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SFB/TR 8
SPATIAL COGNITION

SFB/TR 8 Report No. 001-09/2004
Report Series of the Transregional Collaborative Research Center SFB/TR 8 Spatial Cognition
Universität Bremen / Universität Freiburg

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User-Centered Views and Spatial Concepts for Navigation in Information Spaces[1]

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Abstract

An adequate communication of information on an information system's inner organization to its user is usually crucial for a successful interaction. Focus on the design of user interfaces alone generally can not guarantee successful interaction as properties of underlying structures and features surface through the system's interface in the possibilities and constraints that are imposed upon the user's actions. Thus, the design of a system's inner structure is as critical to interaction as the design of its interface.

Users possess individual views on domains. Often, these specific views are not supported by the pre-ordered structures within information systems. As a result, users are forced to adapt to the system's view and interaction becomes cumbersome or ineffective.

Interaction with an information system is often experienced spatially, much like a movement through physical space. However, the metaphorical transfer of spatial concepts to information systems necessarily fails where the employed structures do not support their use. Some existing approaches try to allow for a more natural interaction by mimicking space literally; we argue that this is not only unnecessary but also introduces additional difficulties for the user. Instead, our focus is structural as we introduce the concept of *multi-dimensional graduated semi-lattices*. It both supports a multitude of individual views and the use of implicitly transferred spatial behaviors and concepts.

Finally, we suggest some possible applications based on this structure and present as an example the implementation of a help system.

1 Introduction

Providing a means of communication between two agents is central to the concept of an interface. In human-computer interfaces, naturally, one agent is human while the other is a computer system. With respect to communication needs one can assume that either agent is in possession of an inner structure which – in a simplified model – consists of two layers: an inner layer which comprises matter that is neither directly visible nor accessible to the world surrounding the agent and a surface layer that provides mechanisms for an exchange of information between the inner layer and the outer world, e.g. with another agent. The surface layer of a communicating agent thus becomes part of the means of communication itself.

[1]This report is a summary and derivative of thoughts and ideas that evolved over the course of several years. It improved and benefited from previous publications and drafts on related topics (cf. Bertel et al., 2002, 2001, 2000; Obendorf et al., 2001).
Sven Bertel and Kai-Florian Richter gratefully acknowledge funding by the *Deutsche Forschungsgemeinschaft* (DFG) through the transregional collaborative research center *SFB/TR 8 Spatial Cognition* (research projects R1-[ImageSpace] and I2-[MapSpace]) and through the German *Spatial Cognition Priority Program*.

Traditionally, primacy of user needs over system needs has been one of the main motives of human-computer interface design and, today, a broad range of methods and techniques exist to help implement this primacy for the individual computer system. We argue, however, that many of these methods fall short of their intended purposes since for the most part they aim but at the surface layer of communicating computer systems. Frequently, communication difficulties are caused by incompatibilities between underlying structures within the respective agents; what users perceive are often eruptions of these incompabilities to surface level. In such cases, it is obvious that superficial modifications to the interface alone will not lead to permanent solutions. Structural features surface to different degrees in the possibilites and constraints that a system imposes on a user's actions.

As a consequence, the approach discussed in this paper is a structural one, aiming at conceptual issues situated *below* the communication level. The structure proposed shows how content in information systems (as part of a computer system's inner layer) can be organized to support the use of different individual views on domains and the expectation of the existance of certain spatial concepts (as surfacing in the human agent's communicating behavior). Support of both concerns is essential; a lack of their support can be considered a main reason for failed interaction with information systems.

2 Individual Views

In most information systems, hierarchical structures are underlying the visible part of the system. There exists a gap between a user's expectations and the structures that actually organize information in a system.

Mental and External Representations of a Domain

When people interact with a domain or an external representation thereof they form mental representations of the domain. These representations are determined by the task at hand (e.g Tulving & Thompson, 1978) and may be influenced by existing mental representations. Since these vary significantly between individuals it can be assumed that even if the basic mechanisms for the formation of mental representations may be comparable among humans the actual mental representations of a domain differ significantly from one individual to another.

Interaction with a domain constitutes concepts on the relevant entities in it which are grounded on mental categories (Rosch, 1978). Since some concepts are refinements of others the categorization leads to hierarchical mental representations. As mental representations differ between individuals the hierarchical categorization can be assumed to differ, as well. Externally representing concepts in a system is accomplished by providing information on the domain composed of meaningful information bits which form the *information set*. This structure usually is hierarchical, as well, but these hierarchies are fixed at the time the external representation is created and are not changed afterwards.

Views

Mental representations are largely hierarchically organized. The nature of these hierarchies conditions an individual's perception of a given domain's structure (cf. Stevens & Coupe, 1978). Both the individual's perception of the given domain and her perspective as determined by the task at hand work as a filter on the domain as they let the individual focus on certain aspects deemed relevant as well as ignore others. The individuality in the two aspects – the perception of a given domain as shaped by the hierarchical nature of mental representations and perspective on the domain as determined by the current task – leads to an *individual view* on a domain. Clearly, views are user- and task-dependent.

However, on using information systems individuals are often confronted with external representations of a domain that differ significantly from their internal hierarchical representations. The greater this difference the higher is an individual's cognitive burden of relating the internal with the external representations.

As seen above, the external representation of a domain in a system is based on the structure that is imposed on the information set. Current approaches to structure information sets are unsatisfactory because the resulting structures are too rigid and only correspond to one special view on a domain. Through the use of these structures systems might be constructed that are cognitively adequate w.r.t. the individual needs of one user but are not for those of many.

We argue that a structure is needed that allows for the support of many user- and task-dependent views.

Deficits of Existing Structures

The most common structure for organizing elements of an information set is a tree. A tree imposes a strict hierarchy on an information set as in a tree for any two sets either one is a subset of the other or both are disjoint (cf. Alexander, 1982).

Therefore – as each set of information elements corresponds to a node of the tree structure – for any node there can never be more than one sequence of nodes starting from the root of the tree that lead to this node, as shown in fig. 1 on the left. Only one predefined *view* can be supported since the hierarchical structure does not change after the system's creation as stated above.

Ordered trees (cf. Hirtle & Jonides, 1985) allow for some overlapping in the structure and, thus, in some cases allow for more than one sequence of nodes leading to an element of the information set (see right in fig. 1). But since this overlapping is restricted just to the children of a node and no overlapping between children of different nodes is allowed the number of *views* supported by ordered trees still is very small. Additionally, ordered trees were developed to

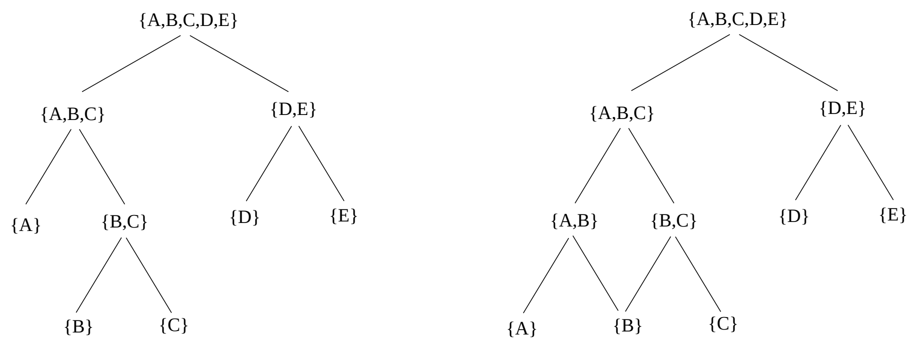

Figure 1: Example of a tree (left) and an ordered tree (right) (compare Hirtle, 1995)

describe the representational structure of a single subject for a domain in recall experiments and, therefore, their construction is quite difficult to generalize to the use of structuring information sets (cf. Hirtle, 1995).

Multitrees (Furnas & Zacks, 1994) seem to be promising at first glance. They are formed by imposing several trees on an already existing one by using nodes of the existing tree and adding new relationships. One of the properties of a multitree is that even if the resulting structure is not a tree the successors of each node form a tree, respectively (see left in fig. 2). Thus, there is not a single root node in the structure but several according to the number of different trees combined. Likewise, there are as many sequences of nodes leading to a node as there are different trees in the multitree. The number of supported views is equally restricted.

A semi-lattice is a structure that allows for multiple sequences of nodes leading to a given node. According to Alexander (1982) a semi-lattice is a collection of sets such that for two overlapping sets the intersection of these sets is also a set of the collection. Thus, elements of the underlying set contained in an information system may belong to more than one subset leading to multiple sequences of nodes to an element (see fig. 2 on the right). Accordingly, semi-lattices support several *views*. However, the support of views is still relatively

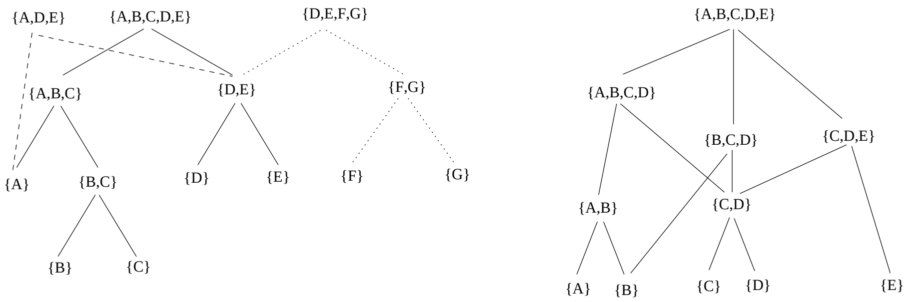

Figure 2: Example of a multitree (left) and a semi-lattice (right)

restricted. Since all elements of the set must be ordered in a single semi-lattice there are necessarily structural relations between these elements that are more or less arbitrary. Thus, without any necessity certain elements of the set might be unaccessible when access would be expected according to some users' *views*.

3 Spatial Concepts

Spatial Concepts in Hypertextual Environments

People often metaphorically conceive of hypertextual environments as of physical spaces (Maglio & Matlock, 1998). They use spatial vocabulary when talking about such environments. Expressions like "going to a page", "at my homepage", or "coming back to" show – according to Maglio & Matlock (1998) – that people think of a hypertextual environment as of a kind of space in which they move.

The use of landmarks is inherent in human navigation; people make use of likewise categories for them in physical space and electronic systems (Sorrows & Hirtle, 1999). Thus, part of the concepts of human navigation in physical spaces trancend to hypertext and virtual environments.

Transition of Spatial Behaviors

One explanation for this transition might be that humans possess a distinct processing ability for matters of physical space. Interaction with physical space is frequent as is the use of many of the mental processes involved. Spatial behaviors are well trained and we are accustomed to the use of external spatial representations and spatial vocabulary for the purpose of communicating spatial matters. Thus, dealing with affairs of physical space seems to come at low cognitive costs to humans.

This might be one reason why we so readily focus on certain quasi-spatial properties of domains that in other, essential properties are largely non-spatial, at least when compared to physical space.

As properties in a system's structure are readily perceived of as spatial cues even a weak (but specific) resemblance of the virtual domain to physical space seems to suffice for the transfer of spatial concepts. Therefore, spatial behaviors, such as navigation, search, and exploration, can easily transcend to virtual domains, such as information or hypertext systems (Modjeska, 1997).

Increasing Analogicity

As these systems are essentially non-spatial trying to apply spatial behaviors often fails when interacting with information systems. In order for a user to benefit from the application of these behaviors a common approach lies in the imitation of existing physical spaces, e.g. cities or shopping malls. This imitation can either be direct through analogies in structure or through explicit metaphors and mimicking the consequences of spatial properties relevant in interaction (Dieberger, 1995; Erickson, 1993, and Dieberger 1997; Andrews 1995; Chalmers 1993, respectively).

However, in the case of information or hypertext systems it is unnecessary to artifically rebuild existing physical spaces in order to achieve an adequate support of the transition of spatial concepts. Below we introduce a structure that allows for the support of navigational concepts without mimicking such spaces.

Even more so, rebuilding physical spaces defies the original purpose of easing interaction as it poses an additional cognitive burden on the user. The transfer of spatial concepts and behaviors is not as extensively supported as the system seems to promise because an emulation of space is impossible[2]. Instead, a user is forced to learn a novel spatial layout, many parts of which are not inherently related by position or property to the information items which they are meant to represent.

Consequently, we focus on how hierarchical structures can be used to support the user's spatial behavior.

4 Our Approach

Graduated Semi-Lattices

As presented in section 2, semi-lattices fall short of the mediation of distances between elements to a user. When navigating in space, distance is an important

[2]We understand the term *emulation* as a way of modelling such that the one that is emulated for does not realize a difference between the emulated and the real environment. Clearly, in this sense an emulation of space that relies just on a simple computer screen and some input devices is impossible.

factor for acquiring a notion of position: the distance from a given starting point or the length of a path is used to calculate an estimate position. In semi-lattices, different sequences of nodes to a certain node are not necessarily of the same length (see fig. 2). It is therefore not possible for the user to employ position estimation by distance.

A less general type of semi-lattice easily fixes this problem. Starting from the root all children of a node are in the same level and only connections between nodes that are in adjacent levels are allowed. This way, all traversals from a root to a node consequently are of the same length, i.e. the distance from the node to the root is the same regardless of the traversal chosen. Thus, it is possible to determine one's position in the structure (cf. section 5). We call this kind of semi-lattice a *graduated semi-lattice* (see fig. 3 for an example) as the application of levels lead to a regular graduation of the nodes.

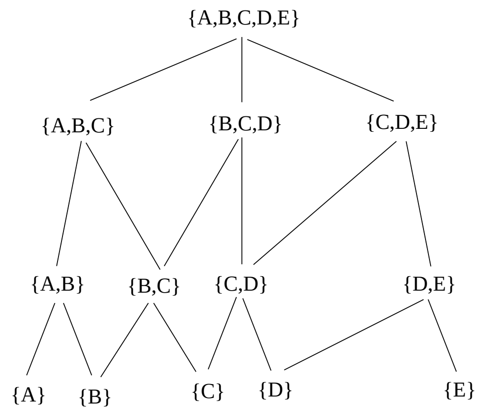

Figure 3: Example of a graduated semi-lattice

Multi-Dimensional Graduated Semi-Lattices

Another shortcoming of semi-lattices is that the number of *views* supported is still small. This, of course, is true for graduated semi-lattices, as well. This shortcoming is due to arbitrary relations between elements of the structure; elements that are not conceptually related have to be structurally related, e.g. a set of blue items and a set of yellow items might be subsets of a set of big items.

Interaction with information systems is mainly constituded by search for information. The information searched for corresponds to elements of the information set and can be characterized by certain attributes[3]. Therefore, search in information systems can be seen as the process of subsequently assigning more specific values to attributes. The preferred sequences of this assignment vary among users according to their individual views. Some of the attributes might be easy to specify for a user at the beginning of a search while others seem to be irrelevant or seem to depend on others. This is especially true for underspecified search for information. An initially vague notion of the target's properties, i.e. the values to be assigned to attributes, needs to be interactively refined while the search continues.

[3]Provided that the information searched for is contained in the information set.

Consider for a example an attribute like "size". At first this attribute is undefined and may be specified by assigning "large" as a value. Next we may assign to "size" values like "very large", "not so large" or "quite large" changing the attribute's current value of "large". These values are clearly refinements of "large" and, thus, can be ordered according to their specifity. This results in a hierarchical structure on all possible values of an attribute.

This can of course be done for any attribute of the information elements leading to hierarchical structures for all these attributes. These are used to structure the elements of an information set. For each value of any attribute all information elements are joined in a set when they are described by values which are equally or more specific than this value. This results in a hierarchical structure on sets of information elements that corresponds to the hierarchy of an attribute's values. In a structure like a graduated semi-lattice these hierarchies on attributes have to be combined. Consequently, this results in arbitrary set-subset relations as sets need to be structurally related even when they are not conceptually related.

But these arbitrary relations can be disentangled. Using just the attributes common to all elements of the information set, the hierarchical structure can be split into several distinct hierarchies. Each hierarchical structure is based on one attribute and since this attribute is common to all information elements necessarily all elements are part of some sets in this structure.

Two attributes can be mutually independent, i.e. specifing one attribute does not influence the other. Examples of mutually independent attributes are "color" and "size". If all attributes are mutually independent the user can concentrate on specifying one attribute without simultaneously altering the value of others or blocking access to them.

Taking a more constructive perspective, these mutually independent attributes correspond to orthogonal dimensions in a structure. A dimension can be seen as a set of values qualifying an attribute; orthogonality is equivalent to the mutual independence of attributes. Non-orthogonality is disadvantageous because it increases the user's cognitive burden of navigating the information structure. Since changes in one dimension might have consequences beyond this dimension, there exists no relation of a user's action and its result that is directly observable. Interaction with such a structure forces a user to explicitly keep track of his actions and the respective changes induced by them; but still the course of the user's search for information will be hard to control. Therefore, we will focus on orthogonal dimensions.

Considering this, in each dimension a graduated semi-lattice is imposed on the information elements. There are no more arbitrary set-subset relations in the resulting structure. Furthermore users can specify attributes in any sequence. We call this structure a *multi-dimensional graduated semi-lattice*.

Views and Transfer of Spatial Behavior

Multi-dimensional graduated semi-lattices clearly support multiple individual views. The possibility of choosing when to specify which attribute enormously increases the number of views supported compared to those supported just by using graduated semi-lattices.

Also, the structure used is suited for the transition of spatial concepts and behaviors. There are identifiable states, i.e. each possible combination of specifications of each attribute is distinguishable from any other. A user can change the specification of an attribute by assigning a different value that is more or less specific than the current one. As this leads to another combination of specifications of attributes and, consequently, to another state a user can actively change these states; as the structure is based on graduated semi-lattices it is clearly hierarchical and states can only be changed to other specific states, i.e. those that are either more or less specific in just one attribute. Additionally, the structure presented here is easy to navigate; this will be shown in the next section.

5 Navigating the Structure

In this section we take a closer look at how exactly the interaction with the structure works. We discuss the structural support for navigational concepts, examine how the user perceives the structure and consider navigation from a user's perspective.

Visible Interactions with the Structure

When a user interacts with a system based on multi-dimensional graduated semi-lattices she does not interact with the complex structure as such but with two different aspects of it: first, only a small part of the underlying structure is visible, i.e. only the children of the current node for each attribute; second, the presented result of a selection is determined by the corresponding subset of information elements.

Initially, a user has not made any assignment of values. As a consequence, each attribute is assigned a general value. Thus, the whole information set is selected; only a very limited subset will be visible, though. When the user assigns a more specific value to an attribute, the selection is narrowed: The selected subset contains only information elements that conceptually match the assigned value. The assignment of a more general value to an attribute by undoing such a specification results in the selection of a larger subset of information elements.

Structural Support for Navigational Concepts

We argued previously that information systems are partly perceived of in spatial terms. Therefore, they must present correct spatial cues to support (presumptions that follow from) the application of spatial behaviors.

In the last section we argued that a notion of position can be determined in graduated semi-lattices as the distance from the root node can be measured consistently. This enables the user to establish a notion of position for each dimension and to combine them to estimate an overall position.

Navigation in our structure corresponds to transitions between states. These transitions have to be comprehensible, e.g. in that the context may only change gradually. If there are rapid changes in the context, the sense of position may be lost. Navigation in our structure is necessarily stepwise, as in each step only values from levels adjacent to the current value's level can be reached, though this can happen in any dimension. Thus, there is just a change in one attribute and the transition remains transparent for the user. As the change takes place in a single dimension, a direction of the change is specified and a context established.

As values of different degrees of abstraction are structured hierarchically in each dimension and the dimensions are orthogonal w.r.t. each other, each attribute that corresponds to a dimension can be specified to a different degree, which supports underspecified search well.

To establish a context for values, we define the notion of neighborhood as follows: Conceptual neighborhood (e.g. 'color', 'red' and 'blue) is conveyed through structural neighborhood (small distances between nodes in the structure). More explicitly, we define the parent, the children and the siblings of a node to be its direct neighbors. Because the formation of values on higher levels is founded on conceptual hierarchies, the ancestor of a node provides a context for the siblings of the node and the node itself. The concepts that they represent are subsumed under a more general concept.

Also, the structure is completely coherent. This ensures that every part of the structure remains reachable, regardless of which node is currently selected. Splitting hierarchies into several dimensions results in a comparatively flat hierarchy in each dimension which in turn leads to easy and fast navigation.

Perceiving the Structure

Users normally maintain beliefs on the target domain even before they interact with information systems. The previously introduced concept of user- and task-dependent views is based on these beliefs. Interaction with the information system begins a reciprocal process between navigation in the perceived structure on the one hand, and the user's notion of the system's structure on the other. The user's notion is first determined by her initial beliefs about the domain, and is thus often incomplete, but may then be complemented or changed due to the interaction with the system.

Our approach allows for both the use of a clearly defined view and the refinement or construction of a view during navigation. Users with well-established beliefs about the domain (and thus a clear, but very possibly wrong notion of the system's structure) will often be able to employ their beliefs in navigating the structure – without the need to realize that the actual structure provided by the system is more complex than their views. This is possible because the user's notion of the system's structure, and thus her *individual view* will often correspond to a view provided by the system. If the user has no clearly defined view, she will construct a view that is based on her beliefs and influenced by only those parts of the structure that are visited during the interaction.

Thus, the complexity of the structure itself poses no immediate problem for the user since she is never confronted with the structure as a whole; she needs not and normally does not build up a representation of the entire structure.

Assuming a User's Perspective

So far we have considered effects of structural properties for navigation as a whole. We will now assume a user's perspective of the structure and argue why navigation becomes comparatively easy through the structure proposed here. To this end, we will try to answer three fundamental questions that well describe most navigational problems: "Where am I?", "Where can I go?" and "Where am I coming from?" (Nievergelt & Weydert, 1980).

"Where am I?" is a question for the user's position. The position can be determined by retracing the temporal sequence of the steps the user has taken. These form a path that spans multiple dimensions. This notion of position is similar to that in navigation in tree structures. When using multiple dimensions, however, several distinct sequences of precision are observable. This makes it easier for the user to form a notion of position. Also, the steps need not be retraced in exact order which further eases positional estimates. Feedback for the user's last selection is given by displaying samples from the currently selected subset. Thus, the user can determine whether she is still on the right path.

"Where can I go?": We defined search as a sequentially stepwise specification of attributes. Thus, possible directions, as determined by the values available for assignment, are most important. Interaction with the structure proposed offers a range of different clues on the nature of possible further selections: The different dimensions offer selections that share a common focus. The structural neighborhood we introduced earlier allows for the maintainance of a gradually changing context: Selections are narrowed with each decision, all possible selections on each level have the same level of abstraction and the concretion of selections is stepwise.

The orthogonality of dimensions assures a clear and comprehensible context as only one dimension can change at a time. Thus, the complexitity of the decisions to be taken is decreased significantly: Only selections that share a similar context need to be considered. To further ease the decision process additional information about the possible selection alternatives is displayed. The user can choose to receive information about each alternative in each of the dimensions before deciding on the next selection (cf. *outlink info* for hypertext systems as proposed in Furnas, 1997). This is done by displaying sample information items from the subset that correspond to the selection in question and by displaying the selections that would become available in the next selection step. Alternatives leading to "dead ends", i.e. empty subsets, are marked. This enriches the context of the user's selection while at the same time it keeps her from unknowingly selecting an empty information subset.

"Where am I coming from?": To find an answer to this question is certainly more difficult in a complex structure such as proposed here than it is in sequences or simple trees. While the answer consists of a trivial or simple structure of past selections in the latter two, information on a user's selection history cannot be unambiguously derived from the user's position within our structure.

We believe, however, that supplying a user with information about her selection history would not result in facilitating the search for information elements as it forces her to delve into structural details of the information system that are beyond the scope of her *view*. The context within a dimension is more important than the temporal position in the selection sequence. Therefore, we chose not to offer an option to undo a given number of steps of the dimension-spanning selection sequence, but rather to offer several selection histories, i.e. one for each dimension. The user can thus undo whatever selection she chooses to undo and the action of undoing a selection takes place in the established context of a dimension. The user may undo any number of selections in a given dimension, the undo action thus being either stepwise or allowing for faster return to a node visited before.

6 Application

In this section we will briefly present a sample implementation of an information system that is based on the approach proposed in this paper.

Application Domains

Though, in principle, any information set could be accessed with the help of our structure, it is desirable for the information set to possess the following properties: First, the elements that constitute the information set possess properties that can be described by mutually independent attributes. This enables the system designer to determine orthogonal dimensions that can be used for selection. Second, the items are not too unevenly distributed w.r.t. to the values in the dimensions. This assures that a precision in any of the values in any dimension will lead to a significant reduction in the selected subset's size.

We have selected two scenarios for sample applications: (online) catalogs and interactive help systems. The elements of the information set in these systems are items for sale or items within the help system and they tend to possess many relevant properties that can well be used to form several orthogonal dimensions. E.g. for a hypothetical online warehouse, articles can be ordered by *purpose of order, age, price, color or size*; for help systems *topic, system state, media type*, etc. constitute adequate, mutually independent attributes.

Sample applications have been implemented for both domains; we constructed the information systems as based on a simple database that contains the information items, the hierarchical structure was accessed through dynamic web pages. We will now briefly introduce the help system prototype.

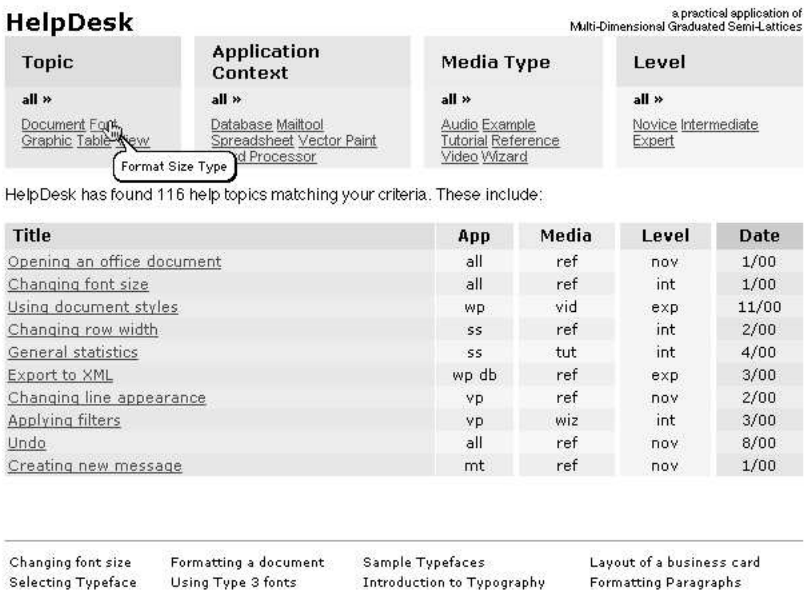

Figure 4: The initial view of the help system

Using HelpDesk

The initial view (see fig. 4) shows an overview of the selections available in each dimension; the dimensions are graphically separated by distinct background colors. Before a user decides on a selection a sample preview of the resulting information subset is displayed in a reserved screen region (see bottom of fig. 4 for items of the selection, and balloon help with some more specific sub-choices). When the user has made a selection, the new values for each dimensions are displayed. In fig. 5 the attribute *topic* was specified by selecting *font* as a value while all other attributes remain unspecified. Below, a list of some of the elements matching the current selection is displayed, i.e. all that match *font* (or values further specified) in *topic*. Note that some alternatives are displayed in grey to indicate that they lead to empty result sets (e.g. *audio* in *media type*).

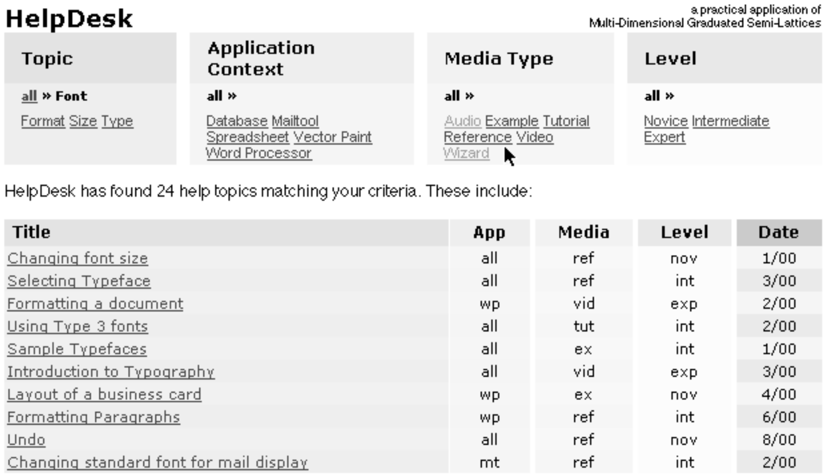

Figure 5: The system after one navigational step

If another selection is made in a different dimension (e.g. *Mailtool* is selected in *application context*), again, for each dimension, the current and available selections are displayed (fig. 6). In addition, in the top region, a selection history is provided for each dimension. Following a convention found on many web pages, this allows direct access to visited ancestors of the current node in the hierarchical structure or, for the user, the generalization of his selection by undoing one or more selections in the given dimension. If selections have been

Figure 6: The available selections after a second step

made in more than one dimensions, every one of them can be undone in an arbitrary sequence. For example, here either the selection of values for *topic* or for *application context* can be undone, leading to a less specific selection and (in most cases) a larger selected subset. If the selection has been specified sufficiently, e.g. target elements are displayed in the selection list, any promising information element can be selected and displayed.

7 Conclusion

The issue addressed is a structural one; so is the approach presented: The inner structure of a communicating agent cannot be fully insulated from its surface layer, e.g. inadequate decisions in the design of a system's inner structure may lead to difficulties in interacting with the system.

We identified two major sets of problems in interaction with information systems: first, discrepancies between the communicated structure of the system and a user's expectation as rooted in his conception of a domain. Second, discrepancies exist between navigational actions permitted by a system and those that a user expects.

We defined the concept of individual views which can be applied both cognitively and technically, i.e. to a user's conception of a domain and her selection of a system's communicated structure. We investigated commonly used structures for their respective advantages and deficits and concluded that sufficient support of individual views cannot be achieved by them.

A transfer of spatial concepts and behaviors to interaction with information systems cannot be hindered. Support for these concepts is necessary. Existing approaches often rely on introducing elaborate, explicit metaphors of existing physical spaces. We argue that this is counter-productive, as unnecesary cognitive overhead is introduced.

The concept of multi-dimensional graduated semi-lattices is introduced as a structure for organizing information which supports the use of individual views and of transferred spatial concepts.

We determined and assessed the consequences on the interface level. We investigated the navigational properties of our structure and examined the system from a user's perspective. Possible application scenarios and an implementation of a help-system were presented.

We were able to show that support of a multitude of individual views can be achieved without the need for a multitude of individual structures and support of spatial concepts in navigating information systems can be achieved through purely structural means. Structures that, like the presented multi-dimensional graduated semi-lattice, provide for many different interpretations constitute an attractive alternative to the design of adaptive systems and prove that an emulation of space in a literal sense is unnecessary.

Future research regarding the consequences of the presentation of structural features on a user's possibilities and constraints in interaction with the system is needed. Furthermore, certain application domains may require specific kinds of structures to support the use of individual views and spatial concepts well. A formal framework might provide further insights regarding underlying principles of the discussed user needs.

Acknowledgements

We are indebted to Jesco von Voss for his contributions to early phases of this work. Also, we are grateful to Christopher Habel for his help with setting up the project. Many thanks to Thomas Barkowsky and Christian Freksa for continuous support of our efforts.

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