* (DCp), which is a metric of the compactness of links from the root;
- *Navigability* (DNav), which is the product of the above two.

In this section we discuss their application to our case study and advantages and limitations that we found in using them.

6.1. Metrics for Hypermedia Navigability

To apply these three metrics we have to introduce the notion of Interface Distance among two nodes. The Interface Distance is defined so that it is 1 if the two nodes considered are on different layers and this means that the nodes belong to different components. Thus the related link implies going in depth into the topic considered in the node origin for the link. For example, if we consider an entity associated with a work (Fig. 8): the links which connect the node belonging to the "GeneralDescription" with the nodes belonging to the components children, are of non linear type, because the nodes belong to different types of components. By traversing these links it is possible to have further information on the topic considered in the root node, in fact from the general description of the work it is possible to get information on a technique which has been used, the state of conservation, bibliographical information, etc.

The Interface Distance is 0 if two nodes are in the same layer (linear link). This means that the nodes belong to components of the same type and thus the traversing of the link does not entail having to go in depth into the topic of the node root of the link. For example the link which connects one work with the next is a link of linear interface because the nodes involved both belong to the component of type "GeneralDescription."

Interface Shallowness (Ish) is defined in the following way:

$$\mathbf{ISh}\frac{\mathbf{n}\cdot(\mathbf{n}-\mathbf{1})^{\mathbf{2}}}{\mathbf{n}\cdot(\mathbf{n}-\mathbf{1})-\sum_{\mathbf{i}}\mathbf{Dp_i}}$$

where $1 \leq i \leq n-1$, n is number of nodes and IDp_i = the sum of the values of IDs (Interface Distance) following the shorthest path from the root to the node i

Analysing the formula it is possible to note that Ish increases with the increasing of the number of nodes and of the nonlinear links (because it increases the value of $\sum_i IDp_i$) and this should mean an increase of cognitive effort.

Downward Compactness (DCp) is defined in the following way:

$$\mathbf{DCp} = \frac{(\mathbf{n}-\mathbf{1})^{\mathbf{3}}}{\mathbf{n}\cdot(\mathbf{n}-\mathbf{1}) - \sum_{\mathbf{i}} \mathbf{Dp_i}}$$

where $1 \leq i \leq n-1$, n is the number of nodes and Dp_i = depth distance from the root to node i

We can note that DCp increases with the increasing of the number of nodes and the distance of each node from the root (because it increases the value of $\sum_i Dp_i$) and thus it increases the structural complexity to reach the nodes from the root.

Since the different user types navigate the hypermedia structure in different ways the processing of the metrics is performed separately for the three types of users foreseen. There is no specific value of these metrics which allows designers to say whether the hypermedia is usable or not. However they help because designers can perform some modifications to the initial structure so that once a different structure has been obtained the metrics can be used to compare it with the initial one.

We have applied the metrics to the hypermedia structure available for each type of user. Since the cognitive loading and structural complexity of the hypermedia depend on the quantity of the nodes and the number of non-linear links we tried to decrease their number. If we modify the hypermedia then the related task model has probably to be modified: some tasks can be eliminated, added or performed in a different way. The purpose of these modifications is to avoid inconsistencies between what is specified at the task level and what is really possible to perform in the hypermedia. Modifying the task specification entails modifying how to perform some activities with respect to what was agreed with the user in the first phases. Thus in some cases the designer has to choose between adopting a structure reflecting the initial task model but whose navigation is not optimal according to the metrics, or modifying it following the indication of the metrics. This choice clearly depends on the case considered.

6.2. Metrics Applied to the Structure for the Tourist User

In figure 9 it is possible to see the structure derived from the task model of the tourist. The elements (i,j) are associated with links connecting couple of nodes and they represent respectively the interface distance and the depth between two nodes.

When we compute the metrics we take into considerations the shortest path from the root to the node considered in case of multiple possible paths.

In the structure of the hypermedia available to a tourist user at the first level (Figure 9) it is possible to identify the four nodes associated to the initial choice (one has no node connected to it because it is mainly a link to the city web site), next we have the interactive

Table 1. Results of the metrics applied to the initial structure.

N1	403
ISh1	404,98
DCp1	403,98
DNav1	163.603,76

Table 2. Results of the metrics applied to the structure modified.

N2	350	−13.15%
ISh2	351.41	−13.23%
DCp2	470.03	+14.05%
DNav2	165174.97	+ 0.95%

map of the town that allows to access to the list of works located in a place and from there to each specific work, then we have the interactive map of the museum from where it is possible to access the general descriptions the rooms of the museum or to access first the list of work located in the room and then the works' descriptions and finally there is the access to some nodes giving general information on the museum.

The results obtained from the initial hypermedia structure are shown in Table 1.

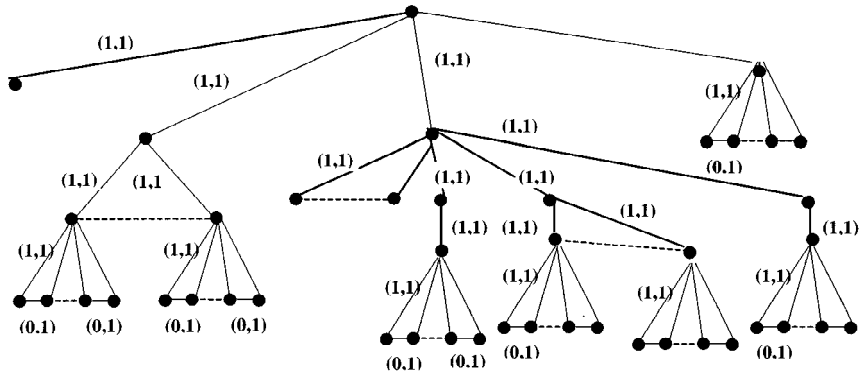

Figure 9. The hypermedia structure available to a tourist user.

To try to obtain a better evaluation some modifications were made. Since the cognitive load on the user and the structural complexity of the hypermedia depend on the number of nodes (they increase with the growth of the number of nodes), we tried to diminish the result of the application of the metric by removing some nodes. We tried to remove the nodes containing the list of works: thus the access to a work is not performed directly from lists but by sequentially browsing all the works. Eliminating these nodes reduces the number of layers of the document and this lowers the interface distance of a node from the root. The aim is to obtain a structure with lower values of the metrics and thus more easily navigable. By applying a new evaluation of the modified structure it is possible to obtain the values shown in the Table 2.

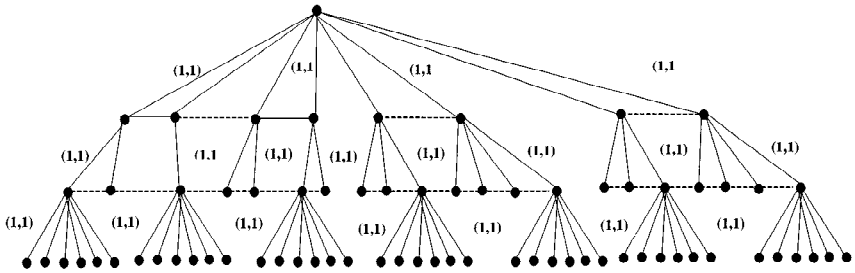

Figure 10. The structure of the hypermedia available to student of art users.

Comparing the values of the two tables highlights that:

ISh2 < ISh1, thus the modified structure requires a lower cognitive load from the user with respect to the initial structure, in fact by eliminating the nodes containing the lists users do not have to decide which work to select;

DCp2 > DCp1, thus with the modified structure it is more difficult to reach the nodes from the root, specifically, to reach one node of work type the distance to cover will be longer;

DNav2 > DNav1, means that the modified structure is more difficult to navigate than the initial one; this implies that the user can reach the information of interest in a longer time and still with more cognitive effort;

Note that even if we have decreased the number of nodes of the hypermedia this has not been sufficient to improve the navigability because of the considerable increase of DCp2. It happened that removing the nodes with the lists of works generated a completely sequential access to the work of arts. Thus we reduced the number of nodes and consequently of layers in the hypermedia structure. This implied a reduction of the interface distance but also an increase of the depth distance that is proportional to the number of links to access to get from the root to the node considered.

This result, along with that obtained during the task analysis phase where we found it useful to enable the tourist both to move linearly among the information (for example to visit all the works in sequence) but also to select directly the information of interest, convinced us to maintain the initial structure which includes the nodes containing the lists of works located in the same room of the museum or in the same place of the town.

6.3. Metrics Applied to the Structure Available for the Student

Students have first the possibility to access the lists of artists, centuries and types of works. From there they can access to the list of works satisfying the requested selected and finally they can access the specific work of art descriptions which are structured on multiple nodes.

Since a student should receive more information than a tourist the hypermedia structure has a higher number of nodes and non-linear interface links. Thus we can expect higher values for the metrics.

The results obtained are shown in Table 3.

Table 3. Results of the metrics applied to the initial structure.

N	2104
ISh1	2105.81
DCp1	2104.81
DNav1	4432343.48

Table 4. Results of the metrics applied to the modified structure.

N	1225	−41.78%
ISh2	1226.68	−38.55%
DCp2	1225.67	−41.77%
DNav2	1503513.79	−66.09%

Table 5. Results of the metrics applied to the initial structure.

N	3407
ISh1	3408.81
DCp1	3410.81
DNav1	11626850.41

Table 6. Results of the metrics applied to the modified structure.

N	1404	−58.81%
ISh2	1405.67	−58.78%
DCp2	1404.67	−58.80%
DNav2	1974501.69	−83.02%

In this case too the initial structure could be modified to reduce the number of nodes: for example, given the amount of some information related to a work is very limited (location, state of conservation, critiques, etc.) instead of planning different components, and thus separate pages, for each type of information, we tried to group them into a unique component and thus a unique page while maintaining separate only the information related to the material used to perform the work because it was more detailed. The results obtained by modifying the structure are shown in Table 4.

Since by performing the modifications described the values of the metrics are considerably reduced and to present some information grouped together has no particular impact on the user (because the quantity of related information is limited) we decided to adopt the modified structure.

6.4. Metrics Applied to the Structure Available for the Expert

The structure of the hypermedia available to an expert user is similar to that of the student. The main difference is that expert users have the possibility initially to select many more lists than students and an expert user needs more information than students and tourists and often wants to go more in depth. The resulting structure of the hypermedia (Figure 11) has a greater number of nodes and it is composed of a higher number of layers and consequently of higher number of non-linear interface links. In the figure we use horizontal dashed lines to indicate that there are multiple nodes at the same level that have the same structure.

The results obtained by applying the metrics are shown in Table 5.

We can try to modify the initial structure to reduce the number of nodes. The modifications performed are similar to those of the student case: we group at the lower levels

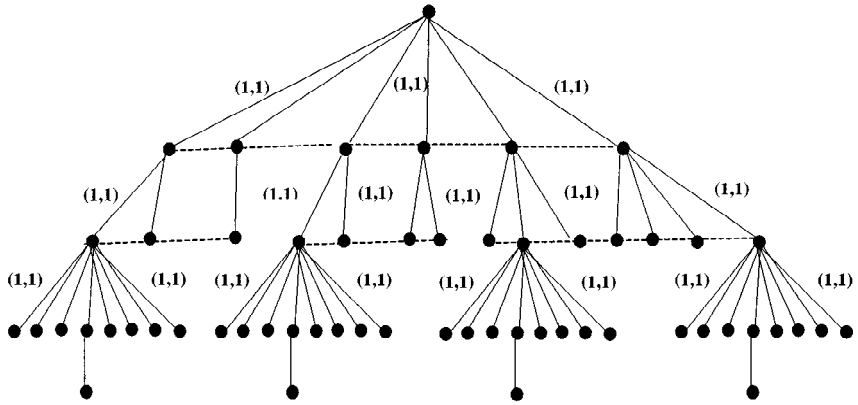

Figure 11. The structure of the hypermedia available to expert users.

Table 7. Summary of the values obtained.

	Tourist	Art Student	Expert
N	386	1225	1404
ISh	397.92	1226.68	1405.67
Dcp	399.02	1225.67	1404.67
DNav	158770.33	1503513.79	1974501.69

some information into a unique component (critiques, state of conservation, historical background, inscriptions (if any) and comments). We keep the components with information concerning the material and the bibliography separate because these are the unique types of information which require considerable space. The results obtained by modifying the structure are shown in Table 6.

In this case too, by performing the modifications described the values of the metrics decrease noticeably, thus we adopted the modified structure.

By comparing the results of the three metrics obtained for the different types of users we can observe that when we move from a non expert user in the artistic field to a more expert user the number of nodes of the hypermedia increases as more information has to be provided, but the number of non linear links also increases because a more expert user needs to obtain more specific and in depth information and thus the number of layers of the structure will be higher. Consequently the values of the metrics increase and thus we can see that the ease of navigation of the hypermedia decreases with an increase in the level of knowledge of the user.

The use of metrics is interesting because they give some quantitative values associated with

some design principle. However the aspects that are evaluated by the metrics considered are relevant but not exhaustive of the possible aspects that should be considered to obtain a usable hypermedia as it is shown by the next section describing the results of empirical testing.

7. Empirical Evaluation of the Hypermedia

During this type of evaluation evaluators observe users who perform specific tasks and take note of the difficulties that they meet in using the application.

It is important to analyse how the users perform the tasks and their opinion of the application. For example, sometimes a simple and apparently non-important feature for the design can be very disturbing for users. Questionnaires and interviews can thus provide a way to collect personal opinions of the users.

A user test of the application was carried out to verify the following parameters of the usability of the hypermedia (Nielsen, 1990):

1) Easy of use, i.e. understanding whether the users can easily comprehend the various options for navigation, the structure of the hypermedia, and the contents of each node;

2) Limited errors, i.e. understanding whether the users during the use of the application make errors (for example selecting the wrong link for the current task) and are able to recover from them.

7.1. The Empirical Test

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. 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 to provide 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.

The choice of the tasks to perform was done so as to force the user to examine all the features of the application. The tasks that users had to perform are described in the next tables.

Instructions for the Tourist

The Marble Museum

This application provides information on:
- **The Marble Museum and the works that it contains;**
- **The town of Carrara and the works which are located in its streets and squares;**

Try to perform the following tasks:

1. **See the "Alma Mater" work sculpted in marble and belonging to the Modern Sculpture Section of the Museum.**
2. **You want to go to the museum: find the opening times and the information on how to get there;**
3. **Choose a street or square of the town and visit the works located there in sequence.**

During the navigation you want some music. Activate and deactivate the music as you wish.

Instructions for the Student of Art

The Marble Museum

This application provides information on:
- **Sculptors and the works that they performed;**
- **Works belonging to a specific historical period;**

try to perform the following tasks:

1. **You want to know the biography of the sculptor Tadeusz Koper and to receive information on the sculpture "Alma Mater," you are particularly interested in the features of the material that was used to create it;**
2. **Find the information on the work "Romana" performed in the XX century.**

During the navigation you can activate and deactivate the music as you wish

Instructions for the Expert

The Marble Museum

This application provides information on:
- **Sculptors and the works they performed;**
- **Works belonging to a specific category (monogrammes, icons, inscriptions, . . .);**
- **Works belonging to a specific century.**

try to perform the following tasks:

1. **You want to know the biography of the sculptor Tadeusz Koper and to receive information on the sculpture "Alma Mater," particularly you are interested in the features of the material that was used to perform it and the related bibliography;**
2. **You want to know whether there are works belonging to the category "altorilievi" and if so you want to visit them in sequence;**
3. **See the available information on the work "Romana" performed in the XX century.**

During the navigation you can activate and deactivate the music as you wish.

During the execution, the observers took note of the behaviour and the comments of the users in the various phases.

Below we indicate some of the main observations which were gathered during the test:

- On the initial page some users did not understand that they had to select the button associated with the language desired to access the information, in fact they tried to select the image or the text which were not associated with any link;
- On the page that presented the museum map users selected the coloured rectangles located beside a room in order to have related information. After several attempts they realised that they had to directly select coloured areas in the map but they were expecting to get a visual overview of the room rather than a textual description as originally implemented.
- Student users could not understand whether the works presented were located inside the museum or in the town.
- When an incorrect value was inserted expert users did not know how to proceed because the application did not provide any error message.

Other suggestions were given for improving the presentation of the user interface such as to highlight the entrance, the way out and the location of information office; when dynamic text moving horizontally across the screen was presented it was suggested to make it wider, faster, red and highlighted; and to use more meaningful feedback when a street in the town was selected.

7.2. Users' Navigation in the Hypermedia

Users were able to accomplish their high-level tasks. The logical structure of the hypermedia obtained after the application of the metrics was found sufficiently easy to understand. When errors were made, for example by selecting wrong links, the user was always able to come back and to select the right option. The motivation for such errors was usually that users had some problems in understanding immediately what links were associated with some interaction techniques. Thus, in a few cases, when a selection was performed they got information different with respect to that expected and, consequently, they had some problems in understanding immediately where they were positioned.

The hypermedia was found preferable to traditional systems. It was generally considered easy to use but not completely flexible: some users would have preferred certain links. For example, an expert user can select a period and obtain information related to works developed in that period but from the works it was not possible to select the artists who developed them.

7.3. Modifications to the Interface

Taking into account the results of the empirical testing we made some small modifications to the hypermedia, for example the initial page was modified to make the image in it selectable, and to have only the button to choose the English language (see Figure 12). It was added the possibility to support from the home page some tasks which were related to the museum but not to the information describing the works contained in it, these tasks are independent from the user type, they are: giving information on fares of the museum, how to get to it, and opening time.

In the museum map the coloured rectangles placed beside the name of the rooms have been made selectable, thus providing descriptive information on the related room and the possibility to access the information concerning the works located in it (an example is in Figure 15). By selecting the coloured areas in the museum map it is possible to activate a video which shows an overview of the room.

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: when the profile selection is available the user can 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.

For both students and experts we inserted the location of the work (room of the museum or street in the town) when additional information is presented. For experts we have enabled them to perform more flexible search of works and to receive an error message when they provide a non correct request.

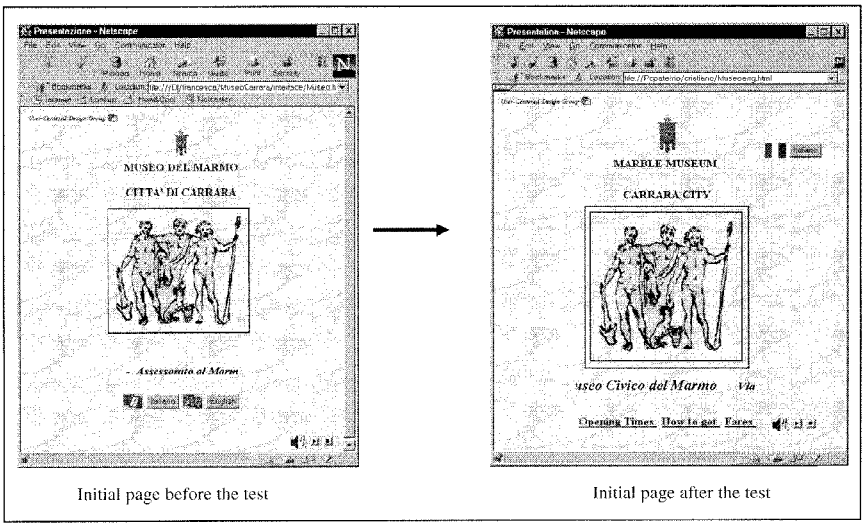

Figure 12. An example of a modification to the hypermedia.

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 was useful to obtain a final design easy to interpret and understand even by end users without experience in interacting with software applications.

8. The Resulting Hypermedia

The resulting hypermedia was designed according to the indications contained in the task model. 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 that can be activated from their initial point of access (Figure 14 shows the three different initial point of access);
- *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.

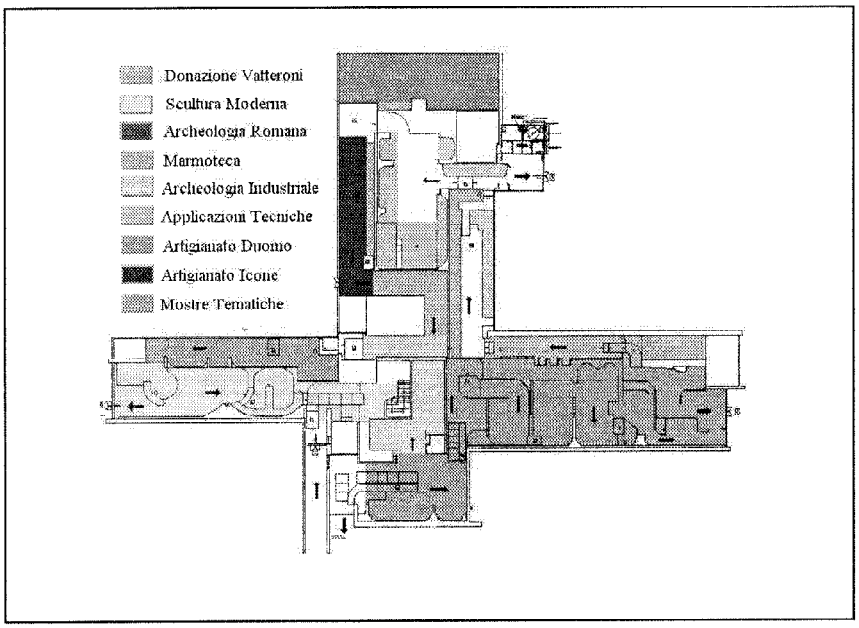

Figure 13. The Map of the Museum.

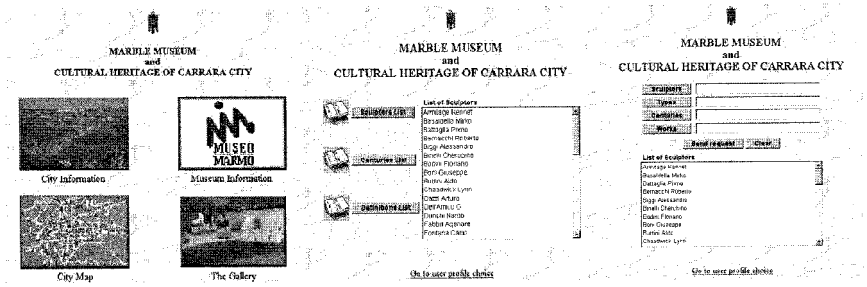

Figure 14. The initial access for the different types of users (from left to right: tourist, student of art, expert).

As an example, Figure 15 shows the presentation of the section of the museum on modern sculpture. The choice of the interaction techniques to make available at this point was made considering the task models and identifying the tasks that should be possible at this point. These tasks are: access the sculptures depending on their material, go to the museum map or the initial choices, activate a video showing the museum room.

As we mentioned above, different views of the same information can be possible depending on the type of users. For example in the left part of Figure 16, we can see the tourist

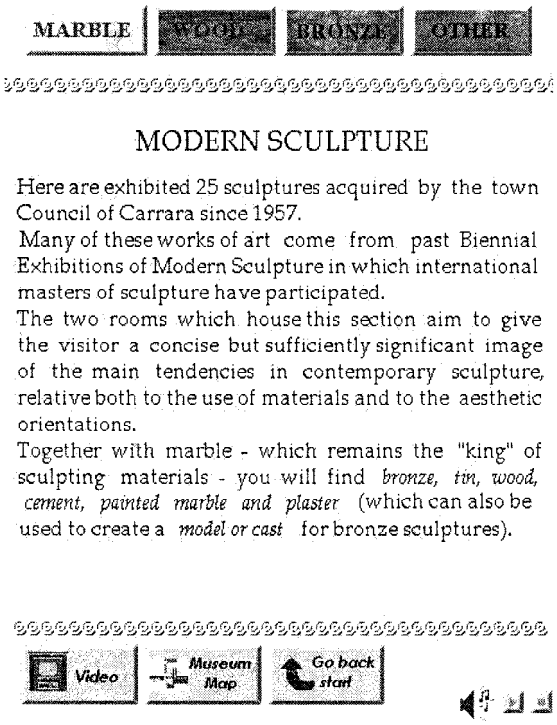

Figure 15. An example of hypermedia page obtained according the task model.

view of information related to a sculpture. As you can see it is possible to access 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 16–right part) the information can be accessed more immediately (for example, by just giving the name of the work), 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.

Users can change the current user profile (tourist, student, and expert) interactively during the session. Thus they have full control on it and can access the different views on the information available and the navigation styles whenever they want without having to start a new application session.

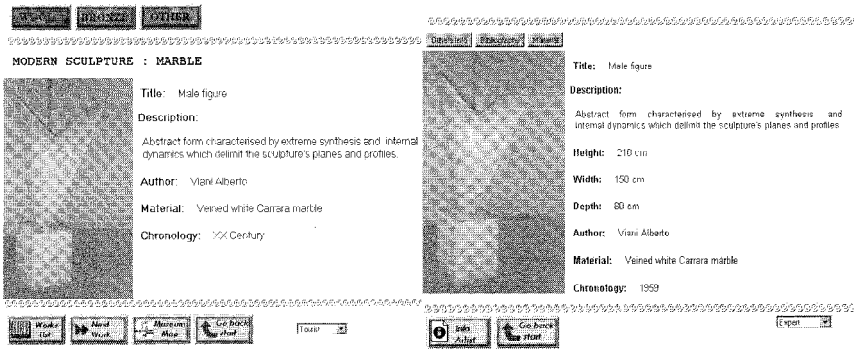

Figure 16. An example of different views of the same information.

9. Conclusions

In this paper we have presented a task-based approach to the design of hypermedia which has been evaluated following both metrics-based and empirical testing approaches. The key idea is that a structured method which takes users and tasks into account throughout the design and implementation process is likely to result in a more usable hypermedia (e.g., user tasks will be supported more consistently across the hypermedia) than previous ad hoc or system-oriented methods. This method also reduces the need for later changes to improve usability that can be more difficult or costly.

We have shown how task models can give useful indications about how to structure the presentation, the navigation, and the information of a hypermedia. They also provide a compact representation of the design choices that have been taken. Different types of users require different tasks to perform; thus a usable user interface should be able to adapt to these different requirements.

We have illustrated the method by considering examples from a case study consisting in the design of a hypermedia for a museum application able to support different presentations and navigation styles depending on the type of user.

We used metrics for an overall evaluation of the structure of the hypermedia. According to such metrics we evaluated some design options and took some decisions concerning the hypermedia structure with respect to the user's accesses. The empirical evaluation gave feedback on presentation aspects and the choice of interaction techniques and it was useful to validate some choices taken on the hypermedia structure.

Future work will be dedicated to improve the method to obtain hypermedia with more adaptive behaviour automatically generated, again exploiting user and task-related information.

Acknowledgments

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References

Bevan, N. 1995. Measuring usability as quality of use. *Software Quality Journal* 4. 2: 115–130.

Botafogo, R., Rivlin, E., and Shneiderman, B. 1992. Structural analysis of hypertexts: Identifying hierarchies and useful metrics. *ACM Transactions on Information Systems* 10. 2: 142–180.

Brusilovsky P. 1996. Adaptive hypermedia: An attempt to analyse and generalize. In P. Brusilovsky, P. Kommers, & N. Streitz (Eds.), *Multimedia, Hypermedia, and Virtual Reality (Lecture Notes in Computer Science, Vol. 1077)*. Berlin: Springer-Verlag, 288–304. http://mac-30.aded.uts.edu.au/projects/ah/Brusilovsky.html

Brusilovsky P., Eklund J., and Schwarz E. 1997. Adaptive navigation support in educational hypermedia on the World Wide Web. *Proceedings INTERACT'97*. Chapman & Hall, 278–285.

Diaper, D. 1989. *Task Analysis for Human-Computer Interaction*. Chichester: Ellis. Horwood.

Fenton, N., and Pfleeger, S. 1996. *Software Metrics—A Rigorous and Practical Approach*. International Thomson Computer Press.

Garzotto F., Mainetti, L., and Paolini P., 1995. Hypermedia design, analysis, and evaluation issues. *Communication of the ACM* 38. 8: 74–85.

Narayanan, H., and Hegarty, M. 1997, Model-based design of hypermedia presentations. *Late Breaking Results ACM CHI'97*. 355–356.

Nielsen, J. 1990. *Hypertext and Hypermedia*. New York: Academic Press.

Paternò F., and Mancini C. 1999. Developing adaptable hypermedia. *Proceedings IUI'99, Intelligent User Interfaces*. Los Angeles: ACM Press, 163–170.

Paternò, F., Mancini, C., and Meniconi, S. 1997. ConcurTaskTrees: A diagrammatic notation to specifying task models. *Proceedings INTERACT'97*. Sydney: Chapman & Hall.

Puerta, A. 1997. A model-based interface development environment. *IEEE Software*. 40–47.

Rivlin, E., Rotafogo, R., and Shneiderman, B., 1994. Navigating in hyperspace: Designs for a structure-based toolbox. *Communications of the ACM* 37. 2: 87–96.

Sears, A.. 1995. AIDE: A step toward metric-based interface development tools. *Proceedings of UIST'95*. New York: ACM Press, 101–110.

Shneiderman, B. 1997. Designing information-abundant Web sites: Issues and recommendations. *International Journal of Human-Computer Interaction* 47. 5–29.

Tylor, R., and Coutaz, J. 1994. Software engineering and human computer interaction. *Proceedings ICSE'94 Workshop, Lecture Notes in Computer Science N.896*.

Yamada, S., Hong, J., and Sugita, S. 1995. Development and evaluation of hypermedia for museum education: Validation of metrics. *ACM Transactions on Computer-Human Interaction* 2. 4: 284–307.

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