Graphical Interaction with a Full-text Oriented Information System:

The Retrieval Component of the End User Interface TOPOGRAPHIC[1]

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Abstract

The full-text oriented information system TOPIC/TOPOGRAPHIC which is based on the textual knowledge of articles of technical journals dealing with micro computers and office automation. The analysis of the articles is performed automatically by a knowledge based parsing mechanism and results in so-called text-condensates (representations of topical structures and facts of the t ext). The textual information extracted this way is stored in a text knowledge base offering several options for information retrieval (conceptual overview, fact retrieval etc.)- The user interface TOPOGRAPHIC employs graphical interaction to offer retrieval facilities.

1. Introduction

1.1 Convenient Access to Information Retrieval Systems: Important, but not Sufficient

This paper deals with one type of contemporary research systems that provide access to information contained in texts. Such systems range from bibliographical data bases to full-text information systems; our emphasis is on the latter. Artificial intelligence (AI) techniques can be used enhancing the performance of retrieval systems. There are two approaches:

(1) "front-ends' that promise a better usage of existing systems through an intelligent user interface (cf Vickery 1984), and

[1] This paper has been published in: Lehmann, K.-D. / Strohl-Goebel, H. (eds): The Application of Micro-Computers in Information, Documentation and Libraries, Elsevier Science Publishers B.V. (North-Holland=, 1987, pp. 434-444.

[2] The development of the TOPIC/TOPOG-RAPHIC System is supported by BMPT/GID under contract 1020016 0. The TOPIC System is implemented in C, TOPOGRAPHIC in C and PROLOG, on a CADMUS 9200 with UNIX.

(2) innovative systems that apply AI techniques to all components – the internal storage and retrieval operations as well as the user interface - and thus offer much more than bibliographical information about texts, e.g. their topical and factual contents.

The 'front-end' approach to intelligent information systems combines conventional system architecture and functionality with a sophisticated user interface, often implemented on a local workstation that is connected to the required host automatically. These systems provide convenient database access by relieving the user of cumbersome tasks like host selection, log-in procedures and formal query formulation. To a certain extent this task can be tackled with conventional software (e.g. Toliver 1982), but the more ambitious approaches to user-friendly interfaces emerge from artificial intelligence research:

- Expert systems that possess "retrieval knowledge", such as knowledge about the specific query language of a database or domain-specific knowledge which can be used to assist the user during the planning of a query.
- Natural language interfaces that translate the internal representations of parsed questions to formal queries which can be processed by the retrieval system.
- Graphical interfaces that employ windows, menus and pointing devices for convenient man-machine communication (cf Tou et al. 1982). Thus, a query can be constructed using graphical operators, which may be less cumbersome than typing in a query in natural language.

These efforts are directed at improving the performance of conventional information retrieval systems. However, enhancing existing non-intelligent systems achieves only a sub-optimal level of performance. Innovative systems employing AI techniques in a new holistic design offer not only user-friendly interfaces but also a new quality of information processing. For this, the manipulation of superficial features of texts with operations like string matching is not sufficient anymore, the new systems should possess functions for conceptual information retrieval like inferring facts which are only implicitly mentioned in the given text.

1.2 Full-text Information Systems: Challenge and Promise

Full-text information systems are gaining increasing importance because large collections of machine-readable full-texts become accessible due to the spreading of electronic text production technology. Such systems have an increased demand for intelligent information processing. The application of conventional information retrieval methods (e.g. free text searching, adjacency operators) revealed the inherent weakness of string matching based procedures which cannot cope with complex linguistic phenomena occurring preferably in full texts (e.g. anaphora)(cf Tenopir 1985, Blair/Maron 1985). AI techniques using semantic background knowledge of the domain dealt with can overcome these problems. This "world knowledge" forms the basis for a content-oriented text analysis that provides topical and factual information from the text. Thus, the following retrieval options can be accomplished:

(1) Retrieval of text segments (a group of articles, an individual article, or part of article) with display of a graphical representation of their topical structure at various levels of specificity

(2) Retrieval of facts extracted from text

(3) From either (1) or (2): Display of the original text passages (cf Hobbs et al. 1982).

The complexity that goes along with the power of this system requires advanced man-machine interaction which hides the complexity of the system from the user and allows the user to pursue his query an easy and natural way. The sophisticated interface needed by this category of 'intelligent' information systems is not intended to compensate retrieval performance deficits of the system (as it is the goal of front-ends), but it is an essential module of the system which guarantees the exploitation of all the advantages the advanced information processing offers. The system TOPIC/TOPOGRAPHIC, whose features will be discussed in this paper (with focus on the user interface TOPOGRAPHIC), combines knowledge-based text analysis and intelligent graphical retrieval facilities. ′

2. TOPOGRAPHIC: The Graphical User Interface of the Knowledge Based Text Condensation System TOPIC

The full-text oriented information system TOPIC/TOPOGRAPHIC which is currently under development at the Department of Information Science at the University of Constance, FRG, is based on the textual knowledge of articles of technical journals dealing with micro computers and office automation. The analysis of the articles is performed automatically by a knowledge based parsing mechanism and results in so-called "text condensates" (representations of topical structures and facts of the text). The textual information extracted this way is stored in a "text knowledge base" offering several options for information retrieval (conceptual overview, fact retrieval etc.).

Based on this specification of the system functions, the following principal modularisation can be made:

- Content-oriented text analysis is performed by text-specific parsing and representation components. These features, together with software for flexible condensation of textual information, form the TOPIC part of the system (cf Hahn/Reimer 1986).
- The user interface TOPOGRAPHIC employs graphical interaction to offer retrieval facilities covering all types of information which result from the text analysis and data extraction or the subsequent condensation process.

In order to give an outline of the possibilities for offering the user various types of information (topical, factual and textual) during a dialog with the system we now concentrate on the interface TOPOGRAPHIC, first describing the structure of the knowledge base it operates on. Afterwards the basic features of the dialog design are discussed.

2.1 The Representation Structures of the Knowledge Bases

The text analysis performed by the TOPIC system is based on previously supplied 'world knowledge' which models the taxonomic structures of the domain the text is about. Thus, the textual information can be integrated into given knowledge structures, in its essence simulating a reader’s ability to acquire information from a text. (The system, however, is not intended to establish a model of the cognitive processes that constitute human text understanding.) The results of the text analysis are stored in a 'text knowledge base' containing both topical and factual information from the text.

The representation of both world and text knowledge is based on a frame representation model (FRM). This approach to conceptual modelling represents a concept by a 'frame' and captures its meaning by associating its semantic context (i.e. properties, parts etc.) with it. These associated features of a frame are called 'slots'. They model its general properties (e.g. the fact that a computer normally incorporates a cpu). The description can be made more precise by adding a 'slot entry', which must be a certain instantiation of the more general feature denoted by the slot.

The statement "A personal computer possesses a cpu, an operating system and as peripheral devices a keyboard and a mouse" is modelled by the following frame:

personal computer_______________________ (frame name)

cpu___operating system___peripheral devices____(slot names)

keyboard, mouse (slot entries)

The FRM used in TOPIC/TOPOGRAPHIC is formally specified (cf Reimer/Hahn 1985). Here is a concise verbalisation of the formalism: A frame consists of a name and a set of slots. A slot has a name and a (potentially empty) set of entries. Each slot is associated with a "consistency rule" determining the domain of allowed entries. Slot entries may be either unstructured strings or frames having a slot set of their own. The latter possibility allows a modelling of aspects (slots) of a concept by nesting the representation structures.

The knowledge representation mechanism of TOPIC/TOPOGRAPHIC combines the modelling of concepts as frames with the modelling of certain relationships between frames (concepts), a technique originally devised in the area of "semantic networks'. Among the relationships modelled in the system, one is of special importance: the is-a-relationship. Two frames are linked by this relationship if one of them is a sub-concept of the other (e.g. is-a (microcomputer, computer), i.e. every microcomputer is a computer, too). The system incorporates a variety of other relations (e.g. is-part-of), which express semantic knowledge that is useful for the task of analysing texts.

Whereas the world knowledge base contains a taxonomic model of the discourse domain, the text knowledge base consists of "text graphs" which represent the knowledge obtained by the parsing process (cf Hahn'1986). Each analysed text is thus stored not only in textual form (i. e. in German), but also associated with its topical and, to some extent, factual content, which is organized as a conceptual graph. The following information about the analysed text can be found in the text graph resulting from the analysis and the subsequent condensation process:

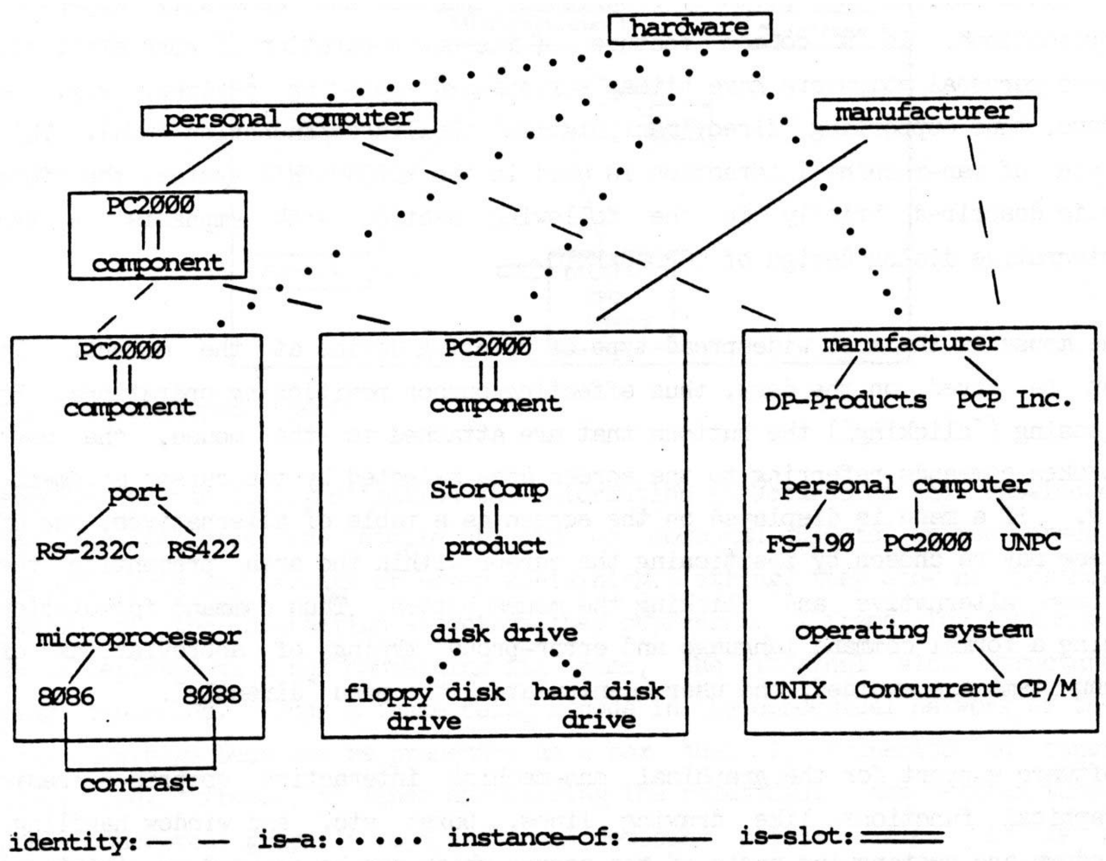

Figure 1

a) A multi-hierarchical graph whose nodes contain the topical structures of the text in decreasing generality. The contents of these nodes are similar to world knowledge structures (cf. Fig. 1, from Hahn/Reimer 1986).

b) Fragments of world knowledge denoting the main topics of the text passages, i.e. the frames that match the most salient concepts in thematically coherent text parts. The frames are connected by relational links, thus a network representing the topical structure of the text passage is given.

c) The frames occurring in the networks may have 'filled" slots, i.e. there may be entries assigned to them during the process of text analysis. The filling of slots contributes to the factual information from the text by adding more precise details to the general information provided by the frames and their slots.

2.2 The Basic Features of the User Interface Design

Graphical interaction, formerly reserved to specific and generally expensive applications, is a common feature of the new generation of work stations. These personal computers have bitmap screens and pointing devices, e.g. a mouse, thus supporting 'direct manipulation' (Bullinger/Faehnrich 1984). This style of man-machine interaction is used in the TOPOGRAPHIC system, therefore it is described briefly in the following section with emphasis on the integrative dialog design of TOPOGRAPHIC.

The mouse is the most widespread type of pointing device at the moment. It can be moved on the desk, thus effecting cursor positioning operations. 13y pressing ('clicking') the buttons that are attached to the mouse, the user invokes commands referring to the screen area selected by the cursor movement, e.g. if a menu is displayed on the screen as a table of alternatives, one of these may be chosen by positioning the cursor within the area presenting the chosen alternative and clicking the mouse button. Thus command formulation using a formal command language and error-prone typing of abbreviations of menu items are avoided, the user 'manipulates' the menu 'directly'.

Software support for the graphical man-machine interaction comprises basic graphical functions like drawing lines, boxes etc. and window handling. Windows are rectangular parts of the screen which may be treated as (virtual) screens themselves by assigning to them data or even processes. Thus it is possible to show the user simultaneously information from different sources (e.g. files). In programming environments like SMALLTALK 80 'objects' (i.e. processes that can store data and emit or receive messages, cf Goldberg/Robson 1983) are depicted as windows and, what is most important in this context, the user can manipulate them with graphical operators. This way of interaction is used in TOPOGRAPHIC, where a slightly different notion of 'objects' has been adopted as a framework for the structuring of the user's dialog with the system. In principle, information is presented to the user in the form of 'graphical objects' (e.g. boxes), which can be accessed with the mouse and operated on by clicking the buttons.

Depending on the dialog situation the information structures of the knowledge base are depicted as 'simple objects' or 'compound objects' on the screen. Simple objects are strings or boxes containing a string, they show no further details of the information structure they represent. A frame, for instance, can be depicted as a box containing its name, the internal slot structure being concealed. Thus a frame being a node in the conceptual network of the world knowledge base can be presented as a box that is connected to other boxes, i.e. frames, by lines symbolizing the relational links between them. Such a conceptual graph is regarded as a 'compound object', i.e. it is a graphical object which contains other graphical objects as parts. Likewise, a frame can be shown as a compound object by revealing its slot structure as a table. Texts are treated as compound objects, too. Each compound object is shown within a window, thus it is possible to manipulate the depicted structure as one entity. This can be done by applying an operator, i.e. clicking a mouse button, to the window identifier, which is located directly above the window area.

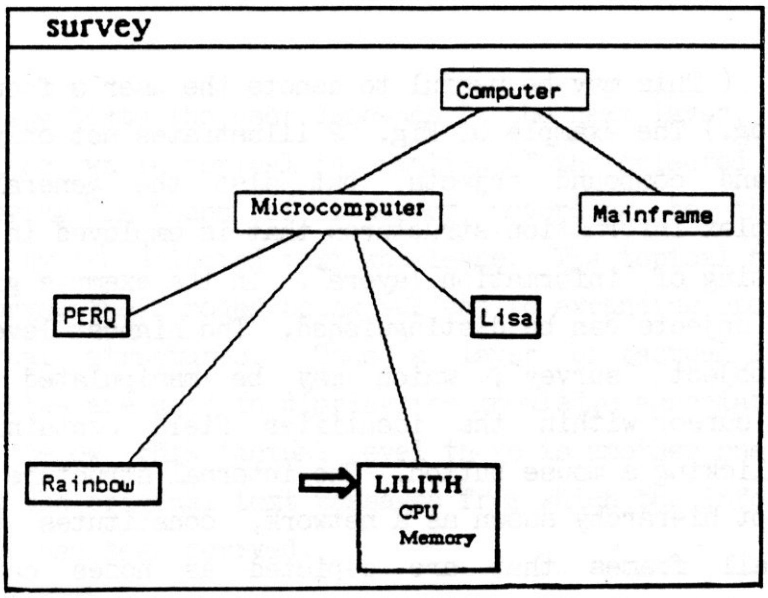

Figure 2 Graphical objects

The compound object 'survey' (Fig. 2) is a window containing a concept hierarchy taken from the domain of computing devices. The more general frames are shown above the more specific ones, thus the user's intuition of generalization as ascending a hierarchy is supported. The concepts integrated in the hierarchy are depicted as simple objects, i.e. boxes, except the "LILITH"-frame, which is presented as a compound object partly unveiling its slot structure. This may be useful to denote the user's focus of interest during a dialog. The example of Fig. 2 illustrates not only the difference between simple and compound objects, but also the general principle of presenting complex information structures that is employed in the TOPOGRAPHIC system: the nesting of "information layers". In the example given by Fig. 2, three layers of objects can be distinguished. The highest level consists of the compound object "survey", which may be manipulated as an entity by positioning the cursor within the identifier field containing the string "survey" and clicking a mouse button. The internal structure of this object, i.e. the concept hierarchy shown as a network, constitutes the next lower level, where all frames that are depicted as nodes can be accessed as self-contained entities. The "LILITH"-frame offers information that belongs to the third layer involved: the internal slot structures associated to each frame.

The example discussed above deals with a single network. The information structures of the knowledge bases used in TOPIC/TOPOGRAPHIC are more complex, because for each text analysed there are several networks, i.e. world knowledge fragments, interrelated by "topical" relationships. Therefore, a navigation in the original knowledge bases would be too complicated for the user. The user interface TOPOGRAPHIC attempts to overcome this problem by providing several layers of information, which are all treated as compound objects like the "survey" network in Fig. 2. Using the mouse the user can explicitly manipulate the current information layer as well as the information structures it contains. Leaving the information layer is accomplished by a simple mouse click, a feature that facilitates a modeless dialog although many different types of information are accessible. In the rest of this chapter a summarization of the layers is given, followed by the specification of the operators that are provided.

The world knowledge base offers taxonomic information about the domain of discourse, therefore it can be used to specify a graphical representation of the user's query, a so-called "search profile", which is a network containing the relevant topics as nodes. (The construction of such a query is demonstrated in the next part of this article.) The next lower level is given by the set of texts, whose topical structures match the search profile.

Choosing one of these texts the user descends to the next layer, on which he can investigate the whole topical information of the selected text, thereby extending or narrowing his focus of interest according to the thematic variety provided by the selected text knowledge. The topical structures are presented as networks, their nodes being subject to expanding operations that reveal the internal structures. Thus a layer of factual information is accessed, where tables are used to display the knowledge associated with the frame expanded. Below this factual level there is another one: the textual level which offers the original text passages from which the information shown in the layers above has been derived.

This arrangement of hierarchical information layers - one of the possible ways to organize the dialog - demands a general operator accomplishing an easy descending to lower levels. The term 'informational zooming' illustrates the effect of the operator by an analogy. As in optics zooming reveals more details of physical objects, the 'zoom' option in TOPOGRAPHIC can be used to access more detailed informational structures, or, in other words, to switch to a layer below. The expansion of simple objects, usually the nodes of a network given, also fits into this model. Zooming alone, however, does not suffice for a goal oriented dialog, because there may be too much detail information on the layer below. Therefore, a sort of focussing is needed. This is accomplished by the 'select' option which allows to mark those features of a given layer, which are to be shown in detail by the zoom operator. Due to the limitations that screen size and human perception impose upon graphical presentation, there may be situations in which the user wants to see other components of a compound object. The 'browse' option can be applied to the component, offering neighbouring objects as candidates for presentation, e.g. nodes which have been invisible so far, but have links the one the user wants to 'browse'. This allows the user to move to any part of a compound object that cannot be shown on the screen in its entirety. It is supported by the automatic generation of situation specific menus that offer navigation alternatives.

The three operators (zoom, select, browse) can be assigned to a three-button mouse like the one used in the TOPOGRAPHIC system. Thus all operators are available at any time during the dialog, which therefore needs no different modes. The effect of a mouse-click depends rather on its dialog context than on a special mode to be adjusted prior to the intended manipulation. Thus an ease of is obtained which encourages the user. Due to the robustness of the dialog - all operations can easily be 'undone' - he only needs to know the mouse operations in general, and then start to investigate the system. He can go back to any point of the dialog by selecting the layer object that was on top at that time. Thus a complicated model results in an user-friendly interface, as may be outlined in the subsequent dialog example.

3. Guiding the User from Search Terms to relevant Text Contents: a Dialog Example

After discussing the theoretical dialog model that provides the components of a 'graphical retrieval language' tailored to the needs of TOPOGRAPHIC we now illustrate the essential features of the user interface by means of a fictitious dialog. This example shows all layers of information that can be accessed in a series of zooming operations in order give an overview over the system's capabilities. On each layer shown the zooming is prepared by selecting operations that facilitate focussing on relevant sections of the layer below. If the items to be selected are not visible due to the limited size of the screen, browsing is used to access them.

(A real life dialog may not have such a straight-forward zooming structure, there might be 'loops' in it in cases the user returns to higher levels to change his focus up there and then zooms again. Thus a feed-back facility for query refinement is given.)

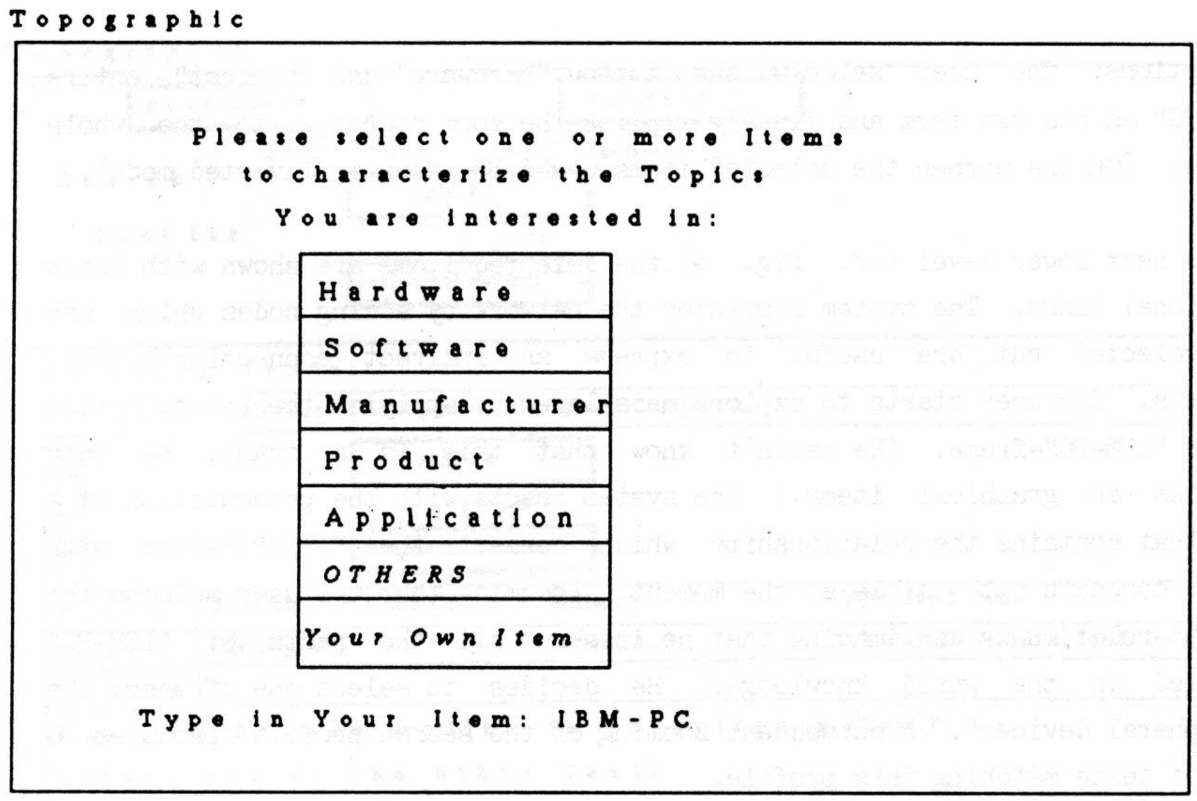

Figure 3

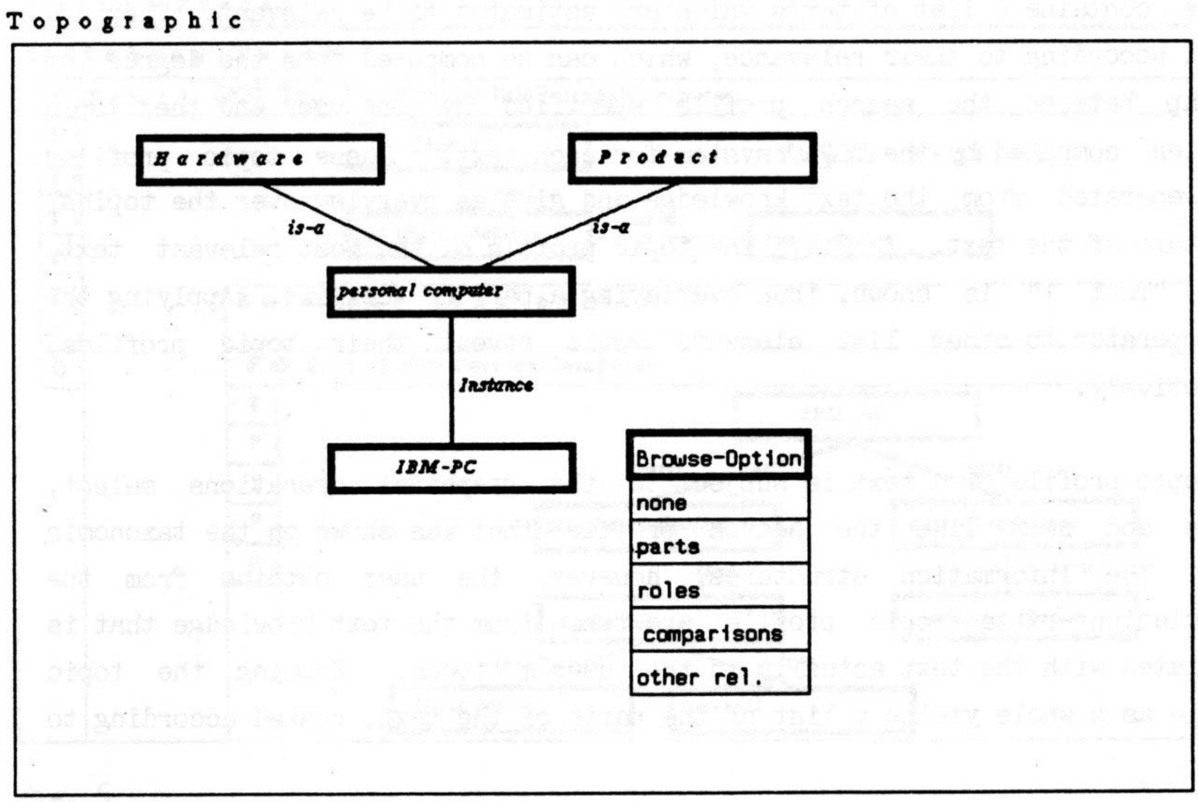

Figure 4

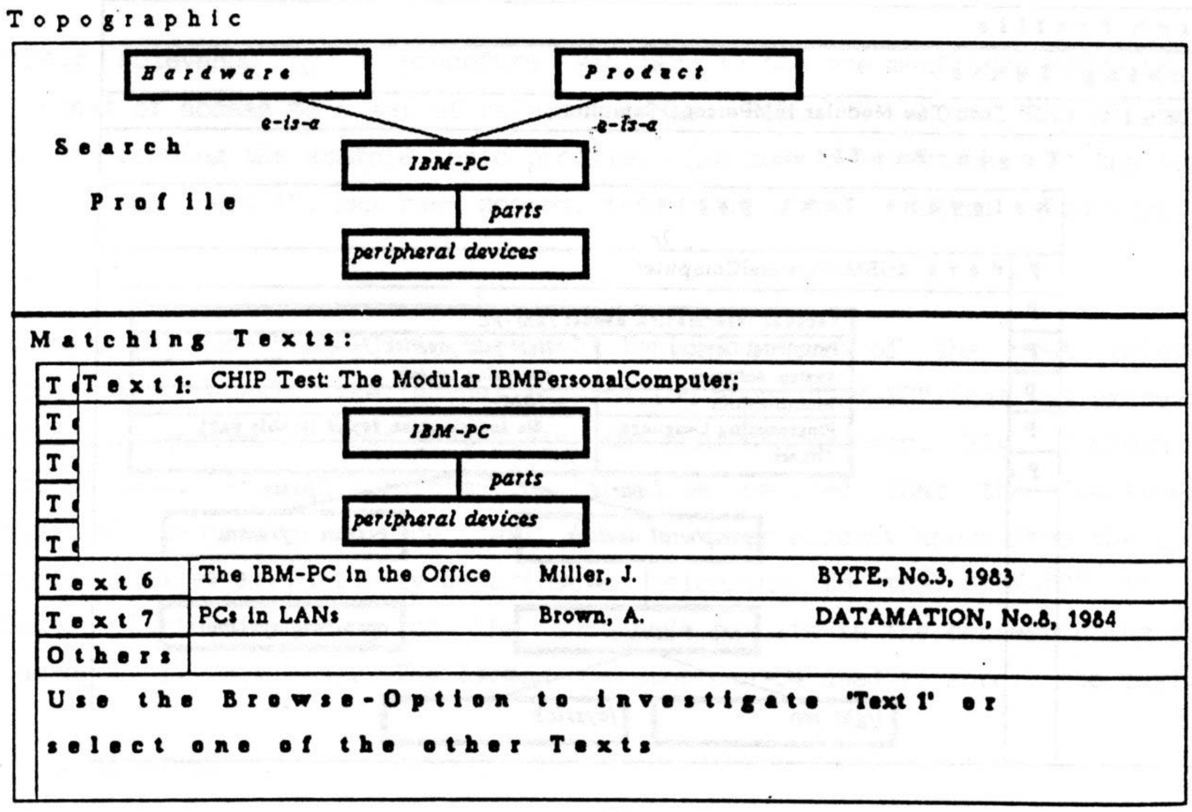

Figure 5

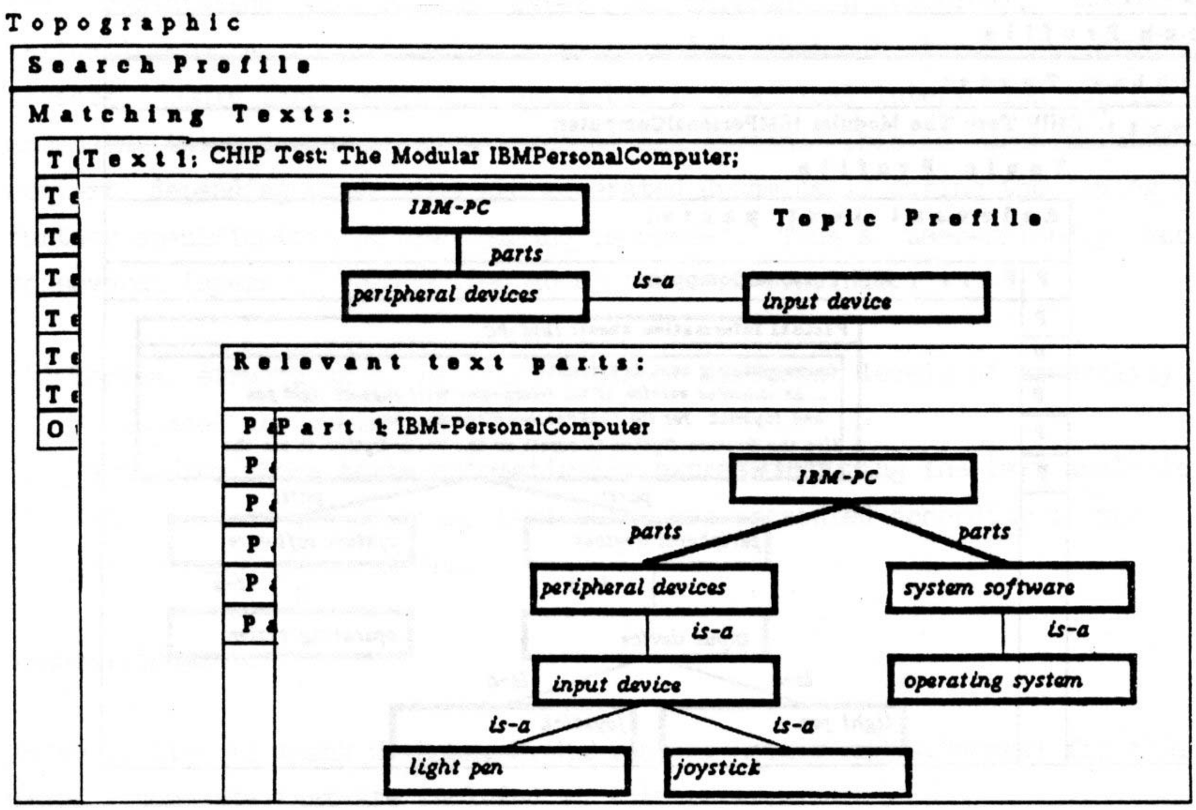

Figure 6

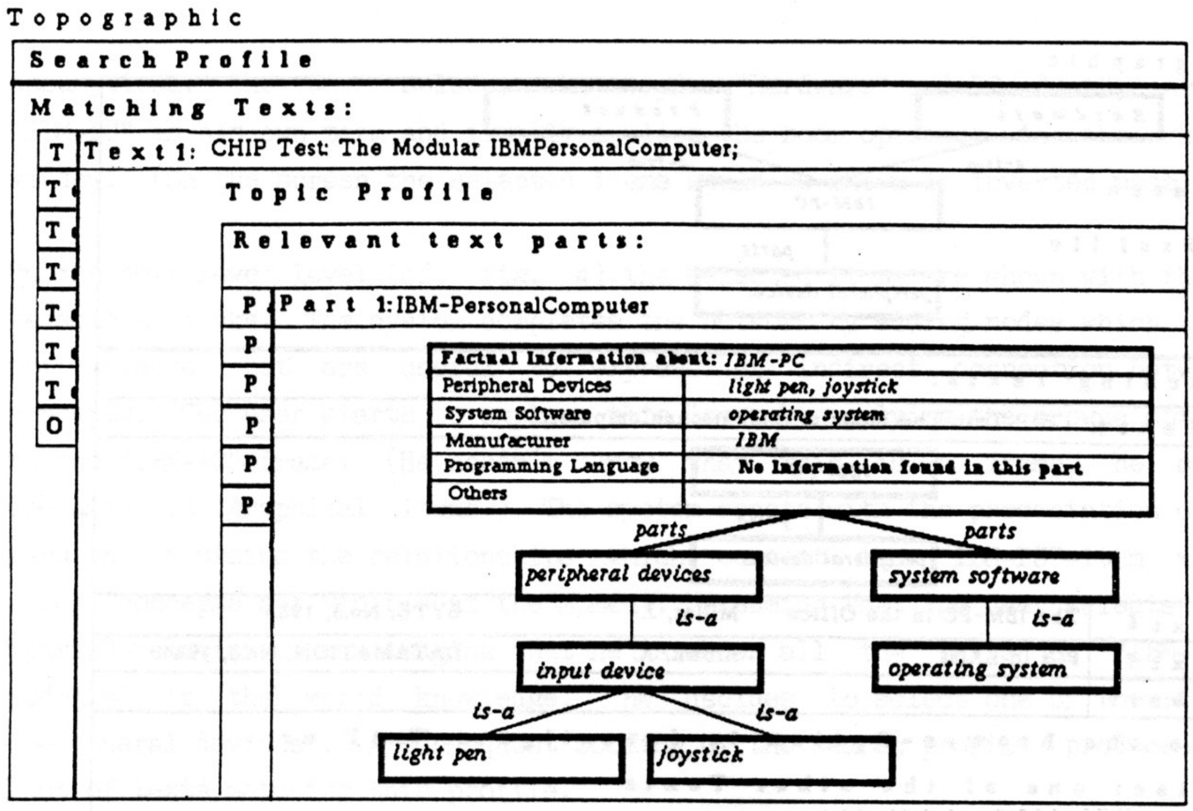

Figure 7

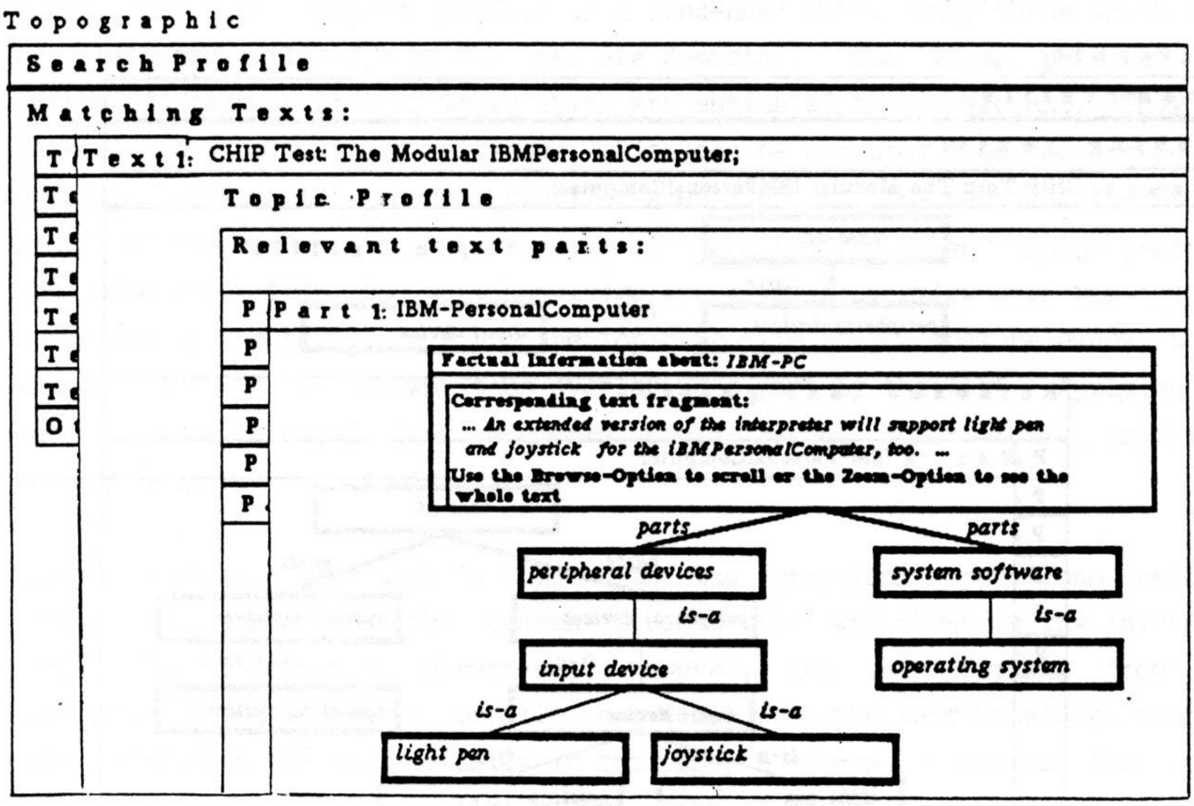

Figure 8

To start a dialog an initialising menu is presented to the user (cf. fig. 3). It offers the most general concepts of the world knowledge base for two purposes: First this menu selection results in the starting nodes of the search profile, i.e. a network representing the topics of interest and their relationships. Besides that the user is informed about the domain of discourse, this is done to give him an impression of the information he can expect. To shorten the process of search profile construction, the user can select a 'wild card': "Your Own Item". Thus he can enter search terms tentatively, which are not offered by the system at the time being. Therefore he is not forced to accept the system's level of generality, he can speed up the focussing process. The example dialog is continued under the following assumptions: The user selects the topics "Hardware" and "Product", enters "IBM-PC" as his own term and finally applies the zoom operator to the whole window. (On the screen the selected items would be shown in inverted mode).

On the next lower level (cf. fig. 4) the selected items are shown with their relational links. The system completes the network by adding nodes which are not selected but are useful to express an indirect connection between concepts. The user starts to explore this layer by applying the browse option to the "IBM-PC"-frame. (He needn't know that this is a frame, he only operates on graphical items.) The system reacts with the presentation of a menu that contains the relationships which connect the "IBM-PC"-item with other concepts not visible at the moment. Assuming that the user selects the "parts"-relation we can imagine that he is shown all the parts of "IBM-PC" modelled in the world knowledge. He decides to select one of them: the "peripheral devices". A subsequent zooming of the search profile produces a list of texts matching this profile.

Fig. 5 illustrates the resulting situation: The upper part of the screen shows the final search profile in a condensed form. Only terms which have been selected explicitly by the user are depicted. The lower part of the screen contains a list of texts which are estimated to be relevant. They are ranked according to their relevance, which can be computed from the degree of overlap between the search profile specified by the user and the 'topic profiles' computed by the TOPIC system for each text. These topic profiles are generated from the text knowledge and give an overview over the topical structure of the text. In Fig.5 the topic profile of the most relevant text, named "Text 1" is shown, thus overlaying a part of the list. Applying the zoom operator to other list elements would reveal their topic profiles, respectively.

The topic profile of a text is subject to the graphical operations select, browse and zoom like the search profile that was shown on the taxonomic layer. The information structures, however, the user obtains from the manipulation of a topic profile are taken from the text knowledge that is associated with the text actually in the user's focus. Zooming the topic profile as a whole yields a list of the parts of the text, ranked according to their relevance by a procedure similar to the one mentioned above in the context of access to a set of relevant texts. Fig. 6 shows the situation after zooming the example topic profile. The most relevant part of the text, denoted as "Part 1", has been zoomed, thus its local topical structure is visible.

Zooming the node "IBM-PC" in the local topical network of the most relevant text part reveals the factual information about "IBM-PC" that was extracted form this particular text part during the analysis process. Fig. 7 shows the zoomed node. From this information it can be assured that the "peripheral devices" mentioned in the text (as the user already knows from the local topic profile) are actually described as belonging to the "IBM-PC" in the text. Further zooming of the same node results in the corresponding text passage (cf. Fig. 8). The browse operator can be used to scroll the text.

4. Conclusions

The knowledge-based full-text information system TOPIC/TOPOGRAPHIC integrates the presentation of various types of information (topical, factual and textual) into a comprehensive dialog model that is based on graphical objects. Only three operators available in graphical interaction suffice for accessing the information structures at all levels. This is accomplished by context depending menus that are generated dynamically during the dialog if a further specification of the command is needed. Thus a user-friendly access to several layers of information about texts is possible:

(1) Topical structures of relevant texts at different levels of generality (cascaded abstracts)

(2) Facts from those texts automatically extracted during the text analysis

(3) Passages from the original text which are presented according to the user's zooming operations.

Acknowledgements

We would like to thank U. Hahn, R. Kuhlen, U. Reimer and D. Soergel for their helpful comments that are included in this paper.

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