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ABSTRACT
In this paper it is argued that there are many aspects of the user-hypertext interaction that represent overheads to the user whilst navigating in a hypertext.

To promote a better understanding of the role of those overheads, a framework which facilitates a systematic analysis of the interaction is proposed.

The main contribution of the framework is the simplicity achieved both in the description of the interaction and in the discussion of related overhead problems.

KEYWORDS: Hypertext, User-hypertext interaction, Cognitive Overheads.

INTRODUCTION

Hypertext depends on the use of the information with freedom and intelligence [19]. The same freedom that makes hypertext so unique and interesting is, in part, responsible for its most notorious problems: disorientation and cognitive overhead.

The process of interaction with a hypertext system embeds cognitive activities that add to the overall effort needed to carry out the goal task.

A framework which explores factors leading to disorientation and cognitive overhead has been developed [21] and is presented here. It is based on the cyclic interaction between user and hypertext system.

This following sections in this paper discuss the problems in general, analyse the user-hypertext interaction, detail cognitive overheads, present the proposed framework and give an example of its application.

PROBLEMS

The research described in this paper was geared towards understanding the *disorientation* and the *cognitive overhead* problems faced by a user when interacting with a hypertext system. These are not minor problems present only in isolated systems, nor resulting from the limitations of current technology and research. On the contrary, as Conklin suggests these problems "... seem to be endemic to the fundamental concepts of hypertext ... and that may in fact ultimately limit the usefulness of hypertext [9]."

The relationship between the problems of cognitive overhead and disorientation is strong and direct: part of the disorientation faced by the user in current systems is caused by the cognitive overhead imposed in the navigation.

Disorientation

Disorientation has been regarded as a natural consequence of the user navigating in large hypertexts [19]. More specifically, Conklin has defined disorientation as: "the tendency to lose one's sense of location and direction in a non-linear document" [9].

As far as the current hypertext technology is concerned, a myriad of aids have been proposed and implemented. Some authors believe that users benefit from a *structured document* as an aid to reduce the disorientation problem. For example, Akscyn *et al.* comment that the hierarchical structure of the hyperdocument, typical in KMS, helps users to built a coherent mental model of the database [2]. Brown, indeed, states that "a strong hierarchical backbone certainly helps the reader to orient himself" [7].

The role of *graphical browsing tools*, which present to users the structure of the hyperdocument has been discussed in the literature. On the one hand Halasz argues that it is a requirement for a hypertext system to be able to offer the user a map representing (part of) the underlying structure of a hyperdocument [13]. On the other hand Acksyn *et al.* suggest that a strong hierarchical backbone makes marginal the need for a such map [2].

Metaphors have been widely used in hypertext: the aim is to help the user by presenting structures and interfaces which resemble known elements. One of the most widely used is the *travel* metaphor where the user is said to be *navigating* the hyperdocument. Several graphical browsing tools extend the *travel* metaphor by providing the user with *map* metaphor, as for instance in NoteCards [13].

Another common metaphor, both in systems and applications, is the *book* metaphor, used, for instance, in Superbook [24] and Hyperties [26]. Both NoteCards and HyperCard [3] make extensive use of the *card* metaphor.

Cognitive Overhead

It is normally the case that reading, learning and understanding the contents of the hyperdocument are natural cognitive processes which are needed to carry out the goal task when navigating in a hyperdocument.

The large number of navigational choices and associated decision making processes, intrinsic from the technology, is regarded by Conklin as engendering an overhead on the reader's decision-making processes In this context, Conklin has defined the cognitive overhead as: "the additional effort and concentration necessary to maintain several tasks or trails at the same time [8]."

When commenting on the risk of presenting the user with too much detail, and therefore causing the cognitive overload to arise, Baird states "Overload results in loss of clarity, irritation, difficulties with mental processing and should be avoided" [4].

Accordingly, Wright remarked that "there is evidence that even changing screens to access information only a click away can impair memory processes" [31].

As far as the problems of cognitive overhead and disorientation are concerned, most of the research carried out so far has explored the hypertext technology as the hyperdocument by itself. The interactive aspect of the user-hypertext interaction has been somehow regarded as a detail of particular implementations.

USER–HYPERTEXT INTERACTION

When referring to the interaction the user has with a hypertext system, the metaphor generally used in the literature is that the user *navigates* or *browses* through the information by selecting those links which are interesting.

In such a scenario, an interactive session could be described as a sequence of link selections along with other navigational operations, such as backtracking and string searching. Each of the link selection operations performed is an important unit of the navigation sequence the user goes through: without the link options and navigation where the user freely chooses among links, there is no hypertext.

Accordingly, the secondary navigational modes (such as bookmarks, history lists, backtracking and search operations) available to the user are probably as important as the link selection alternatives. Firstly, they promote the understanding of the embedded hypertext structure, and the building of a cognitive map. Secondly, they help the users to become orientated when they are lost.

As remarked in the literature, the process of navigation embeds overheads in the users' cognitive processes. Improving the usability of hypertext systems, as far as the user interface is concerned, requires a deep understanding of such overheads. To understand the role of these overheads, focus must be given to the user–hypertext interaction.

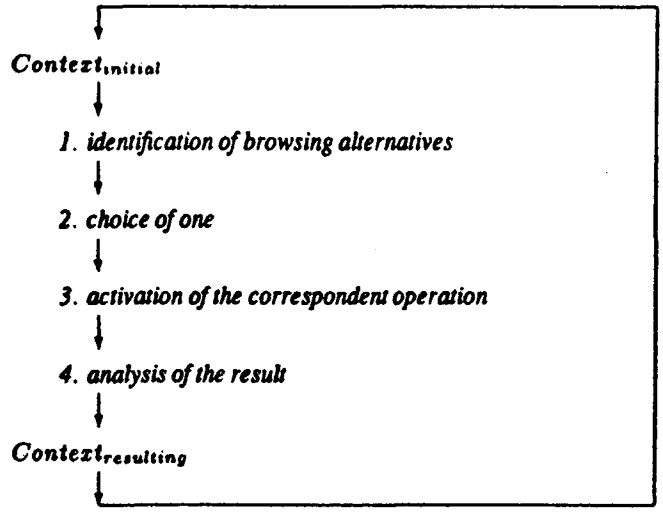

Figure 1: Transfer of contexts in the UCST

Transfer of Contexts in Interactive Systems

In the spectrum of interactive systems, whenever a user requests the system to execute a task, it can be said that the user faces two contexts: the context existing before the request, and the context existing when the user has available the results presented by the system. This transition is referred to in this paper as *transfer of contexts.*

Transfer of Contexts in Hypertext

Interacting with the system, and thus dealing with context transitions, is likely to be the main activity of a hypertext user. As an example, a user, when selecting a link, is transferred from the context containing the source of the link to the context containing the destination of the link.

The cognitive effort demanded for overcoming the associated transfer of contexts is repeated at each navigational operation. Additional effort is needed to perform the operation itself, which includes choosing amongst alternatives and the activation of the correspondent operation.

With the purpose of analysing the overall effort contained in the transfer of contexts, the cyclic set of tasks is studied next.

The User's Cyclic Set of Tasks

Whilst navigating in a hyperdocument, the user performs tasks in a cyclic mode, as illustrated in Figure 1. This *User's Cyclic Set of Tasks* (UCST), as the cycle is referred in this paper, corresponds to operations which lead to the occurrence of *one* transfer of contexts.

The cycle abstracts the sequence of operations which the user, consciously or not, executes when navigating through the information. These operations include not only the activation of the hypertext links but also the secondary navigational modes. The cycle is in accordance with more general models of information search, as for example Guthrie's model, whose proposed process model includes five stages: formation of a cognitive goal; selection of an information category; extraction of information; integration with previously extracted information; and recycling until goal is achieved [11].

OVERHEADS IN THE INTERACTION

In this section, the steps which compose the UCST are used as a guide to discussing the overheads imposed on the user during navigation. The discussion is not exhaustive, but instead focuses on those overheads most related to an operation which leads to *one* transfer of contexts to occur.

1. *identification of the browsing alternatives*

In order to navigate hypertext, Kacmar has remarked that "The user must use visual, mental and physical skills to recognize those objects which are or not associated with links" [17].

It is intrinsic in hypertext navigation that the user has, at the beginning of each cycle, to choose where to go next. Although this repetitive choice is one of the principal selling points of hypertext technology, the related processes embed some overhead for the user, concerning the navigational task.

The problem of properly indicating to the user what a link means (i.e. why it is where it is and where it leads to) has been refereed by Landow as *the rhetoric of departure* [18]. Related work has already stressed the importance of the "optional hypertext information be clearly signed, immediately accessible, and unambiguous" [25].

An associated problem is the one of *linkitis*, where the presentation of too many links is an additional burden for the user [30].

Some of the overheads corresponding to this first step of the cycle are listed next.

- *Identification of available links*

In each step of the cycle the user has to identify what the available links are. Although hypertext systems designers struggle to create clear and unobtrusive ways of indicating the presence of the link (as recommended by Hardman [15]), the identification *is* a task that has to be done. Irler and Barbieri observed that the presence of the link indicators implies, by itself, cognitive load on the process of reading the text [16].

- *Identification of the link type*

Most systems have at least two distinct types of hypertext link. Therefore the user has, when identifying a link, to distinguish among the available types, to reckon what the resulting information would be before deciding whether or not to select the link. In this context, Rada has criticized the link in hypertext which does not give the user enough information on what the result of the selection is [23].

The importance of properly indicating the various link types has been emphasized in the design of several systems, as for instance NoteCards [13], KMS [2] and Unix Guide [6]; it is also one of the design recommendations given in [12]. As an example of the effects of inefficient link type indication, Nielsen has commented on the frustration faced by users of an early version of *Hypertext'87*, when two distinct types were indicated using the same textual font [19].

- *Identification of the source context of the link*

An overhead may be related with the processes of understanding the source context of a link. This is because both textual and graphic indicators may be ambiguous, even if careful authorship techniques are adopted. In such a situation the user has to work out what exactly a link refers to.

When links are indicated by means of small graphic icons, for instance, the user may find it difficult to decide what exactly the icon refers to. Intermedia [32] link markers are an example where, since the author may place the markers anywhere in the window, the semantics of the link may not be obvious for the reader. An example was given by Shneiderman *et al.*: "in a map of the United States, does a particular icon refer only to New York City, or to the entire state of New York?" [27].

- *Identification of possibilities other than links*

Most systems offer other alternatives to link selection, referred to as secondary navigation modes. These possibilities have to be accounted for, as the identification of their scope and/or results may involve in further cognitive overhead on navigation.

Under this analysis, some systems designers have opted for offering the smallest set of operations possible, so as to diminish the overhead related to learning and using them effectively. In a similar approach, it has been suggested that authors should keep the number of links available at any one moment to a minimum.

2. *choice of one of the alternatives*

It is the essence of hypertext technology that the user has the opportunity to choose, with freedom, which alternative to take. Overheads corresponding to this second step of the cycle are discussed next.

- *Cognitive monitoring*

As a consequence of the freedom afforded by hypertext, the user has to make frequent and important decisions as part of the natural way of navigating in the hyperdocument. As noted by Rouet, these decisions require some cognitive monitoring: some awareness of the ongoing comprehension process [25]. The cognitive monitoring process, added to all the processes involved in the choice of alternatives during navigation, imply overheads on the user's processes.

Several aids aiming to help the user on the choice of alternatives are cited in the literature. One example is the presentation of a brief description of the destination article by Hyperties, giving the user the choice of whether to transfer or not to that article [26]. Guided tours facilities available in many systems are an example of trying to help users by reducing the number of choices, or even choosing a particular node on their behalf.

- *User's commitment*

An overhead associated with this point of the cycle is the *user's commitment* to the choice to be done. It is a burden to the user to be conscious that, once the selection is performed, the resulting context will have to be analysed before deciding whether to continue or not through that branch in the navigation.

- *Undo procedure*

As far as interactive systems are concerned, undo is a very important aid for their usability [29] [20], and should be made available by the designer [1].

Undoing of navigational operations in hypertext is a crucial point in permitting the user to explore the hyperdocument. In the case of the user deciding not to continue through a branch in the navigation after selecting a link, the undo of this selection will have to be activated. This is another cognitive compromise in the navigation: in fact, if the *undo procedure* is too demanding the user will be reluctant to explore. Ideally, the undo of each operation should be easily achieved so that, instead of being a problem to the user, it should represent a stimulus for the user to explore.

3. *activating the command needed to carry out that choice*
Kacmar observed that the activation of a link also requires from the user visual, mental and physical skills [17]. In the context of the UCST, the activation of a link is an important operation not only because it represents the main interface between the user and the system but also because it is a repeatedly used operation. Therefore it should be easy to use. The user, after a learning period, should be able to perform the operation automatically. The same principle applies to the secondary navigation modes, as for instance backtracking and the selection of landmarks.

In the context of the environment in which the system is embedded, it is convenient for the navigation related operations to be integrated with the rest of the facilities available. Such integration would represent a step towards helping the user to operate the overall system with the minimum of effort.

• *Knowing how to activate the chosen alternative*
The user has to know how to go about activating each of the available alternatives. This is, in itself, an overhead on the user's cognitive processes.

4. *analysis of the result*
The objective of the user in activating a operation is, ultimately, to access the information contained at the end of the link. After having activated the operation, the user is likely to encounter and have to overcome yet further overheads before achieving that objective. Two of these overheads are discussed next.

• *Temporary disorientation*
When a transfer of contexts occurs, the user faces a situation of momentary disorientation before being able to access the *contents* of the destination information. This type of overhead is referred in this paper as *temporary disorientation overhead*. One of the first tasks for the user is to identify what the new information is, and what information is no longer available. In a frame based system like KMS the identification may represent a straightforward task: in most (navigational) operations the whole frame containing the activated link is replaced by the new frame.
In a multi-window platform, as for instance NoteCards, the user has either to position the new window first (an additional overhead: to find a convenient position) or to recognize what the target window is (in situations where the screen has many windows and the target window is already on the screen: the system brings the target window to the foreground and flash it for an instant).
Situations where the new information is inserted *in situ*, as for the replace button in Guide [6], may also represent an overhead for the user when it is necessary to recognize what is or is not new after the insertion has been done.
Shneiderman *et al.* refer to this as "the disorientation readers of a hypertext inevitably feel each time they transverse a link" [26], and suggest landmarks such as the title of the frames as an aid to overcome such a disorientation.

• *Understanding the relationship established by the link*
As one can expect, this phase in the cycle does require cognitive attention. The user has to identify what relationship exists between the source and destination information presented, a relationship which may not have been left totally clear in the context containing the source of the link. Prior to that, it may be necessary for the user to understand what the destination information itself means. The type of the effort necessary for the user to perform the task depends not only on the information contents but also on the interface characteristics, as reported by Stark [28].
The next step is the integration of the new information with the previous information as a whole, which will permit the analysis of the current stage and evaluation of achievement of the main goal. As a result, a new cycle may or not be initiated.
Landow's rules for authors [18] are mostly concerned with reducing these two overheads: authors of hypertexts are requested to follow the principles established by the rhetoricals of arrival and departures when creating links, so as to help the user to understand the source and destination contexts of the link.

INTERACTION CYCLE FRAMEWORK

Careful analysis of the user interface towards usability of interactive systems has been suggested by many. Hansen and Hassi, for instance, when introducing their framework for explaining differences in performance, states: "It was our hope and that of other system designers that a better system could be deployed if we paid careful attention to the user interface ..." [14]. The same careful attention is suggested by Dillon in the context of hypertext systems, when he reminds system designers that "even in such systems, a user still ultimately interacts with a machine" [10].

The absence of a detailed analysis may lead to wrong assumptions on the users' effort in dealing with the interface. For example, in a study reported by Boyle *et al.* the multi-window interface of NoteCards was expected to help the users to find the information. The results showed, however, that an inverse condition occurred [5].

To facilitate such an analysis, this paper proposes a framework to describe the user-hypertext interaction. The framework, presented next, is divided into two levels:

• the outer level, *interaction cycle*, corresponding to the sequence described in the *User Cyclic Set of Tasks*;
• the inner level, *interaction table*, detailing the steps of the interaction.

The objective of the framework is to permit the interaction be described in a systematic, although informal, way. The description, presented in this form, facilitates the discussion of the cognitive overhead factors described earlier in this paper.

Interaction Cycle

The *User Cyclic Set of Tasks* presented the interaction in one single level, an approach which permitted the identification and visualization of the sequence of tasks performed by the user, and the resulting transfer of contexts.

With the aim of providing a framework which permits a deeper analysis, a mechanism to describe systematically the cycle of tasks is proposed: the Interaction Cycle, illustrated in Figure 2.

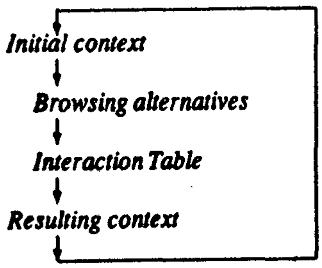

Figure 2: Interaction Cycle

The Interaction Cycle framework is composed by four items:

- *Initial context:* this item describes the overall information available to the user at the beginning of a cycle;
- *Browsing alternatives:* this item lists what the navigational alternatives are;
- *Interaction table:* this item describes the steps involved in the interaction sequence within the cycle (see next section);
- *Resulting context:* this item describes the overall information available to the user at the end of a cycle.

The discussion carried out in these items focuses on the *cognitive overhead* problems previously identified.

Interaction Table

The interaction table is a mechanism which describes the interaction between user and hypertext system occurring in a single operation.

To illustrate how the table presents such a description, a generic operation of selecting a link is taken as an example. From the point of view of the user, the table must detail the sequence where the user:

1. chooses a link among the browsing alternatives;
2. activates the link;
3. observes the result.

It is possible to envisage a similar sequence from the "point of view of the system":

1. waits for the user to select a link;
2. gets the information requested;
3. presents it.

The interaction table corresponding to the user-hypertext interaction indicated above is:

user	1.	<chooses one link >
	2.	activates the link
system	3.	<gets the information requested>
	4.	presents requested information to user
user	5.	<analyses result>

Only a minimum number of the steps involved are listed in this Interaction Table. This was done with the objective of introducing the following notation and conditions:

- the sequence corresponds to an interaction between a user and a hypertext system;
- before the sequence starts, the user is navigating through the hyperdocument and is presented with the *Initial context* of the Interaction cycle;
- by the end of the sequence the user has analysed and understood the transfer of context which has occurred, which corresponds to the *Resulting context* element of the Interaction cycle.
- the numbers indicate steps in the sequence, used for further reference;
- phrases within angular brackets "<" and ">" refer to a user's cognitive process or a system's processing task, which are related to the sequence but are not seen by the other part.

In the next section it is presented and example of the use of the framework.

EXAMPLE: SELECTION OF A REPLACE BUTTON IN GUIDE

As an example of the use of the framework, this section presents the interaction cycle associated with the selection of a replace button in Guide. The example uses the UNIX version of the Guide hypertext system, an analogous situation could be applied to the InfoAccess (OWL) version available for personal computers.

- *Initial context:*

The user is using the system to access a Guide hyperdocument serving the purpose of the UNIX manual page for the commands *rm* and *rmdir*, as presented in Figure 3. The contents of the field DESCRIPTION has been expanded, and the *Initial context* considered here is presented in the figure.

- *Browsing alternatives:*

Consider only the options concerning link selection, i.e., the activation of any of the buttons. The user has available the replace buttons (indicated in bold font) Example and explain as well as the glossary buttons unlink, syntax and write permission (these are indicated underlined in the figure). Other options would be, for instance, the commands on the menu bar or positioning the scroll bar.

- *Interaction table:*

user	*1*	*<chooses to select* **explain** *in Figure 3>*
	2	*positions mouse cursor over button*
	3	*presses left mouse button*
system	*4*	*highlights button text using reverse video*
	5	*sets cursor pattern to indicate button type*
user	*6*	*releases mouse button*
system	*7*	*removes highlight*
	8	*sets cursor pattern to indicate "wait"*
	9	*removes button text*
	10	*inserts replacement text as in Figure 4*
	11	*flashes replacement text (visible portion) using reverse video for about one second*
	12	*sets cursor pattern to normal*

– *step 3*

If the user, instead of holding the button down, quickly clicks the mouse button, the system still executes steps 4 and 5, causing the button to flash quickly.

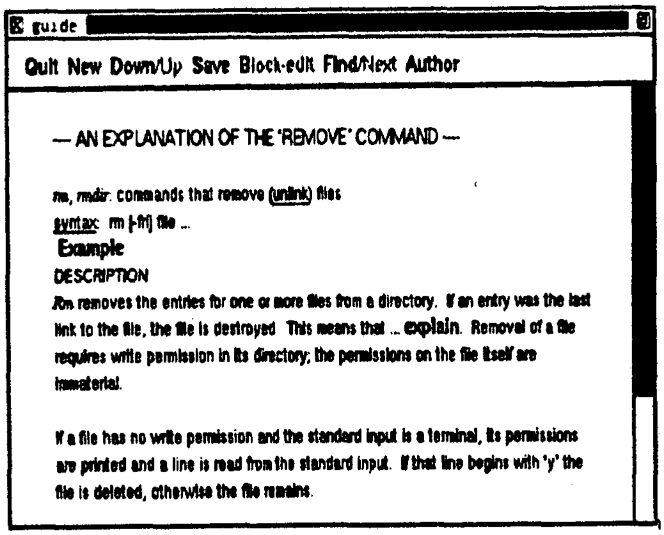

Figure 3: A Guide screen containing replace and glossary buttons

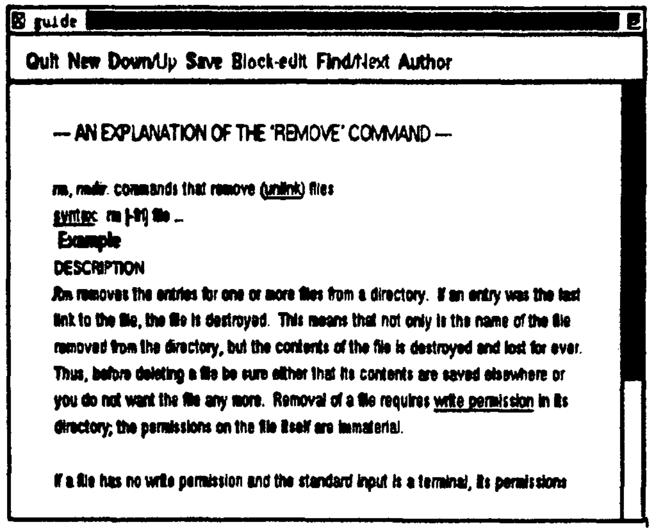

Figure 4: The replacement text associated with explain has been expanded.

- *step 6*
The user may, while holding the mouse button down, move the mouse cursor out of the highlighted area to abandon the operation.
- *step 9*
It is possible for the author, by using a mechanism called an *enquiry*, to specify an area bigger than the text of the button to be removed before the text is inserted; as a result, it is possible to have sources for links that are larger than the button text area.
It is also possible for the user to set an option which specifies that, instead of being removed, the button text is maintained and highlighted so as to indicate that it has already been expanded.
- *step 10*
In the example the document appears to expand as the previous text is scrolled down by the insertion of the new text. Situations exist, however, where the text in fact shrinks because the information removed in step 9 is larger than the information inserted in step 10.
- *step 11*
The purpose of the flashing is to give an impression of what the new information is.

- *Resulting context:*
The expanded paragraph details the information previously contained, as shown in Figure 4.
- *Related overheads:*
- *identification of the available links:*
Although the links are embedded within the text, they are quite visible because of the distinct font types used. It is possible to use other font types to present the normal text; the author has to use such resources with care so as not to create a congested view for the user, making the available links more difficult to identify.
- *identification of the link types:*
As few link types are available and are distinguished by the use of fonts, the identification of the type is not a problem after proper training.
- *identification of the source anchor of the link:*
Such identification is not a problem in this case, where the anchor coincides with the text of the button. The identification may be more difficult, however, in cases where enquiries are used to determine which area of the text is going to be replaced.
- *identification of the source context of the link:*
As in the previously analysed systems, it is an important task for the author to create contextual information which helps the user to decide whether or not to select a link, as well as fully understanding the relationship established.
- *identification of possibilities other than links:*
Other browsing related operations available are related to accessing information out of view, through the use of the command for paging (Down/Up) and the scroll bar, as well as the search command (Find).
- *activating the command needed to carry out that choice:*
Although having considerably distinct results, all types of link in Guide are activated by positioning the mouse cursor over the button and clicking the left mouse button. Therefore this would not represent a problem to a trained user.
- *temporary disorientation:*
With the approach of inserting the new information *in situ*, the user has to identify what information is new and what is not. (When an enquiry is used, the user also has to identify what has been removed.) The flashing of the newly inserted information is done so as to help this identification. Nevertheless, it may still be a problem.
A further problem results from the scrolling interface adopted: if only part of the new information is on view (because it is too big to fit into the current window), the user has no way of knowing the whole extent and/or contents of the new information at once.
- *transfer of contexts:*
Part of the information presented in the resulting context was in the source context. The user is, therefore, able to see the new information as a continuation of the information available previously. This situation helps the user to understand the relationship established by the link.

The hierarchical structure embedded in the replacement scheme — the new text is a level lower in the hierarchy — is another factor which helps the user to understand the relationship between source and destination of the link.

Conclusion

The work reported in this paper has been motivated by the observation that in many circumstances the user-hypertext interaction does demand effort from the user.

The proposed framework helped with the description of a typical interaction operation in hypertext, and also enabled the analisys of several overhead situations imposed on the user when using the operation described. Further examples of the application of the framework to the analysis of KMS, NoteCards and HyperCard is described in [21].

The systematic analysis permitted by the framework may be used to orientated the design of new interactive operations in hypertext. This has been done in the work described in [21], where the framework also helped the definition and analysis of the alternative navigational operations (their empirical evaluation in presented in [22]).

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