The neighborhood of a document is not determined unless the user judges it to be relevant or selects the Expand option from the content menu associated with the document text window. If either of these choices is made, the node is redrawn farther away to provide space for its neighborhood. The user selects the Expand option and the map is redrawn showing the neighborhood of the selected document (figure 6.30).

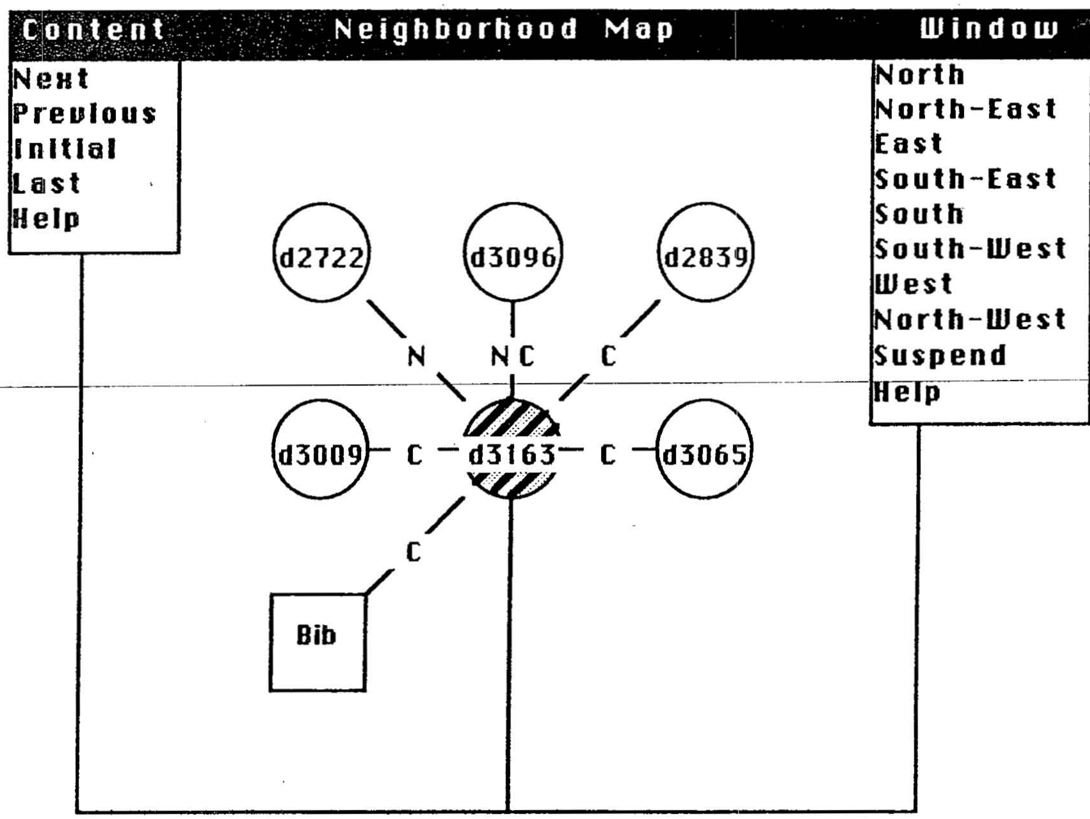

Figure 6.30: Neighborhood Map with expanded document neighborhood.

The user is not restricted to selecting documents that appear on the neighborhood map. He may go back to the current document of interest and select any list of documents associated with it. These are the reference list, the citation list, nearest neighbor list, the author list, or, the journal issue list. Figure 6.31 shows the neighborhood map after the user has examined the recommended node and has decided to examine the other node connected by the nearest neighbor link, marked "N"

The user is not restricted to just moving from document to document, but may also examine concepts. In figure 6.32, the user has decided that the term "multidimensional" is possibly a fruitful path to follow. He selects the `Term` option from the content menu and then the term of interest. This tells the system that he is selecting this as a node to examine and not that it is an interesting term. The node icon with the term's number appears on the neighborhood map and is shaded to indicate that it has been visited. The link is marked with the number of occurrences of that term in the document. The display for the term would appear in its own window, figure 6.20. In this case, there are as of yet no connections to any other concepts. The user could add a synonymous phrase like "n-dimensional" at this point. The content menu shows the different possibilities for domain knowledge entry. The `Select` option allows the user to follow a concept in the same way that the `Term` option was used in a document display content menu. The `Documents` option tells the system that he would like to see the documents that are associated with this term, where the `Expand` option would signal to expand the neighborhood using concept links.

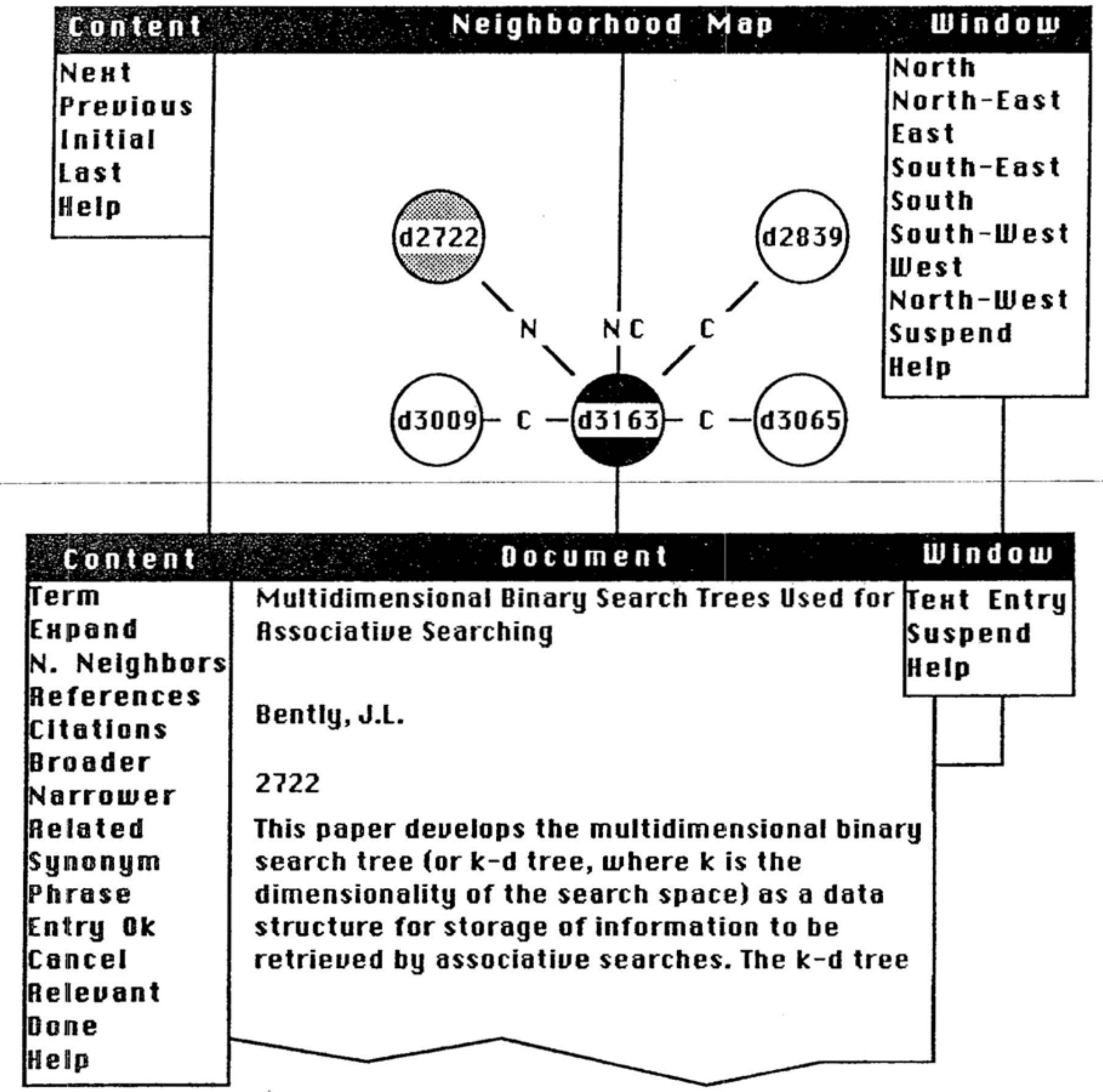

Figure 6.31: User views document 2722 (text is incomplete).

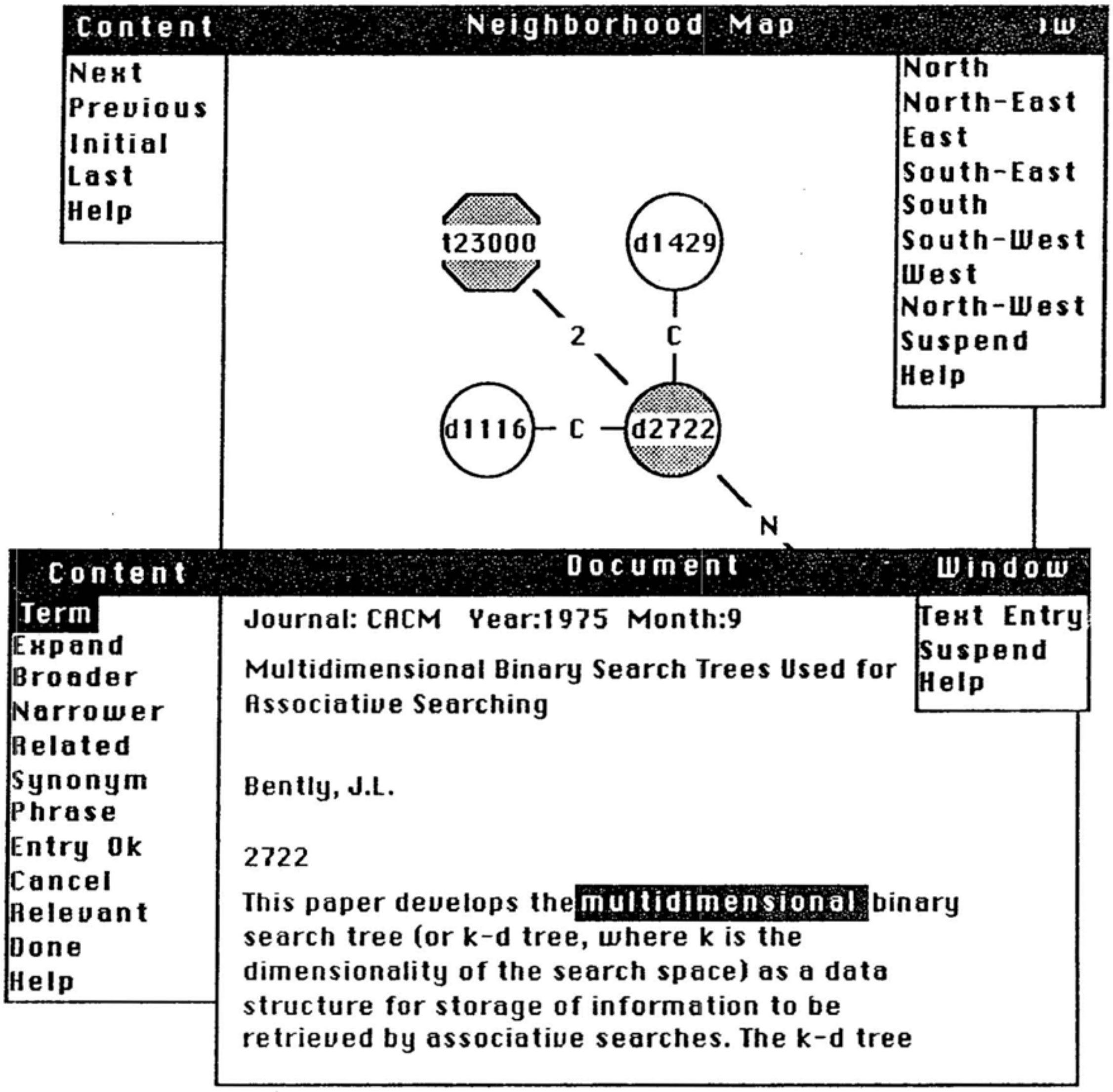

Figure 6.32: User selects a term to examine from document 2722.

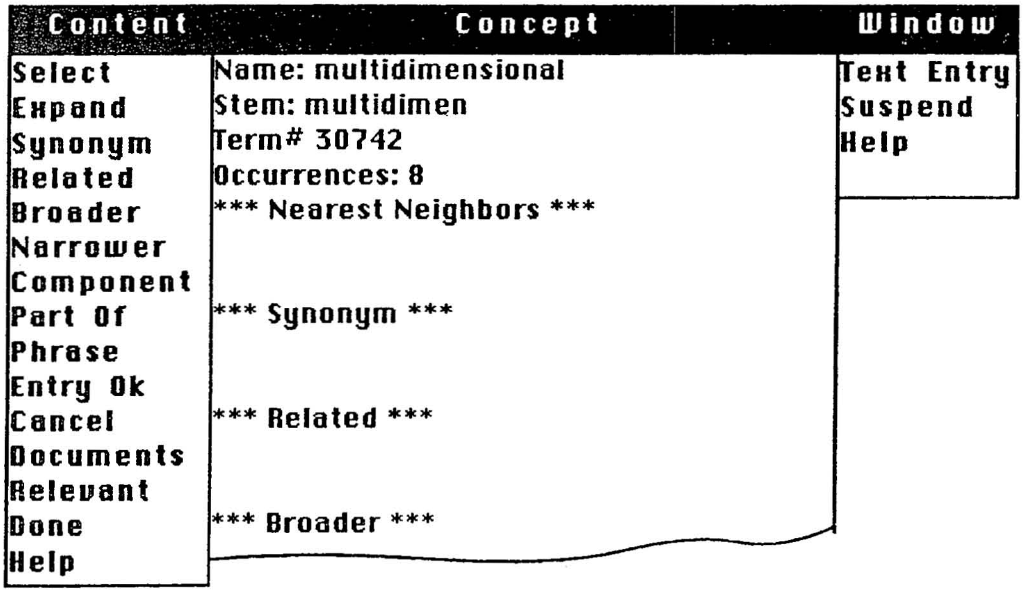

Figure 6.33: Display for the concept `multidimensional`.

Upon selecting the **`Documents`** option (figure 6.34), the browse maps are both expanded and a document list similar to the search results list appears (figure 6.21) with the titles of the documents that have the term "multidimensional" in them.

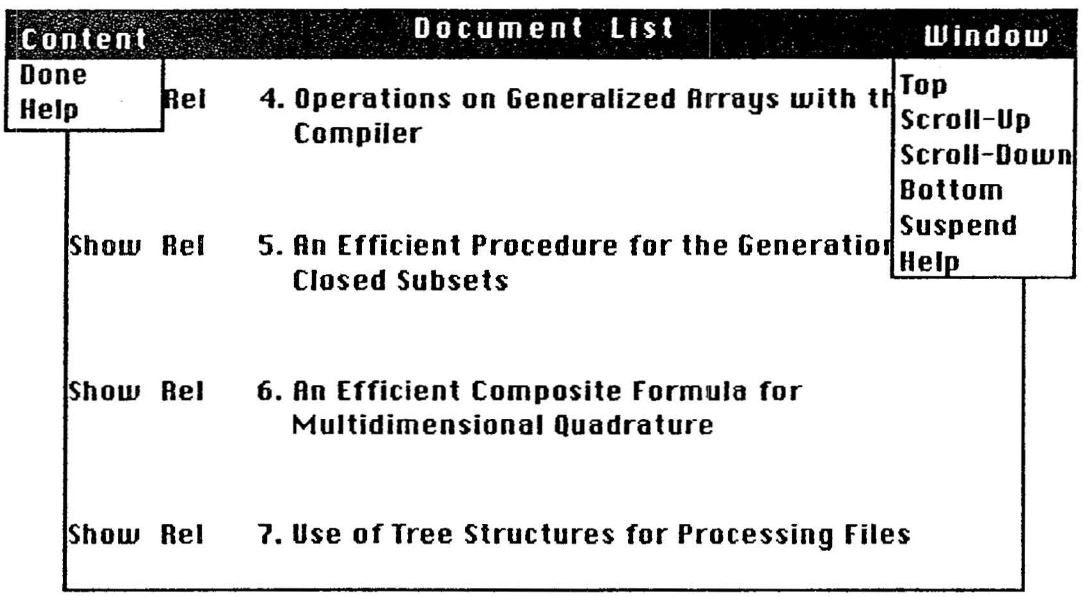

Figure 6.34: User selects **`Documents`** option.

The user selects the seventh document as an interesting one since it has the term "tree" in it. In this document, he sees the term "trie," (which is a particular kind of tree data structure [Horowitz 84]) and decides to find out what documents are connected to it. In the collection, there are only three, but one of the other two is interesting.

Figure 6.35 shows the context map that results from the session as it has developed so far. The context map is smaller scale version of the neighborhood map. The links are still marked as to type, and the nodes marked as to whether they have been recommended, visited, or judged relevant. No node identification information is given since that is available from the neighborhood map. Both maps remain in correspondence with each other, centered on the same node. When the user selects a node in the neighborhood map, the context map is updated at the same time, and vice versa. An example of a context map is figure 6.35. From this map, the user can go to any node by scrolling it into view and selecting it (placing the cursor on it and clicking with the left mouse button). This will cause the neighborhood map to be redrawn with the new node of interest in the center with its immediate neighborhood. For example, in this session the user might decide that he wants to continue investigating the area around the second document he determined to be relevant (marked with an "a").

One problem that may arise in this session occurs if the user decides to expand in the direction of the node marked "b." The neighborhood of this node can be drawn as shown in figure 6.36. If the user would take the recommended node from the expansion of the marked node, it would overwrite the node representing the term "trie." The interface manager attempts to avoid this by expanding in a direction that appears to be clear, such as the location marked "c."

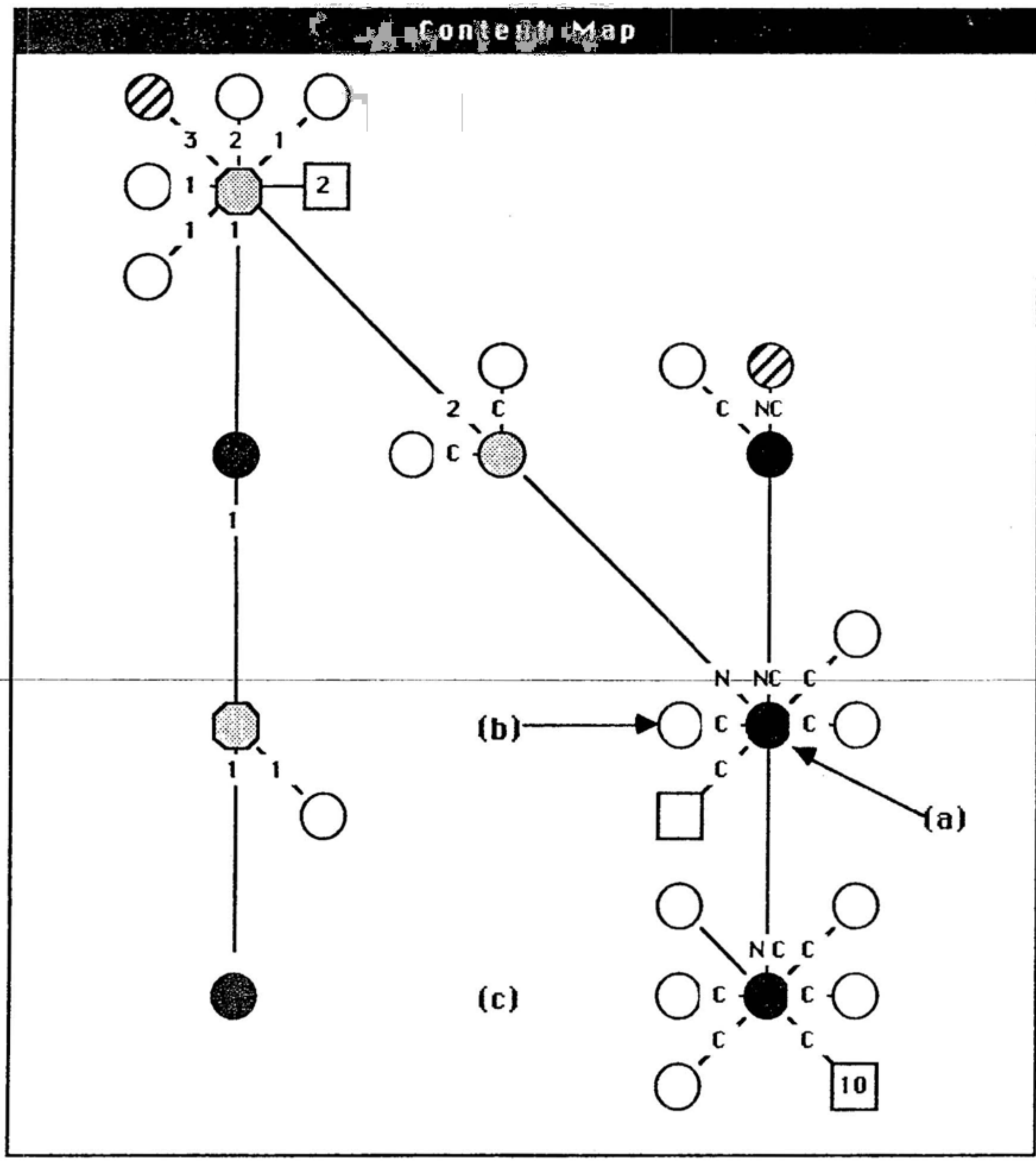

Figure 6.35: Context Map after examining document #2846 (menus not shown, but are the same as those with the neighborhood map).

If this location was taken, as in figure 6.36, the system would draw the node in another region of the map and place a connector icon on a link leading to it (figure 6.37). Selecting the connector would put the map back in the region where the node originally was drawn.

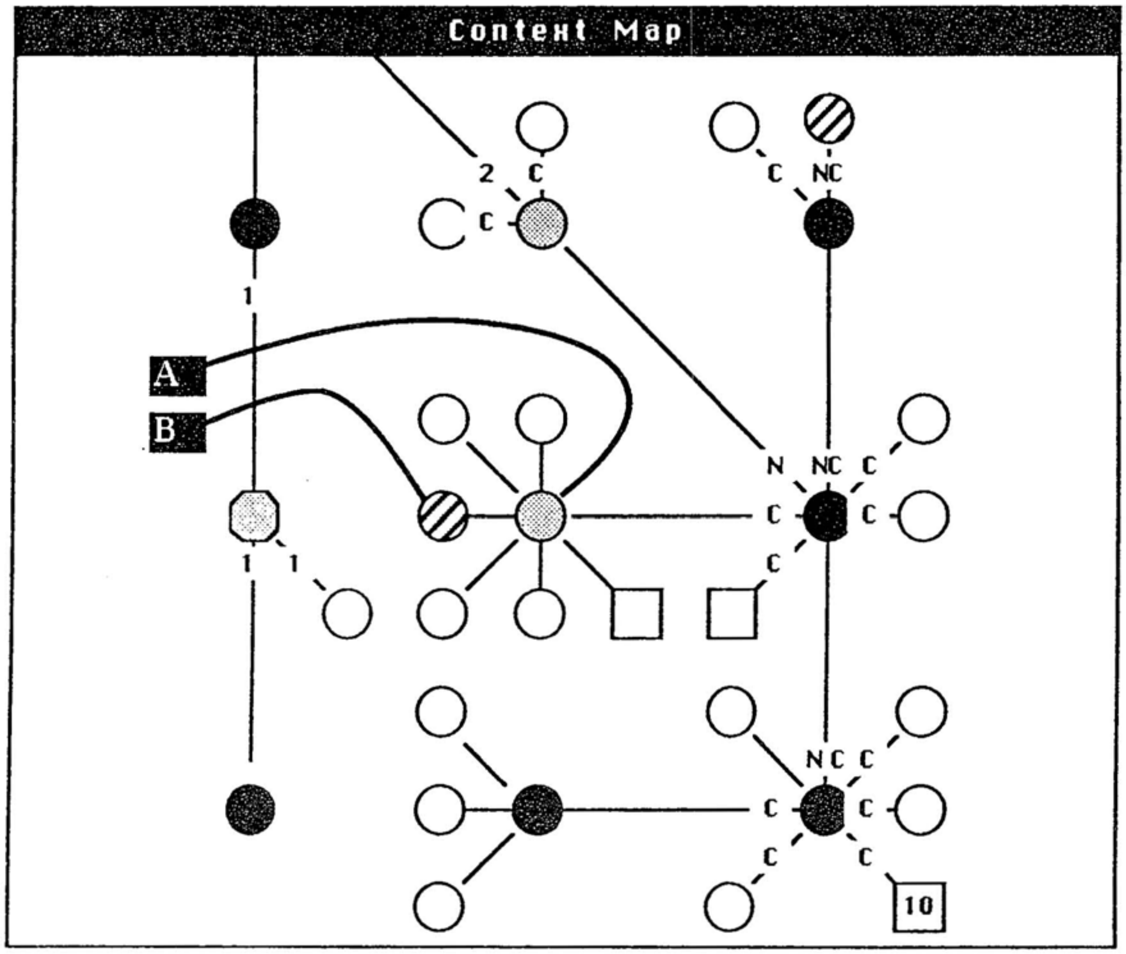

Figure 6.36: Context Map showing crowded region around node "A," and user desires to expand node "B."

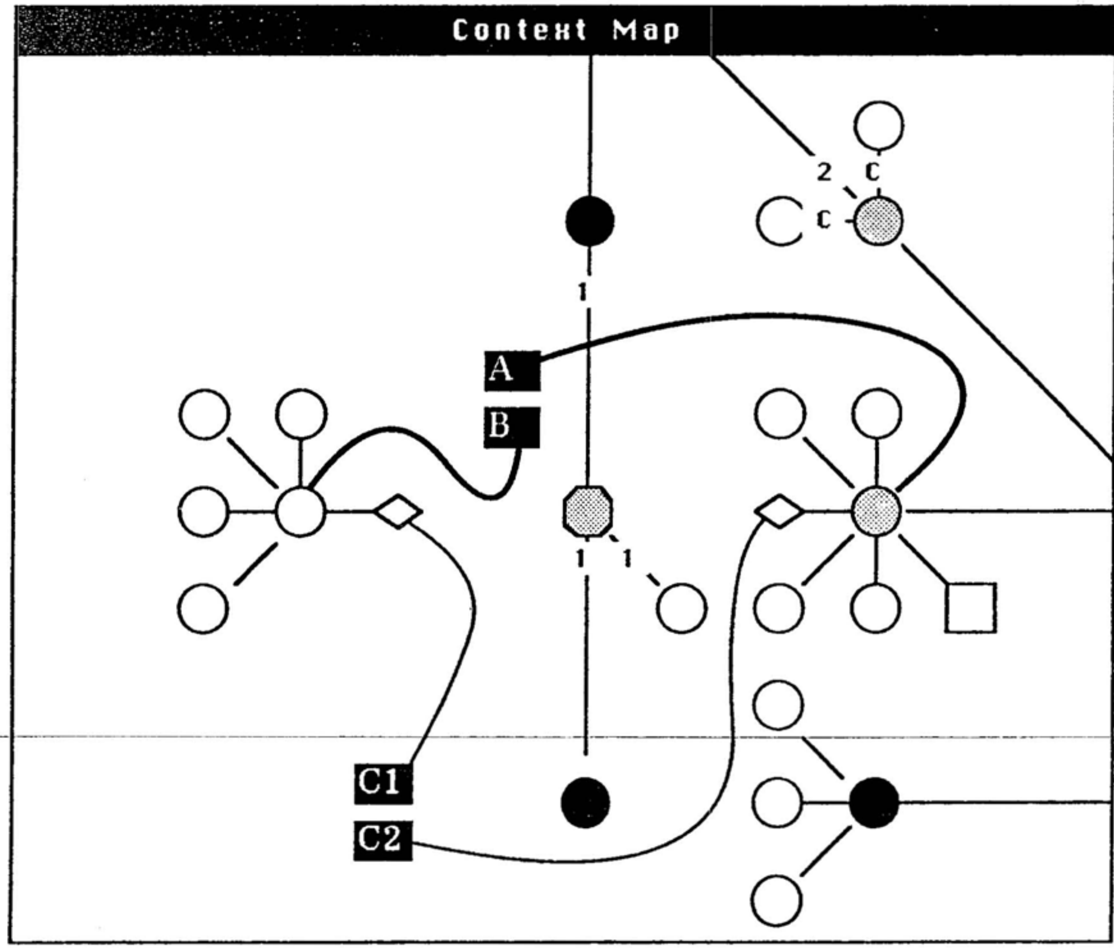

Figure 6.37: Use of connector to expand node "B." Connectors are placed on the links to facilitate the movement between nodes.

The connectors are useful primarily on the neighborhood map, where the context is limited to the immediate neighborhood. When the user selects connector C1 (figure 6.37), the node marked "A" is placed in the center of the map. When connector C2 is selected the node marked "B" is centered. In this way the user can follow the path he has selected. The connectors can be useful in the context map too. If it is very dense in one region the new expanded node can be very far away from the node it was expanded from.

6.4 Possible Behavioral Changes

There are other behaviors that could be observed by changing the control expert and by significantly enhancing the UMB. Currently, the UMB makes only a simple initial assessment of the user, and this assessment remains fixed throughout the session. If the user model had confidence factors associated with it assessments, and if the UMB monitored the activity of the user, it could continually adjust the model to reflect how the user's activity corresponded to the initial assessment. If this fell below a threshold the CE could recognize this fact and move the system back to a state where the UMB could again question the user and change the model. This would simply require for the CE, the addition of one transition (rule) that recognizes the UMB's confidence in the model falling below the threshold and moves the system back to the $CU state and the addition of the UMB to the priority lists of the $GIN, $DNC, and $ER states.

6.5 Summary

In this chapter, scenarios demonstrating the operation of I^3R have been presented. These scenarios show how I^3R provides different facilities to different kinds of users. They also show how the user can get direct access to the information in the concept/document knowledge base by browsing. Indications have been made as to how the behavior of the system could be altered by the addition of transitions to the control expert.

CHAPTER 7

CONCLUSION

7.1 Summary

This thesis has presented an information retrieval system that embodies the concept of an intelligent interface. This intelligent interface is implemented by an architecture that has a number of innovative features that support facilities that help the end-user overcome the difficulties of previous IR systems.

The first major feature is the implementation of the major functions of the system as individual rule-based systems, called experts. These individual rule systems operate independently, posting the results of their activity on a short term memory. This promotes the clean separation of functions and allows new major functions to be added with minor impact on the other experts in the system. The implementation of the experts using rules allows the incremental development of each expert, so that minor changes can be made to the expert without grossly affecting its current operation. The idea of multiple independent cooperating experts communicating using a blackboard [Erman 80] as an architecture for I^3R was developed from a system analysis point of view [Croft 85]. A similar architecture was independently specified by Belkin [1983, 1984]. A later system, CODER, has also adopted this basic architecture, but uses two blackboards with separate knowledge sources, one for documents analysis and the other for retrieval [France 86].

The second innovative feature is the coordination of the operation of the experts by a flexible control structure based on an analysis [Brooks 83, 85, 86, Daniels 85, 86] of actual end-user/search intermediary interactions. This control structure, implemented as a transition network, moderates the activity of the experts to provide a logical dialogue with the user, so that he does not become confused by numerous independent demands for information from the experts. The course of the dialogue is determined by the progress that the user has made in expressing his information need and retrieving documents relevant to his information need. The measurement of the progress is determined by the use of expectations of the number of relevant documents retrieved and the number of searches performed.

The operation of the system and its adaptation to a particular user is controlled by stereotypes, which are judgements about the user's domain experience, IR system experience, and interest in either an exhaustive or selective search. These stereotypes determine the expectations used by the control expert to determine the progress of a search session. They also determine what facilities are available to the user. An expert user has more facilities available to him and can take more initiative to control the course of a session than a novice user can. This idea has been subsequently used in the IOTA system [Chiaramella 87] as a means to adapt its natural language responses to different kinds of users.

Another important innovation in I^3R is the use of user supplied domain knowledge. This obviates the need for a significant investment of resources to derive a global thesaurus for system use. Instead, the effort is spread out, so that the users themselves supply the relevant domain knowledge for the particular information need. If global domain knowledge is available, it can be used. Since the user and global domain knowledge are represented in the same way, the knowledge supplied by the users can be migrated into the the globally available domain knowledge. In this way, as the system is used, its base of domain knowledge can increase and domain knowledge obtained from experts can be made available to all the users. An extension of this concept would be to provide facilities to allow users to explicitly share their domain knowledge models.

I^3R was the first system to propose and implement the use of multiple search strategies in order to take advantage of the differences in performance of techniques based on a variety of retrieval models. In previous systems the concept of adaptable search strategies was based on the experience of human search intermediaries in manipulating the form of Boolean queries to achieve the best possible results.

Another major innovative feature of I^3R is the incorporation of browsing as a method for both query formulation and search. In fact, browsing merges these two phases of information retrieval. In the process of query formulation, browsing can help the user to find concepts that more accurately represent his information need by providing a path from the concepts that he already knows to new ones. He can then check their relevance by examining their use in documents. In the process of search, the user can examine documents to determine their relevance, and from a relevant document can follow links to other documents that are related by citations or by similar content as determined by nearest neighbor links. The user is not restricted to moving from documents to documents but can move to concepts or to journal issues. As the user browses, and makes judgements about the relevance of concepts and documents, the system records this information and uses it to further enhance its model of the user's information need.

The user is assisted during browsing by recommendations made by the Browsing Expert. These recommendations are based on the structure of the concept/document data and the information in the request model. This information provides evidence for the browsing expert so that it can determine what concept or document is most likely to be useful to the user at his current location in the concept/document information.

Another interesting feature of I^3R is the use of graphics to provide the user with visual context to aid him in the browsing process. The maps that the system constructs gives the user a context that helps him determine where he has been, so that he does not get lost while browsing in the highly interconnected network of documents and concepts.

Finally, the underlying organization of concept/document knowledge in I^3R allows it to support multiple search strategies, browsing, and the use of different domain knowledge models. This organization is significantly more sophisticated than previous ones, since it fuses what are normally separate sources of knowledge into a single knowledge base.

7.2 Future Directions

7.2.1 Evaluation of the system

The primary work to be performed on I^3R in the future is the evaluation of its performance. This encompasses not only its effectiveness in retrieving relevant documents, but also its usability with regard to the extra facilities. In other words, how well do the extra facilities help the user to get the results he desires. The difficulties of evaluating a highly interactive system have been discussed in sections 2.2.3 and 6.2.

7.2.2 Extension of the experts

The prototype implementation used basic implementations of many of the experts to demonstrate the functionality of the overall system. All of the experts can be extended in a number of ways.

The most important expert to develop further is the user model builder. By developing the user model to a greater extent, the basis is formed for developing more sophisticated patterns of interaction with the user. At present, the user model is constructed solely on the basis of the user's responses to questions posed by the UMB. A more sophisticated UMB would monitor the activity of the user, as well as asking him questions, to determine the stereotypes that apply. Modelling the user based on his activity requires that the UMB have models of different patterns of system usage. These models can be developed only by studying the patterns of usage by many different users over a long period. Initial work on the functions and structure of a sophisticated UMB has been the subject of study by Dainiels [1985, 1986, 1987]. The stereotypes of the users could take on the structure of those proposed by Rich [1979].

The request model builder can be extended by feeding back to it from the results of the search the terms that were used to make the decision about what documents to retrieve. This information can be shown to the user, so that he may understand what contributed to the selection of documents that were shown to him. Also, in relation to the request model, the user should be given a way to look at and alter the request directly in the form of a request model display. Whether this display is alterable and the kinds of information shown on the display would be controlled by the user stereotypes. For example, an expert user would definitely be allowed to alter the model and could be shown the probabilistic weights of the terms. A novice, perhaps, would only be shown the relative importance of the terms by their ordering based on their weight. In addition to this the user should have the ability to invoke a search manually.

It is also important to make the control expert more flexible in its operation. This is also based on the extension of the user model builder. With a better user model, the system can act more intelligently about the course of the retrieval session.

7.2.3 Addition of an Explainer

One of the major experts defined in the requirements specified in chapter three was an explainer. The need for this expert as well as other considerations lead to the selection of rules as the basis for the implementation of the experts as rule-based systems, so that their reasoning for their actions could be made available to the user.. Furthermore, this expert is particularly important in assisting novice users of the system. Because of these considerations, an intelligent explainer is an important extension to the current capabilities of I^3R.

To accomplish this, the previously mentioned extensions to the user model builder must be made. The explainer needs for its basis a good model of the user representing not only who the user is, but how he interacts with the system. For example, a user may usually express his information need as a full text statement. If he then chooses to use a complex Boolean formulation, the user model builder would notice this, making an assertion that the user is using an unfamiliar method to enter his query. In response to this assertion, the explainer might be more likely to offer assistance These requirements involve some significant research issues.

An initial pass at implementing an explainer would be to provide to the user with help facility like that available on the VAX/VMS operating system and then record the kinds of help that the user requests. The explainer would be integrated into the system in much the way that the interface manager is. It would run as a separate expert, not under the coordination of the control expert.

7.2.4 Natural Language Techniques

I^3R represents a beginning in the integration of AI techniques into IR systems. There are a number of ways that I^3R can be extended. The first way is the incorporation of natural language processing techniques in a number of different areas. Since, in the document retrieval domain, the primary means of expressing knowledge is natural language, natural language processing techniques are prime candidates for inclusion into I^3R. This has already begun in the context of improving the performance of the search techniques. This work is being pursued as an independent system called ADRENAL [Croft 87]. The focus of this work is to define and demonstrate the use of NL techniques that can be applied effectively in systems that contain large numbers of documents. The basic idea is to apply the techniques to compare the query to sets of documents that have been retrieved using traditional methods. This limits the comparison to those documents that have a likelihood of being relevant to the information need. These techniques could be added to I^3R by extending the search controller or by adding a new expert.

Another place where NL techniques could be added to I^3R is in the analysis of the context of citations. While it has been shown that citations are a valuable source of information for finding relevant documents, more information could be determined about what a citation means from its context. For example, some citations point to articles that have a differing point of view than the author's, or they can point to work that contains similar ideas. This kind of information would be valuable for the operation of the browsing expert, since it would allow the BE to make a more informed recommendation to the user. These kinds of citation link types have been partially defined by Trigg [1986]. This kind of information could be incorporated into I^3R by adding link types to the citations links, extending the heuristics of the browsing expert, and adding an expert to do the analysis of the documents.

7.2.5 Representation

Another area in which I^3R can be extended is in the information kept about different kinds of journals and particular issues. For example, in the publications of the ACM, Computing Surveys is primarily directed at providing tutorial kinds of articles, whereas the Journal of the ACM is focussed at highly theoretical articles requiring a relatively high degree of mathematical sophistication. Having this kind of information as evidence would allow the system to provide documents that are better matched to the user's level of domain expertise.

7.2.6 Interface Considerations

Finally, an area of major concern in the further development of I^3R is the enhancement of the graphical presentation of information. One of the ways that this can be accomplished is the use of color to convey other kinds of information such as relevance. For example, the most relevant documents could be displayed in red and decreasing relevance shown by scaling the colors to blue to represent the least relevant. Another use of color is highlighting different groups of links.

Another possibility is to use three dimensional representation to show more of the neighborhood of a node in the concept/document knowledge. Specifically, extending the current organization of the neighborhood and context maps to three dimensions would allow the map to show 18 more nodes for a total of 25. Use of three dimensions to represent the neighborhoods would be available to system experts, since very few people are trained to visualize in three dimensions.

On a purely implementational note, the entire interface could be rewritten using the currently developing X-standard [Scheifler 86]. This would allow I^3R to operate on a much wider variety of architectures.

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