Graphical Support for Users' Inferences within Retrieval Dialogues

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Abstract
This paper describes an approach to support inferences about presented data within a graphical dialogue system. Our approach is based on the usage of cognitive presentation forms which support the user to perceive the essentials of the presented data items. Thus, the user is enabled to draw inferences on the information content of these data. The advantages of cognitive presentation forms are illustrated by sample presentation forms which are discussed in relation to traditional presentation forms.

1 Introduction

Visual reasoning is discussed in computer science [3] with respect to the problem of supporting inferences by graphical means. The concept has successfully been applied in the area of graphical information systems to provide an alternative to formal queries [3]. Instead, the user is provided a visual language for entering a query by means of composing a complex icon on the screen.

However, not only the process of querying a database requires the user to reason about abstract objects. In complex information systems, which are used for document retrieval or knowledge base access, the problem of relevance assessment arises: the user has to decide whether a retrieval result fits his information need. In this situation the system's response should display the items found in the database in a way that supports this decision process. Taking the performance of future information systems into account the main problem concerning visualization will not be the quantity of data items but the need to support users' reasoning about the suitability of the presented data.

This requirement gives rise to several problems concerning dialogue design and information visualization. In this paper, we focus on two important questions:
1. Which are the conclusions the user is to draw from a given presentation?
2. How can the user be supported in drawing the intended conclusions?

Our approach to the first point is based on van Rijsbergen's logical formulation of the retrieval problem [11]: Given a query Q and a set of information items D we have to determine the probability P of the fact that D entails Q: P(D -> Q).

A high probability P(D -> Q) indicates that D is relevant with respect to Q. The purpose of presenting D as a response to Q in a retrieval dialogue is twofold: First, to inform the user about D, second, to convince him that the system's reaction is relevant to the query, and, as a consequence, to the user's information need.

As D may be a complex structure additional information must be conveyed. As an example, the fact that a given part of the visualization pertains to a certain concept or search term in the query will be very useful for the user in her/his interpretation of the query result. In the following, graphical means will be provided in order to facilitate this sort of inferences. They take into account the graphical context of a displayed item, thus the logical structure of the set of information items influences the layout process.

The second question we address is how to make visual inferencing feasible. The graphical means we use to support graphical inferencing on presented data are cognitively motivated presentation forms. In the following we present a set of presentation forms that are used in a graphical retrieval system providing access to knowledge bases. For SIC! (System for Information on Conferences), which is a prototypical implementation of the system, the domain of conference information has been chosen. In general, the user poses a query which is processed by the retrieval component of SIC! The result of such a knowledge base access is then transferred to the presentation planning component, which presents the query result using one of the presentation forms described in this paper. We review them with regard to their ability to set off certain inference processes within a recipient.

In the remainder of this paper we first describe the state-of-the-art in visualization of data structures. The 3rd section introduces the cognitive presentation forms which have been designed to present information within a SIC! dialogue session. Here we discuss the difference between technically and cognitively motivated layouts which plays a major role in inferencing performance in graphical dialogues. The concluding section sketches some of the future directions of our work.
2 State of the Art: graph theory based presentations

We start our examination of presentation forms with an analysis of the one that is most often found in literature: the graph presentation form (sometimes also called node-link diagram). Graph presentation forms are one of the main classes of symbolic graphical displays [1]. They are commonly used to display the organization of data, thereby stressing their structural aspects. In the context of SIC! such a visualization method reveals the representational details of a given fragment of the knowledge base containing workshops, topics, persons and relationships between these concepts. For instance, if the user poses the query "Which workshops in the UCAI '89 program contained in their title "intelligent" or addressed the topic knowledge engineering?", the system comes up with a set of three relevant workshops:

<table>
<thead>
<tr>
<th>Workshops</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intelligent Interfaces</td>
<td>Knowledge Engineering, Learning</td>
</tr>
<tr>
<td>Object Oriented Programming</td>
<td>Knowledge Engineering, Programming Languages</td>
</tr>
<tr>
<td>Workshop on Graphs</td>
<td>Knowledge Engineering, Problem Classes</td>
</tr>
</tbody>
</table>

Each of them is associated with a set topics which characterize the contributions to the workshop. The term "knowledge engineering" occurs in all topic sets. The knowledge base, however, can provide additional information. For example, the members of the organizing committee can be added to the retrieval result, thus the query will be "over-answered". However, the information content of a graphical presentation (Fig. 1) of such a retrieval result stressing the relational structure of the retrieved knowledge fragment is not easily grasped by the user.

Fig. 1 conveys information about relationships in our application, i.e. it presents information items and relationships. Although the level of detail is limited, e.g. there is no indication of different kinds of links, the presentation is overloaded with data and, as a consequence, not informative but misleading. What are the reasons for this effect?

The applied graph algorithm (cf. [13]) is a typical member of a class of algorithms that have been developed in order to display a large amount of objects. The main concern lays on the realization of graph theoretical characteristics (cf [4]) like the minimization of intersections to present pleasing layouts of the underlying data structure. The sort of reasoning that is enhanced by the graph presentation form refers to structural aspects of the data set displayed, e.g. some items are more central than others since their edge degree is higher. The relationships are perceived as symmetrical (lines).

The graph theoretical approach concentrates on the visualization of the logical organization of available data. We now consider approaches to support the user in the perception of the information conveyed by data presentations. This is accomplished by enabling the user to draw informative conclusions from the presented data.

3 Cognitive presentation forms

Our goal is the development of presentation forms which are cognitively motivated and therefore support inferences on the information and not on the display. First, we contrast the graph presentation form discussed above with a modified presentation form to make the difference between technically motivated and cognitively motivated presentation forms more distinct. Then we describe further cognitive presentation forms. At the time being we rely on traditional presentation forms for their familiarity. New and innovative forms [8] have yet to be tested for their usability. The presentation forms and the graphical presentation objects are tailored to the needs of information retrieval systems where in specific situations search terms and their relationships have to be de-
scribed. Since icons are a means to enhance recognition of functions and not of abstract terms, we do not use any icons as presentation objects.

The examples presented in this and the preceding section result from the SIC! environment. They have been designed and implemented for the SIC! prototype with the intention to cover a broad range of diverse information needs occurring in the context of abstract or conceptual data. The domain of our examples consists of abstract information about conferences including workshops, tutorials, people, institutes and conference topics. Therefore, we restrict the discussion to this sort of information.

Instances of the presentation forms are shown in Figures 1 to 4. For technical reasons the color values of the original presentation forms could not be transformed.

3.1 The ring presentation form

The ring presentation form (Fig 2) surveys a structure of given data, i.e. concepts and relations between concepts. The concepts are presented as ovals. The name ring presentation form was caused because of the layout algorithm. All items are positioned on a virtual ring structure. The relations between the concepts are usually presented as single lines. The kind of graphical connection depends on the kind of relation (dynamic/static, directed/undirected) and on the reading direction. In our example the ring presentation form contains two categories: workshop and topic. We use abbreviations of the titles and names of the workshops and topics, e.g. "Int. Interfaces" stands for "Intelligent Interfaces". The lines represent relationships between workshop concepts and topic concepts. The concepts of the workshops are visualized on the left side of the figure: "Intelligent Interfaces", "Object Oriented Programming" and "Workshop on Graphs". The concepts of the topics are displayed on the right side: "Knowledge Engineering", "Learning", "Problem Classes" and "Programming Languages". These data items have been retrieved from the database in accordance to the query (cf. sect. 2).

The ring presentation form gives orientation and encourages exploration of the data space indicated through the structure. Further questions which might be posed by the user are: Which concept is related to given concepts and which concepts are related to a given concept, e.g. the topic "Knowledge Engineering"? Since the displayed relationship is symmetrical, the investigation can start on each of the two categories.

The complexity of the ring presentation form is reduced to a simple shape in order to let the user grasp the relational structure of the data set at a glance. The recognition of presented data items, however, is not so well supported by the presentation form. This is caused by the fact that the recognition is a longer sequence of mental processes: first, the user perceives the overall structure, then he focuses on an item to read its label. This gives rise to the assumption that the ring presentation form is primarily usable to present relational information.

Thus, the ring presentation form supports the association of a concept of one category with concepts of another category. The membership to a category is revealed by the concept's position: the concept is presented either on the left side or on right side of the presentation form. The ring presentation allows to infer that the association is typed by the categories of the columns (sides) - actually, the original display uses different colors for the given categories. The user is encouraged to relate a concept of one of the displayed categories with concepts of the other category. Now, this sort of clustering involves concepts of different categories. In general, the graphical means of clustering are position, color and forms.

In contrast to the graph presentation form, in the ring presentation form the position of a concept is not governed by graph theoretical criteria. Instead, it is used to express a certain meaning: the concept's membership in a category. The graph presentation form does not express the membership of categories of the presented concepts.

Therefore, the ring presentation form enables the user to draw conclusions about the semantics of the visualization: Each concept belongs to a category which is indicated by its position. The category itself is given in the heading of the presentation.

![Ring presentation form](image-url)
Two or more concepts can be associated with a certain concept of the other category. This allows the user to infer directly which aspect the two concepts have in common. The categories are ordered according to the search terms of the query. First, the system shows a set of workshops the user asked for, and, second, it provides the related topics for each of these workshops. The order of the workshops and topics mirrors the order of the search terms of the query. Instead of row presentation, the ordering algorithm uses column presentation since we read from left to right and then from top to bottom. The header of the presentation, a paraphrase of the query, reflects this order, too. The concepts of one category are ordered sequentially in accordance to their relevance. Concepts mentioned in the query as search terms, like "Intelligent Interfaces", are presented at first. All these means - ordering of categories and concepts according to the query, ranking of concepts, paraphrasing the query - serve to increase the recognition of query concepts and let the user understand the presentation and draw inferences.

3.2 The table presentation form

While the ring presentation form presents relations between concepts of two categories, tables (Fig 3) serve to show single concepts, clusters of concepts, and relations between a single concept and a cluster. The table presentation form, which is a 2 column table in our example, appoints a single concept of the first column to a cluster of concepts of the second column. A cluster is a group of concepts of the same category. We do not consider relationships between concepts of the same category. The relationship of a single concept with a cluster is inherently revealed through the position of the items and not explicitly presented by lines and arrows. In contrast to the ring presentation form, the amount of visualized relational links is reduced. As only the connection between a concept and a cluster (in a given row) is made explicit, this relation can be expressed within the table presentation form by a cognitively simpler means: the horizontal arrangement in the same row.

The sample table displays workshops and topics as the ring presentation does. This is indicated by the header of the table. The concepts are separated accordingly their type and represented by their short names and short titles like "OO Programming" and "Kn-Acquisition". Those topics which are referenced by a common workshop are packed together. The inference to be drawn from the table presentation form in the given example is the association of a workshop (first column) with a set of topics (second column). Compared to the ring presentation form, where the reader has to follow each relationship of a single concept to perceive all the concept's relationships, the table presentation form displays the 1-to-many association in a more distinctive way by clustering the related-to concepts (destination). Therefore, the table presentation form is useful if the designer knows the direction of the association, i.e., the designer knows which of the two given categories functions as the source of the association and which category functions as the destination of the association. In contrast to the ring presentation form, the table presentation form displays non-symmetrical relations. Regarding the inherently given direction as an advantage, the cognitive performance of the reader can be increased. Another advantage of the table presentation form with respect to the ring presentation form lies in its well-known layout. Tables are conventional means to display data items joined together.

Supported inferences of the table presentation form are: The categories are ordered sequentially in accordance to their occurrence in the query. The user asked for certain workshops using topics as a filter on the retrieved workshop items. The relevance assessment of the shown workshops is based on the topics and is visually revealed by their position in the presentation form. The first column offers the workshops and the second column presents their topics.

Both the ring presentation form and the table presentation form present relationships between workshops and topics. Thus, they both refer to the semantically oriented part of the sample query where the user asked for workshops providing the topic knowledge engineering. The first part of the query, which is concerned with the substring "Intelligent" in the title of a workshop and may therefore be considered as syntactic, was not revealed by any graphical means: the ring presentation form surveys the relationships between concepts and the table presentation form primarily serves to link concepts to clusters of concepts. Now, we introduce a presentation form which considers less the relationships between concepts rather than the data which are stored within the representation of a concept, e.g., names, titles or textual description.
3.3 The box presentation form

If further attributes or details of the workshops have to be presented, the table presentation form fails to meet this information need, even if we allow additional columns. Instead, we concentrate on the data to be presented, i.e., we alter the displayed attributes of a workshop and develop an alternative presentation form (Fig 4) which fulfills a detail-oriented information need. We keep the clustering of the values of a single attribute, e.g., topics, as was previously shown in the table. In order to avoid a presentation that is overloaded we restrict the displayed items: We take a single row of the table, for example the second row consisting of the concept “Workshop on graphs” and the cluster “Kn–Engineering”, “Problem Classes”, and extend that row by further available attributes of the workshop “Workshop on graphs”: title, workshop topics, organizers, deadline, acceptance, contact person and description which together describe a workshop completely.

The layout of the presentation form shows graphical items that are sized, formed and positioned differently, one item per attribute. These graphical means are used in order to express the relative importance of the information items within the specific context: the most important attributes are emphasized through position. The attributes of the workshop description are arranged in logical units (“chunks”), considering the magic number 7 +/- 2 ([9], [2]) of individual items that a person can cope with simultaneously. Values of attributes that are comprised within one graphical unit are perceived as a set. The units are spatially organized using the available two dimensional space. The unit consisting of the most important attributes is positioned in the upper half of the available space and at a central place whereas less important units share the lower part of the space or the peripheral space. Such a distribution in space is based on the fact that human beings in the western civilization expect the most relevant information to be placed in a prominent position, e.g., the central area of a picture, and read top-down. As texts in western written languages are organized in lines to be read from left to right, the layout of a unit’s items arranges them on a virtual horizontal line.

Figure 4 displays a single workshop. The concept is described by several attributes and their values. Each attribute is visualized in a separate rectangle. The name of the attribute heads the rectangle. The little squares in front of the attribute names refer to pop-up menus from which the user can invoke operations on the attributes.

As important items are displayed in a prominent way, e.g., larger sized, positioned in the upper half of the presentation form, they are perceived more easily. Thus, the user is supported in his judgement about the relevance of the given concept. The more centrally positioned information items are the more relevant information items. The information items depicted in peripheral areas are less relevant information items or are additional items.

4 Conclusion and future directions

In the first section of this paper we assumed that parts of a presentation graphically refer to a previously shown visualization or to terms of a submitted query. These referring data and data relevant with respect to the query or former display have to be recognized by the user in order to make inferences on the presented data. We developed cognitive presentation forms to support the perception and inferencing process of the user. As the examples have shown, we get valuable insights from these kinds of presentation forms in contrast to the more technically motivated graph presentation forms. Questions which now arise are how to systemize and automate the manual design process. We outline future directions.

![Figure 4: Box presentation form](image-url)
The objective to support inferences on presented information is achieved for instance by visually revealing the most relevant data, by reference techniques or by establishing coherence within the graphical display. Therefore, the dialogue situations will be characterized in a way which allows to derive a specification of an appropriate presentation. Based on this specification one of the available cognitive presentation forms will be chosen. This method guarantees the approximation of a situation-adequate presentation of the retrieved information items. In spite of the vagueness of these terms, we can think more perspicuously about the realization on the tactical and operational level: the choice of an appropriate presentation form and its arrangement and shaping. The operative level is based on knowledge about encoding techniques (cf. [7], [11]), e.g. the discriminative power of a graphical variable indicates how many different values of that variable a person is able to identify and which variables could be used to display graphical objects. Six graphical variables can be distinguished: x- and y position, size, color, orientation and shape [1]. The graphical variables are used to encode the given data as well as their relevance in accordance to the dialogue situation or their membership to categories. For example the ring presentation form actually uses position (left and right) and color (yet not visible in the screen dumps for reproduction reasons) to separate the given categories workshops and topics graphically. Knowledge about encoding techniques can be compiled from results of cognitive and perceptual studies (cf. [6], [5], [10], [12]). These studies about the graphical variables will support the realization of cognitive presentation forms for a better inferencing on presented information.

5 References

[12] Colin Ware, John C. Beatty, "Using colour to display structures in multidimensional discrete data", Color Research and Application, 11(6), 1986, pp. 11-14