Metaphors vs. Visual Formalisms in Visual Information Seeking

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SUMMARY
Metaphors and visual formalisms are commonly seen as two different and separate concepts for the design of human computer interfaces. This article describes both concepts and their advantages and disadvantages. We claim that thorough consideration of the use of these concepts enhances the design of human computer interfaces. We also claim that strict separation of these concepts is not always possible or useful. Practical examples are given to support our claims and to demonstrate the problems as well as the possibilities of metaphors and visual formalisms in interface design.

KEYWORDS : metaphor, visual formalism, HCI, visualization, document retrieval, interface design

INTRODUCTION
Design strategies for graphical user interfaces commonly imply the use of metaphors. Since the introduction of the desktop metaphor the advantages of metaphors have widely been agreed on. Nevertheless, metaphors in general have some flaws. Here, visual formalisms are frequently seen as an alternative.

We want to discuss the concepts, advantages, disadvantages, and similarities of both the metaphor and the visual formalism. We demonstrate the advantageous use of these concepts by several visualizations for information retrieval systems.

METAPHORS
There is no agreement on the mode of operation of metaphors. An extended survey and study on the different theories would be out of proportion in this paper. Nevertheless, the basic concept and some customary theories are introduced in the following.

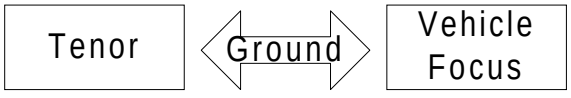

Figure 1: Model of the metaphor

Three elements constitute a metaphor: The *tenor* is the subject of the metaphor. In a textual metaphor this is the actual wording. The *vehicle* [15] or the *focus* [1] is the object of the metaphor to which the subject/tenor refers. The *ground* is the common basis on which the tenor-vehicle relationship is established. Whereas tenor and vehicle are simple and undisputed concepts, the nature of the ground is subject to a fierce controversy. Four common theories will be presented in the following. Since we do not want to focus on the principles of metaphor, but simply want to emphasize the complexity of the topic, we do not go into criticizing these theories. A deeper look into the problems of the theories can be found in [15].

- The *comparison theory* defines the ground of the metaphor by pointing out the several characteristics of tenor and vehicle which found the basis of the comparison. By using a metaphor one introduces a formally unknown term: the tenor. This new term is explained on the basis of the comparison with another already known term: the vehicle. Characteristics of the vehicle are transferred to the tenor. If there exist characteristics of the tenor which are known, they are not erased by the new ones. This principle is similar to the principle of inheritance in object oriented programming: the tenor inherits those characteristics which do not contradict already existing ones.
- While the comparison theory is based on the similarity between tenor and vehicle, the *anomality theory* defines a metaphor by the dissimilarities between them. Those dissimilarities are seen as the basis for the anomality when two terms are linked in order to build up a metaphor. This theory is based on the realization that metaphors are quite absurd read literally. In order to understand the metaphor the recipient has to dissolve this absurdity either by finding similarities or by transferring the elements to a higher degree of abstraction in which the anomalities disappear.
- The *interaction theory* assumes a reorganization of the tenor. Similarity and dissimilarity are treated as equals. The characteristics of the vehicle can not be applied directly to the tenor, because these characteristics are frequently metaphorical themselves (see for example

the „Man is a wolf“ example in [1]). Common places associated to the tenor and the vehicle as well are what gives the metaphor meaning. „These common places are stereotypes, not necessarily definitional, not even necessarily true, just widely agreed upon.“ [15: 213]
- The *domain interaction theory* introduces the concept of domain. Not only the actual tenor and vehicle are taken into account but also their environments or domains. Matching concepts of both domains are compared to each other and lead to a change of view of the tenor.

Metaphors are used in different areas of software. In the following we want to discuss metaphors in interface design. For an overview see [12].

Metaphors in user interfaces can support orientation. They can ease and speed up the work. Consider the desktop metaphor: Because of substantial metaphorical hints the user is enabled to recognize the elements and their functions. The icon of the trash can for example is a strong hint that here something can be thrown away. The metaphor also hints how something is to be thrown away: By putting something into the trash can. The only way to do so in a graphical user interface is by using direct manipulation (drag&drop). The concept of the trash can is easily comprehended.

The main argument for metaphors is that learning becomes easier by using them. They provide hints about the use and the features of software. The improvement of learning does not only apply for relatively small hints like the trash can. [2] claim that learning as such is largely based on metaphors. They describe the steps of learning as follows: First, new information is loaded into the working memory. In a second step a structure of comparable knowledge is retrieved from the long term memory. The process of structuring the new knowledge is performed according to this older structure. This process occurs automatically and every time something is learned. The old structure is modified and expanded in order to suit the new knowledge. In order to achieve successful learning the old structure which is applied to the new knowledge has to be suitable. The minor the modifications the better.

The critique of metaphors is mainly based on three points:

- The fuzzy basic conception of metaphors makes quality measurement difficult. Metaphors are not equally good, just because they are metaphors. There are strong differences in quality. But how can one measure the quality of a metaphor in a formal and objective way if the basic functioning of the metaphor is unknown? The comparison theory studies the similarity between tenor and vehicle in order to measure quality. The similarity should be of medium kind in order to avoid tautologies and incompatibilities. The anomaly theory measures quality by the degree of independence of tenor and vehicle. Here also is a middle course aspired. The interaction theory takes into consideration the possibility of transfer between vehicle and tenor. The domain interaction theory distinguishes between within-domain similarity and between-domain similarity. This different approaches do not allow to put up generally applicable criteria for quality measurement of metaphors.
- The effect and understanding of metaphors is strongly dependent on the environment they are used in. Different cultural and intellectual aspects have to be considered and influence the effectiveness of metaphors.
- Creating a metaphor is difficult and often faulty. Consider again the trash can metaphor mentioned above: The Apple Macintosh OS uses the trash can in order to eject a floppy disc. The user has to drag a disc icon over the trash can and drop it there. This feature exceeds the actual meaning of the metaphor, which is to throw away the disc. It seems to be not much more than a small „bump“, but frequently leads to serious problems and annoyances[13][3]**.** The reason for most of the problems occurring with metaphors is the inexactness of metaphors. They are by nature somewhat fuzzy. Even supporter of the metaphorical interface design provide recommendations and guidelines for the use of metaphors [2].

VISUAL FORMALISMS

Visual formalisms are frequently seen as an alternative approach to metaphors. In the following we want to state some basic remarks on their concept.

Whereas metaphors transfer semantics from one domain to another visual formalisms do not: „Visual Formalisms are diagrammatic displays with well-defined semantics for expressing relations. Examples of commonly used Visual Formalisms are tables, graphs, plots, panels, maps, and outlines.“ [8:44]. [6:528] explains the two aspects of visual formalisms: „visual, because they are to be generated, comprehended, and communicated by humans; and formal because they are to be manipulated, maintained, and analyzed by computers.“

The advantage of visual formalisms over metaphors is that they build up a new and strictly defined semantic. Thus, the user does not have to cope with the semantics of two different domains. He also is not confronted with the fuzziness of metaphors: the semantics of a visual formalism is (ideally) unambiguous and clear. Nevertheless, a visual formalism can be used in different domains and therefore be familiar to the user.

[11:22] state several advantages of visual formalisms in general: „Exploitation of the human skill [...], Manipulability [...], Specializability [...], Broad applicability [...], Familiarity [...]." A further advantage in computer-based versions of visual formalisms is the integration of both the user and the system. On the one hand, they largely cooperate with the human visual perception. On the other hand their formality allows easy and secure implementation. Thus, they can please the user as well as the system and can fulfill their purpose as a human-computer interface very well.

But the advantages of visual formalisms have limits, too. Even their supporters admit that sometimes metaphors are preferable when dealing with simple data. There seems to be a lower boundary of data complexity and quantity for visual formalisms. (Indeed, it would not make much sense to replace the trash can by a visual formalism. Here the metaphor can do a perfect job.) The question remains, were this lower boundary is to be found.

There also seems to be a upper boundary of complexity and quantity of data. Large amounts of data can not be integrated in one single table without the user loosing track of the data. But this problem does generally apply to all kind of presentation of large amount of data. It does not matter whether one uses a metaphor or a visual formalism: computer screens are frequently too small to display all data.

The familiarity claimed by supporters of visual formalisms is not generally valid. It just applies to the view visual formalisms mentioned above (tables, graphs, plots, panels, etc.). But even those had first to be learned by the user. Both - visual formalisms and metaphors - imply prior knowledge. In cases where the user lacks this knowledge, none of the concepts works without further explanation.

Supporters of visual formalisms frequently claim visual formalisms to be something completely different than metaphors: „They are based on simple visual objects such as tables, graphs, plots, panels and maps - objects that contain their own semantics and do not metaphorically recreate the semantics of some other domain." [11: 5] We do not consider the distinction between visual formalisms and metaphors to be that clear. Consider for example graphs. High Y-values are usually above low Y-values. The reason for this positioning is not at all arbitrary but follows the analogy of high, big, good, god on the one hand and low, small, bad, evil on the other. Graphs falls back on these connotations. That is why it seems so natural to look for higher values above the lower ones. Another example are maps. [11] consider a map to be a visual formalism. But concerning features like coloring the shape, there are many reasons to consider them as metaphors. On the other hand maps might need legends in order to be interpretable, because they often include abstract elements, like symbols for different types of land use, which are new to the user. Are maps metaphors using abstract visual elements or visual formalisms using metaphorical elements?

PRACTICAL EXAMPLE: USER BEHAVIOR AND THE ATTRACTION METAPHOR IN DOCUMENT RETRIEVAL

In modern document retrieval systems, visualizations are used frequently as a part of the user interface. They provide a intuitive and easy-to-use access to information.

Searching the database

Systems like VIBE [9], LyberSphere [7], or Vineta [5] present a visualization based on the attraction metaphor. Figure 2 demonstrates the basic idea of the attraction metaphor.

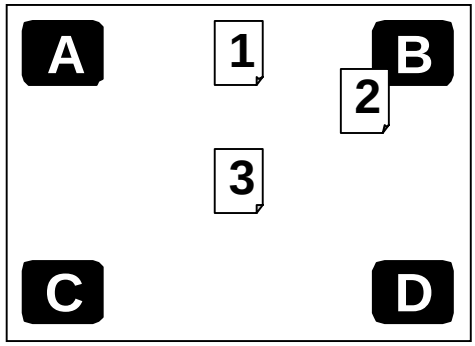

Figure 2: Schema of the attraction metaphor in document retrieval

The attraction metaphor transfers the abstract dimension *relevance* to the physical abstract dimension *attraction*. Figure 2 shows four search criteria A, B, C, D and three documents 1, 2, 3. The documents are attracted by those search criteria they are relevant to. Thus document 1 is placed between A and B because it is relevant to A and B but not to C and D. Document 2 is relevant only to search criterion B. The relationship between document 3 and the four search criteria is ambiguous: It can be relevant to A and C, B and D or even to all four of them. In order to get the real relationship one has to move at least one criterion by dragging it with the mouse. The new positioning can eventually reveal the relationship.

This basic version of the attraction metaphor is used in the VIBE system. In a two-dimensional environment relationships between documents and search criteria are shown in a similar way to figure 2. The advantage of this approach is that clustering of documents within the document space is revealed as well as singular documents. In VIBE the attraction metaphor is basically employed in order to clarify the actual concept of interpola-

tion to the regular user who might not be familiar with the term. The attraction in VIBE is indeed a „one-way“ attraction: The search criteria exert attraction but are not attracted themselves.

LyberSphere and Vineta extend the attraction metaphor and build up a three dimensional display. At first glance the LyberSphere seems to employ a planetary metaphor. Search criteria fly like satellites over the surface of a sphere (planet). But a closer look reveals that the „planet“ is no planet at all but simply a sphere which visually separates the documents from the search criteria. Inside the sphere documents are positioned according to their relationships to the search criteria. Here as well the positioning of the documents is determined by the concept of interpolation. But the sphere evokes the metaphor of a planetary system. Since the only function of the sphere is to separate documents from search criteria, which is already achieved by their different shapes, the sphere could as well be dismissed.

The galaxy metaphor of the Vineta system works without this sphere. Here again the basic principle is interpolation.

The problems of the attraction metaphor can be summarized as follows:

- The attraction metaphor does not guaranty a unambiguous presentation. Documents can obtain positions which define several different relationships. Furthermore, several documents of different relationships can occupy the same place simultaneously.
- In order to dissolve these ambiguities further interaction (moving the search criteria) is needed.
- Even without ambiguities orientation is quite difficult. In the three dimensional versions flawless interpretation of the representation is certainly not possible.
- The introduction of a third dimension may delay the occurrence of ambiguities, but they still occur. The third dimension furthermore leads to superimposition of the elements of the visualization. Documents and search criteria in the foreground might hide others in the background.
- The attraction metaphor and its derivatives galaxy and planetary metaphor employ a one-way concept of attraction, which is in fact no attraction but interpolation.
- The derivative planetary metaphor consists of a satellite search criteria attracting documents inside a sphere. This concept does not seem to be too close to the concept of a planet.
- The derivative galaxy metaphor consists of search criteria suns and planet documents. But their behavior is totally different to the one of real galaxies.
- Since documents are treated individually a large amount of documents can not be presented without superimposition. A large amount of retrieved documents leads to a very complex representation.
- The attraction metaphor is only of use for presenting result sets. Considering the whole retrieval process, the sole focus on the result is quite narrow.

In respect to these problems [4] introduces a visualization for document retrieval systems which uses a visual formalism: DEViD (Design and Software Ergonomics Integration Visualization for Document Retrieval Systems) is based of an extensive user analysis which revealed the serious problems with metaphorical approaches.

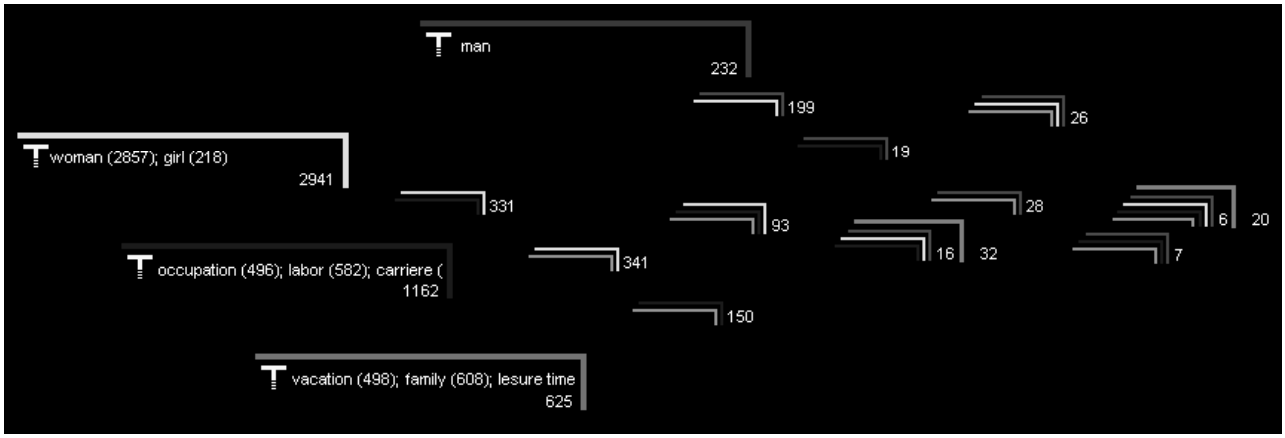

Figure 3: Visualizing the search without the use of a metaphor: The search criteria are represented within large brackets. The sets of documents are relevant to these criteria according to the colors of the smaller brackets.

The visualization is two dimensional, does without metaphors and uses a set representation of the documents. The user enters search terms and the visualization presents all possible combinations of the terms and the resulting sets of documents. The coding is done by colors. The icons of the document sets consist of brackets of the same colors as the search criteria they are relevant to. DEViD also integrates three different retrieval models in one visual representation.

Figure 3 shows DEViD after entering four search criteria leading to 11 different sets of documents. The sets are built by using AND combinations of the search criteria. The positions of the document sets within the display are arranged by using methods of the probabilistic retrieval. Finally two document sets are enlarged by using the vague retrieval model: based on a originally found document set new documents are added to these sets.

Formal user tests proved the visualization to be superior to traditional retrieval interfaces concerning the retrieval results as well as user satisfaction [4]. Thus, in the case of visualizing the search in document retrieval systems, the use of a visual formalism seems to be appropriate.

Browsing the database

Alternatively to keyword searching, browsing is a very important approach to information seeking. The internet has led to growing interest in browsing, which represents a more informal seeking behavior.

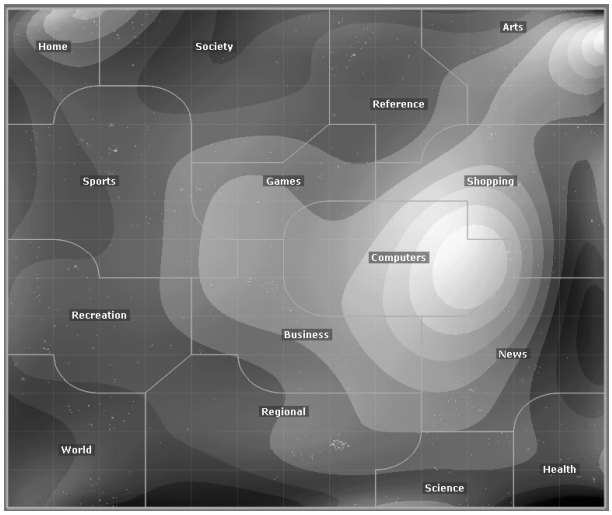

Figure 4 A topographical map: http://www.webmap.com

Browsing strategies resemble the human navigation behavior in the real physical world and users often describe their seeking in electronic environments in terms borrowed from spatial navigation ("getting lost", "exploring"). This notion is exploited by two-dimensional object displays or topographical maps which have gained a lot of interest in the last few years. Figure 4 shows a typical example which can be found on the internet. These maps are designed to support the analogy between navigation in electronic and real environments. They create a two- (or three) dimensional arrangement of the objects and claim, that the similarity between the objects is largely represented by their closeness (figure 4). Therefore, a user moving a short distance is likely to encounter similar objects. In order to find different objects, the user has to move a larger distance away from the current position. The maps are used to display text documents, music pieces, software and other document types.

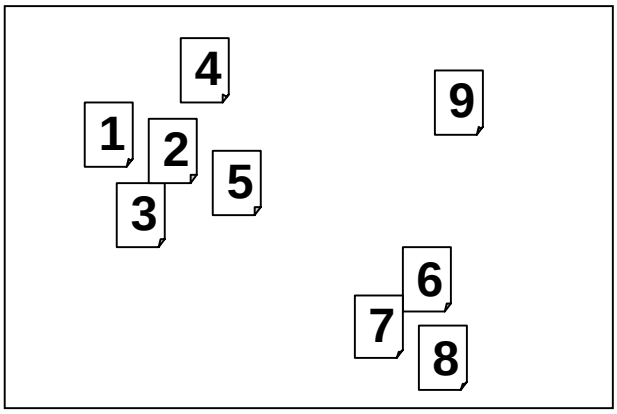

Figure 5 Topographical Map: Basic principle

The obvious parallels between browsing in a map and the navigating in the real world suggests that maps are metaphors. Whereas it seems unlikely to find appropriate metaphorical representations for keyword search, the browsing paradigm for information seeking has become a widely applied metaphor. They are very plausible and easy to use, however, their usability depends on many factors including the algorithms applied for their creation and needs more evaluation. An overview and comparative evaluation methodology can be found in [10].

LEAVING THE STRICT DIFFERENTIATION

Until now metaphors and visual formalisms have been treated as two distinct concepts with no common grounds. In the following example we want to show that these concepts do not exclude each other, but may result in better user interfaces when used in combination.

Figure 6 shows the user interface of MURBANDY [14], an information system for the dynamics of land use. It combines both, a metaphor and a visual formalism.

For presenting the results of a user's query a map is used. As discussed earlier, maps can be seen as metaphors, which seems to be the appropriate interpretation in this context, where the spatial layout of a real city is transferred directly to the screen. Looking only at one city, the data displayed is not very complex: Color for the type of land use and location for the relative position of a specific area in relation to the other areas.

The table in the upper left corner is a visual formalism which displays the more complex relationships between types of land use (rows), cities (columns), and their visibility in the maps (cells). The check boxes show where a connection in the data exists between land use and city, and the status of a check box (checked vs. unchecked) shows if the data is displayed in the map.

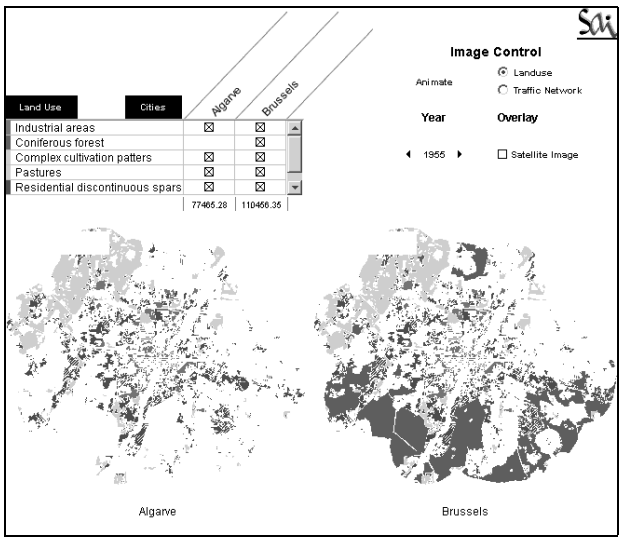

Figure 6 A combination of metaphor and visual formalism

CONCLUSION

There is still a great demand for more research in the area of metaphors and visual formalisms. It seems that even within one and the same domain (e.g. here: information retrieval) different tasks demand different methods of conceptualizing the user interface. The choice between metaphors and visual formalisms depends highly on the specific situation.

One important question is the intercultural comprehension of these interface elements. Whereas metaphors are usually deeply rooted in their culture and difficult to interpret for outsiders, the more abstract interface elements usually considered as visual formalisms may in some cases be culturally independent. The concept of graphs where high values are commonly above low ones seems to be a good example.

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