A GRAPHICAL WORKBENCH FOR KNOWLEDGE WORKERS

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Abstract: We present iMapping, a novel approach for visually structuring information objects on the desktop. iMapping is developed on top of semantic desktop technologies and particularly supports personal knowledge management of knowledge workers. iMapping has been designed to combine the advantages of the three most important visual mapping approaches, Mind-Mapping, Concept Maps and Spatial Hypertext. We describe the design and prototypical implementation of iMapping—which is fundamentally based on deep zooming and nesting. iMapping bridges the gap between *unstructured* content (like informal text notes) and *semantic* models by allowing to easily create on-the-fly annotations with the whole range of content links, from vague associations to formal relationships. Our first experimental evaluations indicate a favorable user experience and functionality, compared with state-of-the-art, commercial Mind-Mapping software.

1 INTRODUCTION

1.1 Motivation

While practically all enterprise information systems, as well as most knowledge management (KM) initiatives, address the level of inter-personal knowledge storage and exchange, recent efforts also address the level of the individual knowledge worker who—though being embedded in organisational processes and communities—nevertheless is in many respects a relatively autonomous "knowledge processing unit" with many personal notes, ideas, and artifacts which shall not and need not to be shared within a bigger organizational context. The knowledge worker has not only to be embedded and aligned with community and organisational information streams and processes, he or she also needs *personal knowledge management* (Abecker et al., 2009) methods and tools which support individual task and time management, individual creativity, individual lifelong learning, as well as personal information management in the widest sense. If one wants to simply use organizational KM systems and approaches for personal KM, this often falls short; especially those approaches which rely on highly-structured information and meta data to be entered and maintained by the user, fail because nobody wants to make such additional effort with immediate, visible benefit. For instance, this may be one of the reasons why semantic technologies have not found very widespread use, so far, although semantic meta data would undoubtedly improve findability, interoperability and, in general, automated processing of information and knowledge items.

With our approach, we pursue the hypothesis that (1) the expected immediate, visible benefit might be experienced when users manage their everyday knowledge resources like personal notes, files, bookmarks etc. (like in the setting of a semantic desktop environment; cp. (Sauermann et al., 2009)), but that (2) it is also crucial to leave it to the user, how much effort she wants to put into formalizing content and meta data.

So, we aim at building an environment that (a) is able to cover the full range from informal note-taking over more structured graphical representations up to formal semantic knowledge models, but that (b) provides semantic functionalities without restricting the user's *modeling freedom* that is offered in informal ('non-semantic') tools.

When formal semantic knowledge structures are used, content is typically fine grained and highly structured. Such content structures are typically more complex than plain text or classical hypertext structures. Even with the relatively simple structures in classical hypermedia, where we just have interlinked information objects on the granularity level of whole pages or documents, hypertext research has shown that users often get "lost in hyperspace" when browsing without additional navigational help (Ter-

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gan, 2002). This stresses the need for user interfaces that facilitate navigation and authoring of such structures without losing orientation.

Using graphical environments for structuring externalized knowledge enables the users to employ their highly efficient sense of spatial orientation on their *personal knowledge and information space*, and it enhances the link between their mental and external models—because it enables the use of diagrammatic depictions whose obvious structure corresponds more closely to the structure of the content because (unlike text) diagrammatic knowledge representations carry a structural analogy to the content they represent (Schnotz and Bannert, 2003).

So, we developed iMapping as a new visual mapping approach that unites the strengths of established mapping techniques and combines them with semantic technologies and modern HCI approaches like deep zooming. iMapping supports the whole range from easy informal note-taking to formalized knowledge engineering in the same powerful, yet easy-to-use, environment. The basic metaphor of an iMap is that of a large pin-board where information items can be spatially arranged, enabling users to gain a visual overview over collections of items at once. These items can represent bits of text as well as (in the near future) any kind of external resources like files, Web pages, pictures or other maps. They can also be nested into each other and interlinked in various ways. Besides browsing by links, users can navigate an iMap by zooming through it.

In this article, we provide a list of requirements for a next generation visual knowledge mapping approach which was created from literature studies, state-of-the-art analysis, and use case requirements elucidation (Section 1.2). After that, the design of iMapping is discussed in Sections 2. Section 3 illustrates our ongoing evaluation efforts and first promising results. Finally, we conclude with Section 4 which contains a summary and some plans for future work.

1.2 Requirements

Based on the analysis of existing tools and approaches in (Haller, 2003) and literature from the areas of design and cognitive science, we have identified a set of functional requirements to be met by diagrammatic knowledge mapping techniques and tools in order to be cognitively adequate for extensive personal knowledge management. This collection of requirements and its rationale is published in (Haller and Abecker, 2009) and will here only be listed in brief:

Requirements for Diagrammatic Knowledge Mapping Approaches.

- Free Placing (Items should be freely placeable anywhere and should maintain their positions—at least relative to their surrounding.)
- Free Relations: Interlinking items in different levels of formality:
  - Formalized / semantic links (Like in ontology editors)
  - Informal labeled links (like in concept maps)
  - Unlabeled links (e.g. just of plain arrows or lines)
  - Free nodes, that do not have any explicit relation to others.
- Annotations: optionally hideable additional notes or highlights
- Overview / Abstraction through clustering and hierarchical sub-maps
- Scalability (Ability to visually deal with large amounts of items)

Requirements for Diagrammatic Knowledge Mapping Software.

- Simple Editing: Adding or modifying items without additional interaction needed.
- Connecting External Content (e.g. local files or remote web pages)
- Focus / Filter: deliberately narrowing down visibility to the essential
- Integration of Detail and Context through smooth and steady zooming, overview functions, levels of detial.
- Interoperability with other related tools

2 DESIGN

2.1 Visual Knowledge Mapping

In the design of the iMapping approach and software tool, we aimed at combining the advantages of the classical mapping approaches and simultaneously fulfilling to the greatest possible extent the requirements both listed above.

We began with the requirement of *free placing*. Items can be freely created at or they can be moved to any position in the map. An iMap can be seen as a virtually infinite pin board. Usually (e.g., for personal note-taking or idea management), these items will be short text passages. The size can vary from just a keyword to a short note or whole paragraphs including rich text marked up by using a Wiki syntax provided by the back end.

These items can contain other items such that one can use microcontent rather than long, unstructured text passages. Longer texts are then a sub-map containing a sequence of smaller text-items. The iMap hierarchy goes down into deeply nested nodes which can be zoomed into (see Fig. 1) such that a *basic hierarchy of information items* is created.

The hierarchical structure is represented by *visual inclusion*: nested items are shown inside one another. Compared to a classical tree view like it is used, e.g., in Mind-Maps, this has the following benefits:

- It leaves more freedom to place items according to gestalt principles (Metzger, 1953) (e.g., grouping).
- Node-and-link representations (like in classical concept maps and many other visual languages) are still possible without interfering with the hierarchical structure.
- The layout principle stays the same on all levels of the hierarchy (in concentric trees like Mind-Maps, all sub-branches point in one direction). Like that, each part of the map can be treated like a self-contained sub-map which largely helps clustering and modularization.
- Nesting by inclusion (which is also widespread, e.g., in the use of parentheses, Venn diagrams, tree-maps), is closer to natural orientation where details are parts of their surrounding. In real life, when we want to see the big picture, we take a step back to see the surrounding context of something.

Of course, this kind of nesting is not new in itself. However, traditional, paper-and-pencil based mapping techniques can not cover many levels of hierarchy like this. Today, however, with computer-based mapping approaches, very deep nesting and zooming is possible which opens up a virtually infinite amount of space for iMaps to grow over time when used, e.g., as personal knowledge repositories.

Adding and creating content to an iMap is done by clicking anywhere in the map and typing some text. It is always possible to add vague and unstructured content. Although allowing for semantic knowledge management, it has been a fundamental design decision to never force the user to specify any semantics. Content can later be refined and formalised incrementally.

There can be multiple visual instances of one and the same information object, because it may be relevant in different contexts.

For *establishing link structures*, we distinguish several different ways of interrelating items which can be used in an iMap:

1. *explicit linking* on an item level (stating a relation between two objects); each of these can be mere navigational links or carry formal semantics if specified; in particular, we can distinguish four kinds of links and ways of establishing them:
   (a) *labeled links:* If no pre-existing relation type is suitable, the user can always just enter the full label of the link to be displayed, e.g., along the arrow. By that, in the back-end a new relation type with that name is automatically created;
   (b) *unlabeled links:* Links do not have to be labeled at all;
   (c) relating items by short *semantic statements* with the QuiKey tool explained below: When relating two items, the user gets a choice of existing relation types selectable by an incremental text search over their names, supporting reuse of existing relation types and avoiding misspellings;
   (d) *hyperlinks:* Links do not have to be drawn as arrows; hyperlinks go from within the text content of an item to any other item.
2. *implicit linking:* Following the principle of Spatial Hypertext, items can also be loosely placed in spatial relations to one another without explicitly linking them at all. These spatial relations can be parsed to extract implicit relations, like sequence, grouping or hierarchy. Currently, the only actually implemented way of implicit linking is that of *nesting items* into another (i.e. placing the link target inside at a specified position) in order to indicate their hierarchical ordering.

In classic graph-based approaches, nodes usually have to be arranged in a layout that minimizes edge-crossings in order to reduce visual complexity. But even then, maps with large amounts of nodes and links often suffer from tangled links (aka “spaghetti syndrome”). To avoid that, unless selected otherwise, links are only shown on demand. Like that, the links of current interest are more salient and easier to visually integrate with the nodes they connect. Depending on user settings, links can, for instance, become visible on an mouse-over event (see Fig. 1).

While iMaps can be freely navigated by panning (scrolling) and zooming like it is known, e.g., from Google maps, our user tests have shown that users much prefer navigation guided by content structure like directly zooming to specific items by point-and-click or following links. Additional to that, a search

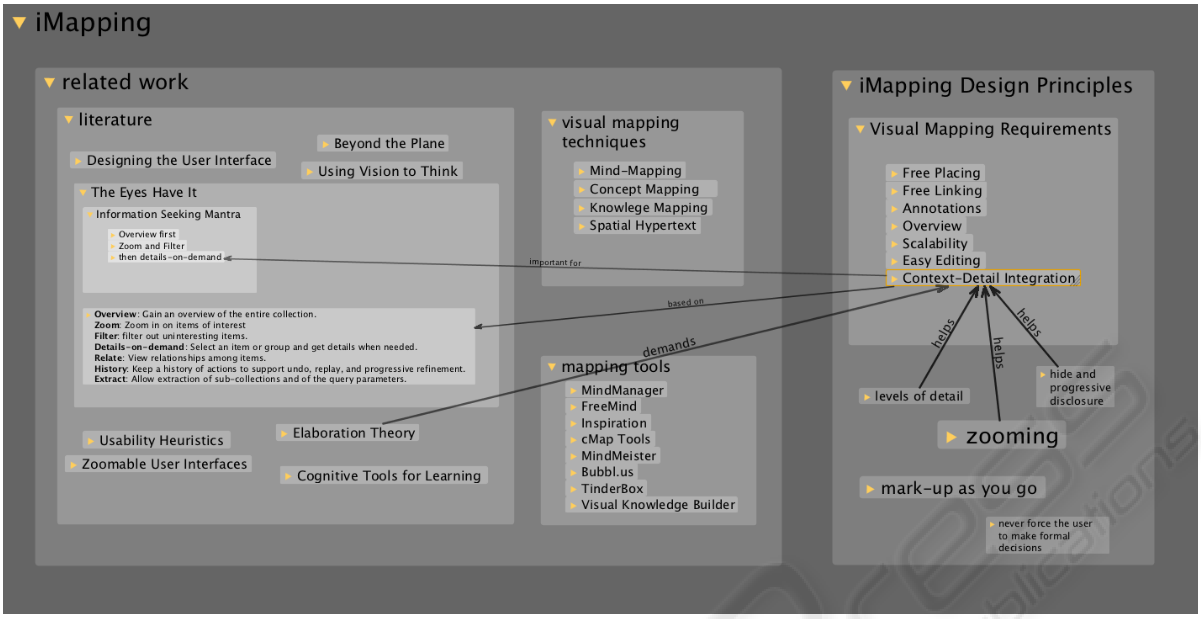

Figure 1: Screen shot with part of an iMap (about iMapping). Only links from and to one item are visible.

function lets users jump to any item directly. However, any transition to another place in the iMap is carried out by smooth panning and zooming to maintain a sense of spatial orientation while moving through the map.

While iMapping focuses on overview and intuitive use through a visual approach, this can also be a burden because every item needs to be deliberately positioned. Hence, it is desirable to complement such a visual tool by techniques that provide map-independent access to the same structured information. iMapping is complemented by QuiKey, a kind of smart semantic command-line that focuses on highest interaction-efficiency to browse, query and author semantic knowledge bases in a step-by-step manner. Among other things, QuiKey allows to jump to any item in an iMap with just a few keystrokes through a incremental search function. QuiKey is explained in more detail in (Haller, 2008); for further information, see `http://quikey.info/`.

3 EVALUATION

We carried out a comparative evaluation study to specifically test the suitability of the nesting and zooming approach for personal knowledge management tasks on a larger scale, because this seems to be the biggest difference to the classical approaches discussed in (Haller, 2003) For that purpose, we compared the iMapping prototype with MindManager 7, the most wide-spread state-of-the-art Mind-Mapping application. The details of this evaluation are described in (Haller and Abecker, 2010).

Test users were presented with pre-filled maps in both applications: A small biological taxonomy. Both maps contained the same content in the same structure—once as a classical Mind-Map and once as a nested iMap.

The sample of testers consisted of 12 rather heterogenous individuals (6 male and 6 female), aged 23 – 64. Their primary occupations were: painter, journalist, interactive media engineer, photo model, students (english and biology, computer science, psychology, economical engineering), PhD students (healthcare, economics, logistics, semantic web).

The average time each user needed for the different kinds of tasks and the ratings given by the users were compared between the two tools and tested for statistical significance with a dependent t-test for paired samples.

3.1 Results and Discussion

There was no statistically significant difference in the interaction times measured. However, as Table 1 shows, there was a clear tendency of all editing tasks (adding, rearranging and interlinking of content) being carried out slightly faster in the iMapping application. This could be explained by users' comments that in the iMap, the topology was clearer and easier to grasp, which is also reflected in the ratings (see Table 2).

The exact mean times and percentages in compar-

Table 1: Mean times and percentages for groups of tasks in comparison (rounded values)—None of them are significant at the 5% level.

	Mind Manager	**iMapping**	**difference**
practice time	5,8 min	8,6 min	2,8 min
adding content	28,0 sec	23,6 sec	-4,4 sec
rearranging content	25,5 sec	21,8 sec	-3,7 sec
drawing links	27,4 sec	25,7 sec	-1,7 sec
visually finding and reading	25,9 sec	33,0 sec	7,1 sec
remembering number without map	33,3%	62,5%	29,2%
remembering content without map	30,8%	37,1%	6,3%

Table 2: Mean ratings given as german school grades for both tools: iMapping is rated better en every category surveyed (1="very good", 2="good", 3="satisfactory", 4="sufficient", 5="insufficient").

	Mind Manager	**iMapping**	**difference**	sig. (p)
navigation	2.4	2.1	0.3	.275
overview	3.0	1.9	1.1**	.003
structure / interrelations	2.7	2.1	0.6	.270
aesthetics	3.3	2.2	1.1*	.038
look and feel	2.5	2.0	0.5	.065
suitability for brainstorming	2.5	2.0	0.5	.137
suitability for note-taking	3.0	1.9	1.1***	.001
suitability for personal KM	3.3	2.0	1.3***	.000
overall rating	3.0	2.0	1.0***	.000
average	2.9	2.0	0.9***	.001

ison can bee seen in table 1. The average subjective ratings that were given as german school grades for both tools are listed in table 2. iMapping was rated better in every surveyed aspect and almost one full grade better in average. Most of these findings were statistically significant—in particular: *overview* and *aesthetics* were rated better in iMapping, which was also perceived to be more suitable for *note taking* and *personal knowledge management in general*. Especially in the overall rating, iMapping was rated 'good' in average as opposed to only 'satisfactory' MindManager.

The good rating for *overview* is also backed by many spontaneous comments made during testing, in the direction of iMapping providing an easier way to get an overview over especially the coarse structure—through the general approach of nested items, the possibility to arrange them freely and through the facility to zoom all the way out and back in a gain with only two keystrokes.

The good rating for *aesthetics* came somewhat as a surprise, since three of the female testers had vehemently complained about the lack of color in the predominantly grey iMapping prototype. But even so, the current visual design of the iMapping application seems to be quite well-received.

We proudly note that the best rating and highest advantage has been given for the aspect *suitability personal knowledge management in general*. However this is not surprising, since MindManager is not designed for very large maps whereas it was a core requirement for iMapping to be able to scale up to extremely large maps as they can evolve over years of personal knowledge management.

All in all we are satisfied with the result that iMapping is in objective measures of time needed for interaction for typical tasks comparabe and in subjective measures even superior to MindManager, which can be regarded as state of the art, has millions of users and is on the market since 1994.

Since the intended usage scenarios for iMapping exceed those overlapping with MindManager, some hypothesized advantages could not be tested in this setting and are subject to ongoing investigation. Namely: Longterm use for personal knowledge management, the use of much larger maps with thousands of items, the use of QuiKey and using semantic links and queries.

4 SUMMARY AND OUTLOOK

Semantic knowledge management technologies might in the future be able to significantly increase interoperability between applications even across context boundaries and they might leverage the creative and productive power of knowledge workers. However, if knowledge management does not start at the personal level, and starts with providing immediate benefit to the individual knowledge worker, it is questionable whether semantic knowledge management systems will ever spread very far. Focusing on user interaction and cognitive ergonomics is obviously an important issue there, especially because in knowledge-intensive tasks, a user can barely afford to sacrifice much of his limited cognitive capacity (Miller, 1956) to dealing with the tool instead of dealing with the content itself. Especially for large knowledge repositories with highly interlinked information items of different levels of formalization, iMapping-based user interfaces can make knowledge management more intuitive, on one hand, and more powerful, on the other hand, because it provides a medium that fosters the use of visual orientation in a flexible and easy way and yet supports more structured knowledge modeling in just the desired degree of formalization.

While we continue improving our first iMapping tool, we hope the general approach will find more widespread application. Its flexible, zooming-based approach, e.g., also makes iMapping a candidate for mobile use on rather small displays. Of course, a central focus of our immediate next working steps is on a broader and deeper qualitative and quantitative evaluation of the approach and its implementation.

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