Exploiting Navigation Capabilities in Hypertext/Hypermedia

Oreste Signore
CNUCE - Institute of CNR - via S. Maria, 36 - 56126 Pisa (Italy)
Phone: +39 (50) 593201 - FAX: +39 (50) 904052
E.mail: O.Signore@cnuce.cnr.it

Abstract

Hypertext/Hypermedia (HT/HM) applications need careful design. In this paper we outline a hypertext design methodology that leads to a consistent design of the nodes' structure, and makes it possible to model the different kinds of links that can exist among the nodes.

The key concept is the formalization of two different spaces that the user can navigate across: the data space and the concept space. In particular, the introduction of the "concept space" permits an effective modelling of the intensional links. The user can navigate across both spaces, and move from one to another. The availability of these two spaces avoids overloading the nodes with too many intensional links, and helps to supply the hypertext with rich associative mechanisms, thus exploiting the potential of the basic hypertext philosophy.

Particular attention is given to the representation of the navigational aspects; they are made evident to the user by means of a map of links, based on the concept of affinity between the nodes. Finally, we discuss some general implementation aspects, and point out the desirability of offering the user multiple and interchangeable interaction paradigms.

1 - Introduction

Hypertext and hypermedia became very popular since several years (Conklin [1], Nielsen [2]). In the following, we will briefly illustrate the importance of the links, that are fundamental components of hypertext, and will discuss some design issues that can lead to the implementation of effective hypertext applications.

The legendary "Memex" (Bush [3]) was defined as: *"A device in which an individual stores his books, records, communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory".*

As a consequence, we can infer that hypertext was originally conceived essentially as a personal, single user tool, intended for the management of information needed by a single researcher for his/her own purposes.

Even when hypertext is designed for multi-user environments, the user is supposed to have a complete awareness of the content and the organisation of information. This implies that all links should be quite evident and natural to the user, whether they represent a "structural" organisation, or some association among different information nodes.

The user may encounter many difficulties in finding a relevant chunk of information, exactly as when we are looking for a book or a document that, we remember, "has been stored in the bookcase, near to other documents related to similar topics".

In addition, we must stress that the richness of hypertext resides in the representation of the associative mechanism, the inspiring principle, by means of links; thus this association among the nodes constitutes probably the most relevant aspect in hypertext.

The main advantage offered by the use of hypertext documents can be summarized as:

- immediate access to nodes containing relevant information;
- non-linear organisation of data;
- possibility to reduce the amount of information stored in each node, suggesting possible items that can give supplemental or deeper information. When additional info is needed, the user can activate the links at his/her will, thus enriching his/her knowledge according specific needs or interests.

To find information in a hypertext system, two separate steps are needed: first, a "satisfactory" entry point is identified in response to a user query; second, starting from this entry point, the user can begin to navigate through his hypertext documents (Croft [4], Croft [5], Frisse [6], Thompson [7]). However, it may be difficult to find an appropriate entry point, and the "noise" effect may become important (Lesk [8]). Accessing information may be performed by *navigation*, *browsing*, or *querying*. Users normally use these access modalities as many times as they want, and in arbitrary order.

At least two problems, however, have been widely discussed in the literature, constitute a real challenge, are common to all implementations: the *disorientation* and the *cognitive overhead* (Utting [9], Parsaye [10], Nielsen [2]).

To our understanding, the cause of these problems in hypertext navigation is frequently poor design of the hypertext. Too often the designers consider the hypertext design to be simply a "creative" task, and implement their hypertext applications intuitively, without a careful organisation of the information and modelling of the associations. This lack of rigour in the design stage will lead to an inconsistent representation of the information with obscure or unjustified design choices often being masked by showy technical effects.

The resulting effects can become particularly relevant when the designer realises that a large number of links can enhance the associative capabilities of hypertext.

Environments like WWW, where information is distributed over the world and organised by different people, for different purposes, highlight these problems.

As a consequence, the modelling of the knowledge and the structuring of information nodes and related links become a major design issue in the implementation of distributed HT/HM applications.

2 - Links

As it is well known, hypertext consists of nodes and links. Links are the basic component contributing to the *enrichment of the knowledge*, as they have a fundamental role in *stimulating the user's interest*, by implementing *various types of connections* among the nodes.

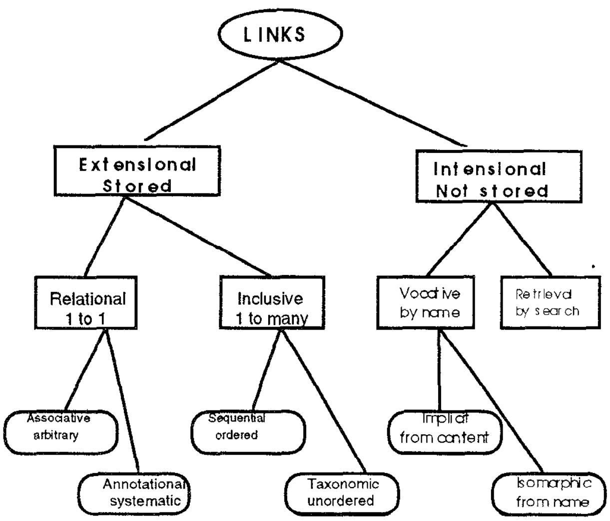

Figure 1. A Taxonomy of Links according to DeRose [11]

2.1 - A taxonomy

In the following, we will refer to a taxonomy of links proposed by DeRose [11]. According to this classification, the links can be divided into two main classes: extensional and intensional links, which can be further split into several subclasses, as shown in Figure 1. In more detail, the *extensional links* can be subdivided into:

- *Relational (or referential) links*: extensional links that connect single nodes (or specific section of nodes). Each end is one conceptual unit.
- *Associative links*: absolutely unpredictable relational links. Normally they are labelled according to type. It must be noted that this can lead to an excessive number of arbitrary types.
- *Annotational links*: relational links that represent connections from portions of text to information about the text.
- *Inclusive (or organisational) links*: extensional links that represent super-ordinate/sub-ordinate relationships between document elements.
- *Sequential links*: inclusive links with multiple, ordered target locations (structure-representing links are a typical example).
- *Taxonomic links*: inclusive links with multiple unordered target locations. They associate lists of properties with particular document elements (cross-reference between words is a typical example).

It is evident that extensional links must be stored explicitly in the hypertext nodes. On the other hand, the *intensional links*, that follow strictly from the structure and the content of the documents they link, can be subdivided into:

- *Vocative links*: invoke a particular document element by name.
- *Implicit links*: vocative links whose target element's name appears within the content of the source document.
- *Isomorphic links*: vocative links whose target element's name appears as an element name in the source document (different documents share much or all of their logical structure).
- *Retrieval links*: intensional links that invoke a process to search a portion of the document for something. The search process may be of arbitrary complexity.

We must also remember that each node can be linked to many other nodes for many reasons, and this is especially true for the intensional links, that can be seen as supplying "added value" to hypertext.

2.2 - Design problems

It is customary that the designer analyses the content of the nodes and identifies the "*anchor point*", which

Proceedings of the 1996 Hawaii International Conference on System Sciences (HICSS-29)
1060-3425/96 $10.00 © 1996 IEEE

constitutes the smallest element in a node that can cause a link towards other nodes.

This is the phase during which a great number of links can be implemented. In fact, many designers, realising that the links are the power of hypertext, introduce as many links as possible. The physical implementation of a link uses buttons, icons, hot-words.

Independently of difficulties caused by the particular tool adopted for the implementation of hypertext, some considerations about links and user interface have more general relevance and can influence the design phase.

First of all, we must consider the *extensional* or *explicit links*: as they are defined by the designer, they are necessarily dictated by his/her knowledge on specific domain and mental organisation, and therefore are "hard coded" in hypertext. As a consequence, we can have a large variety of choices, ranging between the two extreme cases: a "flat" or a "too many links" hypertext. The first one, in spite of some technological effects (sound, animation, special effects, etc.) reproduces a poor quality book or a traditional application (menu cascade). The second case is when the designer realises the power of the links and put on every node a high number of links, referring to the most disparate destinations. In both cases, the user in fact loses his/her intellectual independence, as he/she is either forced to follow a non stimulating path, or receives an enormous quantity of stimuli, and therefore cannot follow his/her logical and conceptual associations.

The need to representing the *intensional* or *implicit links*, implementing interaction mechanisms that will emulate as far as possible the human mind's associative mechanism, constitutes an additional complex factor. In the following, we will discuss this topic in detail .

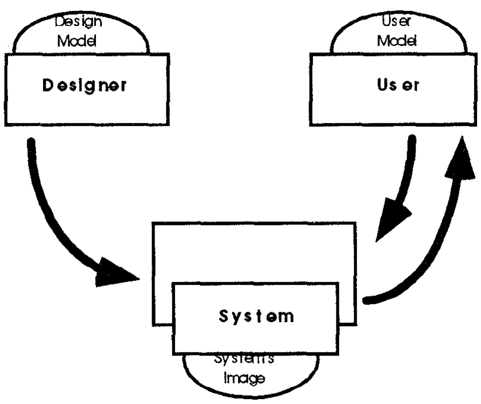

***Fig. 1** - The role of the interface as a communication medium to the establishment of a mental model (from Norman [12]).*

The third problem, that to some extent overlaps with the others, is well known in the context of cognitive psychology, and is much more common than appears at first glance. In all these cases, when an object is "unusable", we face an interface design problem. As shown in Figure 2, the *system interface* communicates the designer's mental model to the user. As a consequence, the user will build a mental model according to the "messages" communicated by the interface. In practice, the two models are rarely consistent, and in many cases can be totally different. Norman [12] reports many examples where poor interface design was the cause of disappointments and even, possibly, of disasters.

3 - Hypertext Design

3.1 - Generalities

Hypertext design requires the definition of the structure and layout of the nodes, as well as the associative linking mechanisms that facilitate navigation. In the following points, we attempt to identify the main characteristics of an effective hypertext application:

- A *purely sequential visit* of hypertext nodes is a too simple interaction, which may help the less experienced user, but will soon appear less appealing than a conventional book.
- Obliged connections should be avoided as far as possible, as they force the user to follow associative paths that are evident to the designer, but sometimes obscure to the user. On the contrary, the user should have the possibility of *associating the concepts* that can be tied to the information nodes, so that he/she will be able to exploit the navigation capabilities at the highest level.
- The user should have the possibility of choosing *several interaction paradigms*, or *metaphors*, as the association among the nodes can be dictated by several reasons (proximity in space or time, relationship among the associated concepts, etc.). In addition the user must have the possibility of *switching* from one metaphor to another, so emulating the way the human mind works.
- The implemented *links* must be of different *types* (or, at least, their meaning must be quite evident to the user). Even more important is to *visualise* the links, so that the user can have a clear idea of how much a link is "promising" in terms of the number of nodes he/she can access. Finally, the *weight* of the links (i.e. the

Proceedings of the 1996 Hawaii International Conference on System Sciences (HICSS-29)
1060-3425/96 $10.00 © 1996 IEEE

importance given to the specific association) should vary accordingly to the user's interests.

Hypertext Design methodology is in some way a contradiction. Hypertext was born as a totally free environment, while a methodology tends to impose well defined steps, sequence of actions, forms, checking procedures, and so on. Several disciplines can help in establishing useful "guidelines" to design effective HT/HM applications. More precisely:

- *Database Technology* effectively helps in the process of *Data Modelling*, i.e. in the phase where we define the structure of nodes and their content;
- *Information Retrieval* is a sound theoretical basis for the identification of the most suitable techniques to be adopted for the *Indexing* of free text information that characterizes the information nodes in hypertext applications;
- *Artificial Intelligence* can contribute to the problem of *connecting data items*, i.e. capturing the relations that can be established among the nodes on the basis of the choices taken by the user;
- *Cognitive Psychology* is essential to implement an effective *User Interface*, capable of conveying to the user the designer's mental model.

3.2 - The nodes

A necessary prerequisite to the implementation of an effective hypertext is an accurate analysis of the information to be represented. Analogously to other application environments, especially the database environment, the definition of a conceptual schema, i.e. a semi-formal description of the information to be represented, is of fundamental importance. The conceptual schema makes it possible to model the relevant objects and the relationships among them.

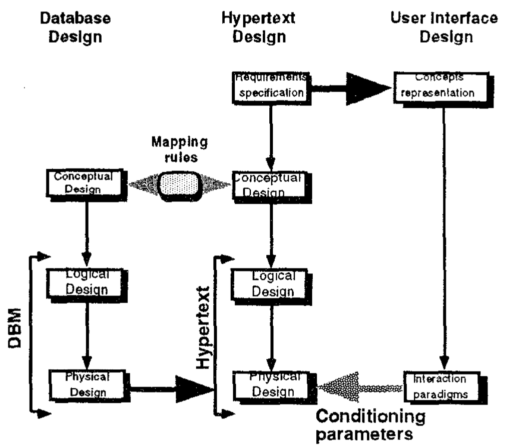

Figure 3. Schema of a hypertext/hypermedia design methodology (DEXA'95)

This approach appears to be very useful as it is based upon consolidated methodologies, that permit the information to be represented independently from the particular tools that will be adopted in the subsequent implementation phase. The architecture of a possible hypertext design methodology (Signore [13]) is reported in Figure 3.

First of all, we can notice that there is a mapping between the *conceptual database schema* and the *conceptual design* of the HT/HM. This is because a class (or entity) maps quite naturally onto a single HT/HM information node.

To design the *user interface*, from the HT/HM *requirements specification* we can abstract the *concept representation*. To be clearer, at this stage we must identify the possible associative mechanisms that can lead the user to look for nodes connected to the node he/she is located on. This, in turn, leads to the identification of the most suitable *interaction paradigms*, or *metaphors*, that can be implemented at the physical level of the HT/HM.

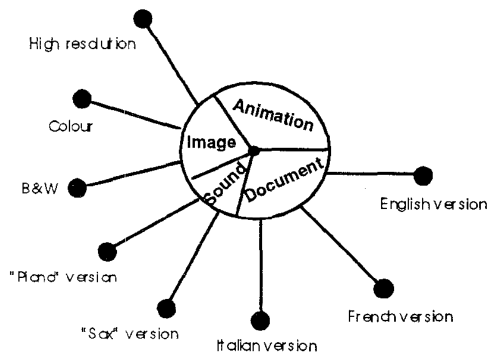

Figure 4. The structure of a node: components and perspectives.

The *physical design* of the HT/HM is, quite obiously, affected by the physical design of the underlying DB physical design.

It can be seen that, once the conceptual schema has been designed, it is possible to proceed to the definition of the hypertext's structure by a straightforward process. Roughly speaking, entities are transformed into hypertext nodes, while the relationships can be mapped into extensional links. Going down to the physical level, the identification of nodes' types and links' types allows the definition of nodes' structure that make them clearly distinguishable, while maintaining a "family feeling". By

Proceedings of the 1996 Hawaii International Conference on System Sciences (HICSS-29)
1060-3425/96 $10.00 © 1996 IEEE

this, the structure of the node can automatically transfer information about the kind of information it contains.

In defining the nodes' structure, we may introduce the additional concepts of *components* and *perspectives*. This means (Figure 4) that every node is made by several components, that can be seen as an enrichment of the concept of "field" of the card or the "attribute" of an entity. In fact, the components of a node can be of several types, e.g. sound, animation, image. This assumption leads to the extendibility of the proposed methodology to the design of hypermedia as well as hypertext applications, by means of a unified approach.

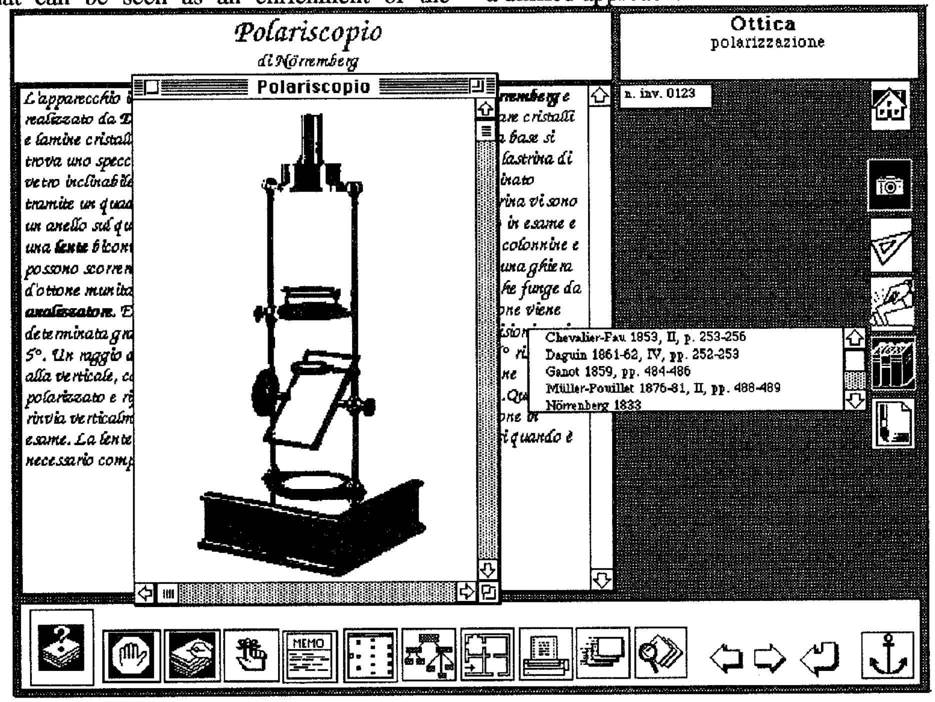

Figure 5. Activation of extensional links visualises additional information pertinent to the node (from Signore [14])

In addition, if we consider that every component can be seen from different perspectives, we can easily manage, at the design level, many problems, like the different resolutions of monitors, user preferences and multilingual support.

Finally, every node may contain several links to other nodes, dictated by the associations modelled during the conceptual design phase.

3.3 - Associations among the Nodes

As we have pointed before, links, extensional as well intensional., are the hypertext component in charge of representing and implementing the associative aspect.

3.3.1 - Extensional links. In fact, *extensional links* are essentially structural links, whose activation can be needed, for example, to show up graphical or additional information.

Figure 5 shows the case when the user, looking at the descriptive card of a scientific instrument, activated links to show up its image and bibliographic references.

3.3.2 - Intensional links. The *intensional links* constitute a different case, as they aim to model the associative process typical of a human mind.

We can emulate this process implementing a "*concept space*", that makes explicit the relationships existing among the concepts that can be attached to a single information node. Therefore, we can distinguish between a *navigational level* and a *conceptual level.*

While at the navigational level we store the explicit links, pointing from one information node to another, the concept space accommodates the implicit or intensional links. More precisely, at this level we can represent:

- all *link types* dictated by the relationships existing at the conceptual level (Figure 6);
- all the *semantic relationships* existing among concepts (Figure 7).

In Figure 6 and 7, the small ellipses represent classes of objects, whose instantiation is made by entities. Each entity is connected to some units, that represent the different perspectives the single components of the entity can be seen from. Finally, the set R constitutes a representation of

Proceedings of the 1996 Hawaii International Conference on System Sciences (HICSS-29)
1060-3425/96 $10.00 © 1996 IEEE

the documents corresponding to the entities, and the set KW includes Keywords corresponding to the concepts, arranged according their semantic relationships.

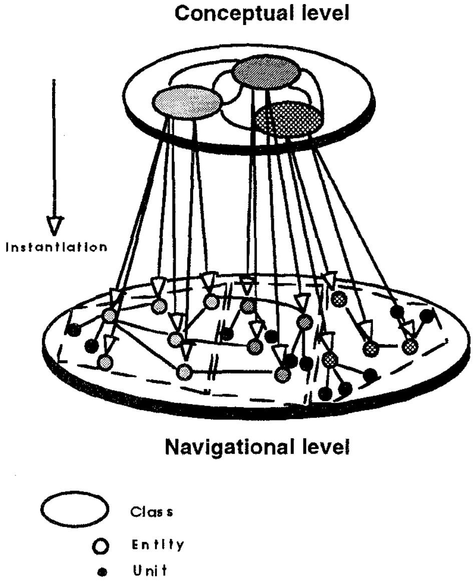

Figure 6. The two abstraction levels in the proposed hypertext model

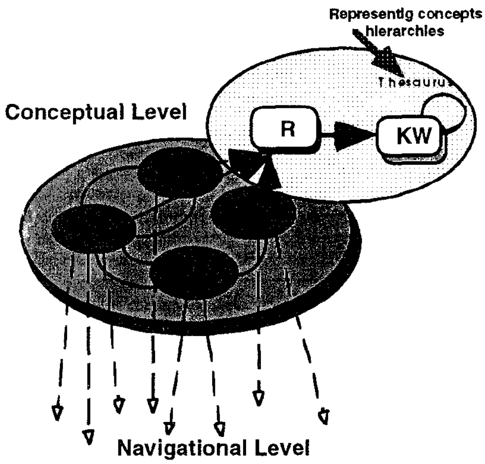

Figure 7. The concept space at a higher detail level

Using this approach, we can represent the knowledge on a given domain and are no longer obliged to make all the possible links between the nodes explicit. Consequently, we can reduce the cognitive overhead implied by having an axcessive number of links on a single node.

It is evident, however, that this solution will be only effective for "active" users. Such a mechanism hypothesises that the user has the ability of abstracting the significant concepts from a single node, and subsequently associating them to produce a personalised cognitive path. Therefore it can be considered especially valuable for applications in the cultural heritage or educational areas. In fact, the implementation of an interaction paradigm based on the navigation through the "concept space" is far superior to the widely diffused concept of "electronic encyclopedia", which is simply a (possibly large) set of nodes, connected by explicit references ("hot words"), mapping predefined relationships.

Navigation through the "concept space", on the contrary, enables the user to operate an abstraction process, then following the associations among the concepts, finally descending again to the information space. This process appears to be similar to the natural process of a human mind. The relevance of the proposed approach consists in the introduction of a large number of potential links among the nodes, but avoiding that their proliferation will overload the node or disturb the user.

4 - Implementing Links and Navigation

As we stressed the importance of links, clearly we must pay much attention to their implementation as well as to the way they are made explicit to the user.

4.1 - Types of links

There is a debate about the opportunity of having "typed" or "non-typed" links. Without going into details, we must stress that the user must be made well aware of the semantic meaning of links, and of a destination node type. As an example, when managing a collection of art objects, there is an intrinsic difference among the links connecting two objects, or an object to a person, and the link addressing a dictionary or iconographic item.

Another difficulty arises from the necessity of making evident these differences to the user, especially when we are facing the case of "multiple links", i.e. the case when a single "*anchor point*" is the starting point to other nodes.

When implementing a hypertext, we must consider that the target user is supposed to be particularly "active" and "curious". As a consequence, we must foresee the implementation of *annotational links*, that may facilitate the capture of user's knowledge and can be added to hypertext. In a subsequent phase, the annotations can be made accessible to the whole users' community and will become part of the common patrimony of knowledge.

In many cases, especially in implementing educational applications, we must provide and implement *vocative implicit links* that may reference dictionary entries.

Proceedings of the 1996 Hawaii International Conference on System Sciences (HICSS-29)
1060-3425/96 $10.00 © 1996 IEEE

Finally, the designer must provide guided tours, that will satisfy some ad hoc needs. However, the user should be given the freedom to leave the tour at his/her will, would he/she desire to perform a deeper investigation of some aspects, or follow associations dictated by his/her experience in the specific field. It is worthwhile to note that guided tours can be useful to the user to become familiar with the hypertext's structure and content.

4.2 - The concept of affinity between nodes

It is possible to reduce the difficulties originated by the cognitive overhead and disorientation by making evident the links that exist among various nodes, so that the user could immediately realize how much the activation of a link can be "promising". To emphasize this concept, it is worthwhile to introduce the concept of link's *weight*, for measuring the *affinity* degree between two nodes. This concept allows the distinction between links that form strong relations between nodes from those that connect nodes loosely.

To have a local representation of navigation proximity, it is useful to define the concept of affinity between the nodes, that is:

k = total number of link types

w_{ij}^{h} = weight of a link of type h from node N_i to node N_j, defined in the interval (0,1];

n_{ij}^{h} = number of links of type h connecting node N_i to node N_j

$T_i = \{N_j : \exists \text{ link from } N_i \text{ to } N_j\}$ i.e. the set of nodes target of links originating from N_i

We can define the *affinity* between the nodes N_i and N_j as:

$$a_{ij} = \sum_{h=1,k} n_{ij}^{h} \bullet w_{ij}^{h} \qquad (1)$$

As we will see in the next paragraph, the concept of affinity can help in displaying a local map of proximity of nodes.

4.3 - Dynamic links and visualization

Looking to the affinity at a higher detail level, we can realise that the weight of a link between two nodes cannot be considered an "objective" quality, but it is related to the specific user's interests. To take an example, would we implement a hypertext on art objects, it will be possible to imagine several links among various objects: components, related objects, initially designed for making a set. In addition, a single object can be related to artists, iconography, locations, and so on. However, the importance of these links depends on the peculiar aim the user has in mind when navigating the hypertext. In particular, some of these links could be of null importance, and the user would be happy not to have them showed.

As a consequence, we must consider the usefulness of defining a "*user profile*" so that the user should be able to modify the weights given to different links.

Therefore, we can give a more general definition of affinity.

Let: $\boxed{Up = (Up_1, \ldots, Up_k)}$ where $0 \leq Up_i \leq 1$, the user profile. We can define the affinity as:

$$a_{ij} = \sum_{h=1,k} Up_h \bullet n_{ij}^{h} \bullet w_{ij}^{h} \qquad (2)$$

that is totally equivalent to equation (1) if a user profile is not provided.

It is quite obvious to give a "spatial" representation of the affinity degree, where the distances among the nodes decrease when the affinity increase.

In a case study, we found very effective the adoption of a circular topology with two levels (Figure 8). The distances vary according to the affinity a_{ij} between the nodes:

$$d_{ij} = \frac{\alpha \bullet A_i}{a_{ij}} + \beta$$

with:

$$A_i = \max\{a_{ij} : N_j \in T_i\}$$

and α, β constants, acting as "scaling" and "minimum distance" normalizing factors.

To take into account the user's behaviour, we must consider the opportunity of re-configuring the map according to the path followed during the visit and the "user profile". In doing this, we can follow an approach similar to neural networks (Kohonen [15]), enforcing the most followed link types, while the less traversed can be weakened. The choice of the most suitable algorithm will take place after a careful evaluation of several case studies.

In its simplest preliminary version:

- let $\boxed{(Nv_1, \ldots, Nv_k)}$ be the tuple whose components correspond to the number of times a specific link has been followed by the user
- let $\boxed{(Up_1, \ldots, Up_k)}$ be the current user profile
- the new updated user profile $\boxed{(U'p_1, \ldots, U'p_k)}$ is given by:

Proceedings of the 1996 Hawaii International Conference on System Sciences (HICSS-29)
1060-3425/96 $10.00 © 1996 IEEE

$$Up'_i = \frac{\left(Up_i + \dfrac{Nv_i}{\max\limits_{j=1..k}\{Nv_j\}} \right)}{2}$$

In a case study (Signore [16]), we considered that an adjustment of the user's profile could not take place while the user is navigating the hypertext: this would produce continuous changes of the map, while the user would like to use the map as a reference. Therefore, the actual updating of the user's profile, and therefore the visible effects on the map, take place only upon specific user's request. As the user choses a profile at the very beginning of his/her navigation through the HT/HM, at the end of the session he/she will be asked to update the profile if the resulting one looks "significantly" different from the initial one.

5 - The Interaction Paradigms

Traditionally, the designer's knowledge is "hard coded" in the hypertext, so forcing the user to follow undesirable cognitive paths. We can reduce this disturbing effect by implementing many and interchangeable interaction paradigms, so that the user will be able to follow the mental paths that he/she will find most natural and significant at will.

The most obvious paradigm is based on the *physical contiguity* of nodes. In this case, we will navigate the hypertext in the same way we would browse the pages of a book. Unfortunately, in many cases this is really the only available interaction paradigm. In fact, links towards other nodes, or the possibility of tracing back a followed path, do not substantially modify the characteristics of this kind of interaction, which very little stimulates the user, and do not much differ from the conventional cascade of menus. In addition, some undesirable effects can arise, like the navigation to a totally out of context node, reached simply because of its physical contiguity with a previous one. In conclusion, this kind of interaction paradigm forces the user to follow the cognitive paths defined by the hypertext's designer. Only predetermined and foreseen associations, explicitly implemented by extensional links, can be followed.

It appears much more relevant to implement more flexible and stimulating interaction paradigms that will allow the user to follow intensional links. On the basis of previous experiences (Signore [17], Signore [14], Signore [16]), it seems that the most useful paradigms could be reconduced to three classes: classification, map and time.

The *classification paradigm* is based upon *taxonomic links*, and allows the navigation through the concept space: from a single node the user will rise up to one of the concepts associated to it. Afterwards, moving across the relationships that map the domain knowledge, he/she can identify other concepts. From these, it is possible to go down again the nodes' space.

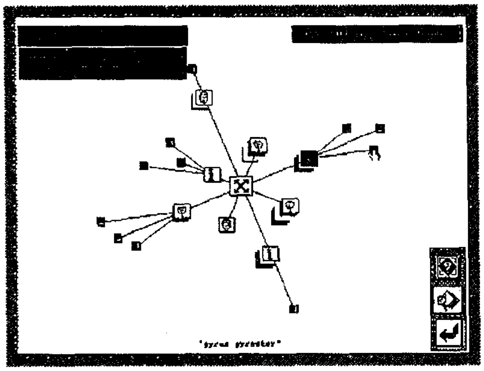

Figure 8. An example of the visualisation of the map of the avai

The most widely used way of representing the semantic relationships among the concepts is a thesaurus, which can be either tree-structured or multi-tree. In both cases, we can easily implement a graphical representation of the thesaurus as a graph, where nodes are the thesaurus terms and arcs are the connecting relationships.

Once the user has identified the kind of relationships he/she is interested in, he/she may select a term, and can then view this term together with all other semantically related terms. Purely hierarchical thesauri can be displayed as a tree (Figure 9), while for multi-tree thesauri a "butterfly display" (Figure 10) constitutes a satisfactory metaphor. In both cases, at user discretion, the arcs may be labeled with the relationship they are representing.

The user can move around the structure (and ask for detailed explanation of the terms and/or an image) using the scroll bar, and may extend the tree toward the root or toward the leaves.

Some examples of this kind of interaction can be found in Signore [17], Signore [18] and Signore [14]. Widely used and useful is the *map paradigm*. In this case, the user can interact with a topographic or geographical map, selecting the interesting zones and choosing the nodes to be reached on the basis of their physical location.

In many applications it can be useful to implement a *temporal paradigm*, that may allow to link together the nodes taking into account the contemporaneity (restricted or extended), the temporal sequence, the overlapping of temporal intervals, and so on.

Proceedings of the 1996 Hawaii International Conference on System Sciences (HICSS-29)
1060-3425/96 $10.00 © 1996 IEEE

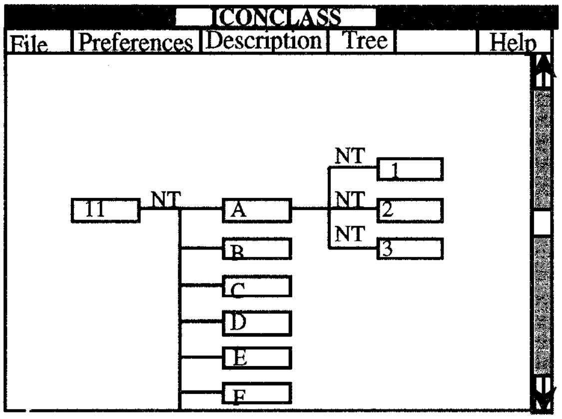

Figure 9. A tree display of an iconographic thesaurus

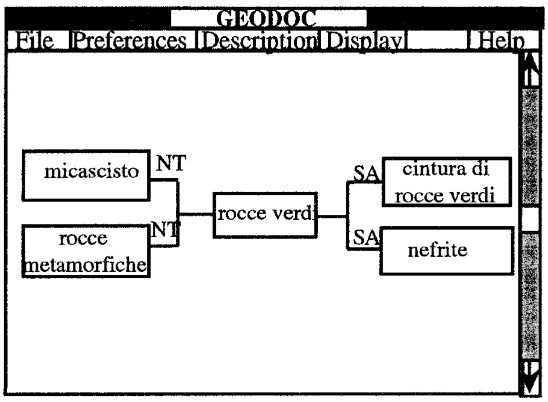

***Figure 10.** A "butterfly display" for the GEODOC thesaurus (Italian version)*

Many applications can be positively affected by the availability of the map and time paradigms at the same time. This permits us to put the information in the right space-time context, according to a conceptual model widely used in many areas, especially in the management of the cultural heritage (Signore [19]).

The implementation of all these metaphors requires the existence of retrieval intensional links, and therefore of a mechanism for retrieving the information associated with every node.

6 - Some experiences

The guidelines presented above have been tested in several case studies.

Signore [17] implements a hypertext structured and figured thesaurus as an effective help in the formulation of queries to a hypertext on heraldry.

Signore [14] reports the case of a hypertext for an interactive visit to a scientific instruments museum. In this project, the main emphasis was on the implementation of multiple and interchangeable interaction paradigms. The concept space was implemented by a classification thesaurus about some topics in physics: from any leaf it was possible to see the list of related instruments, and directly access any of them.

Signore [16] presents a first version of the outlined methodology, tested in a case study for a visit to a botanic garden, with particular attention given to the didactic aspects. In this implementation, the data were stored on a database with a client server architecture, and the link map with circular topology and dynamic user profiles was tested.

In the implementation of the interface of a reverse engineering tool, we adopted the conceptual schema of the underlying software repository as the main interaction metaphor.

Two more test cases are under way. In the first one, we are designing and implementing a distributed HT/HM for the archaeological cultural heritage of the Tuscany (Signore [20]). In the second one, we are working on a prototype that offers a HT/HM interaction towards a conventional information system.

The various applications we have implemented so far are different as far as the technical and development environments are concerned, but can be seen as a series of steps in the process of refining the methodology. In all cases, we realized that the attention paid to the identification of the user needs, the design of the conceptual schema and the selection of the appropriate metaphors resulted in a consistent application design and a reduced implementation effort. It is worthwhile to note that we were able to "reuse" some ideas. In the most recent implementations, we gained greatly by relying on a DBMS for storing the contents of noded and the links (from_node_id, to_node_id, link_type, link_weight). The user profile was also stored in the database.

7 - Conclusions

Many hypertext applications pay much attention to mere technological aspects, while disregarding other important issues, like a consistent and expressive user interface, or the usefulness of an accurate data analysis. In addition, the user is often forced to follow the links implemented by the designer on the basis of his/her knowledge. However, the designer must find the appropriate trade-off between "too many links" and "too few links". As a consequence, the modelling of the

Proceedings of the 1996 Hawaii International Conference on System Sciences (HICSS-29)
1060-3425/96 $10.00 © 1996 IEEE

knowledge and the structuring of information nodes and related links become a major design issue in the implementation of hypertext applications.

In this paper, we have shown that links among nodes in a hypertext give the possibility of representing the associative mechanisms that undoubtedly constitute a point of strength in these systems. Distinguishing between extensional and intensional links leads to the definition of a hypertext design methodology that makes use of consolidated approaches in the database and information retrieval areas and allows a clear identification of the two different types of links. A very effective way to reduce the user's disorientation is by using the map of the links; this can drawn so that accessible nodes are represented at distances inversely proportional to their affinity.

The need for an effective and expressive user interface makes evident the importance of the availability of multiple interaction paradigms, that the user will select at his/her will, switching from one to the other according to the associative mechanism that will appear to be the most adequate.

The proposed design methodology presents some commonalities with the HDM methodology (Garzotto [21]), but differs for the different interpretation of the perspectives and, mainly, for the importance given to the intensional links and their representation.

The spatial representation of the links may recall the proposal presented in Pintado [22], but the implementation and the definition of the affinity are totally different.

All the ideas have been tested in the implementation of small scale hypertext applications, and are going to be experimented in more complex distributed environments.

Acknowledgements

Warm thanks to Giuseppe Fresta and Rigoletto Bartoli for their contribution in many clarifying discussions and in the implementation of several pieces of the case studies., and to the anonymous referees.

References

[1] Conklin J.: *Hypertext: a survey and introduction,* IEEE Computer, September 1987.

[2] Nielsen J.:*Hypertext and Hypermedia.*, Academic Press inc., Harcourt Brace Jovanovich Publishers, USA 1990.

[3] Bush V.:*As We May Think*,in *Atlantic Monthly* (July 1945), 101-108. Republished in S. Lambert, S. Ropiequet (Eds), "CD-Rom: the news Papyrus", *Proceedings of the First MS CD-ROM Conference*, Microsoft Press, Redmond,WA, 1986.

[4] Croft W.B., Thompson R.: *I^3R:: A new Approach to the Design of Document retrieval Systems*, Journal of the American Society for Information Science, 38, pp. 880-886 (1988)

[5] Croft W.B., Turtle H.: *A retrieval model incorporating hypertext links*, In Proceedings of Hypertext '89, 213-224, ACM Press, 1989

[6] Frisse M.E., Cousins S.B.: *Information Retrieval From Hypertext: Update on the Dynamic Medical Handbook Project*, Hypertext '89 Proceedings, ACM, 1989 (ISBN 0-89791-339-6

[7] Thompson R.H., Croft W.B., *Support for browsing in an intelligent text retrieval system*, Int. J. Man-Machine Studies, Vol.30, 639-668,1989.

[8] Lesk M.: *What To Do When There's Too Much Information*, Hypertext '89 Proceedings, ACM, 1989 (ISBN 0-89791-339-6)

[9] Utting K., Yankelovich N.: *Context and orientation in Hypermedia networks.*, ACM Transactions in Information Systems, Vol. 7, No. 1, January 1989, Pages 58 - 84.

[10] Parsaye K., Chignell M., Khoshafian S., Wong H.: *Intelligent databases*, Ed. J. Wiley and Sons, Inc., 1989.

[11] De Rose S. J. (1989), *Expanding the Notion of Links*, Hypertext ' 89 Proceedings, (November 1989), 249 - 257.

[12] Norman D. A.: *The psychology of everyday things*, Basic Books, Inc., Publishers, New York (1988)

[13] Signore O.: *Issues on Hypertext Design*, DEXA'95 - Database and Expert Systems Application, Proceedings of the International Conference in London, United Kingdom 4-8 September 1995, Springer Verlag , ISBN 3-540-60303-4, pp. 283-292

[14] Signore O., Malasoma S., Tarchi R., Tunno L., Fresta G.: *A hypertext for an interactive visit to a science and technology museum*, Proceedings of the Sixth International Conference of the MDA and the 2nd International Conference on Hypermedia and Interactivity in Museums (ICHIM'93) Cambridge, England, 20-24 September 1993, ISBN 0-905963-89-X, pp. 204-209

[15] Kohonen T.: *An introduction to Neural Computing*, Neural Networks, Vol. 1, Number 1, 1988

[16] Signore O., Fresta G., Cimbalo A., Di Lecce S.: *A Methodology for Hypertext Design: a Case Study*, Proceedings of Structures and Contingencies in Computerized Historical Research, IX International Conference of the Association for History and Computing, August 30-September 2 1994, Nijmegen (The Netherlands)

[17] Signore O., Aulisi R., Ceccanti V.: *Hypertext for Hypertext: a Figured Thesaurus*, DEXA 91: Database and Expert Systems Application, Proceedings of the International Conference in Berlin, Germany, 21-23 August 1991, (D. Karagiannis., Ed.), Springer Verlag, Wien-New York, ISBN 3-211-82301-8, pp. 514-519.

[18] Signore O., Garibaldi A.M., Greco M.: *Proteus: a concept browsing interface towards conventional Information Retrieval Systems*, DEXA'92 - Database and Expert Systems Application, Proceedings of the International Conference in Valencia, Spain, 2-4 September 1992, (Tjoa A.M., Ramos I., Eds.) Springer Verlag Wien New York, ISBN 3-211-82400-6, pp. 149-154

[19] Signore O.,Bartoli R.: *Implementation of a historical/geographical database with support of imprecise dates*, DEXA'90: Database and Expert Systems Application, Proceedings of the International Conference in Vienna, Austria, 1990, (Tjoa A.M., Wagner R., Eds.) Springer Verlag Wien New York, ISBN 3-211-82234-8, pp. 271-274

[20] Signore O., Fresta G., Loffredo M.: *A Distributed Hypermedia on Archaeology in Tuscany*, Proceedings of the Third International Conference on Hypermedia and Interactivity in Museums

Proceedings of the 1996 Hawaii International Conference on System Sciences (HICSS-29)
1060-3425/96 $10.00 © 1996 IEEE

(ICHIM'95), October 9-13, San Diego, California (USA) (to be published)

[21] Garzotto F., Paolini P., Schwabe D.: *A Model-Based Approach to Hypertext Application Design*, ACM Transactions in Information Systems, Vol. 11, No. 1, January 1993, Pages 1-26

[22] Pintado X., Tsichritzis D.: *Sa^{Tell}ite. A Visualization and Navigation Tool for Hypermedia*, Proceedings of the Conference on Office Information Systems, SIGOIS Bulletin, Vol. 11, Issues 2-3, April 1990, pp. 271-280

Proceedings of the 1996 Hawaii International Conference on System Sciences (HICSS-29)
1060-3425/96 $10.00 © 1996 IEEE