SEMANTIC POSITIONING

Supporting Knowledge Work through Semantic Spatial Arrangements

Dissertation

Submitted to the faculty of Computer Science, Electrical Engineering and Mathematics of the University of Paderborn, to attain the German academic degree of:

Doctor rerum naturalium (Dr. rer. nat.)

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June 2010

Abstract

Semantics as a research field within computing is mostly based on a textual representations (e.g. Web Ontology Language). Still, interpretation and codification of meaning by *spatial arrangement* seems to be at least as common in every day usage. Humans need to arrange and position knowledge artifacts in meaningful ways to gain differential experience. For instance, documents are placed next to each other for comparisons, are grouped into stacks or sorted into trays for further processing. Each position has a specific semantic meaning, like documents on a certain pile being "to do"-items. Additionally, relevant actions and even social rules are associated with *semantic positions*. E.g. cleaning personnel may empty the trash bin, but not pick up scrunched papers from the desk of an office worker. *Semantic Positioning* refers to these kinds of spatial arrangements in digital media, where an object gains meaning simply by its position in the current context. This allows processing the semantic positions of objects and the invocation of matching responsive behavior in the system. Based on this, the main research contributions of this thesis are a developed framework for the creation of semantic (overlay) arrangements and proving that by respective evaluations of position, benefits can be achieved for knowledge workers. The Semantic Positioning Framework distinguishes five main types of spatial arrangement in digital media (*distance*, *order*, *inclusion*, *combination* and *path*) and describes corresponding objects that map information to space (*mapping markers*). Finally, three concrete knowledge work and learning scenarios are presented to demonstrate how users can be supported through Semantic Positioning.

Zusammenfassung

Semantik als wissenschaftliche Disziplin innerhalb der Informatik wird meist durch textuelle Repräsentationen implementiert (z.B. Web Ontology Language). Im Alltag schein allerdings eine Interpretation und Kodifizierung durch *räumliches Arrangieren* mindestens ebenso gebräuchlich zu sein. Um Differenzerfahrung zu erlangen, bedürfen Menschen der Möglichkeit Wissensartefakte in bedeutsamer Weise zu arrangieren und positionieren. So werden beispielsweise Dokumente zum Vergleichen nebeneinander gelegt, durch Stapeln gruppiert oder für die weitere Verarbeitung in Ablagefächer sortiert. Jeder Position ist dabei eine spezifische semantische Bedeutung zugeordnet, etwa dass Dokumente auf einem Stapel zu erledigende Aufgaben darstellen. Weiterhin können auch relevante Handlungen und sogar soziale Regeln mit einer semantischen Position verbunden werden. Reinigungspersonal darf zwar den Mülleimer eines Büros ausleeren, aber nicht zerknülltes Papier auf dem Schreibtisch entfernen. *Semantisches Positionieren* bezieht sich auf räumliche Arrangements in denen digitale Objekte, allein aufgrund ihrer Position im aktuellen Kontext, eine Bedeutung erhalten. Dies erlaubt eine Auswertung der semantischen Position von Objekten und das Auslösen von daran geknüpftem responsiven Systemverhalten. Vor diesem Hintergrund sind die wichtigsten wissenschaftlichen Beiträge dieser Arbeit: Ein entwickeltes Framework zum Erstellen semantischer (Overlay-) Arrangements und das Aufzeigen möglicher Unterstützungsfunktionen für Wissensarbeiter durch verknüpfte Auswertungen. Das „Semantic Positioning Framework" unterscheidet fünf Typen räumlicher Arrangements in digitalen Medien (*Distanz*, *Reihenfolge*, *Enthaltensein*, *Kombination* und *Pfad*) und beschreibt zugehörige Objekte, die Informationen räumlichen Positionen zuordnen (*Mapping Marker*). Schließlich werden drei konkrete Wissensarbeits- und Lernszenarien präsentiert, die aufzeigen wie Nutzer durch semantisches Positionieren unterstützt werden können.

Acknowledgements

For encouraging me to write a thesis, countless times of support and first introducing me to meaningful spatial arrangements
Reinhard Keil and **Thorsten Hampel**

For showing me what makes a great teacher
Harald Selke and **Johannes Magenheim**

For openly discussing my ideas and not holding back on criticism, which is always important in these matters
Richard Erren, **Christian Schild**, **Birger Kühnel** and **Dominik Niehus**

For teaching me a large deal of the right questions and how to ask them
Wolfgang Schön

For being the only friend who voluntarily offered to help with corrections and thus had to endure the even more elaborate and complex versions of some chapters
Sascha Khan

For opening my eyes to a broader world, fostering my curiosity and loving support
Richard, **Angela**, **Julia** and **Philipp Erren**

For always caring, even after (all) the change(s) and for believing that I can do anything, despite evidence to the contrary
Tu-Binh Dang

For cheering me up whenever I was down and keeping me 'sane'
Petpet

For helping me when I thought the wall I was facing was too high
All of you, who I call friends

And for still being a good friend even after the frustrating last stretch
Tuyet Nhung Tran Vu

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1. Introduction

"Making a speech one must study three points: first, the means of producing persuasion; second, the language; third the proper arrangement of the various parts of the speech."

Aristotle

Knowledge has always been an important determinant of success in the political, business and scientific world. Still, only lately have businesses embraced knowledge as an actual resource that leads to competitive advantage. Understanding it as a resource encompasses that it can be managed to generate benefit. Despite the importance knowledge has been attributed, it remains more elusive than other business relevant resources. This is due to the difficulty of assessing precisely who knows what within a company and mapping that meta-knowledge to all relevant personnel and processes. Even defining precisely what knowledge is seems difficult, with many different definitions floating around (cp. *alternative perspectives on knowledge* in Alavi & Leidner 2001: p.109). Most commonly, it is asserted that it relates to human understanding and experience. Thus, human *experts* may be regarded as the actual knowledge resource requiring management. Such a limited view, however, would exclude the monumental amount of media within companies or the internet from which expert procedures can be understood, learned and thus acquired. Endeavors of *externalizing* knowledge often prove difficult, depending on the type of knowledge, the form of externalization as well as the ability and motivation of the expert to aptly describe personal knowledge. Despite this difficulty, the amount of documented data, information and knowledge in companies is enormous and steadily growing, making it hard to find and distinguish what is relevant and what isn't. This is a sub-problem of what is often called *information overload*.

The colloquial manner of mixing up the terms data, information and knowledge may seem to suggest equality of meaning. Scientifically, however, knowledge is nearly always regarded as more complex than information. In communication technology information is first and foremost a noticeable difference in a signal. (Bateson1979) states this in slightly more polished fashion: "*information is a difference that makes a difference"*. Information, as perceivable difference, gains meaning only in relation to personal expectations and potential discrepancies based on actions. For example, one would expect a regular dice to carry the numbers one to six. Should one encounter one with a printed seven on one side, this is a *differential experience* from one's expectation. Based on the works of (Eigen 1987), (Gibson 1979) and (Leroi-Gourhan1988) the concept of differential experience is described in detail by (Keil 1990). Differential experience builds on the insight that the human brain is not isolated from the environment that humans perceive and in which they act, but has evolved specifically adjusted to it. This means that space is the common ground for human cognitive processes, because it couples perception with the *manipulation* of objects (Polya 1957, Wertheimer 1982, Kuhn 1996). (Arnheim 1969) even concludes that productive thinking, used to solve problems, is equivalent to spatial thinking. In essence, this means that a theory cannot safely be proven or refuted solely within a person's mind (Gibson 1979). This is especially true if complex phenomena cannot be perceived without first creating the proper instruments. Only the clever arrangement of lenses within a tube enabled Galileo to observe the 'heavenly bodies' within the night sky. The obtained differential experience allowed formulating, testing and devising the means to reproducibly prove the theory that the Earth revolved around the sun. Differential experience thus is a key concept to discovering and proving new knowledge through research. To obtain differential experience in realms hidden to our regular senses, instruments like Galileo's telescope have to be devised, thereby also becoming an arranged expression of existing knowledge. Similarly, artifacts allow storage and sharing of information over long periods of time, by documenting which specific differential experiences lead to certain conclusions and how they were acquired. This allows others to try and reproduce the result to confirm it as factual knowledge.

In this sense, media as external artifacts offer specific support to human cognitive processes and problem solving. Both analog and digital media can serve this purpose for *knowledge work*, which grows ever more important in our society. The classic place where knowledge work is conducted is a desk in an office. Here, knowledge assets are produced, stored, ordered, edited and brought into relation. For immediate manipulation of information material, the top of the desk is most accessible. Media objects can be simply placed there or arranged actively to express perceived relations, understand and solve a problem. Putting two papers next to one another makes it easier to compare similar statements, for example.

Over the course of a knowledge work process an arrangement of relevant objects will often form on a person's desk (Kirsh 1995). The documents constitute an active *working environment*, where assumed relations between artifacts are represented by their spatial arrangement. An arrangement of media objects on a desk is a person's expression of their work progress, even though not every expressed assumption may yet have reached a conscious or codifiable state. Similarly, conventions of the daily work process are expressed here. E.g. an "outbox" is a place, where an authorized person may access respectively positioned documents, take them out of the office and mail them. Arrangement allows for quick and easy expression, testing and adjusting of the current understanding of a problem through spatial relations, albeit with less descriptive precision than verbal or formal codification (e.g. in ontologies).

This important support function of personal desks probably is the main reason for conceiving digital desktops in operating systems. Graphical user interfaces allowed for lowering the technical barriers of entry to work with computers, which before had mainly been specialists' tools. Simply speaking, digital *desktops* are two dimensional spaces on which users can arrange iconic representations of working materials and applications. This innovation makes available and perceivable materials directly manipulable, instead of hiding commands and files behind an empty text prompt. Users can create arrangements on their digital desktop similar to the ones on top of their real world desk. However, even modern computer desktops offer only a simple 'canvas'. It is divided into a grid, to which icon representation of media artifacts or applications snap. The most typical spatial arrangement encountered in modern operating systems still is an indexed presentation of hard drive folders and files. It is obvious that, in comparison to the desk, these options of spatial arrangement and interaction are fairly limited. Not even the most typical arrangement feature of the real world desk – *stacks* – can be created without sacrificing versatility on most modern operating systems (cp. Malone 1983, Mander et al. 1992).

Semantic Positioning as the research focus of this dissertation introduces advanced spatial arrangement and respective evaluation concepts to digital media. Generally, it means that one can determine the reason for an object being positioned at a certain point in an arrangement. This *semantic position* details the object's meaning within the given (working) context and in relation to other objects. For that to work, relevant context information needs to be mapped to the arrangement space. In Semantic Positioning this is accomplished by so called *mapping markers*. These are simple graphical means and labels, like an axis, region or matrix. Each type of mapping marker corresponds to a linked semantic and spatial principle. For instance, an axis enables the mapping of values to coordinates that transform spatial closeness into a measurable representation of semantic closeness. Digital media objects can be assigned positions in space, together with graphic and textual elements (like mapping markers) on multiple layers in a so called *medi@rena* (Erren & Keil 2007b). As a continuation of the knowledge work concept (Hampel 2002), it is an object oriented environment enabling cooperative knowledge work in persistent virtual rooms. In addition, a medi@rena provides extensive rights and group management, attribute inheritance and process rules. These features enable evaluation and system responses that can be tied to spatial arrangements as conventions.

The goal of Semantic Positioning is to offer specific support for knowledge workers, through spatial arrangements in defined scenarios. This can be achieved by reducing necessary actions to reach a desired result, for example. In this thesis a Semantic Positioning Framework is introduced, that details five distinct types of arrangement. These are called *Coordinate Topographies*, *Ordered Lists*, *Categorizing Collections*, *Combinatoric Matrices* and *Relational Graphs*. Each arrangement type includes a description of how information is mapped to space. In this context, the basic semantic evaluation capabilities are shown. For instance, Categorizing Collections use a region to map values to spatial coordinates, so that spatial inclusion becomes equal to semantic categorization on the level of the associated attribute(s).

Due to the need of arrangements to convey a certain complexity for solving problems, *overlays* are used. The term "overlay" basically refers to stacking a number of (transparent) layers, each carrying a specific arrangement type, in order to combine them in a medi@rena space. Hence, multiple information dimensions can apply to a single position. This makes arrangements more complex in their ability to express relations, but also in their composition and evaluation. Naturally, the different arrangement types have to be compatible in their mapping of semantic meaning to space. Individual evaluation layers exist for mapping markers which, in combination, detail an evaluation model for a scenario. This enables dealing with the complexity of overlay arrangements step by step, while keeping evaluations compatible over all involved layers. The context, as the mapping of semantic meaning to space, is anchored in the evaluation model of the working environment. It enables the system to internally link object position to corresponding attributes and/or information, coupled to the perceivable expression by mapping markers. Thus a model will usually consist of a number of formulas individual to the presented context. While the concrete evaluation and responsive behavior are individual to each scenario of use, evaluation processes will often default to one or several common *action schemes*.

In Semantic Positioning the meaning of the term "action scheme" differs from that used in philosophy (cp. Wettler 1979). The latter defines them as schematic representations of typical human action characteristics. By contrast, in Semantic Positioning, action schemes define meta-level concepts of interacting with spatial structures and respective evaluations. This goes beyond conventions tied to specific spatial actions, such as dragging an icon onto the recycle bin to represent a delete operation. To provide an example: two basic action schemes are *positioning* and *assignment*. The former means that objects in space can automatically assume a position in space depending on existing attributes. Assignment is the opposed process of writing attribute values to objects, based on their manual positioning. By keeping action schemes on such a general level, they can be assigned to basically any kind of Semantic Positioning arrangement.

The major hypothesis, that Semantic Positioning can support knowledge workers, is proven in three presented knowledge work and learning scenarios. Each of these scenarios employs different action schemes to prove different parts of the hypothesis. While the scenarios have not been implemented in software, detailed descriptions of the arrangement and comparisons to existing analog or digital implementations with similar purposes, clearly show the advantages. Additionally, it is proven that only through overlay, complex meaning can be represented in semantic arrangements and that exchanging the context layers of an arrangement may have beneficial effects.

This introduction (chapter 1) summarized this thesis' main argumentation, including its main concept of Semantic Positioning, as well as the respective motivation and goals.

Chapter 2 details my distinction of the terms data, information and knowledge. It shows that differential experience and arrangements of external artifacts are central to human problem solving processes. Since knowledge work and learning are based on solving complex problems, they too require arrangement.

Chapter 3 introduces the notion of media functions with focus on *arrangement*. Limitations of the current definition of this important concept are shown. Furthermore analog media are distinguished from digital media, which serves as an important basis for the following two chapters.

Chapter 4 analyzes arrangements in analog knowledge work environments (i.e. offices and desks) in order to identify the first four types of arrangement, commonly used to express spatial inter-object relations.

Chapter 5 examines digital desktops as the basic working environment in digital media, in relation to the findings of chapter 4. The four identified and distinct types of spatial arrangement from analog media environments are also present in digital media. An additional new type of spatial relation, called *combination*, is discovered in the common table structures of operating systems. The notions of (digital) *space* and *objects* are examined in detail with regard to the requirements for creating meaningful semantic arrangements in digital media. This includes an introduction of the terms *mapping marker*, *evaluation* and *convention*.

Chapter 6 introduces the notion of *Semantic Positioning*, the respective *framework*, as well as the *motivation* behind this thesis and formulates three hypotheses. The framework describes how semantic spatial arrangements are constructed in space with so called *building blocks*, whose atomic elements are called *PicMents*. Each of the respective digital objects has attributes, including visually perceivable dimensions, called *MarkUps* (e.g. color). PicMents and digital media objects can then be arranged in space, with meaning provided through a visual context that maps information to space, by the aptly called *mapping markers*. The five distinct types of expressing semantic spatial relations, called *arrangement types*, are introduced in detail. Each of these is analyzed regarding how they map semantic meaning to space, how object position is measured, what this position expresses semantically and how it may be evaluated. Finally, *overlays* including their evaluation are discussed and a list of common *action schemes* is provided.

Chapter 7 describes three Semantic Positioning scenarios that support knowledge workers (specifically teachers and students) in reaching their goals in the given context. The hypotheses from chapter 6.1 are proven by comparing the evaluated arrangements, enhanced with responsive behavior, to existing typical implementations of (digital) tools

Chapter 8 presents related research, which is compared to and distinguished from Semantic Positioning.

Finally, chapter 9 summarizes the results of this thesis and critically examines the achieved scientific accomplishments, as well as providing an outlook on potential future research in the field of Semantic Positioning.

2. Data, Information and Knowledge

"We learn by doing. That is the thing. For though you think you know it, you have no certainty until you try."

Sophocles

Knowledge has always been a determinant of success. Productive and creative thinking based on observing nature, testing ideas and understanding concepts found its way into survival strategies including employed tools. Superior knowledge of nature has thus been an evolutionary determinant of success, relative to any situation and danger faced. This basic principle of success extends to personal knowledge of any topic area and translates from survival to any kind of working context. The actual difficulty lies in defining precisely what knowing encompasses.

Even with the acceptance of knowledge as a resource in business, one that may potentially be managed, no mutually agreed definition has emerged. As (Alavi & Leidner 2001) point out, at least within the information technology sector, there is a tendency of describing knowledge in relation to *data* and *information*. In natural language these terms are often used interchangeably, but it does not make too much sense scientifically and logically to coin a term that means exactly the same as another. For this reason alone, one can assume that the terms have distinct meaning, that extends to respective disciplines like *knowledge management* being different from *information management* (cp. Fahey & Prusak 1998).

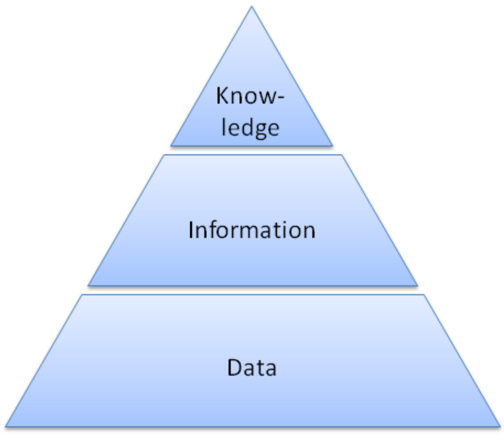


Figure 1: Typical rendering of a "data, information and knowledge (DIK) chain"

To explain the differences between the terms, authors often describe them hierarchically in a so called DIK-chain with data at the base and knowledge on top (Figure 1). This chain is at times extended with the notions of understanding and/or wisdom (compare Ackoff 1987, Ackoff 1989, Cooley 1987, Cleveland 1982, Zeleny 1987), which I subsume under the term “knowledge”.

Data is commonly defined as raw symbols or numbers recorded through measuring processes (Ackoff 1989, O’Brien 1995, Machlup 1983). It may appear meaningless without processing (cp. Ackoff 1987, Jessup & Valacich 2003), because it omits any form of judgment, interpretation or hints at its own relevance (Davenport & Prusak 1998). For instance, the number “20081211876142” by itself is meaningless, but is actually a single datum of a capture process for the Dow Jones course (8761.42) of a specific date (11/12/2008). Thus, each datum of a dataset needs to follow the same structuring schema in order to allow processing. A proposed definition of data in the context of this thesis considers that data requires human knowledge to come into existence[1].

Definition: *Data is the result of human interaction, assigning a common structure to separable values to make captured phenomena processable and thus perceivable*.

Information is more difficult to define, but the relation to data can be defined contextually or technically. In the former view, represented in the DIK chain, data that has been contextualized is information (Ackoff 1987, O’Brien 1995, Machlup 1983). Following a technical perspective the relationship is inversed[2]: As summarized by SearchDataManagement.com – “*In computing, data is information that has been translated into a form that is more convenient to move or process*.” In information theory, information is defined simply as *that* part of a signal or stimulus that is new or surprising (Zemanek 1992). Stimuli that have already been identified, are expected or regarded as irrelevant are not information, but “background noise”. For example, if a person is looking for a cab in New York, he or she will look for yellow cars and simply ignore the rest of the current traffic. Information thus is filtered from the constant ‘noise’ of signals we perceive directly or through instruments. (Bateson 1979) sums this up rather poignantly as “*information is a difference that makes a difference*.” This fits nicely with the originally Latin term *informare*, translated loosely as “to give form”. To communicate, thoughts have to be expressed in perceivable

1 Placing it at the bottom of the DIK chain then might be criticized (cp. Tuomi 1999).
2 Compare also Microsoft Computer Dictionary 5th Edition 2002 and the definition of ‘information processing’ in the Encyclopedia Britannica.

form so that others can notice them as a stimulus difference. Therefore, I define information from both a technical and a human perspective:

Definition: *Information is that part of perception or measuring that gets noticed, making a cognitive or technical difference by standing out.*

Having found fitting definitions for both data and information, we can turn to the difficult question what written texts are. Essentially they are a (potential) *source of information* to anyone capable of understanding the codification and language. Even when a person has already read a text, it does not cease to be a source of information, as the person will not conceivably remember the precise wording or all information potentially presented. Essentially *information sources can be defined as codified collections of information that are not (just) data*. The amount of discernible differences that potentially lie in an information source compared to the 'size' of its codified state can be defined as *information density*.

Knowledge in the DIK chain is regarded as information in a (personal) human context (cp. Alavi & Leidner 2001, Barnes 2002, Judelman 2004, Kock et al. 1997, Probst et al. 1998). That would however only encompass *what* difference a piece of information makes in humans, but not really extend to what they already *know*. A person can *know* anything from simple facts up to complex relations, but also how certain actions or feats like swimming are performed. By postulating that "*we can know more than we can tell*", (Polanyi 1966) expressed that even (pre-conscious) hunches and feelings play a role in a person's *knowledge*. Essentially, one can say that knowledge is related to understanding, which is the reason that what we think we know is constantly measured by acting in reality. A person either knows how to ride a bike or doesn't. The correctness of information we provide in communication is similarly evaluated by other people. Knowing something thus means that one is able to prove it by demonstration or reference (in case it is something that has already been proven by others). The difficulty with defining knowledge amounts to the difference between *factual* and *personal knowledge*.

Factual knowledge can be described as authenticated information (Machlup 1980, Vance 1997). Personal knowledge is what a person knows, modified by his or her feelings and beliefs. The trouble is that no person is able to precisely say all that they know and that understanding is not necessarily required to correctly know a fact. Simply accepting a fact, as an item of public and factual knowledge, without understanding it, often seems to be enough to 'know'. Still, without at least a seeming plausibility and connected basic understanding, most people would reject information as ‘doubtful’, rather than factual.

Gaining (new) knowledge requires reasoning and even creative manipulation of our environment. Hypotheses and ideas can be formulated based on current personal knowledge, perceptions of the environment and respective tests. To become factual knowledge, the hypothesis will have to be tested and proven by manipulations of artifacts in reality, with an objective testing procedure and repeatable results. This understanding is backed by the psychologist (Gibson 1979). He formulated that it is impossible for humans to determine the reality of any imagined concept or idea, just within the sphere of their thoughts. The best test to determine reality is therefore if a more thorough exploration of an object reveals new details. (Arnheim 1969, S.233) formulates a very similar insight, namely that “*…human thinking cannot go beyond the patterns suppliable by the human senses.*” It is thus not possible, even when reflecting mundane objects, to obtain any new information, experience or knowledge that *differs* from what we already know about such an object. Take the example of a regular dice with six sides placed on the table. The side facing up shows a single point. When asked to name the number of points on the covered side, experience and previous knowledge will suggest “six” as the most likely answer. However, to assure that this is indeed a regular dice and that the answer is correct, one needs to pick it up and examine the side. Only through interaction and related perception within one’s environment new reliable insights can be gained.

This concept is called *differential experience* based on (Keil 1990). Learning and understanding are then based on an active investigation of artifacts and conditions found in the environment and registering the effects of manipulations. Differential experience can take many forms, based on what is perceived and the way active investigations and manipulations occur that lead to new perceptions. Verbal feedback by other people can be differential experience just as much as testing a hypothesis through a clever arrangement of objects for experiments. Regarding the personal development of knowledge, the c*onstructivist* perspective (cp. Schulmeister 2002) says that it is based on *active perception* (cp. Papert 1992). Active perception means to specifically manipulate the environment in order to gain new information. Since, personal experiences influence our ways of interacting with the environment (cp. Papert 1992), the concept of differential experience is able to incorporate what has been termed *tacit knowledge* (Polanyi 1967, Nonaka & Takeuchi 1995).

It becomes clear that knowledge is never a static product, but a dynamic process constantly enriched and adapted by learning. This allows me to provide the following definition of knowledge:

Definition: *Knowledge describes the resulting insights of differential experience processes, based on active perception from which understanding is derived. Any new personal insight is related to existing knowledge and experiences of an individual.*

2.1. Artifacts as an External Memory

A process based definition of knowledge can help to explain that knowledge cannot be *transferred* identically between individuals, like some authors appear to desire (Nonaka & Takeuchi 1995). Arriving at the same insight as person "A" requires at least a partial reconstruction of the process that led to A's current understanding. Even then the insight will still be related within the *personal* knowledge sphere. This does not mean however that the effort of sharing and especially of storing knowledge is wasted.

On the opposite, (Keil 1990) writes that if thinking is characterized "*as the active relating of environmental conditions, then it can be concluded, that every tool is also a tool of thinking*[3] *and vice versa. In so far it is justified to regard artifacts, and even the complete environment of humanity as an external memory. Humanity's physical environment is, together with the human made artifacts in its memory carrying capacity, practically a medium of thinking.* "

Media, instruments and any form of tools are the mentioned *artifacts*, acting as an *external memory*. The reason that a number of authors regard knowledge as an object seems to be based upon the necessity of external artifacts for acquiring, storing and sharing knowledge (cp. Carlsson et al. 1996, McQueen 1998, Zack 1998 – *references have been adopted from* Alavi & Leidner 2001). As (Feller & Touret 1980) have stated, the main difference between the early humans and animals was not the use of tools, but their *keeping*. For a steady advance of humanity it is important that scientific achievements are conserved in this external memory. Similar to the

3 This part is difficult to translate. Keil uses the term "Denkzeug" in analogy to "Werkzeug". "Zeug" can loosely be translated as "object" and "werken" is the same as "to work". As such the translation for "Werkzeug" is "tool", as an object for working. "Denkzeug" has no equivalent, but it can similarly be regarded as an object or tool for thinking.

principles of Evolution (cp. Eigen1987) any new adaption towards a better fit tool can only be based on incremental improvements of existing ones. Keeping tools enables adaption to better fit existing or newly encountered problems. This was summarized by (Leroi-Gourhan 1988) as: "*…(human) evolution is mainly that of the means of expression.*"

Based on this principle, writing also started as a tool for supporting the rising need for administration in the first metropoles. For example the calculation and collection of taxes not only required mathematics, but also a documentation of the current state of collection to retain accuracy (cp. Ifrah 1986). The importance of media as knowledge artifacts for the documentation and furthering of scientific progress and culture has increased over the years. One of the reasons is that these texts reference sources for the discussed ideas, which are important for understanding the argumentation. References do not lose their validity over time and are not bound to just one specific process or scenario of use. Media objects, especially those dealing with complex information are rarely self explanatory, which makes authors like (Wilson 2002, Prusak 1999) disagree with the term 'explicit knowledge' from (Nonaka & Takeuchi 1995). Thus I will continue to speak of knowledge artifacts or even just media objects within this thesis.

For organizations and their wide-spread activities the importance of knowledge artifacts as an external memory is evident from context. Any kind of relevant process, transaction and structure needs to be documented carefully, especially "lessons learned" in projects, to not make the same mistakes over and over. Within the general perspective of modern work this was established by (Drucker 1959), who coined the term *knowledge worker* and the derived *knowledge work.* He pointed out that an increasing part of working processes could not be automated or conventionalized, because they are based on (applied) human knowledge. Therefore the next section will shortly explain the notion of knowledge work and combine it with the perspective of differential experience and the importance of media for cognitive processes. The focus will be on supporting knowledge work through the provision of functions in media.

2.2. Knowledge Work Requires Arrangement

As early as 1959 Peter Drucker identified a transformation of society into a new post-industrial form (Drucker 1959). The respective shift was mainly one from manual work towards non-manual work. Manual work consists of transforming physical materials into tangible products. Within non-manual work the transformation process is a cognitive one. It requires the handling of information and active use of knowledge in the workplace (cp. Despres & Hiltrop 1995). To describe the new type of non-manual workers Drucker coins the term *knowledge worker* in his "The Age of Discontinuity": "[A knowledge worker is]…*the man or woman who applies productive work ideas, concepts and information rather than manual skill or brawn* (Drucker 1969: p.264)." It is difficult to ascertain what knowledge work encompasses from this short definition. A little more insight is offered by (Despres and Hiltrop 1995), who say that knowledge work is "…*systematic activity that traffics data, manipulates information and develops knowledge. The work may be theoretical and directed at no immediate practical purpose, or pragmatic and aimed at devising new applications, devices, products or processes.*" The authors emphasize the development of knowledge, stating that any respective activity is aimed at increasing humanities' stock of knowledge. In my opinion this reaches a bit too far: e.g. a doctor as a knowledge worker does not actively increase the knowledge stock by his work; instead the job requires an adaption of existing knowledge to each specific person and case. Hence I believe knowledge work lies in the capability of people, who adapt existing knowledge to *solve* constantly new and unexpected *problems,* thereby trying to achieve *understanding*. This serves primarily as an extension of personal knowledge and only in some cases has a noticeable effect on the human knowledge stock.

Problems in this respect are different from tasks. A task clearly specifies what a person has to do, while a problem only describes a gap between a current and a desired state, but doesn't give clear indications on how to achieve this goal. Hence to solve a problem, one first needs to understand both states and then formulate and test hypotheses to solve the problem. As such Robert E. Kelley states that knowledge workers are "…*hired for their problem solving abilities, creativity, talent and intelligence* (Kelley 1990: p.109)"; these in addition to being able to share knowledge are necessary abilities for the non-repetitive complex nature of knowledge work.

With this in mind, one can understand why lifelong learning is deemed a necessity in our modern society (Delors 1996). Knowledge workers need to constantly familiarize themselves with new (scientific) findings in their respective fields of work in order to stay up-to-date on possible problems and innovative ways of solving them (including instruments and tools). By contrast manual workers often repeat very similar tasks to gain *experience* and eventually *mastery* of the respectively needed skills. Simplified, one might therefore say that a master has learned everything there is to know about his or her craft, while knowledge workers as 'experts' have to keep learning in order to keep up with the fast developing knowledge of their fields of expertise. (Halimi 2005: p. 12) registers a respective transition of how learning is generally approached: "*Today there is another change as education gives way to learning, the former indicating a process established (and therefore, perhaps, imposed) by society, the latter involving rather the voluntary acts of individuals who want to acquire knowledge at their own pace and their own way, for purposes of their own, which may not necessarily be the same as their neighbour's or those of the whole community.*" This reflects well the growing importance of knowledge work in our society. Students in this knowledge society have to *learn how to learn* (cp. Delors 1996, Black et al. 2006). This means they have to be able to not only reproduce memorized facts, but to *reason*, because "*usable knowledge is not the same as a mere list of disconnected facts*" (Bransford et al. 2000: p.9). Students that feel learning is nothing more than memorizing facts will find solving complex and steadily new problems impossible (Bransford & Stein 1993; Bransford et al. 1983).

As I have explained before, problem solving requires the ability to independently and cooperatively research materials as well as critically question contents, understand and test concepts in order to autonomously rate and relate them. Students are asked to demonstrate this ability at the very latest in their final thesis. This final assessment is proof of the student's ability to research a complex topic autonomously, develop an understanding and demonstrate gained knowledge. Not only are students required to find relevant sources on their own, but they also have to independently arrive at results in relation to a formulated hypothesis or topic. In other words: they perform knowledge work. It is then fair to say that complex learning activities resemble knowledge work, while in turn knowledge work is a learning process.

Both knowledge work and autonomous learning are based on *productive thinking* (cp. Wertheimer 1982, Arnheim 1969). Productive thinking relates to problem solving, in that a person starts only with an initial grasp of a problem (cp. Wertheimer 1982). Through active perception one slowly develops an understanding of the problem and the situational context towards developing partial solutions. The process requires among other things looking at, comparing and adapting existing sources by creative applications of existing knowledge. This requires a (re-)*arrangement* of discovered factors, elements and understandings one perceives as relevant and then testing respective hypotheses. While (Zand 1981) describes knowledge work as mental activity within one's head, the introduction of differential experience in chapter 2.1 has made it clear that active perception requires artifacts for any (complex) problem solving process. (Keil 1990) specifies this by saying "*thinking does not take place in the head based on internal representations, but predominantly with the head, as an active relating of encountered external conditions.*"

Because knowledge work deals with data, information and knowledge, the respective arranged artifacts are media objects; text documents typically comprise the most common artifact type. As chapter 2.1 detailed, these artifacts are a requirement for any complex problem solving processes for reference, documentation, note making or even first tests of hypotheses. Media take the form of artifacts that cannot only work as an external memory, but also as a point of reference and learning for others. Essentially, media artifacts allow making information transportable and allow a time delayed or even repeat reception. This makes them important personal storage devices over longer timeframes, but also in cooperative contexts for communicating feedback, insights and new ideas to others. Media enable gaining differential experience by other humans effectively, and thus are invaluable for ensuring the potential, correctness or optimality of developed strategies and solutions.

To conclude this chapter, it can be said that knowledge work as a complex problem solving process is based on productive thinking and active perception, requiring arrangements of and interaction with knowledge artifacts (and other humans) for differential experience. Chapter 3 analyzes how primary media functions enable these interactions with specific focus on *arrangement*.

3. Media Functions - The Importance of Arrangements

"Pure logical thinking cannot yield us any knowledge of the empirical world; all knowledge of reality starts from experience and ends in it...Galileo saw this, and particularly because he drummed it into the scientific world, he is the father of modern physics - indeed, of modern science altogether."

Albert Einstein (1879-1955)

In the discussion of differential experience in chapter 2, the concept of proof (in reality) was mentioned as a necessary constraint for testing theories and establishing knowledge. As (Keil 2007) writes, only the use of external artifacts enables the basic pillars of scientific methodology: observation, measuring, repeatability and verify-cation. For example the inclined plane, ingeniously devised by Galileo Galilei, functioned as an adaptable experimental arrangement, in order to enable an observation and measurement of the effects of the force of gravity. Such *instruments* allow for expanding differential experience to phenomena that lie beyond the basic capabilities of our senses.

Legend has it that Galileo climbed the Leaning Tower of Pisa and dropped objects of different mass but similar size and density from there to the ground, observing that they arrived at the bottom simultaneously. Under closer observation it becomes quickly apparent that Galileo could not have determined any safe information from such an experiment. Objects dropped from the tower (56m high), take about 3.4 seconds to reach the ground (at a speed of 120 km/h). Back in the days of Galileo, such a short interval could not be measured with the required scientific precision to assure that the objects actually hit the ground simultaneously. The reason that Galileo is still revered as a scientific genius is the way he designed the mentioned inclined plane as an abstraction of the principles of gravity.

Basically, the inclined plane is a wooden slope from which balls of different mass can be rolled. The construction includes bells on the slopes which the balls pass, a pendulum to measure steady intervals of time and a water basin (Figure 2). Time needed for a ball to pass down the slope is measured by the weight of a steady flow of water into the basin until it reaches the end of the plane. Weights could already be measured very precisely with scales. Using this weight thus allowed very precise calculations of time. In order to test gravitational acceleration, the bells were arranged on the plane so their passing corresponded to the regular swings of the pendulum. From the resulting arrangement Galileo could determine that per regular unit of time the distance between the bells doubled. The spatial arrangement becomes a representation of the acceleration mechanism of gravity. While the experimental setup may bear a few shortcomings, like ignoring the influence of friction, it allows testing different hypothesis by allowing for manipulations of the arrangement.

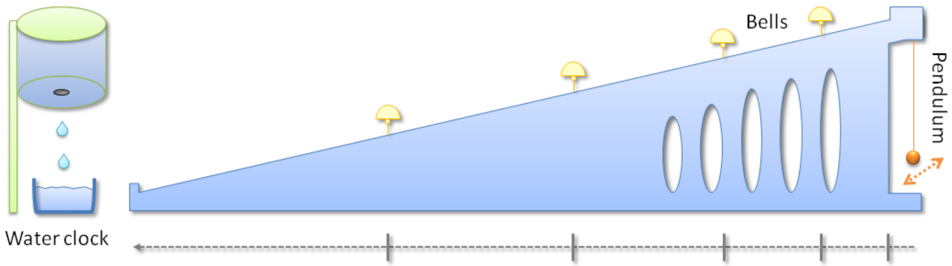


Figure 2: Schematic view of Galileo's inclined plane

(Keil 2007) emphasizes the importance of this kind of interrelation of objects to arrive at a state of relation, where sensible conclusions can be drawn. Intermediate steps on this path, including erroneous hypothesis or experimental setups further understanding. Since the exclusion of wrong procedures can help save time and effort in similar scenarios, ideally the arrangements are saved or at least described in the form of media. However, storing insights in the form of media is also important because memory is unreliable. Proof of this is presented by neuropsychologists (Neisser & Harsch 1992). They questioned forty-four students the day after the Challenger space shuttle accident in January of 1986 about how they first heard about the news and what they felt at that time. Two years later he interviewed the students again, asking the same questions. Despite their claims of having vivid memories of the events, Neisser and Harsch found that none of the memories where completely accurate and that thirty percent of the students even had notably different recollections. Even confronted with their own inaccuracies, they still insisted their new memories as feeling more accurate than their written account from 1986.

Neisser and Harsch conclude that the original memories were most likely lost and that later experiences like news reports had had an effect on the students' memories, altering them to the new form. Thus a person's brain and memories cannot be seen as a reliable *storage* of information, but instead need to be understood as an *adaptive organ*.

While being adaptive is important for facing ever new challenges, knowledge that has been previously obtained should be stored reliably, i.e. in media objects. The combination of the two, then is what leads to the formation of arrangements and the discovery of relations between individual sources. If an arrangement, as a potential solution, does not work when tested, humans can formulate new hypotheses based on the experience. Insights gained, lead to adaption of the arrangement setup and further tests.

Even texts can be seen as arrangements of individual characters that express something very specific by their sequence. When using analog media, however, this arrangement is static, because they are *inscription media.* Inscription media are any kind of media where signs and symbols[4] are inscribed into a carrier material like paper or stone. After the inscription process, the respective signs remain fixed in their visual attributes (shape, layout, color etc.) and positional arrangement. Thus while the signs can be *perceived*, they cease to be *objects of manipulation* once inscribed; they are persistently recorded and have therefore become static. As mentioned before, this can be beneficial when *archiving* factual knowledge. On the other hand mistakes made during the inscription processes become painfully obvious. This is because manipulation in inscription media can only happen on the level of the media carrier. For example in order to sort a row of numbers in correct order on paper, one has to write it anew (Figure 3).

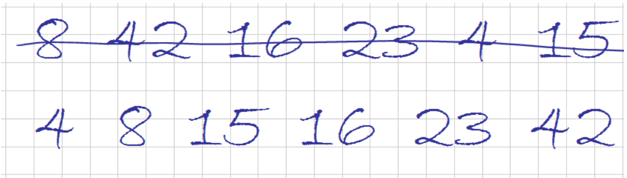


Figure 3: Ordering numbers in analog media requires rewriting

For the purpose of documenting and transporting insights, the creation of such persistent media objects is sufficient. The object itself can even be used as a part in arrangements, but the individual signs remain static once created. Inscription media thus do not allow for combined manipulation and persistency. From such a

4 Signs and symbols here simply refer to any written characters or drawings. In this thesis both terms are treated as being equal, despite some interpretations that symbols are rather graphical in nature and that signs are written characters.

decoupling of perception and manipulation over time the problem of *media discontinuities* arises. A media discontinuity describes any forced swapping of media to complete a cohesive process of working with information: If a reader wants to comment on views expressed in a news paper or even communicate a mistake, he is forced to write a letter or use a telephone. Simply writing comments on the same paper, while no discontinuity, is logically pointless if none of the editors is going to notice. Even after sending the letter, the reader cannot be sure it is read or will be published and if it is, comments on his or her views require repetitions of the same long process.

Both the maladies of long interaction cycles and the division between object(s) of perception and manipulations in analog media can be remedied technically by *digital media*. Each symbol or character one writes in digital media is both object of perception and manipulation. Characters and other objects can be moved, deleted or be assigned attribute changes like color or typeset. Because digital objects remain editable, recipients can on principal be invited to provide feedback directly on the document or even to make changes. One may talk of *immediate feedback cycles*. As soon as a comment is written, it is visible to the author, who can make respective changes on the document or also post an additional annotation as a reply or question. This enables very immediate differential experience. Web 2.0 technologies like *Blogs* and *wikis* use the advantages of digital media, namely fast feedback cycles and dynamic editing capabilities to great advantage.

Digital media manage successfully to couple the space of perception with that of manipulation, creating a new environment in which differential experience can be gained. This may be the reason computers have become such popular tools and instruments for knowledge workers. It stands to reason that the prime *functions of support* offered by digital media enable the duality of perception and manipulation, as basis for supporting knowledge workers. So called *media functions* have been described variedly by other sciences, many of them catering to the perspective of mass media as a communication device or a service to society (cp. Schramm 1964, Nelson 1973, NSSE 1954). Within this thesis, however, a technical perspective following (Keil-Slawik & Selke 1998) is adopted that allows clearly defining functions that make media an external memory in the form of knowledge artifacts.

Under this technical perspective, media functions are defined with focus on those aspects of media that enable and support the use of signs and symbols as carriers of information. One of the benefits of this technical perspective on media functions is that it allows for comparisons between different media and implementations in terms of their efficiency and ease of use. Particularly the dimensions of perception, manipulation and related cognition are under scrutiny in relation to the necessary amount of investment both on the level of time and effort. (Keil Slawik & Selke 1998) describe a model of three general types of media functions presented in a hierarchy:

On the most basic level *primary media functions* bring symbols into the perceptual realm of humans, enabling their manipulation and relation. Creating symbols, for example through writing, is a primary media function as an action with the goal of making the respective signs perceivable.

Beyond that *secondary media functions* consider the specific context of use in which certain media are employed and implement respective support functions within the medium. A typical example is the provision of company specific workflows that automate parts of a document editing process, including the setting of access rights and forwarding functionality. Secondary media functions require an analysis of the context of use, prior to implementation. This includes providing options for (personal) adjustments of existing functions, where necessary or helpful.

Lastly there are *tertiary media functions* as a means of processing user behavior in order to create learning systems, which individually adjust functionality or answering behavior to each user. Tertiary media functions are only beneficial if they learn and adjust quickly and do not hinder the user in reaching functions that are needed less often. While not exactly a learning system, the personalized menus in the Microsoft office XP and 2003 lines are a prime example of the difficulty of implementing actually supportive learning behavior. Most users found them troublesome rather than helpful (Bott & Leonhard 2006: p.30). The complexity of tertiary media functions combined with the rather conceptual structure of this thesis compels me to exclude them from the following argumentations.

Instead the focus here will rather be on the potentials of supporting knowledge work and learning contexts with primary and secondary media functions in the area of spatial arrangement.

3.1. Primary Media Functions

In the first formulation of the concept in (Keil-Slawik & Selke 1998) only three primary media functions are explicitly mentioned, namely *create*, *relate* and *store*. (Hampel 2002) significantly expanded the number of primary media functions and distinguished them into individual and cooperative functions. His individual primary media functions are *create*, *remove*, *arrange* and *link*, while the cooperative ones encompass *transfer*, *synchronize* and *access*. In addition to the above list of primary media functions the function of *markup* is sometimes mentioned (see Keil 2007). This function specifically applies to the manipulation of perceivable attributes.

Digital media allow for providing a working environment, where all of the primary media functions can be dynamically used for manipulations of objects (e.g. knowledge artifacts), while keeping them and performed changes *persistent*. In most settings only a subset of primary media functions is available, which may suffice for the intended purpose of active perception. Primary media functions do not depend on specific contexts of application, but first enable the manipulation of perceived objects so that an active (knowledge) work process becomes possible with digital media. In relation to the discussion of both differential experience and the respective need for arrangement in chapter 2, it can be concluded that primary media functions are a base requirement for these kind of processes. This thesis, based on the developed logic, will in the following focus mainly on the primary media function of arrangement in relation to the functions of linking and mark-up. In the following description of the functions the term *media* refers to types of analog and digital media like text, audio and/or video. The terms *media objects* and *artifacts* used interchangeably refer to instances of analog or digital media.

3.1.1. Definitions of the Primary Media Functions

Two basic requirements for media related work contexts are *persistency* and *object orientation* that ensure reliably that manipulations of objects have perceivable effects. Object orientation on this level means that any perceivable element of a space is seen as an object with attributes, which govern its appearance. Manipulations either affect whole objects or their attributes. Persistency means that object attributes do not change randomly, but only based on acts of manipulation. If a user places an object at a certain position in a private space, the object remains at that position until moved again. The following list describes the primary media functions by (Hampel 2002, Hampel 2002a):

- **Create**
  Refers to acts by which symbols and signs become perceivable through the respective medium. Keeping the respective signs persistent assures access over time. It is assumed that created signs remain persistent until they are explicitly removed by an action.
- **Remove**
  Describes the ability to delete created symbols. This requires that objects of perception are also objects of manipulation, which is not possible in inscription media (erasers manipulate the media carrier, not the signs directly). Remove is also a persistent operation, though in many contexts it may make sense to offer an undo mechanism. Can be combined with a successive create operation into a *replace* function.
- **Arrange**
  Represents the ability to move objects that have been brought into the field of perception and assign them a position. The goal of arranging is not just to enable comparisons, but to spatially represent semantic relations. For instance a number of objects are placed within a box due to shared properties. Arrangements are persistent in so far as a position assigned to an artifact only changes through a new movement action by a user.
- **Link**
  May be described as the establishing and representation of point-to-point or rarely multi-point references. A reference either is a pointer from one object to another or a shared attribute between two objects connecting them. Such a connection can be represented by symbols and artifacts like edges. Pointer references – mostly hyperlinks – allow authors to physically link to the specific sources, their argumentation is based on or even to specific points within a document, without affecting the target. As such hyperlinks are most often found in the contents of media objects rather than in their attributes. Both types of links can be used to connect a sequence of objects. Links are persistent and only removed by an actual disconnect operation or if one of the connected objects is removed.
- **Transfer**
  Refers to bringing an object from the perception and manipulation space of one individual persistently to that of another, either directly or via a mediator

(person or object). Transfer processes are directed at individuals or groups and thus 1:1 or 1:n processes. Multiple objects can be transferred with a single action. A transfer is complete, only once the recipient accesses the received object. Both synchronous and asynchronous transfers exist, measured roughly by the perceived time of reception compared to the time of sending.

- **Access**
  Describes methods by which access to media and media objects can be regulated. A user's ability to access media objects depends on access rights. Most basically read and write rights are distinguished, which neatly fit the notions of perception and manipulation. Each right can either be granted or denied relative to a named set of users and media objects, often including the ability of inheritance. Users with writing rights can usually grant access to other users. Access rights are a basic requirement for actively using any of the primary media functions. In complex systems, access rights are often controlled by a select group of administrators. Defined access rights are persistent.
- **Synchronize**
  Refers to the definition of mutual synchronous views on media objects and respective arrangements. Specifically, it allows users to register changes to media objects and arrangements, including those by other users, as soon as they occur. Synchronization does not have to be a passive function, but can be an active user action such as refreshing a browser window. Users rely on synchronization mechanisms for cooperative work. Synchronization as a mechanism is persistent in always representing the most current state of objects and respective attributes.
- **Markup**
  Is the ability of users to manipulate perceivable attributes of media objects (cp. Bertin 1967, Wilkinson 2005, Zaitsev & Lupandin 2000). The goal is to distinguish a specific object's appearance in contrast to others or to make multiple objects visibly similar, so they are perceived as elements of a group (Figure 4). Markups require an explanatory legend within the same perceptual space and can be freely combined with spatial arrangements and links, so long as interpretational conflicts are avoided. Object markups are persistent.

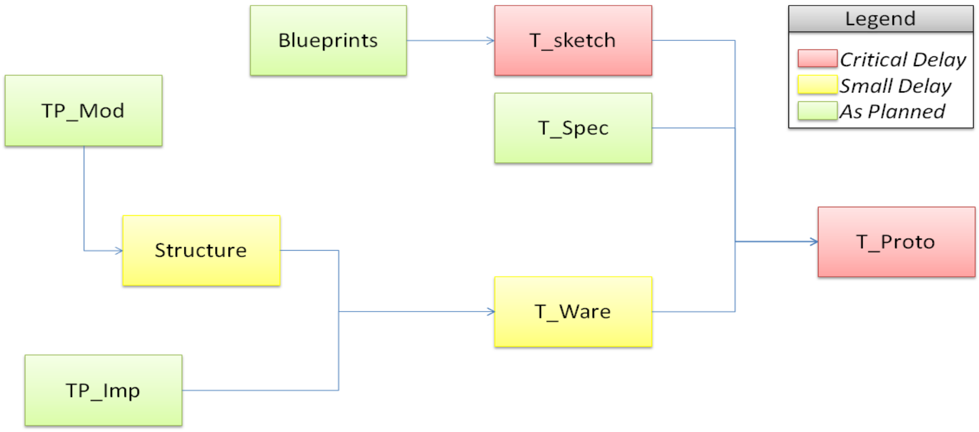


Figure 4: Project status visualized as color markup making logic groupings perceivable

Create and *remove* are the most basic primary media functions, because they bring individual signs and whole media objects into the sphere of human perception and manipulation. Still, in digital media the ability to use them is dependent on *access rights*. Access rights are highly configurable, offering opportunities of implementing different scenarios or processes. Once these rights have been granted, functions that write perceivable attributes of media objects like *arranging* (position), *markup* (perceivable attributes) and *linking* (connection between objects) can be employed. Their goal is to express relations beyond verbal descriptions.

In order to establish communication and cooperation, the function of *synchronization* requires that any change is immediately reflected persistently within the system, meaning that modifications can be made perceivable for potential users. Finally directed *transfers* of media objects enable bringing objects into the area of perception and manipulation of other users, even when the sender personally has no access rights there. The overall relations are depicted in Figure 5.

So far, common technical *co-active functions*[5] employed in Web 2.0 scenarios[6] like comments, annotations or ratings are not considered by the concept of primary media functions, but may be constructed by combinations of the available functions.

5 Refers to the support of multi-person interactions, based on for instance *co*mmunication, *co*operation, *co*ordination.

6 The term Web 2.0 and the often associated social software most commonly refer to web-based scenarios, where any user – traditionally in the role of recipient – on principal has at least limited contribution rights. (O'Reilly 2005) refers to this concept as an "*architecture of participation*". In many realized cooperative or so-called social Web 2.0 scenarios, media objects can be uploaded at a central place and then commented, rated and annotated by other users.

Since their main purpose is to deliver quick (*cooperative*) *feedback*, one may consider in the future if that would be a sensible addition to the primary media functions.

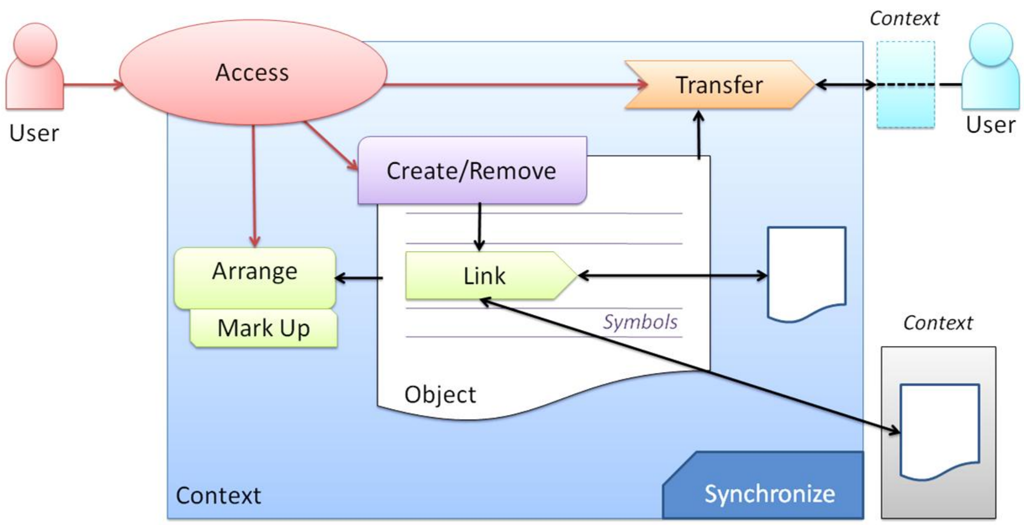


Figure 5: Primary Media Functions displayed in relation to users, objects and spatial context

3.1.2. Difference of Link and Arrange

It may be painfully obvious that link and arrange are not the same functions technically, with one affecting only the position attribute and the other acting as a pointer or logic connection. However, with the described capabilities of links, objects can be connected in branching sequence, creating an arrangement. Regarding the generated construct[7], an object is just as much logically positioned, as it would be if the sequence were laid in a row spatially. Therefore, linking can also be used to express position. For me, so long as the linked objects are perceivable and manipulable in the same space, linked constructs as 'graphs' are also arrangements (cp. chapter 6.5.5). However, a displayed network of hyperlinks is not an arrangement, because it was not created to look that specific way, but rather is a visualization of existing hyperlinks between a set of selected objects. Each of these links was created independent of the other objects. To count as arrangement the set of objects has to be perceived as a whole in space and then have connections added, based on perceived relations. Essentially, one constructs or arranges a graph of relations.

7 Such a construct can be visualized as a directed (pointer) or undirected (connection) graph.

Despite this understanding of a certain part of linking as arrangement, there are still differences at least on the functional level. Links exist (largely) independent of object location. Objects can be linked even if they are in different physical locations. In contrast, if artifacts are meant to express relation by arrangement, they have to be included in the same contextual space. Based on this difference, links can be used to logically 'connect' several arrangements in different spatial contexts. (Selke 2008) mentions two further differences, namely *perpetuity* and *explicitness.*

Perpetuity refers to the fact that links are usually created when a relation between objects has been safely established. For instance, references in scientific literature are stable links, established because the presented argument is based on earlier research. Arrangements on the other hand are often more dynamic, adjusting to new insights and understandings, but also to new work contexts. A few objects grouped in the corner of a work space, because they are relevant to a current student assignment, are likely to be moved or replaced, once a solution has been submitted to the tutor. In that way, links typically express safely identified relations persistently, while arrangements express more immediate relations dynamically. This makes is possible to also express perceived relations that have not yet been verified. Considering that one can also arrange with links, the difference in perpetuity does not apply to any type of scenario.

Explicitness refers to established links that are technically represented as objects or attributes and are immediately perceivable. By contrast, in basic arrangements there is only a blank background and a bunch of positioned objects, but no technical or logical basis that explicitly states *that* a relation exist between any two or more objects. Only the respective author(s) will know if the arrangement is meant to express anything. As we will see in chapter 4 that is also a problem with objects arranged on desks in the analog media world. However, one needs to realize that the inexplicitness rests solely in the plain background and missing legends. Adding *labels*, *legends* or *legend-like-objects* alleviates the problem. For instance objects that are spatially close together may or may not represent a group, but placing them within a circle makes that spatial relation explicit. It is even possible to explain *what* kind of relation is expressed by a note on the circle. These kinds of legend-like-objects will be called *mapping markers* (see section 6.2.2) in this thesis. Naturally the same benefits hold true if one wants to describe *what* relation a link expresses, which by itself is intransparent. Still, links can be evaluated technically with much more ease, while for arrangements a common language of mapping markers and respective grammar need to be developed, in order to establish evaluations based on spatially expressed relations. This is accomplished in chapter 6.3, based on the analysis of analog and digital knowledge work environments in chapters 4 and 5 regarding identified types of arrangement.

3.1.3. Conclusion

Due to the different focus of their works, (Hampel 2002) and (Keil-Slawik & Selke 1998) have avoided a distinction of how exactly 'relation' is expressed through unique types of arrangement. Within a description of application scenarios, Hampel at least implicitly mentions *proximity* and *inclusion* as types of arrangement that can express relation. Given the importance of arrangements for knowledge work processes (chapter 2.1 and 2.2), one can assume that there are more varied distinct types of arrangement. The focus of this thesis is on how semantic relations are expressed through spatial arrangement and how this can support knowledge work. Hence a more thorough appraisal of different types of arrangement and how they can be interpreted and even evaluated by computers is necessary (chapters 4, 5 and 6).

3.2. Secondary Media Functions in Arrangements

The central goal of secondary media functions is the improvement of processes and scenarios based on primary media functions. This can be achieved by incorporating knowledge about the context of use into specific technical support functions. Often this leads to the formation of *conventions*, where specific behavior of users will cause a corresponding system response. Applying secondary media functions to evaluate meaningful relations expressed by arrangement, requires a common language and grammar (chapter 6.3). Conventions then can be expressed in relation to specific types of arrangement and respective placements of objects (cp. chapter 6.8).

In relation to spatial productive thinking, support from secondary media functions can lie in any of the three affected areas of *perception*, *manipulation* and *cognition*[8]. Beneficial support for knowledge work is most likely based either on *reducing or*

8 These three perspectives are derived from Keil's principle of *reduction of enforced sequentiality* within software ergonomics, which is based on reductions of sensory, manual and cognitive encumbrances. The principle is mentioned in (Geißler et al. 2004), but has not been published. It is, however, extensively covered in lecture notes and a respective script. These can best be obtained by contacting the department of *computers and society* of the University of Paderborn.

aggregating necessary actions to reach a specific goal or *enhancing perception* and *facilitating a quicker and more precise understanding* of relations, i.e. *improving differential experience* (cp. chapter 6.1). This does not only apply to the primary media function of arrangement, but also to the functions of linking and markup that will be used in conjunction in semantic spatial arrangements (see chapter 6.3). It remains to be shown how any of these benefits can be realized with arrangements encompassing these primary media functions. This is demonstrated by three scenarios of use based on semantic spatial arrangement in comparison to conventional ways of reaching the respectively desired goals (chapter 7). In the following sections analog and later digital media environments will be analyzed to arrive at distinct types of arrangement (chapters 4 and 5). These build the basic 'language' and 'grammar' for evaluations that establish secondary media functions as beneficiary responsive behavior tied to conventions defined by arrangement.

4. Arrangement in Analog Environments

No clever arrangement of bad eggs ever made a good omelet”

C.S. Lewis (1898-1963)

It has been established that knowledge work is about learning, understanding, adapting and applying knowledge in order to solve problems. This view is consistent with the concept of differential experience, in so far as any insights can only safely be gained through interaction with the real world. The previous section established the importance of media for knowledge work. Media objects enable differential experience as external artifacts of reference, manipulation and perceptive feedback. Thus they function as the building stock of solutions to common or specific challenges in knowledge work.

It is necessary to gain accurate and reliable factual knowledge from media objects. The (scientific) accuracy and reliability is directly related to the provided information having been properly researched, tested, discussed and documented. Paradoxically, the chosen form of scientific publication is still basically that of inscription media. Even though it is common nowadays that digital versions of papers are published, these are still in formats that cannot be edited e.g. in PDF format. In addition there usually is no way to provide feedback to the actual authors at the place of publication[9]. The conference setting of most publications ensures that direct verbal feedback to the presenting author is ensured, but this feedback is not normally made available to the potential later audience, i.e. slow interaction cycles. To be sure of the correctness of the information presented in a paper, one has to manually search for multiple trustable sources, agreeing with results and reasoning. Typically, only basic factual information is accepted immediately, when it comes from a trusted source.

For these reasons, it is necessary to compare, evaluate, rate, understand and comprise information from different sources in almost any knowledge work context. Since such information is not commonly available in an already suitably aggregated form of a single media object, it is the knowledge worker’s task to perform the necessary steps to reach a supportive understanding. This requires rearranging extracted relevant bits of information from different sources and contexts into a form that suits one’s current purpose. Such a *restructuring* requires interacting with different media objects

9 Compare for example http://www.springerlink.com or http://portal.acm.org

in direct relation to another, within the respective area of perception and manipulation, including new inscription processes. Logically, both perception and manipulation cannot take place just within a person's mind. They need actual space in which a person can sense and act. Humans have evolved in a three dimensional environment and thus have adapted to it. This includes their bodies, senses and brains. In order to navigate, explore and survive in the space of the real world, the human brain was optimized for *spatial reasoning* as the most basic requirement of strategizing (cp. Glenberg 1993).

In general, *reasoning* refers to the ability to make sense of encountered phenomena and problems and developing strategies for solving them and achieving goals. Spatial reasoning then describes the human capability of assigning meaning to the location of things in space (Tappan 2004). More precisely, it is about deducing relations from the position of things in space relative to oneself and among one another[10]. This quality allows building theoretical strategies. For instance, knowing where a needed source of water is and where in relation dangerous animals hunt, allows forming strategies about best routes. Even if a working route is already known, should it be unavailable, persons may plot other routes using a simple representation. Whether a chosen path works can only be learned by trying it out. Careful planning, however, increases the chances of success tremendously. Due to the very basic nature of spatial reasoning for any interaction in space, one can say that differential experience and any cognitive planning process is spatial.

This view is supported for instance by the well-known perceptual psychologist (Arnheim 1969: p.232), who states that perception of space is equal to the cognitive dimensions used in theoretical reasoning. Arnheim even specifically refers to putting objects and events into a meaningful relation. The goal of this activity is either to try and gain an understanding of matters or formulate a hypothesis that can then be tested. Similarly, (Kuhn 1996: p.3), a researcher of geo-information systems, believes that "*[s]pace is fundamental to […] cognition because it provides a common ground for our senses as well as our actions*". He argues that human spatial cognition is highly

10 If time coordination issues are involved as well, the term is sometimes enhanced to spatial-temporal *reasoning*. Within this thesis I will not further use the suffix 'temporal'. This is because in contrast to catching a ball approaching at a certain speed from a certain position, knowledge work usually does not require as much immediate time coordination ability. The time frames considered here are more likely date based. In this setting, time is often mapped to a spatial dimension like the underlying time axis in Gantt Charts. While not conclusive evidence, this is at least an indicator that humans are able to easily interpret temporal relations in spatial terms.

developed, while often subconsciously processed, imposing only low active mental effort.

Perception of space alone, however, is not enough for reasoning about it and objects and phenomena within. Only testing ideas (hypotheses), through exploration or interaction, can lead to actual cognitive insights in the real world. In accordance, (Glenberg 1993) argues that human survival would have been improbable without ways of simplifying representations of the natural environment and reasoning about it. More generally, representation is a means of giving perceivable shape to ideas, through manipulation. Humans *represent* through artifacts. While both (Kuhn 1996) and (Judelman 2004) refer to the realized representations as *metaphors*, (Anders 1999: p. 74) convincingly states that "*Space is a medium, not a metaphor. It is a tool for thought, not an iconic presence*." Thus, by using space for representing information, relational understanding can be expressed through arrangements of artifacts.

Due to humanity's natural ability for spatial reasoning, (Kuhn 1996) argues, it is likely that humans developed common *inference patterns* for typical spatial phenomena. Essentially, an inference pattern is a shortcut for cognitive processing, like "round things roll down a hill". The general argumentation is based on the works of (Johnson 1987, Lakoff 1987, Lakoff & Johnson 1980), who suggest that humans developed basic interpretation structures through interaction with their environment. The authors call these kinesthetic *image schemas*, derived from large quantities of perceived information[11]. An example of such a schema is that of a container, which implicitly defines a boundary between the inside and outside. These boundaries allow positioning artifacts inside the container, which forms the archetype of *inclusion*.

A large quantity of these image schemas is introduced by (Lakoff & Johnson 1980), but they are formulated from the perspective of perception, rather than representation. Therefore, they are of varying quality and only in a few instances helpful for creating arrangements of artifacts in order to express information. Another problem is that not all image schemas are based on spatial dimensions, but, for instance, forces or processes like "compulsion" or "restraint-removal". However, even those that bear relevance on spatial arrangements are inconsistent, regarding dependencies on other

11 This information is called 'images' by Lakoff & Jonson, as is usual in cognitive sciences (cp. for instance Glenberg 1993). Within this more technically oriented thesis, however, the term image refers to a specific type of created representation (see chapter 5.2).

schemas or clearly distinguishing, which spatial dimensions are employed for what purpose.

Mainly missing, in relation to the creating of meaningful arrangements of media objects, is a description of the most basic semantic properties that are associated with an archetypical type of spatial arrangement. Books that are placed in a common shelf as an example of inclusion, will often share a mutual topic. Alternately, they may simply be ordered after title or author. They may also be placed randomly in the shelf, but random distributions of artifacts do not count as arrangements, which are instead purposefully constructed. Hence, in the first example the books that thematically belong together are understood as a group, which is then expressed through their common inclusion. In the second example, the common inclusion is less important than the sorting. A simple alpha-numerical order after the name of the author does however provide a backdrop for clustering books in ways that make later searching easy.

These examples describe two distinct ways of arranging for specific semantic properties. *Inclusion* makes sense to describe a group relation based on common properties or contents of media objects. *Order*, in turn, enables easier referencing and finding based on a specific attribute value. Relations in this arrangement are expressed by the choice of a relevant ordering criterion and the respective definition of sub partitions or groups in the ordering. In the example, semantic groups of books may be determined in the shelf for adjacent books. A typical grouping is by shared author or even more simply by authors whose last names begin with a certain letter. If groups were to be determined by thematic similarity, a different sorting criterion would be required. Understanding of the alphanumeric order additionally allows quick estimates of roughly where in a large collection of media objects, specific groups or individual objects will be. In the book shelf example, the author Roman Zankof would, for example, likely be positioned towards the lower end of the shelf. While the alpha-numeric nature of sorting mechanisms is efficient for searching, it does not usually bare any relevance in expressing semantic meaning.

So far it could be observed that a type of arrangement only infers typical ways in which respectively depicted relations will be interpreted, not the personally coded relation itself. Hence, it is possible to map non-spatial information to spatial inference patterns (cp. Glenberg & Langston 1992, Glenberg et al. 1994). There may be other types of basic arrangements used in working with media objects, which may best be identified by looking at offices as the typical working environment of knowledge workers. First, however, the nature of arrangements in this context as well as their necessity and reasons for knowledge work need to be clarified.

4.1. Offices and Desks – Observable Arrangement Types

Within offices, artifacts have assigned and/or sometimes dynamic places. Here, both analog and digital media are kept, organized, sorted and potentially arranged according to the often immediate and more direct context of conducted work. (Kirsh 1995: p.1) specifically argues that "*…whether we are aware of it or not, we are constantly organizing and re-organzing our workplace…*" The respective acts of arrangement are not random. Their common purpose, according to Kirsh, is to enhance the efficiency of performed work. What he calls the *workplace* is the common space in which a person interacts[12] with artifacts towards a work related purpose. While the arrangements themselves are meant to support work processes, their construction is based on primary media functions. The functions of arrangement, markup and linking stick out for establishing perceivable relations in knowledge work, through spatial, visual or verbal composition.

As the direct focus of perception and manipulation, media objects thus form a person's *active working environment*, with the desk as the most immediate place of access at its center. Here, media objects are placed, arranged, consumed and edited. While some of these interactions may only create temporary structures, (Kirsh 1995) describes arrangements of artifacts specifically constructed to accommodate for a wealth of typical problems faced. He gives the example of a kitchen in a restaurant, where knives and common ingredients are stored, so that they can be conveniently accessed and differently combined for a range of dishes. While the problems faced in that environment are predictable based on a set menu, knowledge work is different. One may therefore suspect that the arrangements used for knowledge work purposes cannot be prepared in advance (except for very basic things like where pencils are kept), but have to be individually built for each new problem to be solved.

Hence, while final results of knowledge work often take the form of a *finished* artifact, be it a piece of software or a paper, this is not immediately the case during the process. The *spatial arrangement* of media objects *dynamically* grows, shrinks and changes based on current assignments. For instance, first assessments and

12 This refers to any act of perception and manipulation.

comparisons of documents relevant to a common task are most easily performed if the documents are positioned side by side. Once finished, the respective objects are often moved to new places based on what was learnt about their contents. One can conclude that the *positioning* of media objects in offices is purposefully coded with a specific meaning, relative to contents, purpose or other attributes. Simple *placement* lacks this sense of purpose and can lead to a chaotic storage, where finding things is impossible in a decent measure of time. Mostly, people design the arrangement of their office environments to support their working style and enable organization and structuring of media objects. The goal of *organization* is a classification of objects, encompassing an arrangement to enable more efficient searching and finding. *Structuring* on the other hand means to represent and establish relations between objects by their arrangement. For both purposes different methods of arrangement are employed, depending on factors like the frequency of access and the amount of similar objects (Figure 6).

Figure 6: In offices organization (yellow) and structuring (blue) are employed

A difference between the time and task related purpose and utilization of information in the form of (paper) documents is actually made by several authors (Cole 1982, Lansdale 1988, Barreau & Nardi 1995). Speaking in largely identical terms they distinguish *ephemeral*, *working* and *archived* media objects. Ephemeral objects are mainly relevant for current tasks within a matter of only several days, before they either become obsolete or are archived. Working information is relevant to several tasks or over a longer time frame, such as documents related to an ongoing project. What is archived, then, is mostly documentation of completed work or information that is considered relevant in a long term context. (Barreau & Nardi 1995) found, however, that respective documents are typically only infrequently accessed.

The necessity of the more dynamic personal arrangements is highlighted by (Kidd 1994). While observing that to outsiders these arrangements of media objects often appear as a “muddle”, he also found that knowledge workers are seriously disrupted in their work if these are changed by other persons. The reason behind this disruption is that space is used as a device for making specific ideas and inputs perceivable that have not yet been fully grasped in their complexity, meaning and/or relation and thus cannot yet be safely categorized or applied. Information from different media sources needs to be understood, interpreted, related, adapted and applied in knowledge work. Besides improving the efficiency of common work processes, dynamic arrangements of media objects are used for that exact purpose. They enable slowly giving shape to hunches, ideas and partly understood information and relations in the form of spatial points of reference.

One might in a technical sense speak of a personally chosen *semantic position*[13]. It is then possible to describe these dynamic arrangements of media objects on desks as *snapshots* of a knowledge workers *progress* in relation to his current work tasks and challenges[14]. Kidd calls this role of spatial arrangements for knowledge workers a *holding pattern* or by extension a *primitive language*, when written/drawn annotations and notes are included (Kidd 1994). Alterations of this snapshot of personal work progress by another person, therefore eradicates the arduously created personal insights. While hidden to others, they are cognitively linked to the spatial positions of media objects by the arrangement’s creator.

Aside from media objects themselves, furniture within the working environment may actually support the arrangement, as storage and reference places for media. Beyond the desk itself, these are, for instance, drawers, shelves, file cabinets, boxes, baskets, trays or bulletin boards. Similarly, there are *tools* and *instruments*. Tools are objects that can be used to directly manipulate media objects or that support such

13 The Greek term *σημαντικός* (*semantikos*) from which the English adjective ‘semantic’ and the science of ‘semantics’ is derived originally translates simply to *significant*. In this thesis it will be interpreted as ‘*meaningful*’.

14 (Kidd 1994) argues that this snapshot also acts as a demonstrable indicator of work progress, which in knowledge work otherwise is often difficult to measure until a final solution emerges.

manipulations like pens, staplers, paper clips, rulers, scissors etc. Instruments on the other hand enhance human perception beyond its normal scope for differential experience, like a microscope or a spectral analyzer. Both, tools and instruments, will also be parts of arrangements, though their position is usually chosen for reasons of efficient access, rather than semantics.

With reference to a typical office working environment (Malone 1983) identified two major arrangement strategies, which he termed *filing* and *piling*. Filing encompasses a classification of objects sometimes as early as their arrival and storing in appropriate order in filing cabinets. Malone observes that if this practice is the main means of organization, the respective office is usually tidy, with only few 'loose' media objects lying around. Each filing cabinet represents a specific class of objects and thus can usually be labeled easily, like 'bills' or 'customer complaints'. Semantic interpretation is tied directly to the respective cabinets and drawers as well as the chosen ordering mechanism. Filing a document requires knowing from its contents, to which available category it belongs and which respective value it has. With this value it can be inserted into the typically alpha numerical order. Ordering categories and values are mostly derived from content-related attributes. These can either be inherent to the contents, like the due date of an invoice, or assigned, like a chosen name for a police case. Multiple ordering criteria can also be used within a filing cabinet in a strictly hierarchical manner. The prime criterion determines the main order of media objects, a second criterion only the order within an identifiable category of the first one. Taking the example of police cases, a first-level order could be based on the year in which the case occurred, with the sub-ordering criteria for each year being the name of the case. Filing cabinets overall represent a combination of the already established arrangement archetypes of inclusion and order.

'Pilers' on the other hand use the desk space to group media objects by stacking them (Malone 1983, Mander et al. 1992). All kinds of paper based documents, from simple printouts to books, can be arranged in this way. (Malone 1983) and (Whittaker & Hirschberg 2001) note that compared to filing dynamically constructing piles is a less formal, more natural process, which does not enforce a predefined categorization structure. Indeed, a number of authors observed that knowledge workers found it very difficult to design and implement an effective filing structure in their daily and often diverse work context (Kidd 1994; Lansdale 1988; Malone 1983). Finding consistent labels organized around typical workflows can be a strong help for very regular working contexts (cp. Malone 1983), but when every workflow is unique, this benefit loses its value. Filing requires a pre-coded organizational structure, which requires knowledge about the types of information entities that will be encountered over the course of one's work, as well as respective attributes that will be useful later for finding items. Due to the diversity of tasks encountered in dynamic knowledge work, it is very difficult to anticipate in which contexts a specific media object as an information source may be needed again, hence complicating a sensible classification. The benefit of piles then obviously lies in the ease of creating a very accessible structure for documents. Also, piles represent a loose categorization of included objects, relevant largely to just the current task.

It is difficult to determine exactly what kind of arrangement type piles represent. On the one hand one might say that objects on a stack are 'included' in it or that they largely follow a time-inverse sorting. On the other hand a pile itself acts as an object that may be positioned and arranged. Hence, the common reason for placing media objects on the pile is principally independent of the reason for its spatial position within a larger arrangement. This position, marked by the rough length and width proportions of the respective media objects, could be called a point of reference. This corresponds largely to the idea of *reference frames* researched by (Patten & Ishii 2000), which are cognitive partitions of the available space and may be marked simply by the position of artifacts. Regarding the surface of the desk as a two dimensional pane, piles define areas whose position or size may be compared spatially.

Positions on a two dimensional pane are most simply compared by their relative *spatial distance* either to one another or to a specific reference point. Distance is also mentioned by a test subject in Malone's study regarding piles (Malone 1983). Piles are often used as reminders. The closer a pile is to the knowledge worker the more prominent it is perceived as a reminder. In turn the farther away a pile is from the knowledge worker, the less likely it will be perceived as a reminder and the less often it will be accessed, accordingly. It is a matter of efficiency: Media objects that are currently important and need to be accessed more frequently are placed in direct proximity of a knowledge worker, pushing older or less important ones increasingly farther away. Distance in this setting directly represents the *frequency of use,* even though no precise measuring is used. More liberally interpreted, *closeness* expresses the importance of media objects for the current work context. Should a book in a shelf at the other end of the room become important to a knowledge worker, he or she will likely take it to the desk for as long as needed. This beats the alternative of walking to the shelf each time something needs to be looked up. The natural use of *distance* in space can be regarded as a basic support of (knowledge) work, by reducing necessary actions to reach a specific result. It also marks a new type of arrangement that is different from *ordering* and *including*. Distance as an arrangement type is open to other interpretations as well, such as describing the degree of relation between objects (cp. Marshall & Shipman 1993, Marshall & Shipman 1999). For instance, two piles will more likely be close together on desks than far apart, when both collect media objects that are regarded as semantically similar.

The efficiency of a distance based importance distribution may be thwarted when stacks amass. (Malone 1983), for instance, only encountered an overabundance of piles in the context of messy working environments. Thus, it might be of little wonder that he found it was more difficult for the respective workers to successfully retrieve a specific media object from the arrangement, compared to those utilizing filing strategies. (Whittaker & Hirschberg 2001), in contrast, found that for up to a certain amount of documents, piling actually proved superior to filing. This benefit materialized not only in the better efficiency of creating piles, cleaning up and direct availability of recent information, but also surprisingly in document retrieval tasks. At a certain point of pile amassment, some of these benefits, particularly the ability to find individual documents, cease. Sadly, neither Malone nor Whittaker & Hirschberg evaluate if the nature of regular work tasks more often requires finding specific objects than typically irregular knowledge work processes.

In a comparison of retrieval techniques (Jones & Dumais 1986) found using space alone for document organization purposes severely lacking, compared to using names or combinations of the two in delayed tests. That would seem to oppose the findings of (Whittaker & Hirschberg 2001), if the studies could actually be compared. However, Jones and Dumais basically eliminated personal working environments as well as job related information sources in their study. They ignore structures and conventions that have developed over time and support regular tasks. Respectively coded information of working with media artifacts is thus lost. The task was to come up with a new spatial organization system for random newspaper articles. However, for later retrieval tasks these articles were not visible. Compared to stacks on which at least the topmost document is in plain view, this seems like an unrealistic portrayal of the actual application contexts. In addition, filing is described as opposed to spatial arrangement. This assumption seems strange, considering that filing too is spatial arrangement; documents are put *inside* labeled boxes for each category and *sorted* along an equally labeled alpha-numerical dimension. Therefore, the only thing that can accurately be concluded from (Jones & Dumais 1986) is that a purely location based organization of media objects is not very apt for long-term archiving purposes.

While one may discuss which of the strategies better fits which task, it seems that studies often rely on just the two already mentioned purposes of finding or reminding (Malone 1983, Barreau & Nardi 1995, Fertig et al. 1996). The question is, whether these are the only two sensible purposes for spatial arrangements. Additionally, piling as grouping by inclusion, filing as ordering and distance relations may not be the only arrangement types employed. It seems strange that most authors do not consider the more immediate dynamic arrangements of ephemeral media objects for work or their specific purpose. Malone at least shortly mentions spread documents, but does not delve deeper into the specifics of their arrangement. My interpretation is that arrangement of ephemeral media are far too dynamic and seemingly unsystematic, to be captured prominently in research.

On this level there are, for instance, comparisons of information from different sources by placing media objects side-by-side. Their spatial closeness indicates estimated semantic closeness, while supporting bringing the related bits of information from the two sources into a common field of perception. However, it may be necessary to carefully distinguish the use of distance from *adjacency* or *overlaps*. Adjacency means that the distance between two objects is zero, while overlap means that the distance of the object borders is less than zero. Neither principle seems to specifically express semantics, beyond the already mentioned ones, but instead exist to cope with spatial constraints. Thus overlapping documents so that only necessary information remains visible, on principle allows bringing more objects into the field of view at the same time.

A last type of arrangement that can be inferred from studying office environments is that of *spatial paths* in the form of workflows. One of the interviewees in (Malone 1983) mentions that his work is strongly organized around a set of standard forms. These forms need to be filled out in a certain order and are always in a specific state in relation to the whole process. The arrangement in the participant's office reflects both the sequence of steps and states. For instance, purchase requisitions are first placed in the worker's inbox and then sorted into two groups. Some requisitions can be directly processed and then placed in the out box, others require further information. Therefore, workflows are generally multi-step manipulation processes. In spatial workflows individual steps are linked to defined spatial positions, where respective media objects are kept for manipulation. The sequence itself is best described as a *path* along individual stations and steps. Expected results, specific actions and semantic interpretations are cognitively linked to the path with its individual stations. As described in the example, paths can branch along the way to cope for different conditions and outcomes.

Overall, spatial workflows are most similar to the scenarios found in (Kirsh 1995). Logically, paths are mostly established in environments with regular tasks. In that context they represent the process spatially and shorten ways between 'stations'. In addition each step, as a reference frame, may act as a reminder of specific work to do just by objects being positioned there. For instance, if information is missing to process a stack of objects, respective inquisitions are necessary. In turn, an empty inbox signals that all current purchase requisitions for that day have been processed. Spatial workflows might also be created for ad-hoc tasks with steps that have to be repeated for a larger number of times. An example of such a process is, having to add stamps and signatures to a hundred graduation papers, but only once a year. While distance between individual stations may play a role for the efficiency of the overall process, *paths* themselves are a new arrangement type for our list. They spatially describe semantic connections between defined reference frames consisting of media objects at established stations of a process. While each station may thus only be visually distinguishable (a difference making a difference) by media objects that are positioned there, neither the paths between stations nor the conditions by which the next station is selected are usually directly perceivable in analog working environments.

4.2. Conclusion

It seems that most of the working and long-term spatial arrangements of media objects found in offices can be described either by a single one of the four identified principles of *distance*, *inclusion*, *ordering* and *paths* or by respective combinations. For instance, a filing cabinet can be understood as a container grouping a number of objects semantically by shared properties, while at the same time ordering them after a chosen sorting criterion. The term combination can also refer to aggregations of previously separate arrangements. Two piles of documents may for example easily be combined into one, by placing one atop the other.

In short-term arrangements the same spatial principles apply, but with slightly different focus. Regions, paths and orderings are less often encountered for instance, with the possible exception of piles (inclusion). For imminent perception and manipulations media objects will usually be taken out of regions, containers, workflows or linear orderings. Spatial closeness on the other hand plays a more important role in dynamic arrangements. The goal is usually to bring information from multiple sources into a common area of perception and manipulation. Here, one can employ markups, annotations and formulations, which remain in the field of peripheral vision. These verbally or graphically expressed ideas may function as persistent but dynamic reminders of developed ideas and concepts or relations that are already believed to be understood. (Schilit et al. 1998) call the respective annotations, markups and notes *active reading*.

What this chapter has tried to emphasize was the *necessity* of spatial arrangements for knowledge work and some of the potential benefits. The ability to spatially arrange (knowledge) artifacts supports knowledge work. This is accomplished by enabling ways of formulating, testing or simply thinking through incomplete ideas and to develop an understanding of relations. One reason is that arrangements make working with media objects as information sources more efficient, on any level of the interrelated perception, manipulation and cognition processes. While research has brought forward the idea of typical inference patterns, in relation to offices only two very general structures – files and piles – have been established. By focusing on office environments and the respectively present arrangements of media objects four distinct basic types of arrangement could be identified (see Table 1). Distance, inclusion, order and paths seem well devised for describing large variety of arrangements of at least analog media objects both by themselves and in combination.

Arrangement Type	Function
Distance	Semantic closeness depicted through spatial closeness
Order	Semantic rank depicted through sectioned order
Inclusion	Semantic class/category depicted through inclusion
Paths	Cognitive semantic connection of related work steps

Table 1: Overview of identified arrangement types in office environments

The same basic four arrangement types have been identified by (Richards 1984, Horton 1994, Engelhardt 2002) as a subset of other graphical means in reference to how relations can be expressed visually (including for instance color or shape). Paths are graphically expressed as connectors linking objects. Both Horton and Engelhardt mention two further object to object relations, namely *separation* and *superimposition* (*overlap*). In my opinion, separation is not different from separating space into regions in which objects are contained. Superimposition, however, does hold a lot of value for arrangements (see *overlay* in chapter 6.6). Bearing in mind that Richards, Horton and Engelhardt all attribute the mentioned arrangement types to visual constructs, in order to express relation between objects, it is to be expected that these dimensions apply to digital media as well. Hence it should be possible to identify them in typical digital media based working environments.

In that environment, however, rules and restrictions change. For instance the graphical nature of modern operating systems allows simply putting images or texts in the background of arrangements (*overlay*). This on principle allows making a chosen reference frame perceivable without included objects and even to label it in relation to what it is meant to represent. Since gravity does not apply, a large number of flat surface layers can be employed as transparent levels, with media objects freely distributable on each. So while stacks might be recreated, layers allow for more options of arrangement that go beyond the ones we found in relation to analog media objects. Specifically, overlays and complex combinations of several arrangement types are possible. Furthermore customs or conventions associated with certain spatial arrangements can be depicted and actions partially automated. The next section, therefore, will examine arrangement capabilities within computer desktop environments, including an analysis of the spatial dimensions utilized to express relation.

5. Arrangement in Digital Environments

"Some archeologists believe that Stonehenge - the mysterious arrangement of enormous elongated stones in England - is actually a crude effort by the Druids to build a computing device."

Dave Barry (*1947)

Spatial arrangements are not just common in relation to analog media; they are a beneficial necessity (see chapter 4). When thinking about spatial arrangements in digital media, boundaries and physical restrictions are different than those of analog media, often less restrictive, in others more so. The physicality of space, virtual or real, influences anything from the way media can be displayed, accessed or manipulated up to the way they can be processed. For example, there are often less spatial constraints when it comes to storing digital media objects due to the available hard drive space. Actual arrangement capability is limited by the resolution of the computer screen. Still, digital media on principle allow for a wider range of support functions for knowledge work processes, through evaluations and responsive behavior based on the fact that objects of perception are also objects of manipulation.

5.1. Basics of Digital Arrangements

An object in digital media can be anything from an individual symbol or character up to complex compound objects like a file or folder. Information is generally represented by the arrangement of these objects and enhanced by markups and links (see chapter 3.1). Technically, each of these primary media functions refers to *editing* attributes of the respective digital objects. Arrangement changes the attribute of position, markup changes other perceivable attributes like the color or size of objects and linking adds a new target object to the attribute list of connected objects. Object orientation in modern operating systems allows applying any operation that can be applied to a single object, to a group of objects as well. This *batch processing* is a very basic, but efficient support function for knowledge work in digital media. In addition, prominent secondary media functions like spell-checks often seem to analyze the specific arrangement of symbols, rather than that of compound objects. Content level and other support for knowledge work sets digital media apart from analog ones.

This is evident from the typical usage patterns and preferences for either group of media. Writing text on computers bears the advantage that any written sentence can still be edited and changed. Multiple types of media like verbal and graphical ones can be easily combined on an object level. In addition, support functions like the mentioned spell checks or cut, copy & paste capabilities are superior to paper. This is reflected in the preferred use of digital media by students for writing study related texts (Wallis & Howcroft 2006). When it comes to reading, paper is preferred in turn for reasons of portability, reliability and the comparative ease of adding annotations or other markups according to (Spencer 2006). She links her results to earlier studies of (Sellen & Murphy 2002, Cragg et al. 1999), who discovered similar patterns. Digital source materials are printed mainly when they are needed for concurrent work on other documents, if the text is long or complicated or if they are relevant for studying, specifically for exams or taking notes (Spencer 2006). Even for simple comparisons of text passages, it is much easier to place paper sheets side by side than to display them on the same computer screen. Another reason for this preference might be based on the generally higher reading speed with paper (Muter & Maurutto 1991, Kurniawan & Zaphiris 2001).

It seems then, that analog media, including printouts of digital documents, are a better fit for arriving at a first understanding of materials and their relations. This in turn would mean that at least for arrangements related to current problem solving processes analog media are a better fit. In most cases, however, there is an important duality of media use. Often analog media objects are kept beside the computer keyboard, as quick perceptive references for manipulation processes on digital media objects. Therefore, arrangement processes at the very least take digital media objects into account. Digital media objects have become common parts of arrangement processes, with insights gained in either type of medium being reflected in the respective other. Their access to larger and more varied sources of information (e.g. the internet) and the faster and more direct communication capabilities, have made digital media necessary assets for knowledge work and learning processes (cp. Nardi et al. 2000).

Since many digital documents will have to be accessed over longer time frames, at least for archiving purposes, people will try to accomplish a satisfactory arrangement structure in relation to digital documents saved in the file system and on the desktop. All these terms are analogies derived mainly from the context of office environments, often in relation to archiving activities. One might validly ask, whether arrangements in digital media rather take the form of archiving structures or if something similar to the immediate and dynamic arrangements found on desks in analog media exists. Before considering diagrams and their benefits, it is necessary to understand what kinds of arrangements are typically found in modern operating systems, in which digital media objects are managed.

The general setup of modern operating systems was pioneered at the famous Xerox PARC laboratories (Smith et al. 1982a, Smith et al. 1982b). They introduced a graphical user interface called STAR, intended to significantly support business professionals in handling information. In order to deliver an immediately understandable, simple analogy from real offices, while avoiding respective limitations, the designers decided to call the initial surface from which a person operates computers the *desktop*. On this two dimensional area objects can be assigned a spatial location, usually along a defined grid[15] (Figure 7). Objects within this user interface were represented as icons. Smith et al. distinguished *data icons* and *function icons*. The position of digital objects on storage media is not physically determinable by human senses, because it is simply an address on the respective storage media. Providing a pointer to this address in form of an icon allows accessing objects within the operating system.

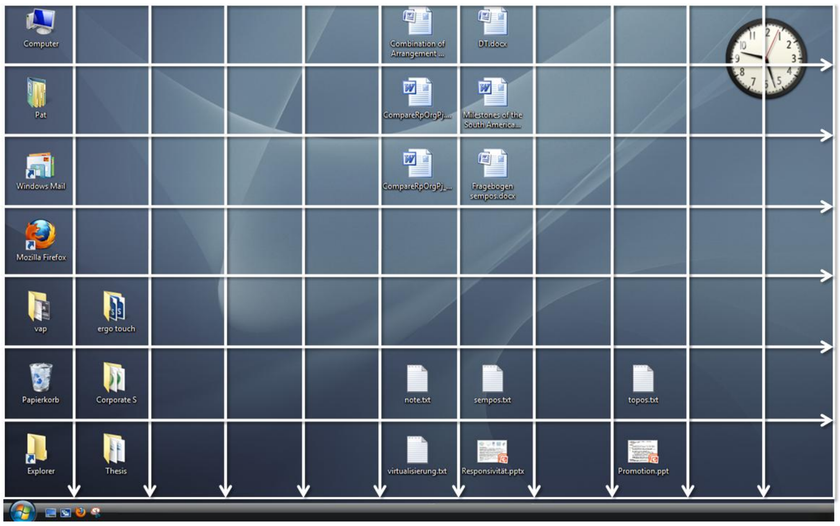


Figure 7: Visualization of the invisible icon grid on desktop computers

15 It is possible, for freely arranging files within the two dimensional plane of a folder in Microsoft Windows XP or later. This is however is rarely employed in the light of the more common list based sorting.

5.1.1. Function Icons and Actions

Function icons are files or placeholders, like shortcuts for system operations, with coded responsive behavior that can be applied to objects. An example is a printer icon that sends documents to a connected printer. The responsive behavior is invoked by a user's *spatial actions*, in this case moving data icons on the function icon. Bundled operations in a responsive convention will typically amount to an application of one or more primary media functions. There are mainly three distinct types of spatial actions that are common in modern operating systems with different associated evaluation depending on the context of application:

- *Click(s)*: Evaluate the spatial location of the pointer, the pushed button(s) and click type (single or double) on a mouse as the pointing device to determine if responsive behavior applies in the given context.
- *Drag & Drop*[16]: Evaluates source and target locations and only rarely the distance between the two. Again the respective locations as the action's context determine the interpretation and potential ensuing system operations.
- *Select*: Is performed through derivations of clicking and drag & drop[17]. Its purpose is to form a temporary group of selected objects. This group is handled like a single object for ensuing user actions. Responsive behavior then applies to all selected objects (typically in order of selection).

Drag&drop is the main function by which digital documents are moved and thus positioned within desktop environments. Different conventions of how a drag&drop action is processed exist in modern operating systems, based on source and target locations. For instance, a file dragged over a folder icon on the same storage device will be moved there. If the folder is on a different storage device, however, the file will be copied. Another well known convention is that function icons representing applications, will attempt to open objects dragged onto them.

The function behind an icon expresses a *convention* within the system and as such can be easily learned. Conventions can very generally be described as acquired customs of

16 Drag&drop describes the action of pressing down a mouse button with the cursor hovering over a specific point (usually an object) and then while keeping the button pushed, dragging the pointer to a new position where the button is released.

17 An object can be selected by a single click and further objects added by holding either the shift or control keys. Alternatively clicking on free space and dragging the pointer to another location will open a transparent selection rectangle, selecting all objects it completely covers upon release of the mouse button.

a specific society that apply to specific contexts. They can serve multiple purposes, but mainly represent mental shortcuts based on sensory recognition of established patterns like gestures or signs. As shortcuts they allow for others to quickly determine the nature of a situation in a known environment. While conventions usually apply to every person of an established society, customs are more personal and can apply to smaller groups like a family or even a single individual. Customs and conventions have been important parts of human life for a long time, reaching back to tribal life where they are the foundation of trust. A stranger can be easily identified, if not by his looks, then at least by his ignorance towards local customs.

The basic concept holds true in modern times: Conventions define clearly expected behavior and thus may take the status of social rules. The 'female' sign on a restroom door expresses such a generally accepted rule and would surely provoke angry reactions, should a man try to enter. Conventions, as defined schematics of appropriate behavior, do not only apply to human behavior however. They also influence our perception of (media) objects and their associated attributes depending on changes to the object's appearance or their position.

Placing an object into the garbage bin signifies to everyone 'in the know' that it can be disposed off. Here, the custom and its interpretation is tied to both the action of 'throwing something away' and the rubbish bin, as a container of garbage. Hence, even placing a perfectly fresh piece of pizza into the trash bin, immediately changes our perception of its edibility. Essentially changing its spatial context affects its semantic context, turning the slice from food into inedible rubbish. A native tribesman, who does not understand the associated convention, would probably cause revulsion among more 'civilized' observers, if he ate the thrown-away slice.

In our modern society, with large numbers of humans living and working together, practically any sector of human life has been conventionalized. This includes knowledge work and also applies to both digital and analog media. Within this thesis, the term convention describes a socialized codification of an agreed understanding into a specific behavioral context. *Spatial conventions* are reflected by a defined combination of human actions in space that lead to a specific spatial setup of objects.

In relation to functional icons, conventions exist on two levels. The more immediate convention lies in operations a specific icon represents and will perform. Secondly, established analog office conventions first described by (Smith et al. 1982a) coded into icons have spawned their own digital conventions (Smith et al. 1982b). For example, printing functionalities are next to always indicated by a printer symbol and despite the practical abandonment of the floppy disk format, their image still signifies 'saving' files.

5.1.2. Data Icons – Documents and Folders

Data icons are objects of manipulation, whose contents are important in work contexts. Here, the Xerox scientists describe *documents*, *folders* and record files, which can be understood as simple databases (Smith et al. 1982a, Smith et al. 1982b). Documents are media objects and the main carriers of information, usually represented as named files within the system. Contents depend on the type of media object like text, sounds or graphics. Documents are *displayed* and *edited* in what Smith et al. termed (*application*) *windows*. Editing refers to any application of primary media functions on the level of contents. Not every file is a document, but every document is a file object.

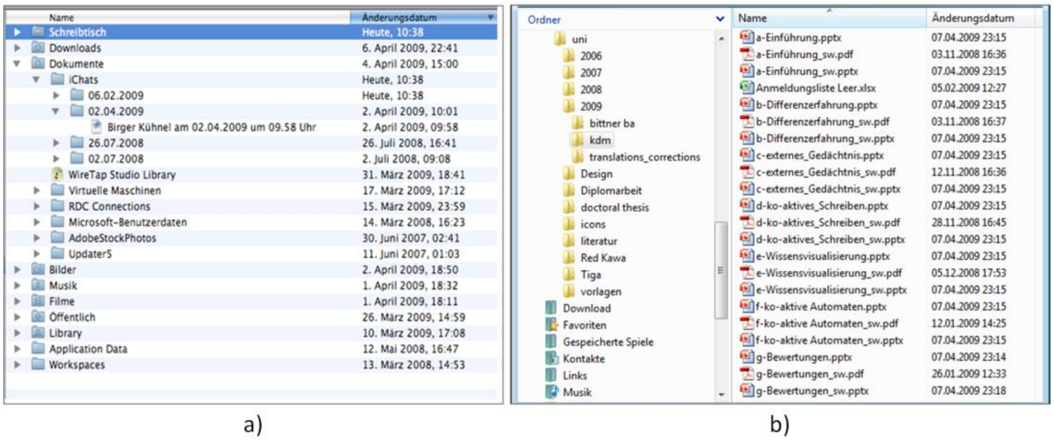


Figure 8: Index view of folders in Mac OS X (a) and Windows Vista (b)

Folders are manually defined and labeled containers, grouping documents and other folders by *inclusion*, without limitations as to numbers or size except those imposed by the system. They are typically displayed alpha-numerically sorted in a collapsible and expandable hierarchical index (Figure 8). Apple's Mac OS X additionally uses a column view in finder, where for each selected sub folder a new column is added representing the current path from left to right (Figure 9).

Folders are objects with attributes and can be positioned anywhere in the index structure including the desktop. Within folders, files are commonly represented in form of a *tabular list* that can be sorted after object attributes like name, size or file type. Their sorting allows quickly locating media objects with certain attribute values within a folder. This is meant to remind users of analog filing cabinets, with the added advantage of a much quicker ability to change the sorting depending on the current needs. A further difference is that, instead of content-related attributes, only external and very general attributes are available for sorting in the explorer view. This is because values like file-size can be computed easily, while in a crime novel "name of victims" cannot be as easily determined. For document searches, simple computed attributes, seem less intuitive than self-assigned ones like file-name or keywords. Displaying objects in list form persists in modern contexts, even in (the) Web 2.0, where folder locations are principally irrelevant (Erren 2007, Erren & Keil 2007a).

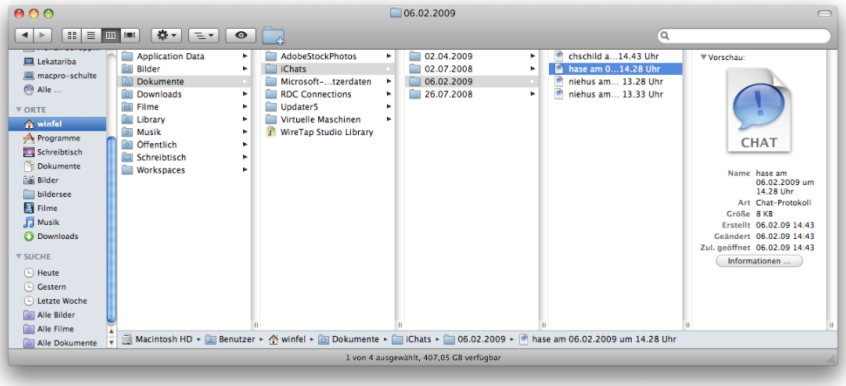


Figure 9: Apple Finder in its standard column view

5.2. Arrangement Structures in Digital Media

The previous analysis served the purpose of introducing the desktop as the spatial environment in modern (graphical) operating systems, with the respectively possible actions and the objects they can be performed on. Within this environment it seems that arrangement of digital media takes place mainly on three levels, namely that of *contents*, the *desktop* and that of *folder structures*. Among these, desktop and folders are concepts that compare to the spatial handling of documents in the real world. They have been featured well in research of digital media organization, specifically in relation to the ever present purposes of finding and reminding (Henderson 2005, Nardi & Barreau 1997, Teevan et al. 2004). The research suggests that folders are mainly used for long-term storing and categorization purposes, while the desktop houses objects currently relevant to a process that need to be accessed day to day. Of the latter objects at least those deemed potentially relevant for future processes, will at some point in time be saved to folders.

5.2.1. Folder based Arrangement

The storage purpose of folders is different from just archiving, though they can be used this way. This is underlined by (Henderson 2005), who describes that folder names, used in knowledge work contexts, can be categorized in relation to ten categories. She points out that folders indicate classifications, associated with the included objects. Since folders can be easily renamed and rearranged within the folder tree, storing objects is much more flexible and dynamic than analog archiving. Hence, folder structures are often created even for immediate and short term projects (cp. Jones et al. 2005). What a folder and by extension the included objects represent (associated meaning), is established mainly by folder-name and location in relation to other folders. Hence, each folder according to (Henderson 2005) acts as a semantic classification of the contained items. Since folders basically work as containers, a folder path is defined as a containment chain or *path* from a chosen top-most to an equally chosen lowest level sub-element. Along these paths the expressed semantic meaning is most simply the sum of respectively used categorizations. For instance, one might start with a very general folder like "music", which contains a folder called "rock", which contains music albums by different rock bands. The arrangement in the folder tree is not necessarily a traditional hierarchy, where elements on a specific depth level share a common meaning or relation. To reuse the previous example, the folder "rock music" is a level 3 folder under a local hard drive "c:\", just like a "system32" under the "windows" folder. Despite the same depth level, the importance and meaning of each folder is different. Without "system32" the operating system cannot run, while many people could do without "rock music".

Folders enable personalized storing of media objects simply by creating, arranging and naming. Hence, they become the standard type of arrangement employed in everyday work, using a combination of *inclusion*, *order* and *paths*. Because of the mixed use of folders, both to store media objects in short- and long-term working processes, finding relevant documents has a high priority. Modern operating systems typically offer basic and advanced search functions, which can scan attributes of digital file documents or even text based contents.

Despite the existence of these functions, studies have shown that initially in both graphical and non-graphical user interfaces, people prefer location based searching[18] over a tool based one (Nardi & Barreau 1997, Teevan et al. 2004). The researchers found that people often had problems specifying attributes of documents they were searching for, including the relatively important "name". The majority of participants therefore resorted to step-wise location based searches, starting with just a hunch at the related context of meaning represented by folders, tied to a position, in which the document might be stored on the computer. What makes this process difficult is that the presented alpha-numeric order of folders, in the folder tree, is only based on names and therefore does not often carry specific meaning. It simply serves the purpose of improving access. It is also unclear how current improvements in speed and content based accuracy of search functions affect this behavior.

The "smart folders" of Apple operating systems do not constitute active arrangement, as they simply visualize pointers towards the results of an associated search query.

5.2.2. Desktop based Arrangement – Grids

On the desktop, the icons representing media objects can be freely arranged on a two dimensional pane. By default, the mentioned *grid* invisibly parts the desktop area into a matrix of equally sized cells, each of which can hold one icon and its label. The grid only becomes apparent trough interaction with the desktop. When icons are positioned, they will always 'snap' to the closest cell when 'dropped' on an empty space. It is possible to deactivate the standard function of icons snapping to the grid, both on the desktop and in folders allowing for actual free positioning (Figure 10).

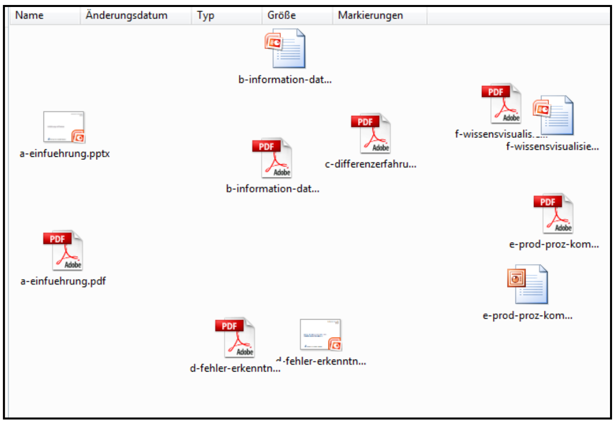


Figure 10: Spatial arrangement in Windows' folders and the Desktop

18 A file's location here is its path from parent folders up to its root storage device.

The desktop can accommodate *distance* arrangements and even *ordering* to a certain degree, but is unsuitable for inclusion. Order requires manually building and changing sequences or alternatively calling a sorting function on all icons on the desktop, which may not be intended. Inclusion would only work in relation to so-called *desktop wallpapers*. These are *images* that can be put in the background of the displayed icons on the desktop itself. However, any manipulation regarding regions or other objects on these wallpaper images, would require editing or recreating the image plus a reload. In terms of the arrangement process these are media discontinuities. Digital desktops do not seem all that attractive for arrangements then. Even the grid is nothing but a set of coordinates; no meaning or functionality is tied to specific cells on the level of the operating system. Its primary function is to keep icons accessible, that could otherwise overlap or even cover each other entirely. Hence, the most common arrangements on the desktop are groups, formed solely by spatial closeness of icons on the grid. These groups part the desktop space into noticeable *regions* (Ravasio et al. 2004). Each of these spatial regions carries informal meaning and may serve a manual reminder function, similar to the situation on real world desks. For instance, a group may contain commonly needed applications for editing media objects.

However, the concept of a grid can also be transformed into a unique way of semantic arrangement for knowledge work contexts. A grid consisting of horizontal and vertical vectors forms a *matrix* of intersecting cells. When each row and column of this matrix carries a specifically assigned meaning, inner cells, as respective meeting points, express the semantic principle of *combination*. Although, they have identified the other four types of arrangement, the concept of combination is not mentioned as a spatial means to express object relations in (Richards 1984, Horton 1994, Engelhardt 2002).

5.2.3. Combination as an Arrangement Type

In its most basic form the term combination can be defined as taking two previously independent things and putting or mixing them together so that the result represents something new. It may still be possible to identify the individual components, but additional and specific (informational) value can be derived from the combined state (cp. Figure 11)[19]. Matrices are formed from sets of overlapping horizontal and vertical vectors, each comprising a number of cells, arranged to form a rectangle. Hence, there are identical numbers of horizontal and identical numbers of vertical cells in a matrix for all vectors. By counting the number of columns (vertical vectors) against the number of rows (horizontal vectors) one can describe the size of a matrix; e.g. Figure 11 is a 3x3 matrix (counting headers).

Figure 11: Example of a simple combination matrix for hot drinks[20]

The meeting point of any two vectors and the associated information, describes the specific result(s) of their combination. In some matrices, a specific combination may yield several either related or alternate results. Thus, while the number of possible combinations in a matrix is defined by the multiplied numbers of non-header rows and columns, this does not necessarily reflect the number of existing results. In digital media, matrices can be implemented easily, based on the ever present tables. By contrast, matrices do not really occur as arrangements of artifacts in analog environments, outside of media carriers. One reason for that may lie in the fact that artifacts are limited and hence will be used for the actual combinations, while a matrix is used for documenting what has been combined and the respective results. Despite matrices constituting a distinct arrangement type in digital media, one must

19 It is also possible to express combination by paths visualized as arrows from two independent sources that lead to a common target. However, displaying even the results of a simple 4x4 matrix this way leads to quite a complex graph. Matrices offer better overview and manipulability.

20 Photos from en.wikipedia.com (*artists: Robert Knapp, KBh3rd*) and freedigitalphotos.net (*artist: Francesco Marino*)

admit that the desktop grid is not a matrix. As mentioned, the grid and its cells are invisible and there is no information perceivably associated with vectors.

5.2.4. Semantic Attributes and the Concept of Layers

The semantic attributes that are cognitively associated with positions in digital media arrangements on the desktop and folders are equally similar to those used in analog media arrangements (cp. Kwasnik 1989, Henderson 2005). Both authors note attributes in the areas of work context (e.g. *task*), document (e.g. *topic*), relevance (e.g. *keep*), time (e.g. *currency*) and person (e.g. *author*). Digital folders allow combining two or even three of these attributes as their name. This might be seen as added complexity information wise. The fact that the associated attributes on the desktop remain hidden, just like they do in arrangements on people's desks, makes the enterprise of expressing more complex relations nearly impossible. Remembering multiple associated bits of information for each implicitly defined region on the desktop, is very difficult without helpful clues. A simple legend could already help to remedy this problem in part.

Theoretically, such a legend could be realized through graphical and textual labels on desktop wallpapers. However, as mentioned, wallpapers are only static images and thus do not allow manipulations of perceivable elements. Any necessary change to the ground structure would therefore result in additional work for the user, to edit or exchange the image. Especially in highly dynamic knowledge work contexts with constant adaptions this would not be feasible. A more substantial mechanic, where any kind of media object, including graphical and textual elements, can be arranged on at least the fore- and background, would be necessary to go beyond the scope of analog media.

This is at least partly realized in vector graphics or diagramming software like Omni Group's Omnigraffle or Microsoft Visio. These applications allow for complex digital object arrangements on so-called *layers*. Principally, each layer in these applications can act as a transparent, two dimensional pane, on which an indefinite number of objects can be positioned[21]. Usually at least graphical primitives[22] and text boxes are supported media objects in these arrangements. This means that multiple semantic relations can be expressed through positioning and labeling digital media objects

21 Diagram software like Microsoft Visio often assigns each object to an individual layer. The only way to handle objects as if they were on a common layer is to manually group them.

22 Primitives are atomic vector shapes like points, lines, rectangles, circles etc. or composites.

across layers. It is this benefit of combining several different levels of information visually, which makes *representations* so capable for transporting and communicating information quickly and accurately (Chou 2009, Larkin & Simon 1987, Tufte 1983, Tufte 1990).

When speaking of representations in knowledge work, most people refer to diagrams and charts. The problem is that due to the wide range of possible definitions of the terms it is hard to exactly say whether a representation is a diagram or isn't. A simple definition could be that diagrams are (computed) visualizations of data. Despite being correct in some contexts, the definition for instance does not apply to *UML diagrams,* which are manually constructed from previously unstructured information. For this thesis the terms of *visualization* and *illustration* seem better fit to distinguish different types of digital representations. Both share the concept of utilizing spatial dimensions through an arrangement of artifacts to convey information.

Visualizations are generated from data through defined parameters and algorithms with the purpose of finding and displaying patterns and relations. The final result is often a static image relevant to a specific context. Even when adjustments are possible, the underlying (evaluated) data cannot be manipulated without falsifying it. Many diagrams thus can be described as visualizations.

Illustrations are manually constructed from graphical and textual elements in order to communicate specific bits of information. The resulting images are static and cannot be easily expanded or changed. The less metaphoric or pictorial illustrations are, the more they tend to look like diagrammatic visualizations.

Both kinds of representation allow for making complex and highly expressive visual statements, from which one may deduce new information. However, due to their static nature, they are different from the dynamic, always adjustable arrangements.

(Larkin & Simon 1987) show that representations (called 'diagrams' in their paper) can be more efficient for solving problems than sequentially represented textual information. They offer three explanations:

- Graphical representations can group all necessary relational information in a specific problem solving context.
- Just by the position of an element multiple unique bits of information about it and its relations to other elements can be inferred.
- Representations support logical inferences.

Similarly, it can be derived from Tufte's deliberations that the reason for the high degree of expressiveness attributed to complex representations, lies in mapping multiple strains of information to the available spatial dimensions (Tufte 1983: p.40, Tufte 1990: p.24). Despite being limited to two or three dimensions in space, it is possible to have a larger number of information strains within a single representation. Digital media can employ layers for this purpose, each enriching the space with a specific arrangement type and respectively expressed information (see chapter 6.6). Object orientation furthermore enables the use of legends and labels as descriptive objects in each context or even as perceivable attributes.

5.3. Digital Space, Context and Arrangement Requirements

Digital two dimensional spaces are usually rectangular in shape and can be described as a set of horizontal and vertical coordinates. Without any supportive visual elements regarding the employed arrangement types, a *distance* based arrangement is the most likely alternative. While precise distance can be easily measured by the system, the same feat is difficult for a human 'arranger' as long as no unit and respective interpretation are provided. Another problem in digital media is that digital documents of the same file type all carry the same icon. On the desktop or even in folders they often cannot be distinguished until opened (or preview), without at least one label reflecting a unique attribute (usually the name). In analog environments, by contrast, media objects are visually more unique and often have an arrangement state where portions of their contents are immediately perceivable. Put simply: Placing an open book on a desk provides direct access to up to two pages of content. For the arrangement itself that means other media like a related paper can be placed next to the book with the most relevant page on top. It is even possible through text markers to highlight related passages on the open pages of the two documents to show a relationship in a directly discernible and debatable way. The comparable situation in digital media, namely keeping media objects opened and trying to arrange the respective windows, is often impossible due to constraints of screen size.

The alternative is arranging the icons representing complex media objects in relation to a provided visual *context* – most simply a descriptive background – that provides an immediate, yet precise description of the objects' specific or interrelated meaning (cp. Sauermann et al. 2005). Such a background context can consist of objects that make the employed arrangement type(s) perceivable. These objects make the context a dynamically arrangable legend for the arrangement's semantic interpretation. For instance, by drawing a rectangle labeled "To Do" on the desktop, a region is marked and information is mapped to it. With such markers semantic arrangement becomes *measurable* and *communicable*. In contrast to an analog desk, where a stack is not typically labeled, a visualized mapping allows other users to understand what is expressed by the arrangement. Hence, the mechanism allows to clearly distinguish multiple types of arrangement by the respectively provided graphical context. To express and measure distance, an axis seems appropriate; a single arrow besides a sorting criterion may be enough to indicate order, regions can be marked by surface primitives, paths by edges and combination by a matrix. Each of these graphical helpers – subsequently referred to as *mapping markers* – enables to clarify the mapping of information to spatial dimensions (see chapter 6.5 ff.).

5.3.1. Customs and Conventions – Evaluation of Arrangements

Customs and conventions are also parts of analog environments, but do not offer the same flexibility or inherent support functionality that digital media can provide. This support stems from a purposeful evaluation of the arrangement and spatial operations – i.e. secondary media functions – triggering responsive behavior that leads to either expected or unexpected results. From these results of system responses, respective users potentially gain differential experience.

Responsive behavior requires a constant processing of a user's inputs, in relation to defined conditions, i.e. an object being moved into a perceivable region. In relation to arrangements of digital media objects, I prefer speaking of *evaluation*. Manipulations of an object's position can affect the expressed spatial semantic relation to other objects. Hence, a re-evaluation of these objects may be required, too. Since position often expresses a (personal) custom, the coded responses are the individual analogue of conventions as cognitive and manipulation shortcuts. For instance, a region on the desktop signifying documents that need to be worked on, by positional placement, already acts as a minimal reminder. Responsive behavior allows setting up automatic pop-up reminders for the respectively positioned objects, based on an evaluation of a 'due date' attribute. The added complexity of evaluation in overlay arrangements is covered in chapter 6.6.4.

5.4. Conclusion

The creation and use of these kinds of conventions requires a deeper understanding of what a specific arrangement context comprises. Due to the systematic nature of digital media it seems necessary to identify a standard set of *arrangement types* and *action schemes* able to express personal as well as common conventions through evaluations and responsive behavior in arrangement and interpretation contexts.

Arrangement Type	Function
Distance	Semantic closeness depicted through spatial closeness
Order	Semantic rank depicted through sectioned order
Inclusion	Semantic class/category depicted through inclusion
Combination	Semantic combination depicted through crossing vectors
Paths	Cognitive semantic connection of related work steps

Table 2: Overview of identified arrangement types in digital environments

Hence chapter 6 will examine the identified five arrangement types (Table 2) from our analysis of both analog and digital working environments and put them into a sensible construction-oriented framework. This will include a deeper look at the potential of responsive evaluations of respective semantic arrangements, their overlay (chapter 6.6) and introduce a basic set of action schemes (chapter 6.8).

6. Semantic Positioning

"New ideas pass through three periods: 1) It can't be done. 2) It probably can be done, but it's not worth doing. 3) I knew it was a good idea all along!"

Arthur C. Clarke (1917-2008)

This thesis is based on the simple fact that *information* can be expressed spatially (chapters 4 and 5). We have seen that in performing knowledge work, humans necessarily create arrangements of media objects, be it in analog or digital environments. This especially applies to problem solving situations of a certain complexity. The reason is that humans need to individually structure and then restructure a problem to personally understand and solve it. Parts of these arrangements are stable over multiple processes, because they constitute conventions or customs. Other parts are more dynamic, assigning only a current semantic meaning, as perceived relations between the respective media objects are still being questioned, checked and ultimately solidified. Considering this, it becomes clear that media objects in arrangements, both individually and in (spatial) relation to others, support gaining differential experience. Both the objects themselves and their overall arrangement, serve as an external memory. As the arrangement reflects current progress, complex problem solving processes can be continued directly from the last point of insight and understanding. For this reason, arrangements are not only uniquely qualified to support knowledge work processes, they are a necessity.

Arrangements are the natural solution to organizing and managing a number of different artifacts as sources of information. Their purpose is that of active perception, i.e. gaining an overview of the assembled items, formulate and test hypotheses and relations, filter out irrelevant artifacts and finally to develop a verifiable understanding of a given context. The progressive and easy self-structuring of knowledge objects can start very simply, but still reach a high degree of complexity, when more and more information dimensions are mapped to space during the learning process. Due to arrangements being based on position, evaluation is also comparably easy. Each position in the arrangement has a semantic connotation, i.e. related information mapped to it.

This is where the titular notion of this thesis – *Semantic Positioning* – comes into play. Most basically I subsume the discovered set of distinct basic spatial arrangements and actions humans typically employ in expressing, ordering and structuring knowledge spatially under this term. *Semantic Positioning* was first introduced to the scientific community in a paper by (Erren & Keil 2006). In that publication, no specific definition of the term was provided. Instead, it was simply used as a synonym for a *visual* semantic structuring of knowledge media. The reason for calling it *positioning* instead of *placement* is that in common usage of the words, *placing* an object somewhere can happen without a reason behind it; the object has simply gained a place in space. *Positioning* is a more careful endeavor, where a place for an object is chosen in relation to other objects; the assigned position has a *purpose* and by extension is *meaningful*. Over time, the concept of Semantic Positioning developed into the more concrete idea presented in this thesis, which was already evident in a later publication (Erren 2007):

"Semantic positioning describes the process of arranging objects graphically with the requirement that objects already gain meaning solely by their position in the construct."

Despite being much closer to my current understanding of what Semantic Positioning comprises, the term "construct" was regrettably a suboptimal choice, referring rather to something build to a static shape from meaningless parts (e.g. bricks). Also, this early definition still misses a distinction of the terms context and materials. *Context* describes any objects and mapping markers arranged purely to map information to space and/or evaluate it. *Materials* are the specific objects one works with. Arranging materials in relation to an arranged context provides perceivable semantic meaning.

This simple explanation of Semantic Positioning might at first seem reminiscent of background/foreground arrangements like the knowledge maps of (Burkhard 2005). Similarly, in these, a background provides contextual information to graphical objects perceived to be in the foreground. Burkhard's goal is to achieve a more efficient knowledge transfer by employing knowledge map visualizations. Their cited benefit is that of any map, namely offering overview and detailed information depending on how closely a person examines the map. (Burkhard 2005) provides the example of a tube map adapted as a plan of project milestones, represented by stations, and the connecting sub-lines depicting relevant target groups in the foreground. In the background tags, colored areas and symbols are provided for descriptions, grouping, dates or instructions. This visualization structure is a great example of the successful application of a metaphor, illustrating relevant target groups for each milestone. Despite the benefits of providing overview over project status and dependencies, Burkhard's knowledge maps remain static illustrations, where back- and foreground are only *perceived* as distinct.

While knowledge maps are static, arrangement is a process of gaining understanding by *active perception*. This takes place both on the contextual parts of the arrangement, as well as the positions of material parts (as content providers). Trying to express understanding in a complex context requires iterations of arrangement and discussions of where an object should be positioned and why. Thus, both the arrangement of materials and context objects has to be adjusted at times. Respective changes often become necessary to reflect new insights[23]. Even upon solving a problem the arrangement is not finished per se, as it typically remains open to later improvements or additions or extensions. For instance, the matrix in Figure 12 can be easily expanded by adding further systems or new/different properties of communities. In relation to Semantic Positioning this means, a dynamic working environment adaptable over time is a requirement.

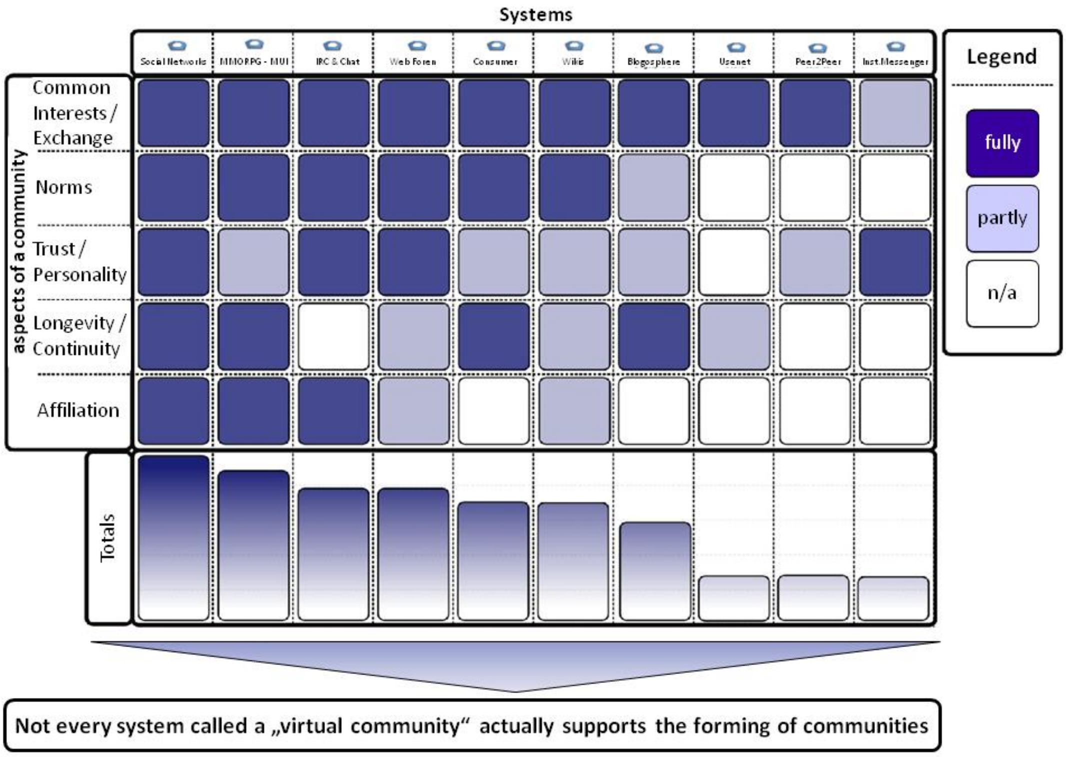


Figure 12: Matrix can be easily expanded to cover further systems by adding columns

23 For instance, an adjustment is necessary, if no fitting semantic position within the depicted context can be found for a relevant object.

Therefore, employing the term 'graphically' instead of 'spatially' in the above definition from (Erren 2007) was not an optimal choice either. The difference of these terms was explained in chapter 5, illustrations being graphical and static compared to arrangements as spatial and dynamic. Strangely, that doesn't mean graphical means can be excluded from digital arrangements. In fact, the underlying context as the map between information and space can contain detailed graphical elements (cp. Figure 13). Overall, the definition from 2007 was formulated to describe the aptness of Semantic Positioning for communicating knowledge. With this purpose in mind, the goal of semantic arrangements shifted towards a final product as a depiction of knowledge that could be communicated.

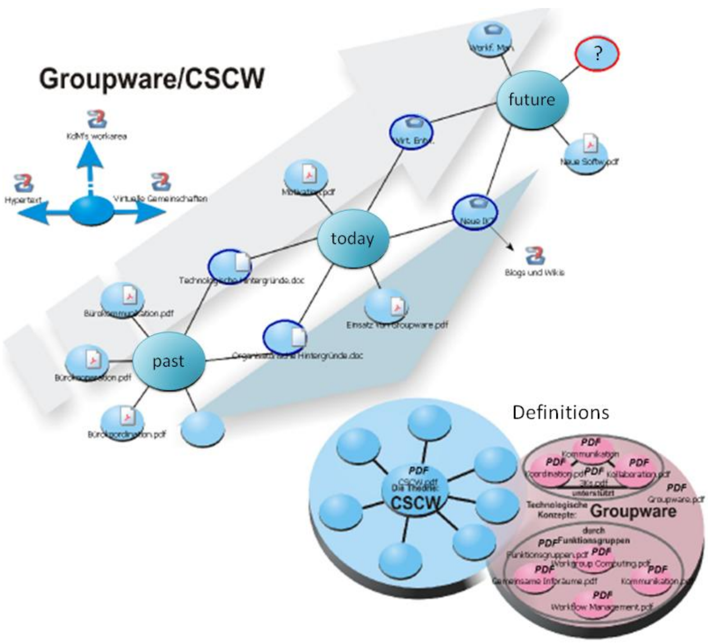


Figure 13: Example of a graphical background in a simple Semantic Positioning arrangement

Arrangement entails more than just an *organization* of knowledge artifacts, as a simple grouping, based, typically, on a single common property. It may provide a very first basic overview over available objects. Since relations between objects have at this level not been explored, a recipient can only hardly assess the completeness or correctness of the artifact grouping. Semantic Positioning is *knowledge structuring*; i.e. it allows a spatial arrangement based on a multitude of applicable contents and attributes, depiction of complex layered relations, as well as non-sequential construction and exploration. As the respective information is visibly mapped to space, recipients or cooperation partners can provide very immediate feedback on perceived imprecisions, mistakes of placement or missing objects. Knowledge organization and structuring are complimentary and thus may be used in combination for problem solving processes.

The goal of Semantic Positioning is to *support media object based knowledge work*, by enabling *structured* and *meaningful arrangements* of digital media and by extension gaining differential experience, understanding and finally solving problems. Under this perspective, it is important to recognize, first and foremost, what position does express in a specific context and systematically break this meaning down to one or more attributes and associated conventions. Objects in semantic spatial arrangements carry a wealth of associated attributes that can be evaluated and written in relation to information mapped to space. This enables a computer scientist to develop evaluations, tied to responsive behavior, that provide objective benefits to knowledge workers, i.e. support can be delivered either by *reducing necessary actions* to reach a goal or *extending differential experience* (cp. chapter 3.2). Summarizing, the definition of Semantic Positioning needs to be rendered more precisely for the purpose of this thesis:

Definition: *Semantic Positioning means that (media) objects gain semantic meaning, by their position in a perceivable context, alone. The context, as a dynamically adjustable arrangement of (media) objects, determines the semantic interpretation of position by mapping information dimensions to space. This allows the definition of perceivable spatial semantic relations between objects by their relative positioning.*

Semantic Positioning arrangements act as an external memory even for long term operations and can be extended over time with new media objects. The mentioned, *semantic interpretation* refers to understanding how and what information is associated with spatial positions. The above definition is a direct reference to the previous discussion of spatial differential experience and active perception. In order to incorporate evaluation and the coding of conventions to the arrangements the following additions can be made:

Specification: *Object position and user actions, influencing the arrangement, can be evaluated by an underlying model, which interprets spatial conventions and action schemes. Evaluations are based on the attribute of position, but may include further object properties. In an underlying model, conditions can be defined that cause system responses. This way objects can be assigned attributes that fit their position and vice versa, essentially a bi-directional processing.*

There are several new terms in the specification that require further explanation. First of all, the *underlying evaluation model* refers to a coded processing model, as the computerized expression of the spatial information mapping. It also implements conventions, within the arrangement's specific context. In most cases, the model ties evaluations to absolute spatial coordinates as meaningful positions within the working context. This is best explained by revisiting a simple example from chapter 5. A file is moved from a shared editing space to a defined region of private documents, visualized as a square in that space. On principal the 'move' operation only changes the object's position as a pair of coordinate values. When predefined conditions are met, corresponding evaluations and system operations take place, whose effects are reflected to the user. The evaluation model ensures that the coordinates, belonging to the region's area, are recognized as 'different' from the rest of the room. The visibly expressed convention, that the objects in the region can only be accessed by the region's owner, is technically realized by conditions within the evaluation model. If a file is moved inside the region, the evaluation model calls responsive behavior into action. Based on this, a wealth of object attributes, in this case access rights, are changed, to reflect the object's new positional and related semantic state. The model also needs to cater for the situation, when objects are moved out of the region, ceasing to be 'private'.

Since system reactions are directly caused by user actions, active perception takes place, as new (relevant) information is immediately reflected as differential experience. Evaluation models are tied to a context, but it is possible in Semantic Positioning to exchange the context layer (see chapter 7.3). Due to the distinct possible ways of mapping information to space, an otherwise identical movement action will be evaluated differently for the old versus the new context. For instance, with the same movement from coordinates (a,b) to (x,y) an object is put into a region (*inclusion*) in one context and in another positioned closely besides another object (*distance*). *Conditions* can on principal evaluate, not just the attribute of position, but available (system) attributes, including status flags or even attributes derived from contents. Though responsiveness could apply to any object in the manipulation space, in most cases it remains centered on the directly moved objects.

The next notion from the new definition that requires explanation is that of *bidirectional processing*. It means that attributes can be evaluated to define an object's semantic position or vice versa that attribute values are changed based on an assigned position. In generated diagrams or even simulations every process has three steps. A specific input of data, a processing or calculation stage and the representation of the results. Since data are formalized information, produced as the result of measuring, they cannot be changed. Similarly, altering the results would defy the purpose of the processing. Any action or manipulation by the user can only apply to the processing that affects how data are transformed into the output presentation. Semantic spatial arrangements are not based on data, but on media objects and their contents and attributes, meaning any attribute and object could be exchanged. Media objects that appear relevant to the arrangement at first may later be deleted or exchanged. Often, contents will have to be adjusted or at least marked up to fit the presented problem. Lastly, attributes have to be changed to reflect new insights. The only limitations stem from rules that have been defined for the working environment, like demanding that certain documents remain in the arrangement with their contents unchanged. Processing can take place on two levels then: First, movement actions by a user are processed by the evaluation model, causing responsive behavior. Secondly, the attributes of arranged objects can be analyzed, for instance, to assign an initial position, when added to a new space. The same helpful concept applies when a context is exchanged (Figure 14). The context, in which a spatial arrangement takes place, is highly important; it defines the precise semantic interpretation of position, which may differ strongly from scenario to scenario.

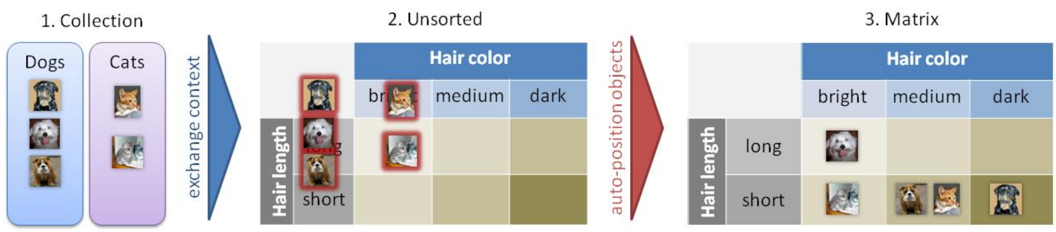


Figure 14: Objects assume fitting positions, based on their attributes, after the context is exchanged

In the following sections, I will detail, which kind of information the arrangement types are suited to express and how each is to be used and interpreted. The respective insights comprise a basic building stock for evaluations of spatial semantic arrangements in a two dimensional digital knowledge space. Semantic Positioning makes use of evaluations to map individual and general customs, in the form of action schemes, to spatial positions. Even in complex *overlay-arrangements*, these evaluations are possible, albeit with the need of ensuring compatibility across the system responses associated with a specific position or arrangement state. Hence, semantic arrangements might support communication, but they will definitely bind logic consequences to a user's arrangement actions, enabling active perception.

6.1. Hypotheses

My research is strongly motivated by my own interest in furthering the quality of the digital workplace and providing support to knowledge work and learning processes. Digital desktops often seem to offer less freedom regarding the arrangement of artifacts, compared to traditional desks (see chapters 4 and 5). This is, however, simply a technical challenge, which can be remedied to support scenarios that more clearly depend on arrangement than others[24]. Essentially defining and distinguishing sensible arrangement types and emphasizing them as a basic language or setup for knowledge work, can already be regarded as an improvement over analog media by itself. However, this effect is difficult to measure, since the necessary tools do not yet exist. What can be analyzed is how Semantic Positioning fares in providing more specific or expansive differential experience or reducing necessary user actions to reach a desired result. The former is specific support for mainly dynamic knowledge work contexts, where a problem has yet to be solved, while the latter helps with steady processes in arrangements tied to conventions. Both types of support require the identification of sensible responsive functionality, based on the arrangement of working materials, like secondary media functions applying to spatial conventions. Hence I propose the following basic hypothesis:

Hypothesis 1*: It is possible to support knowledge work and e-learning by Semantic Positioning, as the semantic spatial arrangement of (media) objects in a concrete context. Support can be offered by reducing necessary actions to reach a desired result or expanding differential experience. These benefits are often based on responsive functionality, implemented in specific evaluation models.*

In previous publications (e.g. Erren & Keil 2007), the communicative aspect of Semantic Positioning was the main focus, different from this thesis. Still, a respective hypothesis referenced the ability of formulating new and interesting arrangement-based learning scenarios with Semantic Positioning. A few examples like pyramid discussions, route plans or the Medi@Thing concept, were provided as first indications of proof (Erren 2007, Erren & Keil 2007a, Erren & Keil 2007b). In how far

24 Writing an essay on a specific topic for instance, is an arrangement process on the level of finding, assembling, reviewing, selecting and relating appropriate information sources, as well as bringing them into a sensible written form. Still, when compared to a puzzle game as a problem solving process, where each piece has a specific interconnected place in the overall structure, the latter, though having a static solution, is more readily accepted as spatial arrangement by laymen.

learning scenarios, based on semantic spatial arrangements, are an improvement over those without, a clear answer could not be provided so far. Therefore, in chapter 7 hypothesis 1 will be tested in relation to three scenarios, demonstrating advantages of employing Semantic Positioning in learning-based knowledge work scenarios, compared to traditional means of accomplishing set goals.

My second hypothesis focuses more closely on how benefits for reducing necessary actions or extending differential experience can be realized. The basic means to achieve these goals in digital semantic spatial arrangements is through *overlay*. Overlay refers to using multiple arrangement types and different kinds of information in *conjunction*, within a single spatial arrangement by stacking transparent layers. This means, that any specific position, like a coordinate in space, can be interpreted in relation to several bits of associated information. The same complexity applies to conditions and expressed conventions within evaluation models. A single user action may meet more than one condition tied to responsive behavior in an overlay setting and thus reach more than one effect by a single action. It can be logically concluded, that overlays enable the expression of more complex relations and conventions. This is summarized in my second hypothesis:

Hypothesis 2*: Overlays of mapping markers and the respective information dimensions, in semantic spatial arrangements, may deliver a higher complexity of expressible semantic meaning, than the sum of their individual interpretations. This enables the support of knowledge work described in hypothesis 1.*

The term *information space* describes a conceptual space, holding all possibly relevant bits of information, for a given context, in unrelated form. Selecting a subset of related information from this space, that can be matched to a single arrangement type (spatial dimension), is called *defining an information dimension*. An overlay of different arrangement types produces specific requirements, to ensure compatibility in the evaluation model, conditions and responsive behavior. A conflict can occur if at a specific position in the arrangement, two separate conditions with opposed results apply. For instance, if the evaluation model wants to change an object's color simultaneously to green and red, a processing conflict occurs. These conflicts need to be avoided for efficient work contexts. Each of the three scenarios in chapter 7 proves aspects of hypothesis 2.

The last aspect of Semantic Positioning in this thesis, for which I will formulate a hypothesis, is the mentioned exchange of the context in its arranged state. By this I refer to the meaningful 'background' in front of which media objects as materials have been carefully positioned. Since evaluation models are tied to a specific context, exchanging it affects both the evaluation model and media objects at their assigned positions:

Hypothesis 3*: There are scenarios, where the exchange of the arrangement context, including the evaluation model, is sensible in Semantic Positioning. In those cases, there is an associated benefit other than the necessity, of abolishing a previously constructed context, because it has become obsolete under the most recently gained understanding of the problem (area).*

Since exchanging the complete context of an arrangement, including the evaluation model, is not practical in every situation, chapter 7.2 deals specifically with a scenario demonstrating where it is and where a clear benefit can be demonstrated.

Before we come to the Semantic Positioning Framework, it is necessary to understand the terms of *space*, *objects*, *attributes* and *context*. Hence, the following chapter 6.2 will establish a few of the basic requirements regarding spatial arrangements in digital media and a few necessary constraints for Semantic Positioning and the respective framework.

6.2. Requirements: Space and Object Orientation

Space is central to any form of arrangement, because it constitutes the environment in which position can be interpreted. Without space, there is no place to perceive, position and manipulate artifacts. Any empty space, according to (Card 2003) has a *metric structure*, no matter if it extends into infinity or has defined borders of some kind. Most basically Card refers to coordinates. *Coordinates* are a scalar representation of a (linear) projection, from a chosen point of origin in space. Unit and scale of coordinates are chosen by humans, for example based on existing features in space that allow a precise measuring. For two-dimensional spaces they are typically represented as a tuple, with a single value for each dimension, i.e. height and width. Semantic Positioning will focus on the typical two dimensions employed in digital desktops, though to be precise one needs to talk of 2.5 dimensions. The extra half dimension refers to the existence of layers through which objects can be overlaid. Visually, it is not necessary to always show the complete space. Windows, showing only a specific section of a space, can easily be defined (Figure 15).

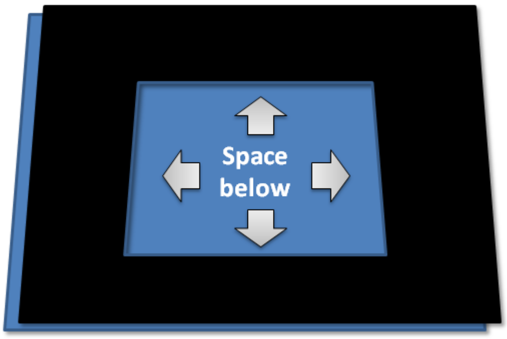


Figure 15: Visualization of a smaller viewpoint, akin to a window onto a larger space

The term *object* in Semantic Positioning refers to addressable artifacts within digital media, that have a visual representation and thus at least the attribute of position. Hence, anything, from a database entry, over purely graphical elements, to complex media documents, can be considered an object in a digital working environment. It is even possible to define objects, consisting of or containing other objects. *Attributes* are descriptive properties of digital objects that are stored directly on the object. In most cases they are represented by text, numbers or by other perceivable dimensions like color or size. Attributes can also be inferred from object-contents, like the number of characters used in a text document. Objects can have an assigned function (see chapter 5.1.1) and/or media contents like text, audio or video. For instance, it is viable, to have hyperlink objects that connect several spaces. Within semantic spatial arrangements, objects either take the function of active working materials (i.e. documents) or of legends. A legend is also an object and associates information with either specific perceivable attributes, objects or even positions and dimensions of coordinate space. Legends are necessary parts of semantic spatial arrangements.

The basic premise of Semantic Positing is that an object gains meaning solely by its position in space. In such a space, "*a spatial position stands for something…*" and hence, "*[…]a change of position of an object will correspond to a change of meaning*" (Engelhardt 2007). Engelhardt calls this concept a *meaningful graphic space*, which is very close to my own term of *semantic space*. Despite these similarities, his research focuses on illustrations, rather than dynamic arrangements (cp. Engelhardt 1998, Engelhardt 2007). For a spatial position to become meaningful, it is necessary that information is *mapped* perceivably and functionally to space. In relation to meaningful graphic spaces, (Engelhard 2007) describes this as "*an interpretation function from spatial positions to one or more domains of information values*".

In Semantic Positioning this perceivable and functional mapping of information to space is called the *context*. The context functions as the *legend* that explains, which arrangement types are used and what they mean, by using *mapping marker* objects and an evaluation model. Hence, perceivable meaning stems from both the arrangement of the *context* (see chapter 6.2.3) and that of materials (=*objects*) in space (cp. Wexelblat 1991). Such a digital space for arranging and evaluating media objects in 2.5 dimensions, before the backdrop of a perceivable and manipulable semantic context, will be referred to as a *medi@rena* (Keil 2007, Erren & Keil 2007b), a concept derived from virtual knowledge spaces[25].

6.2.1. Positioning Objects in Space

Within a defined medi@rena space *objects* can, on principle, be positioned freely. Despite most objects having a surface spanning multiple coordinates, their position is typically inferred by a *single point* on their surface. In many contexts the top left corner of an object's *bounding box*[26] is used for this purpose, meaning that the *reference point* may not even be on the object's visible surface, e.g. a circle. Independent of which point is chosen, it needs to apply across all objects. Though, height is not part of the position value, its purpose is to define, which objects will be displayed on top of which others.

Objects can be evaluated on both their relative and absolute position. *Relative position* refers to comparing the position of an object to that of other objects, as an expressed semantic relation within the given context. *Absolute position* in contrast, refers to the coordinate position of an object in space and the respective interpretation by the given context.

6.2.2. Mapping Markers - Legends for Spatial Contexts

Mapping Markers consist of a graphical object and one or more textual labels. As indicated, one can think of mapping markers as legends that explain what information is mapped to which spatial dimensions in arrangements of media objects. This describes the relevant spatial context to provide a semantic interpretation (or at

25 Virtual knowledge spaces are 'rooms' designed as meeting places for continuous cooperation with synchronous and asynchronous communication channels, awareness functionality, customizable views, self-administration possibilities as well as persistent object storage (Hampel 2002). The rooms can be interlinked and feature an open infrastructure.

26 A bounding box is defined as the minimal rectangle enclosing a chosen two dimensional figure. E.g. for a circle of radius r the box would be a square with a height and width of $2r$.

least a respective starting point). The graphical element explains how the arrangement is composed and position has to be read, while the label provides the semantic context. For instance a time axis (horizontally) maps a certain date value to each coordinate of the observed space. The label explains *that* time is mapped to coordinates, while the axis as a segmented arrow explains *how*. Thus, mapping markers support transporting insights over time and even to other persons. Essentially, each arrangement type has a distinct set of associated mapping markers.

Sometimes mapping markers may also take the form of a *visual cue*. A visual cue is an iconic visualization that associates well with a specific semantic concept. For instance, a bottleneck can be depicted as the neck of a bottle or a funnel, which both visualize the tightening of a tube. The famous line that a picture is worth more than a thousand words[27] highlights the potential problem of using visual cues: They are open to interpretation and hence, need to be properly embedded into the context and possibly explained. In Semantic Positioning, visual cues can only serve to visually emphasize a spatially expressed relation.

6.2.3. Deriving Context from Arrangements

Information dimensions are mapped either to position or at times visual markup attributes of objects, like color or size. Spatially, information dimensions are associated with a specific arrangement type. After a mapping is implemented, a specific position in space will be associated with concrete information values. These values correspond with certain attributes of object artifacts, which can be accessed and even written by a computer, based on the object's position. In turn, existing attributes can be evaluated to determine position (bi-directional evaluation) or can be used in other contexts, such as a search function. The physical relation, between object attributes and position, is the reason for me to speak of the *semantic position* of an object. For example, positioning a document in relation to a time axis, would write the respective 'date' value into the document's attributes. Repositioning an object in Semantic Positioning scenarios will, therefore, change at least one attribute beyond that of position. The assignment of attributes through positioning is similar to assigning *tags* (cp. Gaiser et. al 2008). It is however easier, and more efficient, since multiple values can be written based on a single positioning action. In turn, some flexibility to the manual assignment of tags is lost.

27 Interestingly (Blackwell 1997) notes that complex diagrams take on average 84.1 words to describe

Since, the context itself is also an arrangement of mapping markers and other objects, like explanative text boxes, it is sensible to a minimum of one user (author). The encoded evaluation model behind the arrangement ensures, that the semantic meaning expressed by positioning, is translated into semantically appropriate system responses, in most cases only changing attribute values. If the responsive behavior is consistent with the spatial context and supports one's work effort, one can speak of an established spatial convention within the medi@rena's overall evaluation.

Imagine a simple region indicated by a rectangle in a two dimensional space. The rectangle as the graphical component indicates a boundary, either something is inside or outside of it. Labeling this box "Tom's private documents", makes it possible for other team members accessing the shared work space to understand, they are not to edit or read documents placed inside. Digital media allow connecting semantically correct changes of access rights to the spatial coordinates marked by the region. Conditions can be automatically set at the time of inclusion so that any document in the region can only be seen, read and edited by authorized persons. Similarly, Tom can easily share private media objects by moving them out of the region into the public space.

A single 'move' action is all that is required to change a host of access rights on the media object. Since this requires precise processing of the presented context, it is time to concentrate on the distinct modes of arrangement and their interpretation

6.3. Semantic Positioning Framework

The Semantic Positioning Framework is not a framework in the technical sense often used in computing. It is meant to provide an overview of the main aspects of semantic spatial arrangements and how these come together. The most basic elements are *building blocks*, which are arranged in space, using one or, by *overlay*, even multiple of the identified (distinct) five arrangement types. Since each type of arrangement defines a meaningful mapping of information to position, by using so called mapping markers, any arrangement is logically divided into *context* and *working material* levels. Evaluations, too, are based on this division, with an evaluation model tied to the context layer(s) and effects usually applying to media objects on the material layer(s). This framework is depicted in Figure 16, consisting of three connected columns, starting with *building blocks*, (arrangement type) *overlays* and the resulting *Semantic Positioning*.

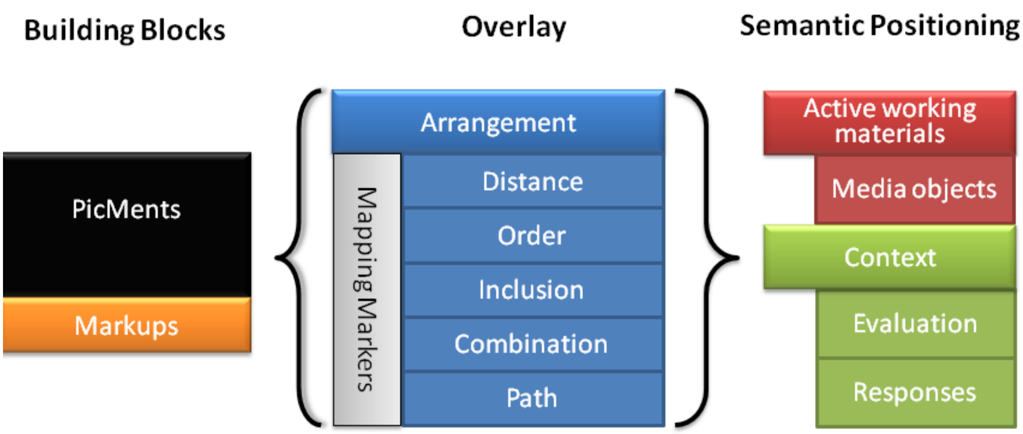


Figure 16: The Semantic Positioning Framework

- ***Building Blocks***
  PicMents form the atomic building blocks of any media arrangement, providing all the necessary primitives and stencils available, for instance points, lines, rectangles or even images. Each primitive can act as a singular object or can be combined with others to form a compound object.
  Markups gear visual attributes beyond that of position like color or size.
- ***Arrangement Types***
  Arrangement Types detail in which distinct ways position can be interpreted and used to express semantic meaning and relations. Multiple arrangement types can be overlaid within a single arrangement.
  Mapping markers are the result of using specific PicMents in combination, to act as a visual legend for the mapping of information dimensions to space.
- ***Semantic Positioning***
  Takes place, when the arrangement possesses recognizable *context* for evaluation and interpretation. This context can be rough at first, with need for further rearrangement, so long as it already is an active working environment. By this I refer to a base for arranging working materials (i.e. media objects), according to the current understanding of their meaning and relation in one's work context, i.e. a *medi@rena*.

The following subsections will describe the functions and relations of the individual parts in the Semantic Positioning Framework in greater detail.

6.3.1. PicMents

PicMents are the atomic (i.e. indivisible) elements of any spatial arrangement that can be manipulated and arranged. They are the basic entities that make up more complex objects. This is why they are described as the building blocks of spatial arrangements. The name 'PicMents' was chosen based on the notions of ele*ments,* and de*pic*tions[28]. PicMents require at least the writable attribute of position; other attributes can be inherited as part of the used stencil or the resulting object. Examples of PicMents are points, lines, arrows, rectangles and other polygons, images, icons, characters, symbols and further indivisible representations.

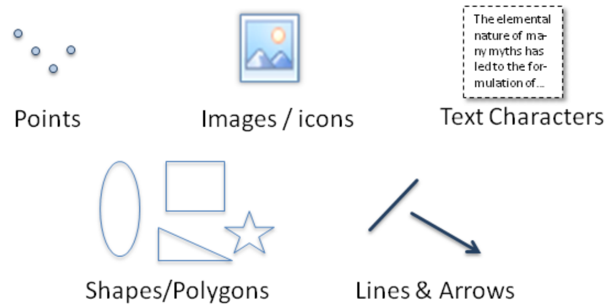


Figure 17: Common types of PicMents

Text can be understood as a linear spatial arrangement of characters, equaling PicMents, or as an atomic entity in itself, if one cannot access or rearrange its characters. This use of terminology is not simply limited to text. An object that consists of several primitives, which cannot be 'ungrouped' and individually manipulated in the working context, is a PicMent in the respective context.

On the level of the active working materials, it may seem more difficult to distinguish, which objects are PicMents. In reality the distinction is easy: Within the arrangement space, the icons representing digital media objects are atomic entities. Once opened, the environment and context changes towards the manipulation or perception space regarding the object's contents. Here, individual signs and symbols exist as arranged PicMents. It is, therefore, possible to understand the icon of a media object as a PicMent, representing an addressable entity linking to another working environment, like a *sub-space*, as a lower arrangement level. To summarize: any kind of graphical representation can be subdivided into PicMents as its atomic elements.

28 The similarity to the term pigment, which is a material that partially absorbs light and therefore appears in a certain color, is mainly coincidental.

6.3.2. Markups

Markups are any perceivable attributes or properties of PicMents in spatial arrangements besides that of position. Therefore, the essential quality of Markups is that they are location independent visual indicators. They can be employed to add perceivable non-spatial information dimensions to an arrangement. Typical examples of Markups are shape, color, texture, size, text labels or even font faces (cp. Bertin 1967, Wilkinson 2005, Zaitsev & Lupandin 2000). In their simplest utilization, the only semantic sense behind Markups is to distinguish singular objects or groups of objects from other ones, by visual qualities. Figure 18 highlights a few of the more typically encountered Markups in digital arrangements:

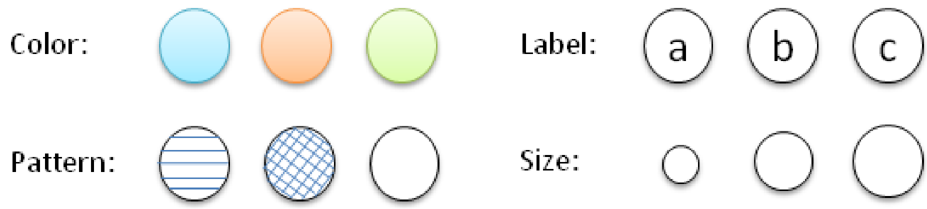


Figure 18: Common types of Markups, as distinction attributes of otherwise identical objects.

Using Markups for distinguishing objects, represents a position-independent semantic categorization, similar to grouping by inclusion. In this way, it is also possible, to depict developments or intensities by scalable markup attributes like color or size. For example, traffic light colors green, yellow and red could express increasing criticality. Like arrangement types, Markups always require a legend, whose position in space is irrelevant, so long as it is visible and does not cover other viable information. While changing the attribute of position is a simple drag and drop operation, Markups often require specific tools for changes – e.g. a color palette.

Overall, it should have become clear that Markups are intriguing enhancements to digital spatial arrangements. Since they do not influence the spatial position of objects, they will not be considered in more depth within this thesis. Based on their practicality for arrangements of any complexity, it does seem important to conduct further research into the primary media function of markup, in relation to arrangements. Specifically, this research should focus on what conditions and specific operations may spring from the use of Markups in arrangements and how they too, may support knowledge work.

6.4. Spatial-Semantic Concepts behind Arrangement Types

Through examination of both digital and analog working environments, five logically distinct spatial arrangement types could be identified (chapters 4 and 5). To reiterate these are *distance*, *order*, *inclusion*, *combination* and *path*. Except for 'order' these same types were already described in (Erren 2007, Erren & Keil 2006). The slight difference in terminology can be ignored as these are only owned to further time spent on finding fitting names and also personal preferences. The terms skillfully manage to convey the basic associated unique *spatial semantic concepts* of the five arrangement types:

- *Distance*
  …describes the direct linear relation of objects, based on their spatial layout, in one or two dimensions. Semantic closeness is expressed quite literally by objects being arranged in spatial proximity.
- *Order*
  …describes objects being sorted based on a chosen search criterion. The spatial order is a reflection of an associated semantic order or ranking based on attributes values.
- *Inclusion*
  …describes the visible containment of objects within a common spatial region. This grouping through mutual enclosure expresses semantic categorization or classification by shared mutual properties. Included objects are differentiated from objects on the outside of the region.
- *Combination*
  …describes the cross-wise overlap of linear vectors as factors of information dimensions. The overlap represents a combination of the respective factors. Objects positioned there depict the result of this combination.
- *Paths*
  …in two dimensional settings are based on a graph visualization with edges and objects as nodes to describe semantic relations like influences, dependencies or even routes through the inter-relational object arrangement.

In essence these five spatial-semantic concepts expand the primary media function of arrangement (see chapter 3.1.2) that was only defined on very general terms of arrangement being linked to semantic relation. The spatial-semantic concepts are all associated to distinct types of arrangement.

6.5. The five Arrangement Types

Despite their imprecisions, the established names from (Erren 2007) have been used as a basis for the nomenclature of the corresponding *arrangement types*:

- *Coordinate Topography*
  Distance/closeness arrangements were previously referred to as topographies (Greek 'topos' = place, 'graphein' = write), a term commonly interpreted as the study of landforms, including that of the shape, expansion or distance of properties. Realistically, however, in digital media, respective arrangements are likely coordinate systems. In this case, both the specific point (topos) of an object and its distance to other objects are important.
- *Ordered List*
  Order is expressed alpha-numerically along a single spatial dimension, sometimes with groups forming, due to objects sharing the same attribute value. An alpha-numerically ranked list of objects is the major result of this type of arrangement.
- *Categorizing Collection*
  Essentially, a region is distinguished from its surroundings. Objects placed inside are 'collected' as parts of a common category or class based on shared properties. Collections are related to the more universal concepts of *part-whole* or *set relations* from mereologies and naïve mathematical set theory respectively, but do not directly represent either. Mereologies originated as a sub discipline of ontology science and describe parts (objects) and their respective wholes (regions) (cp. Casati & Varzi 1999). Simple mathematical sets in contrast understand sets as *collections* of actual objects. Categorizing collections are more akin to the collections of naïve set theory, but visually enable empty inter- and sub-sections, which in mathematics is not possible. The term "categorization" as the weaker concept, was chosen over that of "classification".
- *Combinatoric Matrix*
  Combinatorics in mathematics have the goal of calculating the number of possible combinations of objects to fit certain conditions. A matrix is a system of vectors, as separate information dimensions parting a space horizontally and vertically, so that each row crosses with each column. Semantically each

vector has associated properties, but each cell of the matrix is the resulting combination of the qualities of a crossing row and column vector.

- *Relational Graphs*
  Graphs are the resulting spatial arrangement of semantic paths represented between objects as directed or undirected edges. Both edges and paths express specific relations.

In the following, it will be necessary to perform a deeper analysis of the individual arrangement types, in order to establish the kind of information (dimensions) they can aptly express and how they may be evaluated. This requires an analysis of how the relevant semantic information dimensions are mapped to coordinate space. For the *evaluation process*[29], the individual interpretation of spatial actions for each of the five arrangement types is relevant. With respect to digital media, a change of an object's position means simply that its attribute of position is adjusted. Spatial actions refer to the user *moving* an object.

In digital media this is commonly achieved by *drag and drop* actions. Here, a number of *selected* objects is moved to a new coordinate position. Relational graphs, where position is not determined by coordinates, are the exception. Here, position is measured along paths and thus, is influenced by *connect actions* along paths the object is a part of. As only relative position is semantically relevant in relational graphs, this makes their processing difficult. A single (dis-)connect action can affect a large number of paths. For the other arrangement types, once an object or multiple objects are dropped at a new coordinate, the respective attribute of position is adjusted to the new location and evaluation occurs depending on the (new) context.

Hence, a user can take any of the following (spatial) actions regarding media objects, which are evaluated as positioning within the context of the arrangement type(s):

- Add object (Drop)
- Remove object
- Move object
  - Drag and Drop
  - Connect/Disconnect

29 The evaluation process includes the writing of attributes, corresponding to the expressed meaning at the object's position, and any ensuing responsiveness. While usually single objects are evaluated after they are moved, they are not evaluated in isolation. At least the semantic spatial concepts of distance, order and relation may require an evaluation of relative position in relation to objects. Only *inclusion* and *combination* can be sensible as isolated evaluations of separate media objects.

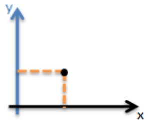
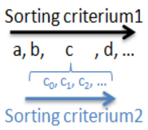
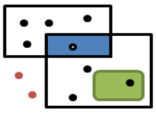
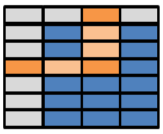
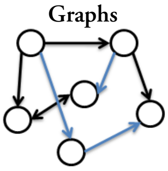
Type	Semantic Concept	Evaluated Spatial Actions[30]	Type of Problems	Suited for Type of Information
Coordinate Topography 	Distance/Closeness	*Objects* ▪ move apart or together *Axes* ▪ change scale, length or orientation	Problems where the relation of objects is best described by numeric values and may eventually be explained by a mathematic formula	Relevant numeric information that can be expressed by a formula that allows for comparisons based on values
Ordered List 	Order	*Objects* ▪ move within list *List* ▪ change sorting criterion, change order (ascending or descending)	Problems where a rank of objects needs to be established or where specific objects among many need to be accessed quickly and reliably	Alpha-numeric information indicating rank or order that can be expressed as values of a single sorting attribute
Categorizing Collection 	Categorization/ Classification	*Objects* ▪ Move into or out of region *Region* ▪ move, change size, intersect	Problems where items need to be clustered (as classes/categories) by conditions and shared properties	Factual information on properties and conditions that in a specific constellation express category/class
Combinatoric Matrix 	Combination	*Objects* ▪ Move onto cell *Vectors* ▪ change width or height, exchange position of vectors	Problems to either determine the number of possible combinations or compare the quality of results of different combinations	Information on two sets of factors that allow a cross-wise combination of each factor from set one with each of set 2 with specific results
Relational Graphs 	Specific Relation	*Objects/Relations* ▪ Create edge, delete edge, (re-)connect edge, re-label edge	Problems where working/optimal paths have to be chosen among many or where inference based on expressed relations is necessary	Information on existing relations between a set of defined objects, connecting them semantically in complex ways

Table 3: Matching type of information for each arrangement type

Table 3 summarizes the five arrangement types of Semantic Positioning, associated spatial concepts, processable spatial user actions and problem types. In addition the types of information, each arrangement type is most suited to express, are represented. This does not exclude the possibility of creatively applying an arrangement type to other kinds of information. It simply focuses on the most logical association.

In the following analysis, each of the five arrangement types will be discussed according to:

30 Add or remove actions are not represented in Table 3 and actions changing the mapping marker are only exemplary, other attribute changes at least need to be considered.

- How *semantic meaning* is *mapped to coordinate space*, including mapping markers and what kind of information each type aptly expresses.
- What the *position of objects* entails, in relation to values written to objects in the evaluation stage, including necessary constraints.
- How the expressed *spatial-semantic concepts* can be evaluated, how respective user actions may be analyzed and *what* consequences for other objects a change may have.
- How *refinement* can be realized and how it affects information.

Due to limitations of screen space, it is sometimes necessary to filter out certain information or objects of an arrangement. In this regard, *refinement* is a specific concept that will also be discussed briefly for the arrangement types. Refinement is defined as an action that extends the currently available information, in the form of new details for an existing and otherwise unchanged context. A very simple example of this is expanding a sub tree in the file explorer.

Since any semantic evaluation and interpretation is based entirely on object position, objects in Semantic Positioning aren't *placed* randomly, but *positioned* for a reason. The reason is detailed by a mapping of information to space, with aptly called *mapping markers* and respective labels as descriptors. The mapped information is then technically bound to an evaluation process of respectively positioned objects. Any evaluation process will write at least a new position attribute to a moved object. Typically, at least one further associated attribute will assume a new value fitting the current position. For instance, a teacher moves a student assignment in front of a timeline. The position attribute is changed, but also a new due date attribute is set, corresponding to the axis value at the object's new position. This attribute can then be used for responsive feedback, such as a reminder for students to hand in assignments. Responsive behavior is based on the fulfillment of *conditions*. These are statements that include variables and are either true or false, e.g. "if distance between old position and new position is greater than 10". The concrete system responses are tailored to each specific scenario. Examples range from writing attribute values, to publishing media objects or changing editing rights for multiple groups of users. The scope of possible system responses is too wide, to be covered within the following analysis; one simply cannot match specific responses to specific arrangement types. Mainly, responsiveness in Semantic Positioning is supposed to support the user, in his or her current working context. This claim is proven in three concrete examples, each demonstrating sensible degrees of responsiveness, in chapter 7.

6.5.1. Coordinate Topographies

Definition: *Coordinate topographies are arrangements, where the coordinate position of objects, in relation to spatial axes, allows inferring associated numerical values, since each axis represents a single- or multi-information dimension. Within the space of a respective knowledge work environment, spatial closeness is a direct expression of semantic closeness of positioned media objects, based on related attribute values.*

Mapping semantic meaning to position

Coordinate topographies set objects in relation to *n* information dimensions, mapped visibly and logically to a *coordinate space* of up to two dimensions. The relevant mapping markers are (Cartesian) axes. Generally, *axes* are linear continuous projections, visualized as segmented arrows, setting a clear scale, with either steadily increasing or decreasing numerical values. Based on this fact, axes are only sensible for displaying numerical information values and thus relations that can be expressed numerically. Any axis has a set of defined attributes, namely a *start*, an *end*, a *direction*, a *unit*, a *binding*, an *interval* and a *scale* (see Figure 19).

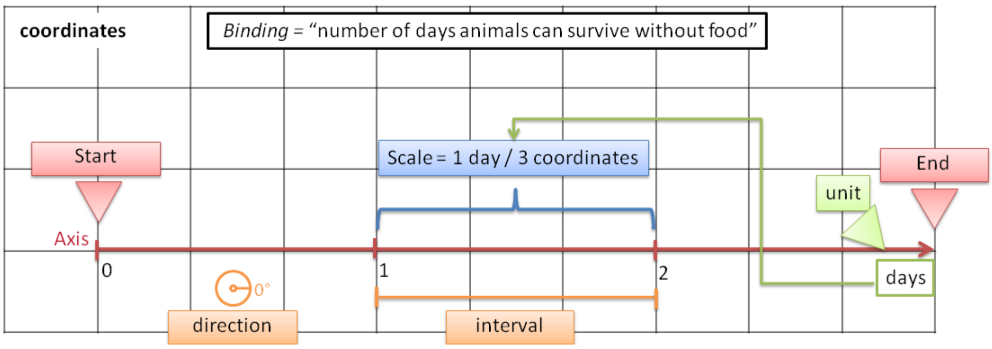


Figure 19: Axis - mapping marker and the respective attributes explained

The *start* defines where an axis logically begins. This refers to the first coordinate, to which an axis (visibly) applies and maps information. Often, the start will have an associated value of zero. Do not confuse the term with an axis' origin, which is only optionally identical to the start. The *end* defines the last spatial coordinate, to which an axis maps numerical information. *Direction* can simply be described by the angle, measured from the point of origin, to the logical end (0° in Figure 19). The *unit* of an axis, essentially a *unit of measurement* (e.g. days), defines the basic mapping of information dimension to space. *Binding* relates this unit to the broader semantic context, defined by the relevant information dimension, for instance the "number of days animals can survive without food" from Figure 19. Generally, bindings should be positioned in space, for instance as a text box. Axes are parted into regular numeric segments. The term *interval* describes the numerical *step* associated with a segment (e.g. 1 day in Figure 19) and *scale* describes the relation of the *interval value* to the number of coordinates each segment covers (see Figure 19). Finally, it is also possible to speak of the *type* of axis, being either single or double sided.

Any coordinate (*position*) to which the axis applies, has an associated *semantic value*, like "2 days (until an animal dies without food)". Mapping semantic meaning to space, in relation to an axis means that the respective numeric values apply not only to the coordinates an axis covers, but to those atop/under for horizontal and right/left on vertical ones (see Figure 20). If the start of a horizontal axis matches the coordinate (0,10) of the space, then the associated value of 4 applies to all coordinates (0,y). Principally, coordinates define the finest 'resolution', to which object position can be measured and assigned. This is called the *coarseness* of an axis. Despite this fact, an infinite number of values logically lie between one coordinate and the next. This may lead to problems in the interpretation of position within an arrangement (see section *evaluation* below).

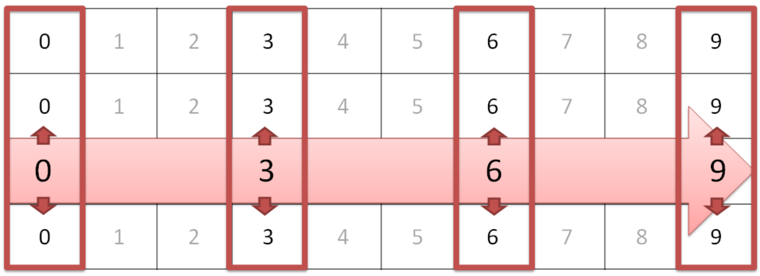


Figure 20: Coordinate mapping of horizontal and vertical axes applies to entire space

If axes are not vertical or horizontal or in the case that more than two axes are employed (see Figure 21) the respective mapping of spatial coordinates changes. Only those coordinates that lie directly on any of the axes are associated with the information dimension values; the coordinates in between axes remain unmapped. The same principally holds true, if circular or spiral axes were defined.

So far, we have talked about absolute positional mappings of information dimensions to space, however, the relative position of objects holds the more important associated semantic meaning in coordinate topographies: *Distance* (or *closeness*), in one or two dimensional settings, can be described as the length of the shortest direct line between two points, in addition to the respective angle, if the direction of distance is meaningful. The length can be measured by coordinates, and translated into the appropriate numerical values represented on the axis/axes.

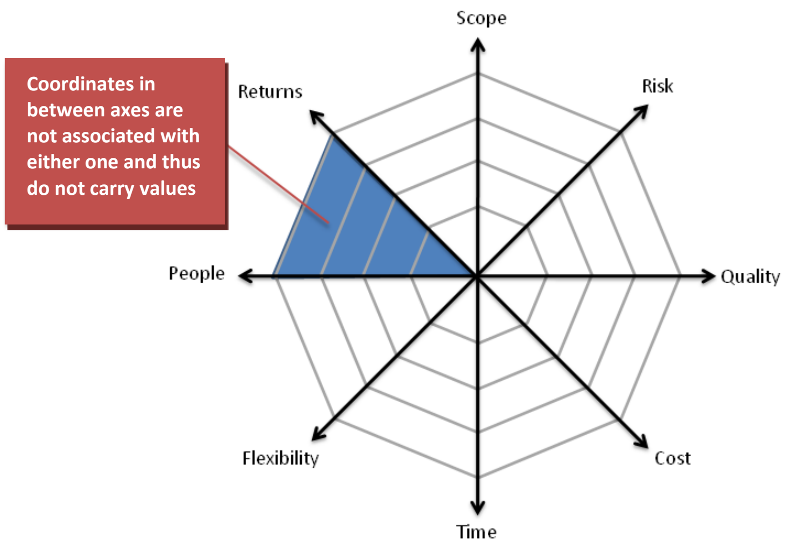


Figure 21: Spider-Diagram as a possible implementation of multiple Coordinate Axes

Semantic closeness, as the main expressive concept behind coordinate topographies, identifies relation between objects by their spatial closeness. Media-objects, that are close on two spatial dimensions, are also close on the respective information dimensions, because they share similar attribute values. Objects that are spatially close together are often perceived as a semantic group by humans[31] (cp. Figure 22).

Positioning objects in relation to axes

Media objects positioned on spatial coordinates that are associated with an axis, 'inherit' respective semantic values. *Inheritance* refers to the concept of writing the *semantic values*, associated with the coordinate position of the object, to respective object attributes. In the example of Figure 19, this attribute might be called "endurance without water". If an object, representing an animal, already possesses a respective value (*pre-assigned attribute*), for instance "3 days", it could automatically be positioned there.

31 This is the relation (Metzger 1966) describes with his law of closeness ("Gesetz der Nähe"), among other so called Gestalt laws. While Gestalt laws offer interesting perspectives as to the expression of semantics by shape or position, they are not distinguished clearly enough to provide further benefits to this discussion and miss a strong distinction of ground versus objects.

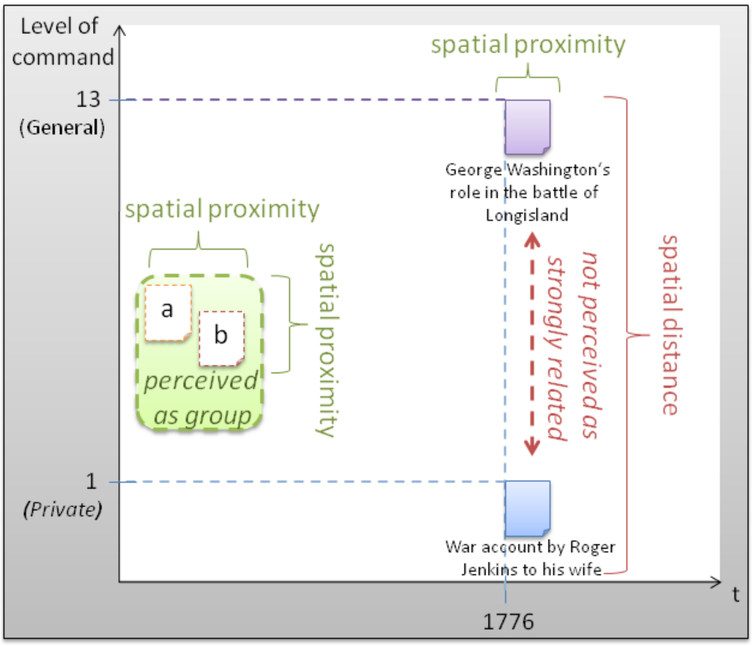


Figure 22: Closeness on both spatial dimensions leads to perception of objects as a group

While in most cases, a single attribute will be associated with the represented semantic values, it is possible to have a formulaic association regarding multiple attributes as variables (cp. Streule et al. 2006). This *multi-factor analysis* typically features a weighed function, by which a single value is calculated from multiple (weighed) supplied arguments, e.g. "*(2x + 3y)*0,5z*".

In relation to axes, mathematical functions can be depicted as PicMent *lines* or *curves*. These represent optional mapping markers, allowing comparing the position of arranged objects to the function's course.

Position of objects is also influenced by changes of the axis mapping marker[32]. For instance, enlarging a horizontal axis' scale from *1 cm* to *1 mm* means that an object positioned at *1 cm* equaling an x-coordinate of "6", would now be positioned at x-coordinate "60". Other changes could affect origin and end points of the axis or simply its length or direction. The resulting necessary rearrangements should be handled automatically by the evaluation model. Changing the unit or binding of the axis makes more extensive recalculations necessary, since new semantic object attributes may apply.

32 For simplicities sake, I assume only the existence of horizontal or vertical axes, but one could imagine multi axis setups of any radial degree in space.

Evaluation of coordinate topographies

Each axis of a coordinate topography can have a separate evaluation model. Generally, this model includes all necessary translations from object position to the concrete semantic values in the mapping and vice versa. Evaluation can be based on the *absolute position* of objects, their *relative position*, *existing attributes* or comparisons with *reference points* on depicted mathematical functions. Any processing is triggered by user actions, affecting the arrangement, most commonly by moving one or more selected objects. The respective actions in coordinate topographies are creating, deleting or moving. Any evaluation and subsequent responsive behavior, only directly applies to the moved object(s).

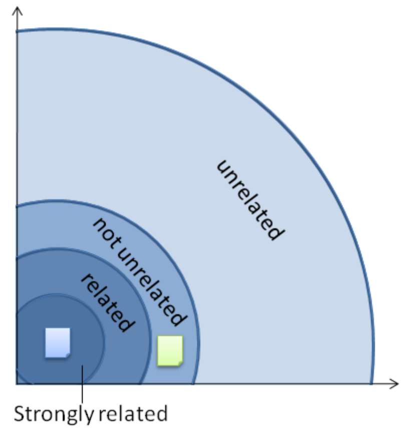


Figure 23: Visualization of relational thresholds as distance based evaluation zones around objects

- *Absolute position*
  Through either movement or creation, when an object is 'dropped' at a new *target coordinate*, its old position and/or respective attributes are analyzed. If no defined rules speak against it, they are then overwritten with semantic values according to the new coordinate position. The respective formula, measured in the supplied unit, considers the number of coordinates before the point of origin "b" and the axis' scale:
  "$sem\_value_{abs.pos.} = (target\_coordinate - b) * scale$".
- *Relative Position*
  Refers to bringing objects further *apart* or closer *together* by creation, deletion or movement actions. All possible distances, between any two objects in the arrangement, can be calculated on the event of a movement. Essentially, the respective formula for the distance on a horizontal or vertical axis is the same as the one used for absolute position:

"$sem\_value_{rel.pos.} = ((pos_{objA}-b)-(pos_{ObjB}-b))*scale$"
In most cases, evaluation will focus on semantic closeness rather than distance, considering objects within a specific *threshold* of each other. It is necessary to define this distance threshold within the evaluation model. Naturally, a system of multiple thresholds can be defined, with increasing distance as a kind of invisible evaluation zone around objects (Figure 23). In Cartesian coordinate systems, with two axes one might also evaluate the radial degree or the gradient between two object positions. For example, in baseball one might analyze, if a batter has a tendency to hit balls into a specific direction, with a typical distance. Based on the analysis the defensive team may devise adapted rosters, formations and ball return tactics.

- *Existing attributes*
  An object newly introduced to the space, might also be positioned automatically according to its existing attributes. In this case, the formula is simply inversed: $coordinate\_Pos_{ObjA} = (attribute\_value_{ObjA}/scale)+b$
- *Reference points*
  Comparisons, with reference points on mathematical functions, work just like comparing relative position. Lines or curves offer valuable insights as to the overall arrangement of objects, especially to test hypotheses about an assumed correspondence of object position with a mathematic formula.

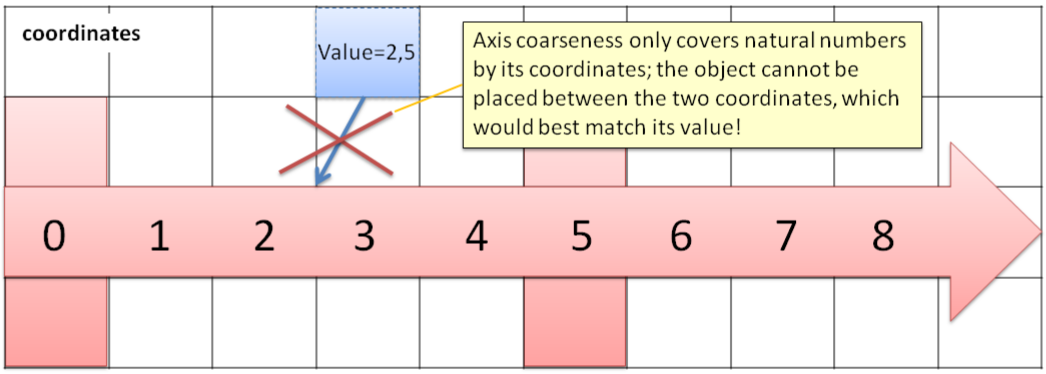


Figure 24: Axis coarseness relates to the mapping of values to coordinates by the defined scale

For all calculations, the coarseness of the axis plays a role, since not every numeric value from the associated information dimension, may be represented by coordinates (see Figure 24). Logically, it might help to define the coarseness of a coordinate topography, so that the smallest encountered difference in mapped information values, matches a single coordinate. Alternatively correlation and rounding may help to position an object at the most appropriate coordinate position. A third alternative is zooming, which optically allows for increasing accuracy as needed. Zooming will not add any new information or details, but only enhance the perceivable size of already existing objects.

Refinement

Refinement in coordinate topographies simply refers to making previously hidden segments of an axis or an entire axis visible and to automatically adjusting the position of material objects in space accordingly. This can happen, for instance, by collapse or expand actions.

6.5.2. Ordered Lists

Definition: *Ordered lists are arrangements, where the coordinate position of objects is inferred, from an alpha-numeric sorting of objects in sequence, based on the objects' values in relation to a chosen sorting attribute. An associated semantic order or rank of the sorted objects is expressed, along a chosen directional vector, with regular distance between individual objects.*

Mapping semantic meaning to position

Ordered lists set objects in direct sequential relation to one another, based on the values of a shared attribute representing an information dimension. From this an *alpha-numeric sorting* is inferred and mapped to the position of objects, along a linear spatial dimension (coordinate vector). The relevant mapping markers, as the overall name implies, are *lists*. Lists are linear projections of *semantic order*, visualized as tabular structures, where objects are displayed *sorted* with regular distance in between. Sorting is performed *alpha-numerically*, thus, lists have to be based on textual and numeric attributes or combinations thereof. Generally, lists are suited for expressing relations of a clear order or rank between objects based on already existing attribute values as information dimensions. Any list has a set of defined attributes, namely a *starting point*, *first line point*, *step-value*, *direction*, *order*, *sorting criterion*, *associations*, (optional) *identifier* and *binding* (cp. Figure 25).

The *starting point* defines the first coordinate of the list mapping marker, where *descriptors* are displayed, regarding the object attributes selected for display. Below this, is the *first line* of media objects and their attribute values, which are also mapped to concrete coordinates. Starting here, information is perceivably mapped to spatial position in regular sequence. Each object, with its relevant values, is represented as a single line of the list (cp. Figure 25). Objects are separated by the *step-value,* as the standard coordinate distance between list-lines.

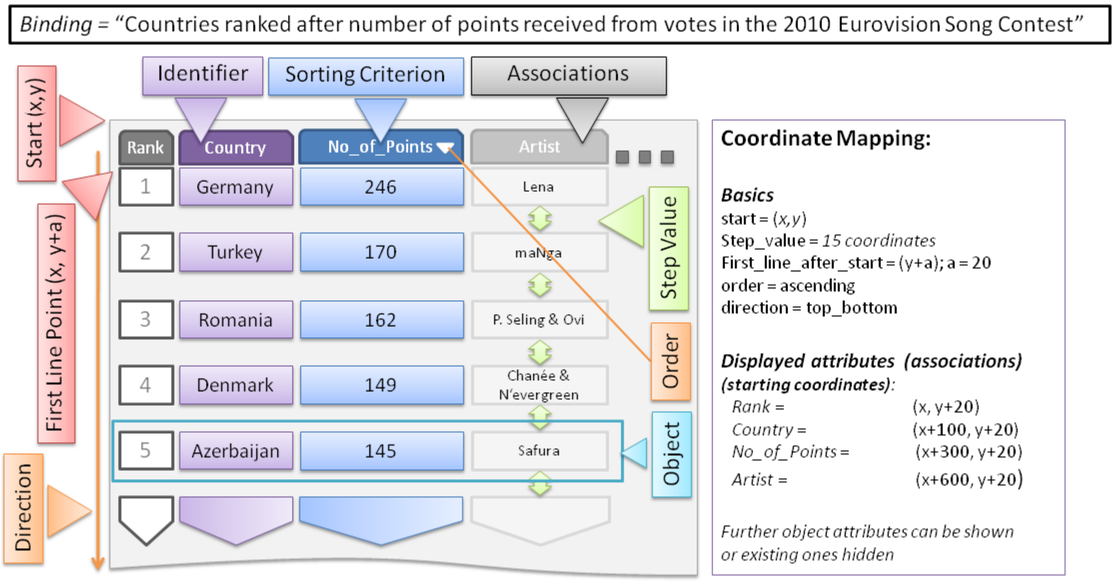


Figure 25: List - mapping marker and respective attributes explained

Direction specifies, if a list runs from left to right or top to bottom (in some countries conventions may differ). Lists are sorted either in ascending or descending *order*. This is often displayed by a simple triangle on the searching criterion marker. If the triangle points downwards, the order is *ascending* (see Figure 25), of it points upwards, the order is *descending*. The *sorting criterion* is semantically the most important attribute of a list mapping marker. It defines, which information dimension, represented by an object attribute, is responsible for mapping semantic order to spatial position. The descriptors for the searching criterion ("points" in Figure 25) and other *associations* (i.e. attributes chosen for display like "artist" in Figure 25) are displayed as buttons. This enables users to choose a (new) sorting criterion, by simply clicking the button of another displayed attribute. Similarly, the ascending- or descending-indicator on the chosen sorting criterion button and the respective order can be changed by a click. It is necessary that the sorting criterion and respective values are at least perceivable in space, since otherwise, the reason for a displayed sorting of media objects may be lost to observers (cp. Table 4). Sorting attribute values can theoretically appear more than once among objects, forming clusters within the sorted results, hence an *identifier* represents a unique attribute value, by which objects can be specifically addressed. Finally, the *binding* sets the chosen sorting criterion (information dimension) into the broader semantic context of the expressed relational order. The binding should be positioned in space, for instance as a text box.

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University of California
Carnegie Mellon University
University of Illinois-Urbana Champaign

Table 4: Without a given sorting criterion[33] the list is confusing

The semantic relation of *order* is expressed perceivably, by the spatial order of objects. Order is a one dimensional vector sequence, with regular distances. An object's absolute position in space, is also its assigned *rank* within the list, i.e. the natural number associated with a line-position, counted steadily from the lists first line. Its display is optional, but helpful, especially for larger lists. Objects sharing a sorting attribute value, do not share an absolute position, but are instead placed simply one after the other. Regarding the relative position of objects, order is expressed solely in terms of one object being in front of or behind others and sometimes by how many ranks lie in between. This does not express a precise semantic distance however. Objects can be close, but still very different from another. In Figure 26 object A is just as close to B, as B is to C, but both pairs have very different delta values: 699 between A and B compared to only 2 between B and C. Based on this fact, displaying at least the attribute values for the searching criterion is almost always a necessity.

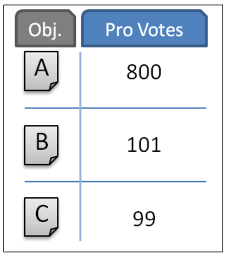

Figure 26: Searching criterion values do not have to match regularity of positioning

A single attribute, chosen as a sorting criterion, is all that is necessary to automatically position relevant objects. In essence this would make lists simple visualizations, whose order depends only on selected parameters. Still, the order in lists can depend on more than just a single sorting attribute. It can be based on a complex argumentation considering multiple attributes. For example, indexes are lists with a

33 Sorting represents: Ranking of top US computer engineering schools 2009 by 'www.usnews.com'.

logical and manually defined order of objects, based on complex reasons that can hardly be tied down to a single attribute value. This makes lists an active part of the working environment, rather than static sources of information[34].

Positioning objects in relation to lists

Ordered lists are different from other arrangement types, because they do not pre-structure the perceivable context. Additional lines are only added, when new objects are added to the space and thus become sorted. The list's length adjusts with the number of elements it sorts. Hence, the list mapping marker, consisting of just the descriptor line, only defines a 'field of potential' in the lists direction, but does not pre-assign coordinate positions with specific meaning. Positioning an object in an ordered list space can have one of two effects: Either the object's pre defined attribute values determine its position in relation to an existing list or it is inserted at the list rank closest to the 'drop point'. In the latter case, a fitting sorting attribute value needs to be assigned to the object, reflecting its new position. This can be done manually or automatically.

Lists do not feature a strict information value mapping regarding object position or coordinates. Hence, an object inserted into a list does definitely receive an updated position attribute, but only inherits further attribute values, if they have been previously assigned to a specific rank. For example, the object on rank one might receive the title "winner" as an attribute. If objects share a sorting attribute value, they are simply positioned one after the other in order of occurrence. The respective blocks of objects with a shared value are called *groups* within lists.

Insertion of objects into lists or *moving* existing objects within a list is handled by *sliding*. Sliding refers to the mechanic of objects automatically changing their rank and position, to cover for object movements within a list or to make space for a newly inserted object. Very essentially, if an object is moved from rank 3 to rank 1, the object previously occupying rank 1 slides to rank 2 and the one on rank 2 slides to rank 3 (cp. Figure 27). Sliding objects affects the sorting criterion, requiring semantic and attribute adjustments to reflect the new order of objects (see subsection "Evaluation of ordered lists").

34 The difference between a mere visualization and ordered lists lies in the immediacy of potential changes (a simple click, can immediately change the order), as well as the necessity of these changes in a dynamic working situation. Visualizations are *results*, while lists are semantic instruments and tools, for instance to quickly find an object with a specific attribute among a group of others.

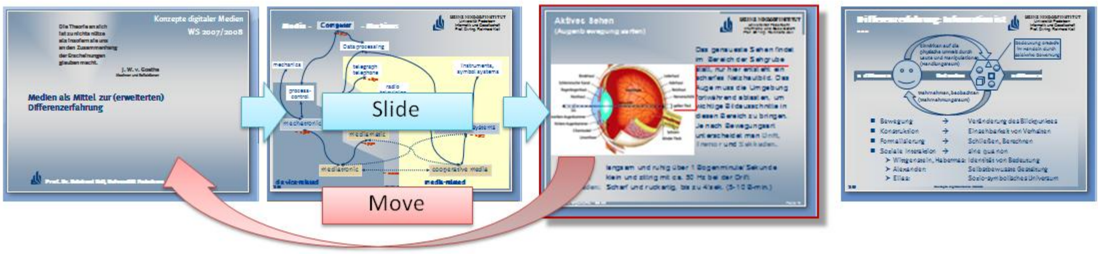

Figure 27: Objects slide to compensate movement of objects

The position of objects is also affected, when a user changes any of the following list parameters: starting point, first line point, step-value, direction, order or search criterion. Changing starting point, first line point or step value does not change the expressed order, but affects the coordinate position of objects or the size of the gap between elements. Changing the direction, order or search criterion calls the sorting mechanism, defined in the evaluation model and performs the necessary evaluation of each object's respective attribute, creating a newly ordered list in coordinate space.

While lists typically expand only in one direction of the coordinate space, it is possible to split the list at a certain entry and then continue it in a new 'row' or 'column' next to the original starting point. These lists can be called *split lists*.

Evaluation of ordered lists

Evaluation is a basic necessity in lists, regarding the analysis of sorting attribute values, to determine object position. Based on the supplied sorting criterion, a sorting algorithm (e.g. *BubbleSort, MergeSort, BucketSort etc.*) calculates the alpha-numeric order of objects, which can then be mapped to list ranks as absolute positions by a simple algorithm, e.g.:

```
Obj_1.pos = first_line.pos
For i = 2 to n
{ Obj_i.pos = Obj_i-1.pos + step_value}
```

Evaluations can be based on the *absolute position* of objects, their *relative position* or *existing attributes*. Any processing is triggered by user actions, affecting the arrangement, most commonly by moving one or more selected objects or choosing a sorting criterion. The respective actions in ordered lists are *inserting*, *sliding* or *deleting*. Lists are different from other arrangement types (except graphs), since changes of object position necessarily affect the *absolute position* of other objects. The ranks of objects change, based on insert, slide and delete actions in the list. Hence, evaluation and subsequent responsive behavior apply to all respectively affected object(s). Another difference is that obtaining a position in the list does not automatically associate a specific attribute value with an object. A rank has no clearly assigned value, its only semantic association is, that the respective attribute value is higher than that of the previous rank and lower than the next[35]. When an object is added to a table, without possessing an attribute value for the chosen sorting attribute, the user needs to manually supply one or the object assumes the value of the object previously occupying the assigned rank.

- *Absolute position*
  The current rank of an object in the list and the associated coordinate position counts as the absolute position. An evaluation of absolute position in lists refers to conditions mapped to a specific rank or a range of ranks. For instance, attributes may be associated with the "top 10" ranks in the list. An object moved to a new absolute position, has its old position analyzed in relation to the new one. The goal is to determine, at least how many objects are affected by the action and the necessary sliding operations, ensuring the object can assume its new position. All affected objects, have their position values rewritten, with the evaluations and conditions of their new position applying. For instance moving a new object into the "top 10", means that the object previously on rank 10 loses all the associated properties.
- *Relative position*
  Evaluating the relative position of objects in a list is possible, but is simply based on comparing rank, i.e. *before* or *after*, optionally qualified by the number of ranks in between, rather than coordinates. Distances in rank are not equal to distances in sorting attribute values. Therefore, comparing individual objects on this level is less sensible than evaluating absolute position in many scenarios.
- *Existing attributes*
  In lists the basic evaluation mode of 'sorting' uses existing object attributes to determine (absolute) position. The searching criterion defines, which attribute values are used to calculate the ordered sequence of objects and respective coordinate positions. A coordinate position value is written to each moved object (including insertion) and those affected. The evaluation model

35 Under an ascending sorting. Notions of higher and lower also apply to letters or other characters, usually following the ASCII table, with "b" higher than "a" and lower than "c".

monitors changes to object attribute values and if necessary, automatically re-sorts the list.

Moving objects within a list, will often change the associated sorting criterion, affecting the *semantic relation of order*. In effect, a movement action destroys a previously “enforced” sorting based on a selected attribute, if the object’s sorting attribute value does not automatically change to reflect the new position. One way of keeping the searching attribute intact, is letting the object assume the exact value of the object previously occupying the new rank or having the user enter a matching value (the fitting range of values can be shown to the user). However, sometimes a user may want to abandon the previous sorting attribute to establish a *manual ranking* or other order. In this case, to keep the order technically and semantically correct a *helper attribute* has to be created, e.g. the first object having assigned a “1”, the second object a “2” and so forth. The user has to provide a fitting semantic description for the manual order relation and/or establish new attributes, reflecting the manual ranking. This can have a certain semantic strength: Imagine a simple list of web pages that have been generated by an algorithm, based on a search query. The sorting based on numeric calculations of “relevancy” could be overridden by a user simply dragging those entries considered most relevant to the top of the list. While the enforced order is destroyed, an individual relevancy ranking is created that can be presented to the user at a later time, if the same query is submitted. Even better, the data of all privately sorted lists can be fed back and integrated into the algorithm or attributes that defines the order of the list in the first place.

Refinement

Refers to either enhancing object groups with further sorting criteria or expanding a single object, encapsulating further objects. Within groups media objects are not sorted, thus, potentially nullifying the benefit of finding specific items quickly. These media objects can be treated as a separate list, with their own secondary sorting attribute assigned or be integrated into the parent list. Guiding-lines or indention could be used to distinguish respective groups.

6.5.3. Categorizing Collections

Definition: *Categorizing collections are arrangements, where the coordinate position of objects within defined spatial regions expresses both the fulfillment of conditions and the possession of properties, associated with a region. Within the spatial working environment,* *inclusion in regions is a direct representation of membership of a class or category with respectively shared properties.*

Mapping semantic meaning to position

Categorizing Collections set objects in relation to *n* information dimensions, mapped visibly to *coordinate regions* defined in space. These regions constitute the main mapping marker for this arrangement type. Generally, regions are areas of connected coordinates, forming an identifiable unit in space. A region's theoretical minimal size is a single coordinate, while the practical minimal size is that of the largest (potentially includable) object in space. Categorizing collections and their regions are most suitable for information that needs clear structuring into categories or classes, so that shared properties become clearly understood. Conclusions for a problem solving process can then be derived for a class or category, instead of individually for the included objects. As mapping markers, all regions have defined attributes, namely a set of *covered coordinates*, a *binding* and *associated properties* which is depicted in Figure 28.

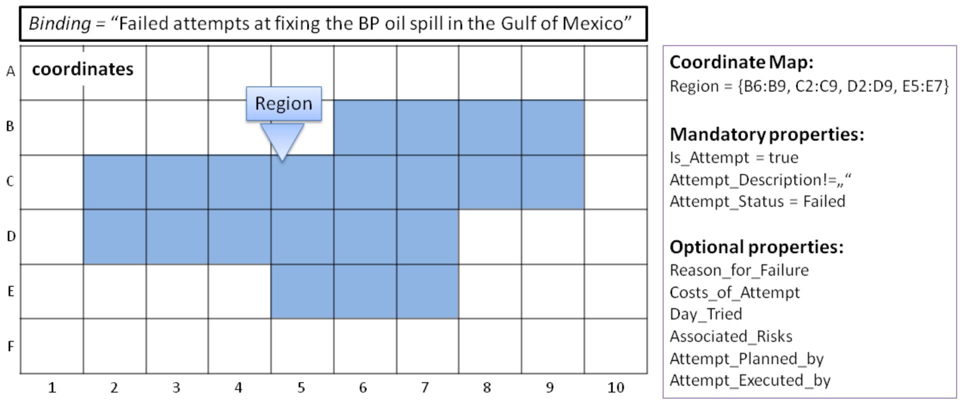

Figure 28: Region – mapping marker and the respective attributes explained

The *covered coordinates* are all the coordinates associated with the region, defining its position and shape. The only requirement is that the region's coordinates are all connected (i.e. adjacent). In most cases, regions will assume the form of graphic primitives, like rectangles or ellipsoids. Information is mapped directly to each coordinate of the region. This information is the same for each coordinate. The *binding* defines the semantic context, meaning and information expressed by the inclusion of objects. It is in fact, a summarizing description of the region as a category or class, in terms of the associated information dimension(s). Therefore it makes sense, to position the binding as a label in the respective regions vicinity or even directly on it. As regions are meant to represent a category or class, *associated properties* logically exist. These specify the general semantic description of the binding. Properties can be mandatory in relation to the semantic inclusion. Optional properties are *associations*, derived from binding and/or mandatory properties. In Figure 28 mandatory properties are: Objects represent attempts, have a description of the procedure and must have failed.

Any coordinate position belonging to a region, has the same associated mandatory *semantic properties,* which is the reason for calling it a collection, in respect to the included objects. However, a property does not have to be a specific value associated with an attribute, like “attempt = failed”. Semantic properties can also take the form of descriptive conditions that add information about included objects, as instances of the represented category or class. A ‘*has description*’ property, derived from the above example, associates an expectation with included objects: It has to have a value for the description attribute, but this can be any value. Properties can function as conditions and hence, objects without matching properties can be denied entry to a region (see *evaluation of categorizing collections*). In terms of transparency, especially in cooperative and long-term work contexts, the (mandatory) properties of a region should be stated visibly or at least be accessible (e.g. on a right click).

Inclusion, within a two dimensional space, refers to a complete enclosure of the object’s graphical representation within the region. Through common inclusion within a visibly distinct region of space, objects are perceived as a group with shared semantic properties. These semantic properties define a *category* or *class*. In my understanding the difference between the two terms lies in their explicitness:

- ***Categorization***
  Categorization does not aim for a precise differentiation of a whole ‘population’, but instead for supporting the handling and understanding of shared properties of its elements. Instead of defining large and very definite sets of associated properties and conditions of entry, categorizations are often based on a single shared attribute value. Hence, grouping is not mutually exclusive. An element can be included in several categories.
- ***Classification***
  A class has very explicitly defined conditions and details shared properties of its instances (i.e. the included objects). The purpose of classification is a precise differentiation of elements, within a larger ‘population’, into groups of elements sharing specified properties. This requires rather precise knowledge

> of the attributes of objects. Ultimately, one tries to achieve a state, where each object in space can be described as the instance of *exactly* one class. Classification, as a knowledge work process, aims at identifying classes, conditions and parameters to reach such a state by testing through dynamic changes. Once reached, however, dynamic changes to the context will logically become more scare and difficult, due to the depicted intricate distinctions. Arranged knowledge artifacts can still be changed dynamically.

A basic support for either classification or categorization is that after changes of a region's properties or conditions, objects automatically assume fitting positions or display conflicts. In categorization scenarios, this includes the extra challenge of recognizing and realizing potential inter- and subsections automatically. Media objects positioned completely within the spatial coordinates of a region, are checked for fulfilling conditions and inherit respectively associated semantic values.

Positioning objects in relation to regions

Only objects, whose graphic representation is positioned fully within the region's covered coordinates, count as *included* (cp. Figure 29). The exact position of objects within regions is irrelevant semantically. Only *inclusion* expresses classification or categorization and associates information to the respectively positioned objects. Due to the mapping of regions to coordinates, each region has an inside and outside. This defines a semantic border as a division of space. Objects placed inside regions, represent *instances* of the respective category or class. In turn, objects not included in any region have no associated class or category in the defined context.

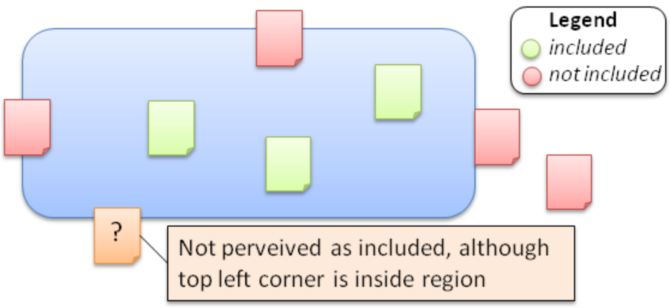

Figure 29: Objects perceived as included only when full-body is contained

Media objects only have one coordinate position in space. If it is to be included within two or more regions, the regions need to intersect. Technically, the respective regions share a common set of spatial coordinates. Objects 'contained' in these overlapping zones, still count as separately included in each of the respective regions, though specific evaluation and responsiveness could be defined for the intersection. An *intersection* represents objects common to two separate collections. A *subsection* is a special case of an intersection, where all objects from one region are also objects of a second (larger) collection[36], i.e. one with additional elements (see Figure 30). The size of regions may have to be dynamically adjusted, to cover for increasing numbers of included elements, so that each remains directly addressable[37].

When regions as mapping markers are moved or resized, this affects the position of included and possibly even excluded objects. If objects, that were not previously included in a specific region, become visibly enclosed, an evaluation process has to ensue regarding the changed *relative position*. The same basic rule applies to objects suddenly becoming part of an intersection or subsection and objects that become excluded by manipulations of the position or size of regions. Generally, expressed classifications or categorizations should be kept intact.

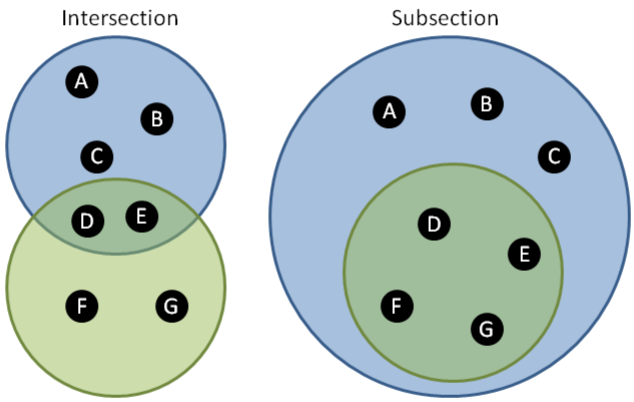

Figure 30: Visualization of the concepts of intersection and subsection

Evaluation of categorizing collections

Each region in space has its own evaluation model, based on its specific properties and conditions. Properties express shared combinations of existing (and through conditions even non-existing) attribute values of objects. One might for instance categorize animals after their genus. In this case each region and the respective objects share an attribute 'genus' with a *value v* (e.g. "Felinae"). Generally, the model describes the mapping of concrete semantic values to the region's coordinates and

36 If two sets contain identical elements, they are considered to be equal.

37 An object that is completely covered by other objects, cannot directly be addressed through mouse pointer interaction.

applying conditions, their processing and associated responsive behavior. Dealing with objects that fail to fulfill conditions, can be resolved differently. Options range from simply denying entry into the region, to automatically changing all relevant values to the object, which is difficult due to potential semantic conflicts (cp. Erren et al. 2008). A user may be required to manually choose between logical options. For instance, a condition of "A = 1 or B = 2" leaves a choice between three possible options for compatible objects. Conditions can be linked by connectors like "*and*", "*or*", "*xor*" and even "*not*". By chaining these together, complex semantic classifications can be formulated. This will not be analyzed here in any more detail, because it only affects what information is expressed and not how it is expressed spatially. Changing properties of a region or associated responsive behavior, changes the expressed semantic classification, requiring a re-evaluation of the included objects.

Evaluations can take place in respect to the *absolute* and *relative* positions of objects or *existing attributes*. Any processing is triggered by user actions affecting the arrangement, most commonly by moving one or more selected objects. The respective actions in categorizing collections are *inclusion* or *exclusion* of objects by creating, deleting or moving selected objects or by adjustments to regions, including changes of position, size and intersection. Any evaluation and subsequent responsive behavior apply only to the selected and moved objects. If regions are adapted, all objects that change in status of being included or excluded have to be considered.

- *Absolute Position*
  The absolute position of an object and coordinates covered by its graphical representation determine, if the object is included within a categorizing collection. When an object is 'dropped' at a coordinate, belonging to one or more regions, its relevant (previously existing) attributes are analyzed. If the object matches the defined conditions, it is assigned the new position value and inherits semantic properties, in the form of attribute values associated with the collection. Responsive behavior that changes an object attribute or status, like access rights or its perceivable publication, is tied directly to the *inclusion*. Hence, once an object is later excluded from such a region, logic dictates that any effects applied, because of the inclusion, will be undone.
- *Relative Position*
  Evaluations of relative position in categorizing collections, refer to the common inclusion. Respective objects share relevant properties, making

comparisons of these objects, senseless in most cases. Similarly, while individual objects can be compared on the level of their inclusion in different regions or in different states of being included or excluded, evaluations of these constructs seem superfluous, as these objects share no semantic relation. Other attributes than position of objects or regions may be more sensible for evaluations, e.g. the number of objects in a region.

- *Existing attributes*
  Generally, evaluation of objects dropped onto regions, was already covered under absolute position. Under certain conditions, like categories or classes being distinct from one another, objects newly introduced to the space might be positioned automatically, according to previously assigned attributes.

Possible evaluations may be caused by changing the size or position of regions, especially when intersections or subsections are created. Changes of a region's position or size mean that the included objects should move along with the region, while no new objects become included. This makes evaluation and responses like 'evasion' necessary. *Intersections* and *subsections* are overlaid regions, which can be evaluated separately, keeping associated properties. It is possible to assign specific properties, evaluations or behavior to an intersection or subsection, but then the respective description should be provided, like it was a separate region. In all other cases, objects moved into spatial intersections are evaluated separately for each region. Objects moved from a parent section into a subsection[38] only need to be evaluated on part of the additionally applying conditions and properties. The simultaneous application of properties and evaluations of intersecting regions can cause errors or even deadlocks, if responsive behavior or defined conditions are incompatible. A prevention of these states may require the processing of operations performed on regions, an error tolerant implementation and the caution of the user.

Refinement

In Categorizing Collections refinement refers to the definition of subsections, as further diversifications of existing classes, which can be blended in or out (filtering). Removing a subsection, does not destroy the semantic classification or categorization expressed by the parent section, but adding it will specify additional information, regarding the included objects.

38 Subsections are further specifications of their parent section and thus share all of its conditions plus at least one additional condition and bestowed property.

6.5.4. Combinatoric Matrices

Definition: *Combinatoric matrices are arrangements, where the semantic combination of two defined elements from the overall information space, is expressed by the coordinate position of objects, at the meeting area of orthogonal matrix rows and columns. Within the space of a respective knowledge work environment, each cell of such a matrix expresses specific (semantic) results or consequences of the associated combination. It is at times also possible to derive the overall number or combinations and results from the matrix.*

Mapping semantic meaning to position

Combinatoric matrices set objects in relation to unique combinations of $n + m$ elements of q information dimensions, mapped visibly to cells of an n-by-m-matrix. These matrices act as the relevant mapping marker in coordinate space. Generally, matrices consist of rows and columns of rectangular cells, which are arranged to form a rectangle without gaps. Each cell is mapped to a coordinate area in space, considering additional coordinates for perceivable dividers (borders) between cells. The minimal sensible size of a matrix, regarding combinations, is 2x2 (or 3x3 counting descriptor cells). Combinatoric matrices are most sensibly employed for mapping (related) information dimensions against each other, to investigate the results of their cross-wise combination. Knowledge artifacts arranged in relation to these matrices represent (known) results of certain combinations. Combinatoric matrices support problem solving processes, by detailing (all) possible combinations of relevant information dimensions and respective turnouts. All combinatoric matrices, as mapping markers, have a defined structure and attributes: *Start*, *rows*, *columns*, *row heights*, *column widths*, *binding*, *headers* and *associations* (cp. Figure 31). Additionally cells may be seen as individual objects with attributes like *fill_color*, *fill_pattern*, *border_width*, *border_color* etc. Cells and their attributes will not be analyzed specifically here for reasons of effectiveness.

Start refers to the coordinate, to which the top-left corner of the first matrix cell is mapped. This first cell is typically non-functional, due to simply dividing row and column headers (colored dark blue in Figure 31). *Rows* and *Columns* specify the number of horizontal and vertical 'vectors', which define the matrix (6 x 6 in Figure 31).

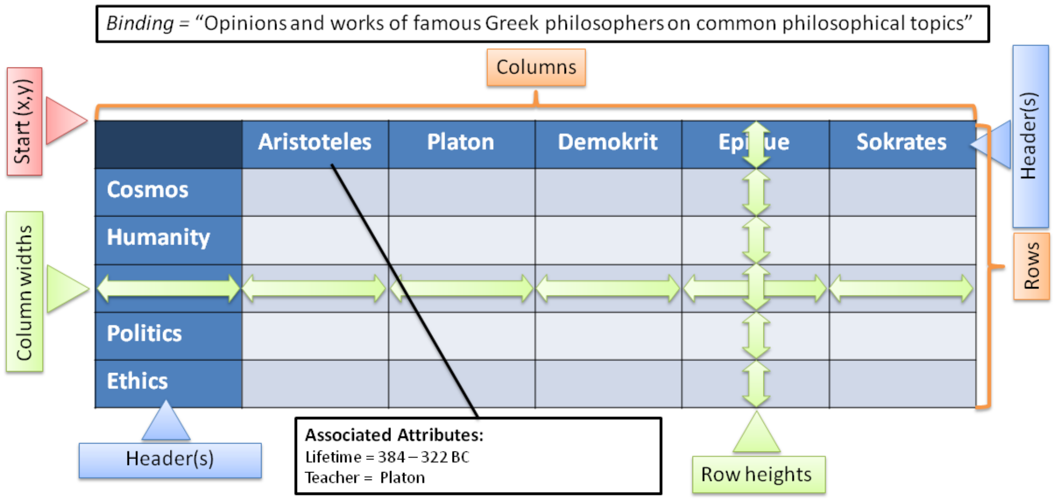

Figure 31: Matrix – mapping marker and respective attributes explained

Each row has a specific *height* and each column a specific *width* measured in coordinates. From these numbers, based on the defined starting point, the precise coordinates, to which each cell is mapped, can be calculated. A simplification would be to assume common heights and widths for each row and column or that a matrix covers the entire available space. Each column and row of the matrix represents an information dimension, called a *factor* (e.g. an abstract or concrete concept) with specific *associations*[39] (attributes). *Headers* are the descriptors (legends[40]) of the row and column factors and thus are responsible for the perceivable mapping of semantic meaning to cells and their coordinates. The *binding* defines the general semantic context, regarding what the *combinations* in the matrix represent and their purpose. *Associated attributes* typically do not refer to the entire matrix, but to headers and other cells. They express information that can be relevant to the expressed combinations and should be perceivable or at least accessible to users, for instance as an explanative text object. Generally, the order of headers is irrelevant and can be rearranged without changing the (number and meaning of) expressed semantic relations (*combinations*). It does, however, require a remapping of coordinates.

The semantic relation of *combination* is visibly expressed, by the meeting of coordinates of a row and a column[41]. Since every row meets every column, the

39 Elements can be anything from actual objects, to pieces of information or properties (e.g. "temperature below 0°C").

40 Including the possibility of „multi headers", i.e. a second row/column of headers grouping the primary vectors (staying with the example of philosophy, topics like "love" and "sense of life" could be grouped under the term "humanity"). See section *refinement*.

41 Both rows and columns are represented as rectangular areas in space.

interpretation is distinct from intersections (see chapter 6.5.3). The area where a row and a column meet, expresses the *semantic result* of the combination, which is often different from the sum or coexistence of the associated factors. Depending on the context, combination can literally refer to the result of mixing two components like chemicals. Cells define new information dimensions that are related to or dependent on the respective factors, but do not have to share any of their attributes. As such, cells often carry their own specific attributes (and possibly descriptions), which they inherit to respectively positioned objects. Any cell, as a combination, may have more than one result. It is also semantically possible for different cells to arrive at the same (combination) results. For example, different substances may be combined chemically with the shared result of an explosion. When describing all possible two-way combinations of factors in an information space, row and column headers are identical (Figure 32). Typically a triangular matrix[42] results, since most often the order of combination is irrelevant (A with B or B with A).

	A	B	C	D
A	Result (AA)	Result (AB, BA)	Result (AC, CA)	Result (AD, DA)
B		Result (BB)	Result (BC, CB)	Result (BD, DB)
C			Result (CC)	Result (CD, DC)
D				Result (DD)

Figure 32: Triangular matrix for all combinations of a given set of concepts/objects

Adjacent cells can be merged, in order to express that the respectively combined factors have the same result. For instance, in Figure 33 the authors A and B have collaborated on a paper with the topic "Missionaries of the 1600s". In top-bottom lists, rows represent *objects* which are *ordered* and columns show respective *attributes*. In combinatoric matrices, by contrast, objects are arranged in relation to individual cells as the semantic *results of combinations*.

<table>
<tr><th></th><th>Missionaries of the 1600s</th><th>Conquistadores of the 1600s</th></tr>
<tr><td>Author A</td><td rowspan="2">The South American Crusades.pdf
Adobe Acrobat Document</td><td>Battle over El-Dorado.pdf
Adobe Acrobat Document
14,9 MB</td></tr>
<tr><td>Author B</td><td>Milestones of the South American Invasion.doc
Microsoft Office Word 97</td></tr>
</table>

Figure 33: Combined cells to express the equality of results in adjacent cells

42 A triangular matrix is a matrix where either all values above or below the central diagonal are zero.

Positioning objects in relation to matrices

Media objects, positioned on a cell's coordinates, inherent the properties of the respective cell and sometimes additionally attributes of the parent vectors. The object is understood as *related to the result* of the combination of the semantic factors, associated with the crossing row and column. A philosophical text placed on a cell in the example of Figure 31, could inherit authorship attributes from the corresponding philosopher. It will in any case be assigned information only present in the combined state; like that a certain philosopher was a pacifist. A positioned object can describe the result or parts thereof; it can also represent a result itself, wholly or in part. Responsive behavior may ensue based on the fulfillment of *conditions*. In turn media objects can also be automatically positioned according to pre-assigned attributes that link them to exactly one row and column combination (either by vector or cell attributes). A text by Plato about the structure of the cosmos would have a clear position in Figure 31.

Specific matrices may enforce restrictions to a user's ability to position objects, like only being able to position objects in the top half of a triangular matrix. Generally, the exact spatial position of objects on a cell's coordinates is unimportant. For evaluation purposes, it makes sense to assume a similar condition of full body 'inclusion, as was defined for categorizing collections. Therefore, cell borders act as dividers. A certain level of positioning support, i.e. snapping[43], can support users working with matrices or regions.

Evaluation of combinatoric matrices

Each cell of a combinatoric matrix can have a separate evaluation model and unique responsive behavior. Generally, an evaluation model tied to a cell, describes the mapping of concrete attributes to the cell's coordinates and the inheritance of respective values to objects positioned there. Media objects positioned on header cells are not evaluated, they simply represent an additional descriptor, e.g. for associated attributes. Evaluations focus mainly on the *absolute* position of objects in relation to cells or on *existing attributes*. An evaluation of *relative position* is possible, but more complicated and thus will be less common. Processing is always triggered by user actions in relation to a combinatoric matrix, i.e. moving media objects onto cells.

43 It is sensible, to have objects move entirely onto a cell's or region's coordinates, based on the drop-point, even if only a small percentage of the object's body was hovering over the coordinates.

The respective user actions evaluated in combinatoric matrices are adding, deleting or moving objects within space, thereby affecting, which factors they represent a combination of.

- *Absolute position*
  When, through moving or adding, an object is 'dropped' at a coordinate belonging to a cell, it assumes the new position and inherits respective attribute values. An object leaving a cell may have to have these attributes (and associated effects) removed, similar to categorizing collections.
- *Relative position*
  Objects in different cells of a matrix are not usually understood as sharing any relation. A possible exception being objects in the same row or column, which may share respective attributes. An evaluation of the relative position of these objects refers to the changing orthogonal vector and how it affects results. Similarly, objects in a common cell can be evaluated, for instance regarding how partial results sensibly fit together. The number of objects on cells or in rows and columns can also be evaluated.
- *Existing Attributes*
  Objects may be positioned automatically, based on existing attributes, if these are unique for each cell.

Changes on the structure of a matrix, like changing the height/width of rows/ columns or exchanging the position of two vectors has an influence on the absolute (coordinate) position of objects that needs to be resolved automatically. Objects will move with the cells they are associated with. For objects that have not been on a cell previously, a process needs to be defined. Special kinds of (mathematic) matrices with their unique (operational) properties can be implemented through specific rules, conditions and evaluations. A triangular matrix for instance, may impose the rule that objects can only be placed on cells above the central diagonal.

Refinement

Refinement in matrices refers to headers spanning multiple columns (cp. Figure 34). As a triggered action it requires that these sectors can be collapsed or expanded. In that case, separate information needs to be tracked and displayed for the collapsed 'group' vector and the individual expanded vectors. For instance, in Figure 34 the expanded header reads "Total IT Cost (Mio €)", with columns for 2008 and 2009. In its collapsed state this changes to a sensible delta-analysis of the two values.

Expand for individual values

Company	Total IT Cost (Mio €) Delta 2008 vs. 2009
A	54,24
B	-1,74
C	-10,73
D	20,12

Collapse for Delta

Company	Total IT Cost (Mio €)	
	2008	2009
A	233,92	288,16
B	65,77	64,03
C	109,40	98,67
D	58,29	78,41

Figure 34: Example of vector refinement by expansion and coarsening by collapsing

6.5.5. Relational Graphs

Definition: *Relational Graphs are arrangements, where the coordinate position of objects is largely irrelevant for expressing semantic relation. Instead, relation is directly expressed by the position of objects along paths as perceivable connections between objects in a graph. Within the spatial working environment relation is expressed by connecting objects with labeled edges. Under the restriction that all connections express the same numerical relation, optimal paths can be calculated.*

Mapping semantic meaning to position

Relational graphs set objects in relation to one another, by mapping *n* related information dimensions to connections between objects. Connections are realized, independent from the coordinate position of objects, as perceivable lines or arrows between them. Essentially, the arrangement forms a graph, where objects are nodes and lines are edges. Generally, each edge represents a specific (directional) semantic relation and maps it to two objects. Hence, edges are the basic mapping marker of relational graphs. They can freely describe any type of relation between objects, making relational graphs a very flexible arrangement type; in fact, one could logically express most semantic relations associated with coordinate position in the other arrangement types. However, this may cause respective graphs to become highly complex.

Relational graphs are also regarded as a spatial semantic arrangement type. They express logic relations, by the relative position of connected objects along *paths*. A *path* is defined as a set of valid edge transitions to reach one node from another, passing a finite number of nodes in between. A path expresses a specific semantic relation, considered as the logical sum of the individual edge relations passed along the way. Hence, paths can be understood as advanced mapping markers of relational graphs.

All edges as mapping markers, have defined attributes, namely *two object IDs*, *associations*, a *direction* and a *label*. Attributes of paths are an *object sequence*, *source*, *target*, *transitions*, *associations* and a *binding (see* Figure 35*)*. The graph itself, as a network of objects arranged by edges and paths, is not a mapping marker, but constitutes the arrangement. It still carries a *unifying binding* and optionally a *type* as an attribute.

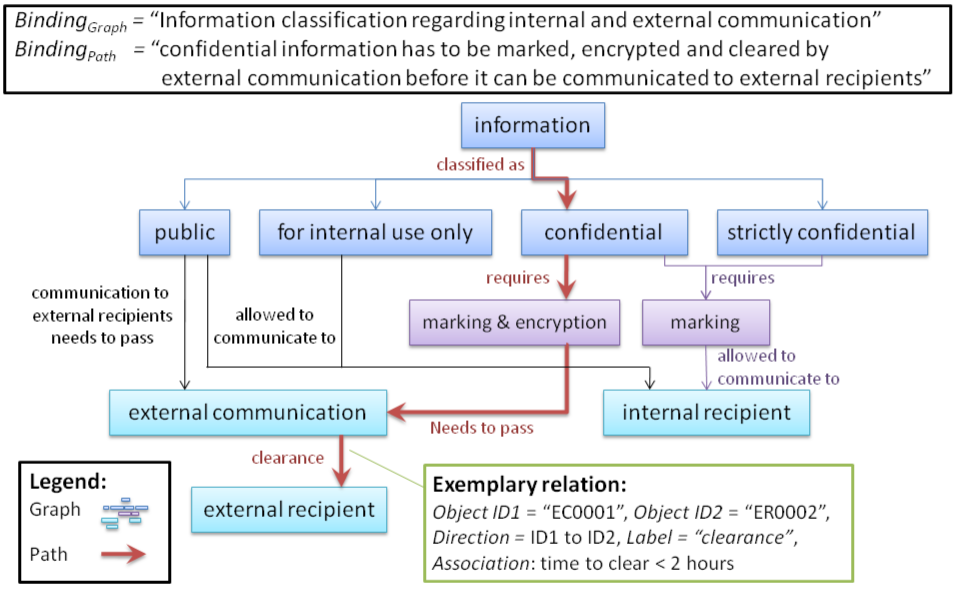

Figure 35: Graph, path, edge – mapping markers and respective attributes explained

The two *object IDs* of an edge define which objects it connects. The *direction* specifies if the edge is undirected or directed, with the definition of source and target. In the case of Figure 35 all edges are directed. The direction defines the relative *position* of the connected objects, either as "A before B", "A follows B" or "both". The mapped semantic meaning, in the form of a *label*, follows the direction in its interpretation. In Figure 35 information can be classified as public, not the other way around. The *label* is an edge's descriptor and defines the expressed information dimension of relation. Labels are typically displayed besides the edge. *Associations* can be any attribute and value combination, such as the "time to clear < 2 hours" in the example of Figure 35. *Paths* are defined as a sequence of objects, including a *source* ("information" in Figure 35), a *target* ("external recipient" in Figure 35) and the respective *transitions* in between. Listing the transitions is necessary, as there may be different possible paths between source and target object. Similar to edges, paths can optionally have *associated attributes*. A path's *binding* defines the specific relation between its source and target, derived from the "sum" of relations expressed along the transition sequence. The relational *graph* itself will in most cases sport a *unifying binding* that explains the overall semantic context.

The semantic concept of relational graphs, namely *specific relation*, is expressed between any two connected objects. Source and target objects count as connected if the target can be reached via an edge or path from the source. Edges represent *direct relations*, as paths with a length (=number of transitions) of 1. However increasing path length is not necessarily an indicator of decreasing relational strength. For instance, an organigram defines a hierarchy. A group leader is the direct boss of his team with the associated authority. Still, an executive director, with a longer path to an individual team member, has more authority. In the formed network of objects and relations, semantic interpretation will often focus on paths rather than edges, as paths are more complex. Edges and paths are addressable, but for paths to become perceivable among the others in a graph, it needs to be marked up and receive a visible binding. Paths can only be compared, if the overall relation they express is compatible. This is most easily ensured, if only a single type of relation exists in a graph. Enforcing a limitation of one relation type, allows comparing all possible paths between a chosen source and target node, at the cost of lower diversity of expressible information.

Edges can be distinguished roughly into those with qualitative (e.g. "belongs to") or quantitative[44] (e.g. "42") labels. In the latter case, the value typically indicates a *weight*[45] that has to be explained in a separate legend or the graph's overall binding. Weights allow for comparing different paths between the same two objects, by the actual numerical sum of the relations passed. These kind of graphs are typically used for optimization problems, for instance to identify bottle necks or cost sinks and solve the problem by finding ways around. Paths, based (mainly) on qualitative edges, can express advanced *logic relations*, like *transitivity*; e.g. if A is the father of B and B is the father of C, then A is also C's grandfather.

There are many possible types of graphs, e.g. trees, and identifiable relational structures within graphs, like circles. These will not be discussed in this thesis, due to the massive scope of possibilities, which cannot be covered here. As rules can be mapped to graphs and different logic types of nodes and relations can be introduced, the arrangement type is even by itself quite complex. Future research might address,

44 In that case, a separate legend or binding is needed to explain what relation the number expresses.

45 Weights in graphs refer to relations that express semantic meaning by quantity rather than quality. E.g. "cost of passage between location A and B".

if different types of spatial positioning can also be distinguished within relational graphs. Also, the fact, that graphs can express semantic relations (largely) independent of the respective objects' coordinate positions making them similar to markups in this respect, may have to be discussed.

Positioning objects in relation by edges

Position is a complex issue in Relational Graphs, as only objects with formulated relations *to other objects* have a position that can be evaluated in the graph network. Graphs are different from the other arrangement types, with the exception of ordered lists: Objects are not positioned in relation to a mapping marker in the background, but put directly in relation to other objects. Edges, as the mapping marker, form the graph arrangement's structure, making coordinate position (largely) irrelevant semantically for relational graphs. Instead, any interpretation of position is based on relative position. Here, relative position refers to where in the network one object is compared to another and what (path) relation exists between them. Thus, to be perceived as part of a relational graph, an object has to be connected with at least one other node of the graph by an edge.

Objects are positioned by connect operations in this arrangement type. An object's position is adjusted by altering at least one of its existing relations (or corresponding attributes), represented by edges, adding a new one or removing an existing one. Connections are established manually or inferred from existing attributes. *Adding* a new edge means direction, label and associations have to be supplied. Connected objects keep their *coordinate position* (attribute), but have a specific *relational position attribute* whose values are rewritten. This attribute records incoming or outgoing edges and the ID of the respectively connected object. Thereby, an object's graph-related (relative) position is determined[46]. Additional attributes may be written, based on associations of an edge or of a specific type of edge, defined in the evaluation model. *Removing* a relation means that the respective attributes of both connected objects are removed together with the edge as the mapping marker. A problem that needs to be solved in graphs is that deleting a single edge can disconnect a whole sub-graph (see Figure 36). Any two compatible graphs (like the disconnected sub-graphs) in the same space can be (re-)connected, by creating a relation between any node of the first and any node of the second one. *Altering* an edge is a move operation. It

46 There are several ways of implementing edges in graphs and representing position, this is only one of these. Depending on the given scenario, another implementation may have to be chosen.

refers to changing the direction of an edge or exchanging a connected object for another. In the latter case, one object looses an existing connection, while another object gains one.

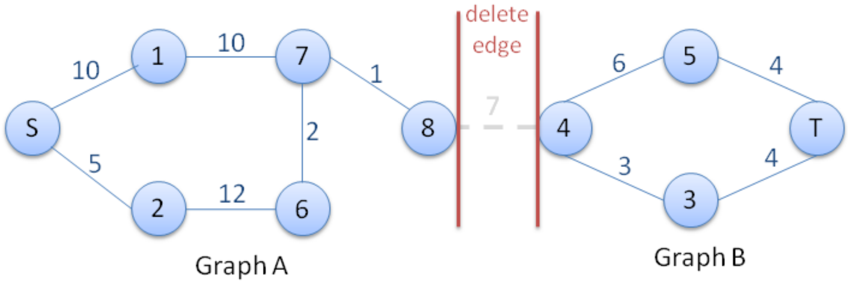

Figure 36: Deleting the last remaining edge connecting two sub-graphs

Evaluation of relational graphs

Each type of relational edge can have a separate evaluation model and respective responsive behavior. Paths are the second level of evaluation. Any analysis of position in graphs is *relative* to other objects. Alternative paths can be compared, when relations are compatible, which in most scenarios will come down to either weighted graphs or those with a single qualitative relation type. Creating an evaluation model for a specific path seems less sensible, as paths can change quickly in dynamic arrangements. However, it may be possible to define path types, such as "a path of length 4" or "a path where a relation A is followed by relation B". These path types can have an evaluation model with specific applying attributes and responsive behavior. Evaluations on this level can refer to the position of an object in sequence (e.g. the "third" object receives the attribute "contract=yes"). Additionally, evaluations in graphs may check for keeping defined rules, such as having no circles in directed graphs. Graphs can also be scanned for (relational) patterns, like identifying objects with a certain number of incoming relations. Finally, an evaluation can highlight the semantic expression of *choice* in the form of possible paths, by which a selected target can be reached from an equally chosen source.

Evaluation in graphs only works on *relative position* or *existing attributes* that already define links to other objects. Processing is triggered based on spatial user actions within the arrangement. Within Relational Graphs these are limited to *connecting* or *disconnecting* objects to or from a relational graph, thereby affecting their position and relation to other objects along other paths. Generally, responsive behavior comes into play following connect or disconnect actions based on the fulfillment of *conditions*.

- *Relative position*
  Through a connect, re-connect or disconnect action an object assumes a new position in the relational graph. This affects the relational position of at least those objects that can be reached by paths starting from this object and vice versa. Attributes of the directly involved two objects (those between which the edge is established) are analyzed and written first. An analysis of previously existing or new paths, on the level of changes to object position or semantic relation, may ensue, depending on the defined model and conditions. The nature of these conditions is tied to the represented relations, semantic rules mapped to the graph and/or available object attributes. For instance, in a mathematical tree a relation creating a circle would be denied. Similarly, one could define conditions or rules on what kinds of objects can be connected by a specific relation. A “son of” relation for instance requires two objects representing either animals of the same species or humans and the ‘target’ object being male.
- *Existing attributes*
  Automatically establishing edges for objects in space, based on their attributes[47] matching certain criteria, requires the definition of conditions and edge types in the model. Generally, an evaluation model is tied to *edge types*, i.e. all edges with a shared label. It describes attributes that connected objects inherit, which can be different for source and target. The evaluation of paths has a similar process and requirements. In weighted graphs, evaluations can identify and highlight optimal paths, based on parameters and an analysis of the sum of the individual quantities. Paths with a singular qualitative relation type may be analyzed by their length or against a set of defined transitive transitions, to find out if any apply, with the respective consequences. Multiple types of relation in a single graph make evaluation more difficult and require that *path types* – in addition to *edge types* – are defined. These too, can be analyzed in relation to defined procedures, e.g. if defined transitive relations apply.

Changing the label of an edge is equal to a change of semantic position, since the relation of the two connected objects and in extension all other connected objects is altered. In contrast, moving a connected media object to a new coordinate position

47 Inferring object position (= relational position) from attributes is difficult in graphs, except if existing attributes already link to other objects.

only requires an adjustment of the attributes of its edges that govern its appearance, without affecting the expressed logic relations.

Refinement

Refinement in graphs refers to node elements that encapsulate a sub graph (cp. Figure 37). Defined points of entry and exit are necessary in the sub graph, so that it is functionally connected, in both collapsed and expanded state. Thus edges leading towards or from the encapsulated entry or exit points are respectively projected to or from the capsule element (see dotted lines in Figure 37). Refinement can then add or remove detail about a specific path relation, as further nodes and edges are passed. It is important that each refinement object or node applies only to one specific closed sub graph that it condenses.

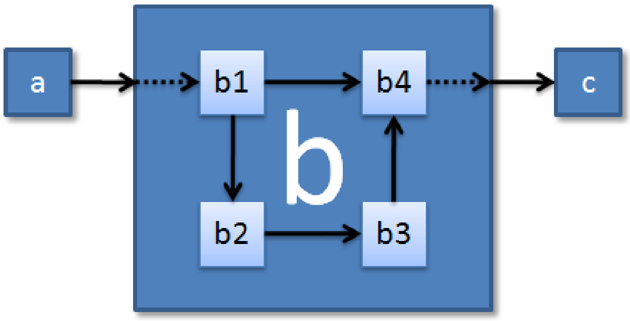

Figure 37: Refinement in Relational Graphs

6.5.6. Summary

While there are usually lots of possibilities of evaluation (and responsive behavior) for the spatial actions of each arrangement type, in most cases there will be very few (1-3) predominant evaluations taking place. This has both reasons of practicality (including the effort to set up an evaluation model) and second of poignancy. If every coordinate is evaluated differently and can have drastically different effects, a user would probably not be able to discern the overall context and meaning. Hence, a bit of advice is to keep the evaluation model within an arrangement type poignant and clear, with as few specific evaluations as necessary.

6.5.7. Conclusion: Formulating Hypotheses with Semantic Positioning

The *binding* used in all arrangement types, makes the expressed relation of the respective semantic dimension perceivable (i.e. distance, order, inclusion, combination, relation). It refers to the overall arrangement and thus provides an understanding of the general mapping of information and relation to position. The binding together with its associated evaluation model define the context of any semantic arrangement. Object position becomes meaningful, because of the perceivable textual, spatial and systemic layers being matched in Semantic Positioning. Here, a positioned object in space formulates at least a single hypothesis about its own interpretation in the given context. Hence, arranging objects in relation to interpretable contexts and/or one another is equal to formulating hypotheses about the objects that have been positioned. In case these have already been tested and approved, the arrangement states factual knowledge regarding the corresponding objects. Technically, position becomes meaningful by writing attributes to the positioned objects, by processing movements in relation to programmed conventions and applying matching operations. Still, room may be left for interpretations. Any hypothesis, expressed by object position or context, can be questioned and discussed.

Figure 38 is a representation of the maturity and interest associated with modern technologies, akin to a *hype cycle*[48]. The public presence and expectations regarding a technology called 'hype' is mapped against its technological 'maturity'. A standard formula curve represents experience values of how hype develops over time in relation to maturity. Each position chosen for a technology object, as well as the predicted duration until it reaches maturity, are expressed hypotheses that might be questioned in a Semantic Positioning scenario, since object positions can be regarded as assumptions. One might for instance question if tablet PCs as a technology have already reached main stream adoption. The example demonstrates effectively that an object's *semantic position* expresses a *hypothesis* that needs to be explained. Even the fact that all objects are placed on the line in Figure 38 or that there is only a single line, implying each technology is hyped to the same heights, may be questioned. Explanations for an object's position can be supplied in its contents or as an attribute, on which basis the positioning may become either clear or lead to discussions.

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48 The term "hype cycle" was coined and copyrighted by Gartner Inc. (ww.gartner.com); While the basic likeness was adopted from Garnter Inc.'s hype cycles, Figure 38 is not a hype cycle, but only a rough personal rendition similar to hype cycles to illustrate how hypotheses can be formulated and questioned assuming Figure 38 is a Semantic Positioning Arrangement. Figure 38 and its description above do not reflect Gartner Inc.'s respective views or assessments; the illustration does not depict actual technologies and had its labeling changed to not infringe on Gartner Inc.'s copyright. Gartner Inc. hype cycles, are published as extensive research documents explaining the positioning of technologies by their analysts. The following is a link to the actual Gartner Inc. "hype cycle of emerging technologies 2010" in context: http://www.gartner.com/it/page.jsp?id=1447613 (last accessed 31.10.2010)

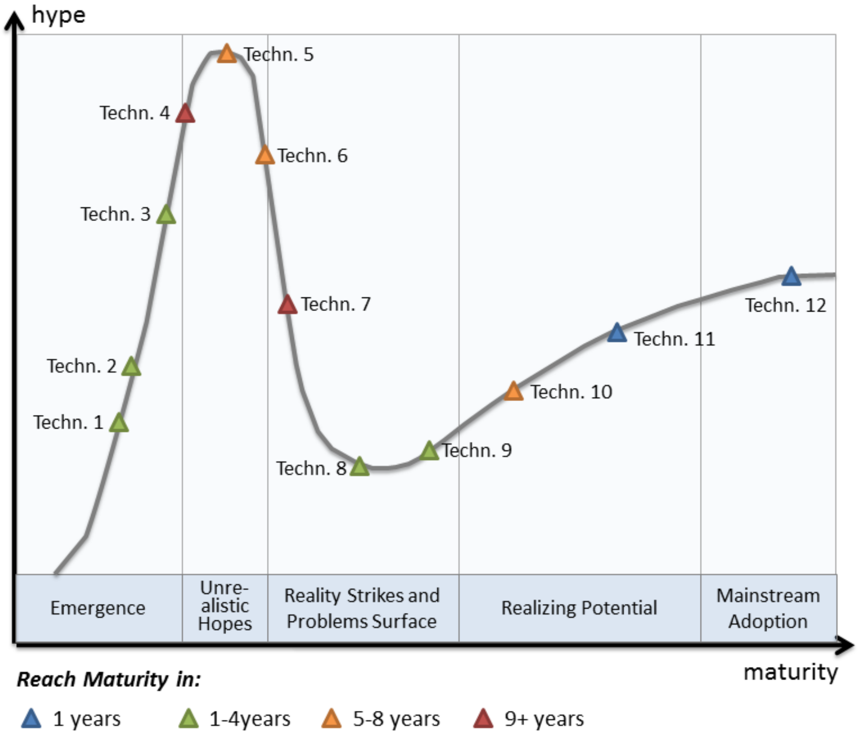

Figure 38: Example of a hype cycle (inspired by those published by research institute Gartner)

The clarity of the five arrangement types and the overview they provide, help address chosen *semantic positions* directly for discussions and allow asking questions poignantly. This makes Semantic Positioning a strong communication tool regarding hypotheses, already on the level of individual arrangement types and even more so on the level of overlays (see chapter 6.6). First indications that this strength can be realized and recognized in scenarios of use were offered in (Erren & Keil 2006, Erren 2007, Erren & Keil 2007a and Erren & Keil 2007b). In addition, a questionnaire of 84 students that worked with Semantic Positioning, within two parallel courses in 2008, revealed that 59 students (approximately 70%) regarded it as effective for displaying and communicating information. More than this indicative proof will be necessary, if Semantic Positioning, with its framework, is to be established as a tool for effective communication. This is however not the focus of this thesis.

6.6. Overlays

The focus of the previous sections was on the individual arrangement types and what makes them spatially and semantically distinct, regarding the expression of meaning by positioning objects. Based on this analysis each arrangement type is specifically apt at expressing and evaluating a certain (single) kind of information. Depending on the complexity of knowledge work problems faced, several different kinds of information may be relevant and/or have to be related. For instance, classification through inclusion can be enriched by also expressing through distance that a few classes are semantically close, while others are more distant.

These kind of enrichments are essentially a combined use of two or more arrangement types by an *overlay* of respective mapping markers. The five arrangement types are not simply distinct spatially and semantically, they are *spatially compatible* regarding overlay. Any arrangement type can be overlaid over any other, though of course not all such overlays make sense for each situation. One must, however, deal with an increasing complexity of a semantically correct arrangement, which especially poses challenges for evaluations. This is because *semantic compatibility* is more difficult to ensure. Before dealing with the respective problems, let us first focus on what the term overlay means in the context of Semantic Positioning

Overlay is based on the 'height' property of 2.5 dimensional digital desktops that allows projecting media objects onto layers. A *layer* is on principal a transparent plane covering assigned coordinates. To ease things, Semantic Positioning assumes layers cover all the available coordinates of a space. Layers work like a slate of glass, on which two dimensional object representations (typically icons) are positioned. These glass plates can be stacked and thus have objects 'hover' above or below another i.e. *overlay* (cp. Figure 39). An object, three layers above another, does not fall down.

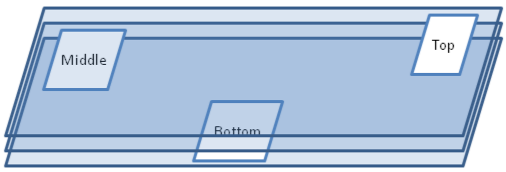

Figure 39: Three layers stacked on top of each other, with one object each

6.6.1. Requirements and Difficulties of Overlays

Layers in Semantic Positioning are a necessity, both to arrange media objects in 2.5 dimensions and to enable the use of mapping markers in the 'background' of working materials in the foreground. Here, the term *overlay* specifically refers to the simultaneous use of two or more (different) arrangement types, in a single working space[49]. In the simplest case, each of the arrangement types of a knowledge structure is represented by an individual layer[50], on which its mapping markers are placed and that stores its evaluation model. Using the mapping markers of two arrangement types technically involves putting one of the respective layers above the other. Evaluation processes at first remain separate, which may be error prone, without checking the evaluation models for semantic incompatibilities and resolving issues. For instance, at a certain position the evaluation of one arrangement type might return a *true* condition for publishing an object, while another might return *false*.

Errors typically happen in two situations: Either both evaluation models write different values to the same attribute(s) or have other two responsive operations setup that try to apply opposing operations to the same object. Both types of errors stem from the fact that two or more evaluation models address the same object position, which can be identified when layers are overlaid. It may however require the user to find and resolve issues. Even without evaluations, when arrangement types on layers express semantically opposing or incompatible information at certain positions, it is the user's task to adapt the knowledge structure.

Keeping the necessary compatibility of evaluations in mind, the benefits of using overlays in Semantic Positioning outweigh potential problems. To simplify the evaluation process, it is sensible to enforce the following restrictions. Arrangement types in their most condensed form (i.e. just one spatial axis for coordinate topographies or one type of relation for graphs), only represent a single information dimension. In addition there is only a single associated object attribute, to which values are written, based on responsive behavior. Using just one arrangement type, with these restrictions in place means, the arrangement structure is as simple as respectively possible and only very basic relations can be expressed:

- **Distance:** ***A single axis as the mapping marker***[51]
  - Object *A* at coordinate *P* => Attribute *Q* of *A* has value *V* that is mapped to *P*
  - Object *A* close to object *B* => *A* similar to *B* based on the similar value for attribute *Q*

49 Overlaying a horizontal and vertical axis in order to create a Cartesian coordinate system is the same as overlaying different arrangement types like a region overlaid on top of a graph.

50 Technically these layers may group object layers, which still need to exist so that the digital objects (which also make up mapping markers) can be properly handled.

51 Two axes would already be overlay.

  - Object *A* not close to object *B* => *A* not similar to *B* based on a large(r) delta between respective values for attribute *Q*
- **Order:** ***A single sorting criterion***
  - Object *A* at coordinate *P* → *A* is on 'rank' *R* of the list, mapped to *P*
  - Object *A* higher/lower in list than object *B* → *A* is ranked higher/lower than *B* based on respective values for sorting criterion *C*
- **Inclusion:** ***A single region as the mapping marker***[52]
  - Object *A* at coordinate *P* and *P* is covered by region *R* → *A* is included in *R* and thus an instance of the respective category/class *C*; attribute *Q* of *A* has value *V* mapped to *P*
  - Object *A* and *B* included in region C → *A* and *B* share value *V* of attribute *Q*
  - Object A is included in region C, but object B is not → A and B do not share the same value for attribute *Q*
- **Combination:** ***A simple x*y matrix as the mapping marker***
  - Object *A* at coordinate *P* and *P* is associated with cell *C* at the intersection of column *F* and row *G* → *A* is the result of combining factors *F* and *G* and attribute *Q* of *A* has value *V*, mapped to *P*.
  - Object *A* and *B* positioned at cell *C* => *A* and *B* are possible or partial results of combining the factors *F* and *G*, with both having a shared value of *V* for attribute *Q*
- **Path-relation:** ***A single type of relation, either textual or numeric***
  - Object *A* connected to *B* by edge *C* expressing relation *R* => *A* and *B* are directly related in the depicted direction; attribute Q for both objects has a value V of "A-R-B".
  - Object A can reach object B over existing path => A and B are related to a degree, based for instance on the number of passed edges or the accumulated values of the relation expressed by the edges

These restrictions do affect the expressiveness of overlay knowledge structures, but still leave enough room for complexity: Even with just a second arrangement type applied to a space, each relevant coordinate[53] gains a mapping of an additional attribute and information dimension, which are thereby related to the existing ones. The complexity of information that can be represented spatially, increases with every

52 Two or more regions would be possible as long as there is no intersection or subsection, but the logic consequences are the same as detailed.

53 If relational graphs are involved the mapping instead directly applies to objects.

further overlay, as it will have effects on each of the existing arrangement type layers. Complexity does not only stem from coordinate positions being enriched with information and evaluations. It also comes from the fact that the arrangement schemes and respective mapping markers instantly form dependencies and relations among themselves. Chapter 6.6.2 shows by example, how the expressiveness of overlays lies in the formation of these spatial and the respectively derived semantic dependencies.

6.6.2. Expressiveness – The Reason for Overlays

Since semantic meaning can be freely mapped to the arrangement, an example needs to suffice as an explanation of logic dependencies, stemming from the way mapping markers on layers are arranged in relation to one another: Imagine a time axis (Coordinate Topography) that runs linearly from left to right (cp. Figure 40). A region that spans the height of the space, but not its width, semantically and spatially indicates a phase or period, e.g. "Space 1" in Figure 40. In contrast, a region that does not extend the whole vertical space rather expresses a process, event or a series of events. For instance, if the region in "Space 2" of Figure 40 represents World War 2, a lot of media objects referencing that time frame touch on topics related to the war. These should be included within the region, but a Mexican poem about the beauty of nature coincidentally written in 1943 probably should not be included.

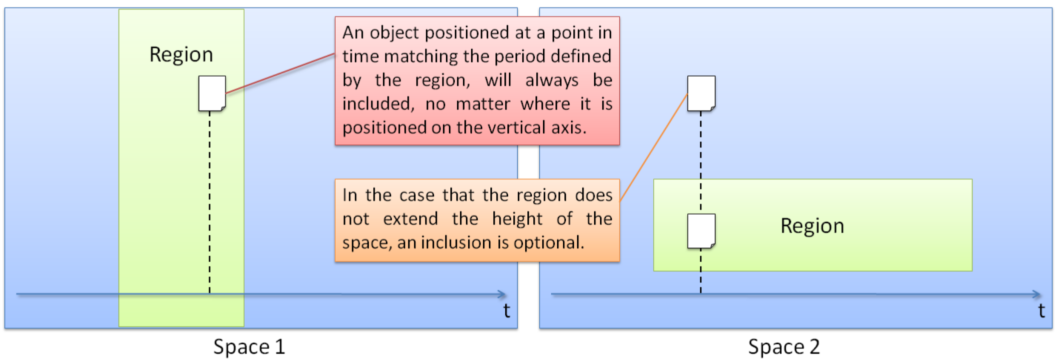

Figure 40: A region spanning the entire vertical space is different from a region that does not

The important conclusion is that through overlays multiple qualities relevant for a problem solving process can be expressed simultaneously at a *semantic position*. Though it will in some cases be a complex problem to find an apt representation, the descriptive nature of Semantic Positioning allows in any stage of arrangement the formulation of *questions*, to *test* if the current representation is suitable. For instance, take an overlay arrangement, created by students in a seminar displayed in Figure 41.

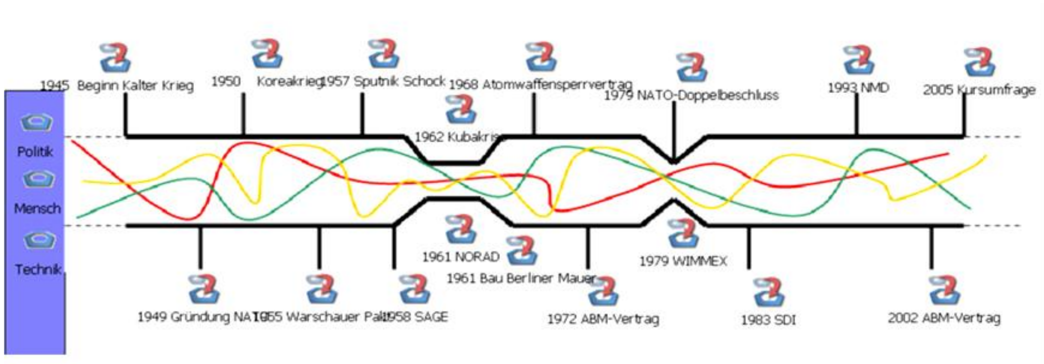

Figure 41: Time tunnel – overlay of collection, basic time axis and function lines

In earlier publications[54] we have called this form of arrangement a "*time tunnel*". The depicted knowledge structure basically is an overlay of a time axis and a region (i.e. the tunnel), derived from a function line that is mirrored horizontally. The tunnel's tightening indicates periods of crisis that did almost lead to an "accidental nuclear war". Three additional function lines represent human, economic and technologic influences and faults that may have almost caused a catastrophic accident. The students chose to depict these lines chaotically interwoven within the tunnel, to represent the hypothesis that for every incident in time, a mixture of all three factors was responsible. Since these objects are a perceivable (and manipulable) part of the arrangement context, any viewer can question the presented assumption. Looking at the provided literature for each event, it was easy to demonstrate that often technical faults had been responsible for a crisis, which was only prevented by human intervention. Hence it might be more sensible to choose a representation, where these two factors are represented as lines[55] within the tunnel, along a middle ordinate showing the respectively causing (positive value) and correcting factors (negative value) for each incident (Figure 42).

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54 The depicted time tunnel is one result of a learning scenario called Medi@Thing that has been introduced in (Erren & Keil 2007), as a refinement of the Jour Fixe concept presented in (Hampel et al. 2003). Its goal is to make students find a semantic representation of a given complex topic, by creating a knowledge structure, through spatial arrangement of relevant documents, instead of writing a document. Semantic Positioning enhances the immediate understanding of what the presented materials are about and how they are related.

55 Please note that lines have not been properly adjusted to their actual values, the figure is only meant to illustrate the general point.

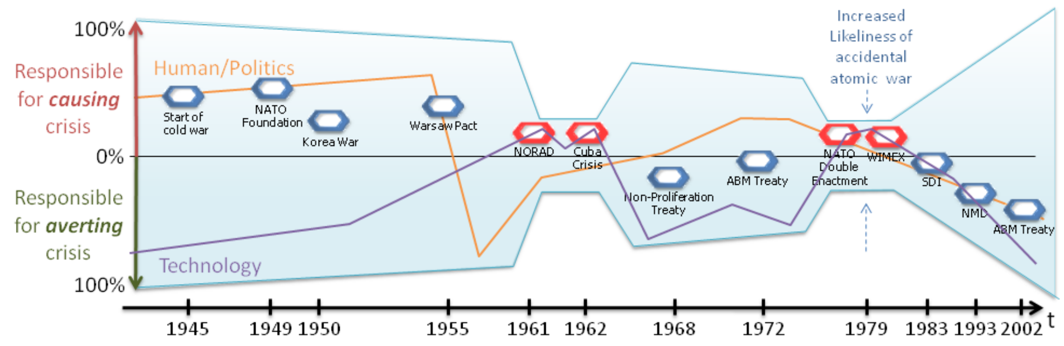

Figure 42: Updated time tunnel that details the responsibility of the influence factors

The time tunnel example and its discussion demonstrate how the position of media objects in overlay arrangements, represents hypotheses semantically. It also indicates, how important a perceivable representation of bindings is. While each arrangement type by itself only represents a single semantic concept (e.g. closeness), overlay enables the use of multiple concepts within the same arrangement, at the same semantic position. This adds complexity to the overall construction and evaluation, but also, as the example has shown, to the interpretative dimension. Each piece of available information about an object or the chosen arrangement can be questioned, just like hypotheses in a complex text could. However, using Semantic Positioning makes it easy to point to potential problems. This in turn means, the construction of arrangements is an equally complex process, if the arrangement is meant to represent gained understanding and ultimately knowledge. Working with just a single arrangement type is easier, simply because not as much thought has to flow into the logic of the composition compared to using overlay.

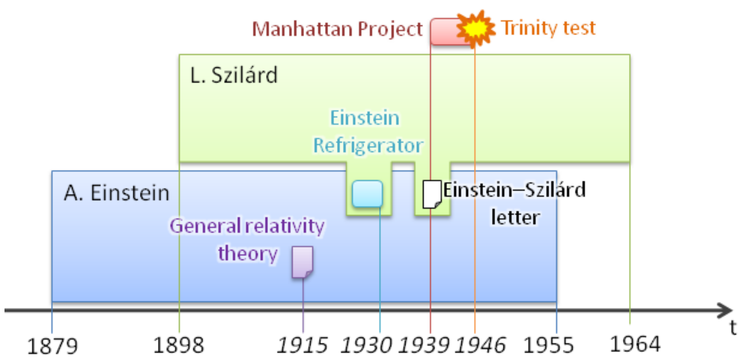

Figure 43: Overlay of three mapping markers demonstrates semantic complexity

Overlay allows increasing the complexity of arrangements, by mapping multiple dependent or independent information dimensions to a single spatial position.

Questions arise not only regarding the correctness of the semantic *interrelations* depicted, but even if mapping markers have been arranged compatibly. Finally, depending on the relational arrangement of mapping markers in overlays, distinct semantic meaning is associated with a mapping marker, their spatial relation and by specific positions.

Figure 43 demonstrates this: Essentially, it represents an overlay of two regions and a time axis. Arranged knowledge artifacts describe inventions, correspondence or projects. Each mapping marker, taken by itself in relation to the arranged objects details information (cp. Figure 43):

- *Green region*: Represents inventor Leó Slizárd, who has (co-)invented the “Einstein refrigerator” and (co-)written the “Einstein-Szilárd letter”. He has not worked on “general relativity theory” or the “Manhattan Project”.
- *Blue region*: Represents inventor Albert Einstein, who (co-)invented the “general relativity theory”, the “Einstein refrigerator” and wrote the “Einstein-Szilárd letter”. He has not worked on the “Manhattan Project.
- *Time axis*: General relativity theory was postulated in 1915, the Einstein Refrigerator developed from 1926 to 1930, the Einstein-Slizárd letter written in 1939 and the Manhattan Project took place from 1939 till 1946, ended by the successful Trinity Test.

Additional information can be concluded from the sum of the individual bits of information: Slizárd and Einstein cooperated on both the Einstein refrigerator and the Einstein-Slizárd letter. Meaning they must be contemporaries. However, looking at the overlay, even more information can be deduced, because of the spatial-semantic relations formed mapping markers:

- Einstein lived from 1879 to 1955
- Slizárd lived from 1889 to 1964
- They were contemporaries for 57 years

In addition, the information that they collaborated on two works, is immediately perceivable from the intersecting regions and does not have to be deduced. This demonstrates that the interpretation of an overlay arrangement can express more information and semantic meaning than the simple sum of the individual arrangement types.

This is proof of the first part of **hypothesis 2**: "*Overlays of mapping markers and the respective information dimensions, in semantic spatial arrangements, may deliver a higher complexity of expressible semantic meaning, than the sum of their individual interpretations…*"

This level of argumentative detail in a knowledge structure requires a developed understanding of the (overlay) relations between objects within the problem solving context, starting with the question of relevancy. The higher complexity and expressiveness of overlay arrangements enable spatio-semantic reasoning in a working environment. Reasoning is the basic foundation of problem solving processes, which as we discussed in chapters 2.1 and 2.2, requires the formulation and testing of hypotheses.

6.6.3. Refinement in Overlays

While refinements for each of the five arrangement types were discussed briefly, the individual refinement methods are often difficult to apply in composed overlays. In overlays, the added detail of refinement may best be represented by a separate Semantic Positioning arrangement, in the form of a linked sub-space. This sub space is a separate spatial pane, on which a part of the parent arrangement may be explained in more detail.

My personal experience is that if the sub-space features a very different arrangement context from its parent-space, confusion ensues about how parent and sub-space and the respective information are connected. In addition one should keep the depth of the hierarchy of sub-spaces low, best only using a single sub-level. Otherwise one risks destroying the purpose of Semantic Positioning to provide a helpful mix of overview and detail.

6.6.4. Evaluation with the Layer Model

Evaluations of overlays are difficult to accomplish, because of the multiple arrangement types employed to map at least an equal number of information dimensions to space. Any evaluation is based on objects from *working material layer(s)* being positioned, in relation to the *context layer(s)* that describe semantic information spatially by mapping markers. Each mapping marker is on a separate layer with an associated evaluation model, called *evaluation layers*. Figure 44 demonstrates that topographical axes are on the blue evaluation layer(s), while the orange evaluation layer carries a region. The evaluation model, associated with an evaluation layer, specifies analyses of object attributes and responsive effects based on the positioning of objects. Taken together, the evaluation layers of an arrangement form the *evaluation context*.

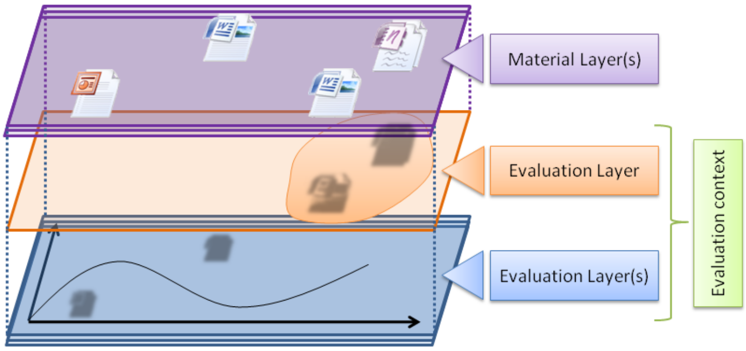

Figure 44: Layer model of Semantic Positioning

Any object above another object, including mapping markers, will be analyzed as part of the context set by lower evaluation layers. Hence, one needs to define a fitting stacking order of layers, since even mapping markers will be evaluated in relation to lower layers (though differently from materials). Evaluation models of the individual layers can also be linked, with the lowest layer as an ideal hub for connecting the individual relations. This enables the definition of responsive functions, tied to conditions spanning multiple evaluation layers and arrangement types.

6.6.5. Two Basic Layering Concepts

Each layer is equal in 'size' to the whole of the space. As described, coordinate topographies, ordering lists and combinatoric matrices define mapping markers that apply to the whole of the available space, while Categorizing Collections define resizable areas in space and Relational Graphs form networks between objects. It makes sense then that either of the first three arrangement types acts as a lowest layer, while collections and graphs can be arranged on higher layers. While all arrangement layers are compatible for overlays, I will describe a few typical issues regarding the spatial compatibility of whole-space arrangement types among each other as well as with regions and graphs:

- *Compatibility of collections with topographies, lists and/or matrices*
  Regions should logically be positioned before these arrangement types.
  Logically, it only makes sense to build collections for objects that are located

spatially close within the respective other arrangement types (topographies, lists and/or matrices). In relation to lists and matrices, this refers to directly adjacent objects and cells. Trying to build collections, over spatially highly distributed objects or cells, is ultimately bound to fail. This is because it is difficult or even impossible to find an area shape that includes all relevant items, while at the same time excluding all other objects (Figure 45). In those cases markups are better fit to define position independent groups, for instance, by assigning the respective objects a common color.

- *Compatibility of matrices with topographies and/or lists*
  On principle, matrices have to be sorted to fit the linear progression of a list and/or axis. In relation to axes, widths and heights of columns and/or rows may have to be individually adjusted to match the defined coordinate value structure.
- *Compatibility of topograhies and lists*
  While it is easy to sort objects along the opposing vector of a single existing axis, the situation changes if order is imposed in direction of the axis. If the order of objects along the axis matches a search criterion (different from the attribute associated with the axis), a new relation is expressed. Otherwise, the Topography simply is the only recognizable arrangement type.
- *Compatibility of graphs*
  Graphs enjoy a special status due to connecting objects independent of their coordinate location. They should always be positioned on the highest possible context layer, in order to keep, for instance, regions from covering edges.

Semantic Positioning does not formulate restrictions of exchanging data from one layer with another, though these can be enforced in certain scenarios.

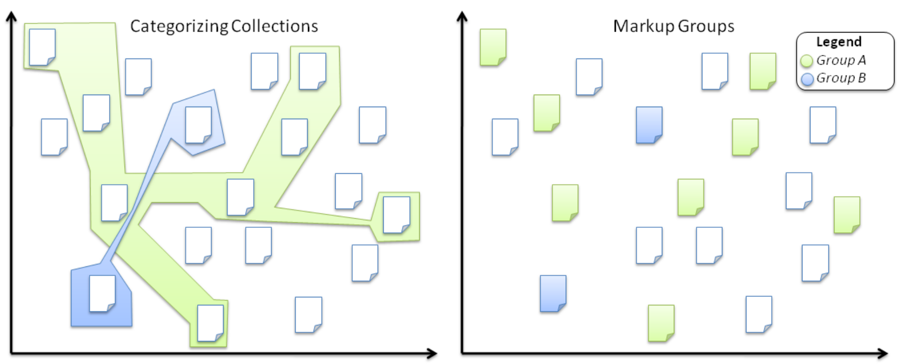

Figure 45: Collections fare worse than markups in grouping distributed objects

6.6.6. Object Overlays

It is possible, in Semantic Positioning scenarios, to employ secondary sets of object attributes. For instance, two users might assign individual positions to the same object, with both being stored as separate values of the same attribute (Figure 46).

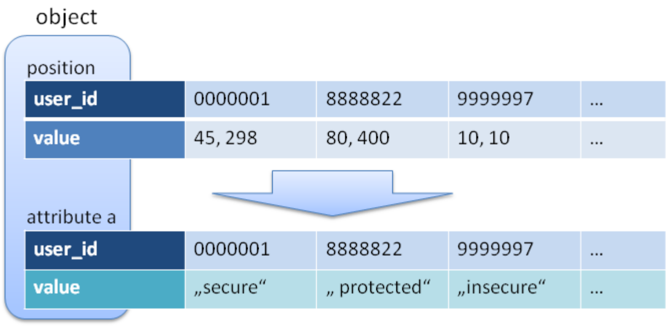

Figure 46: Object with attribute values individual to a set of users (e.g. via hash tables)

This expresses an opinional or alternate view, regarding the object's meaning. Though, for a specific user, only the self-chosen values might be displayed. If the alternative views are overlaid for comparisons, that is called *object overlay*. This specific kind of overlay is practical for learning scenarios. For instance, a teacher might have already assigned positions to objects, which students have to place in a semantic arrangement context to demonstrate their knowledge (see chapter 7.1 and Figure 47).

Now, the evaluation could simply state for each object if the position the student chose is right or wrong or using *object overlay* can actually show the correct object positions on a separate layer. In order to support quick comparisons, the new layer or more precisely the respective alternative object instances and their positions should be easily identifiable. This may, for instance, be achieved by marking them up by a different color or even drawing edges between diverging instances (cp. Figure 47).

Object overlay could also be used in cooperative scenarios to compare different opinions of users, expressed by object positions. Chapter 7.2 describes a scenario that makes extensive use of object overlays, in order to foster differential experience in a multi user knowledge work effort. Objects with multiple alternate position values will be referred to as *individualized* or *personalized (media) objects* in the following.

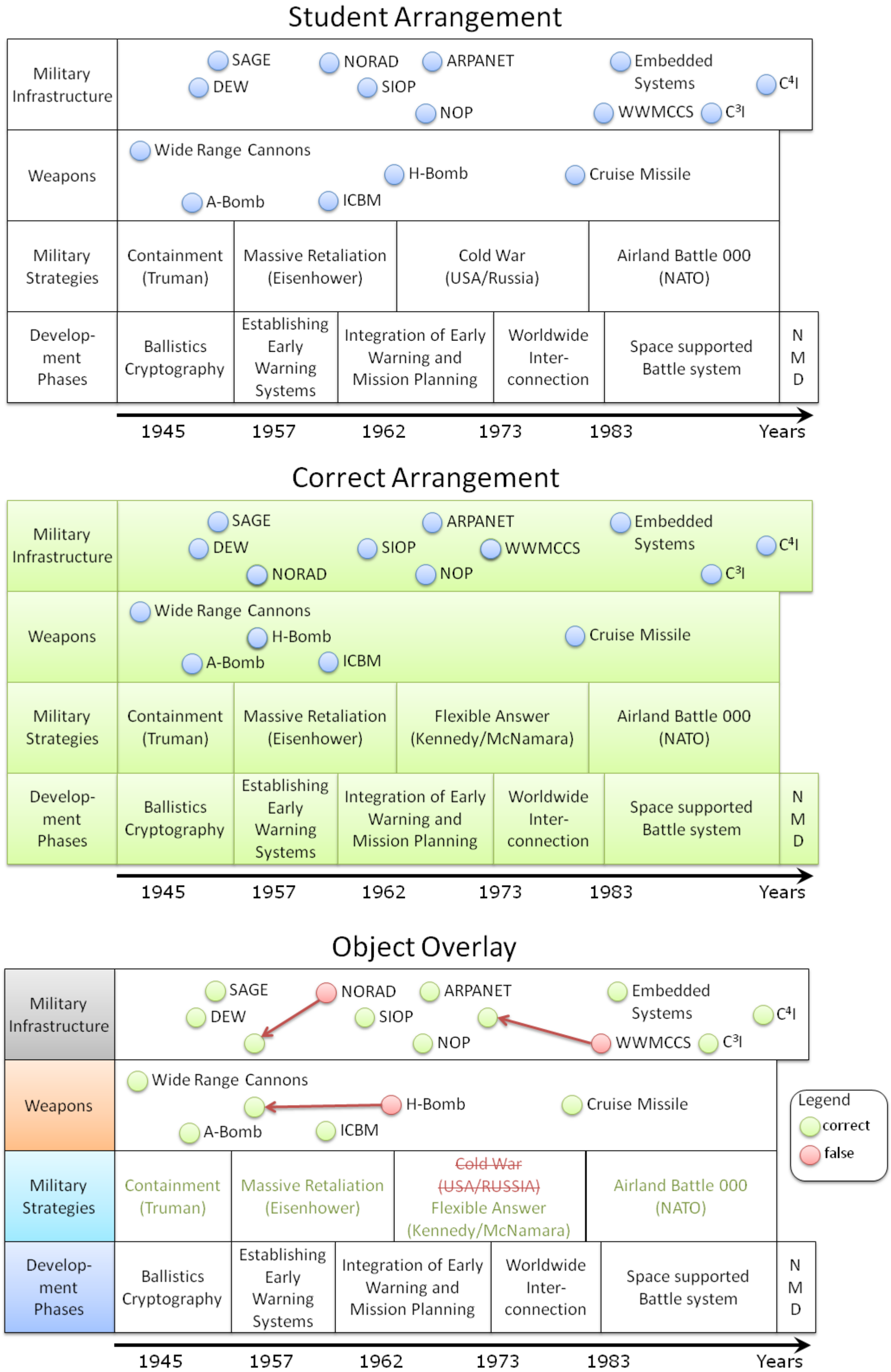

Figure 47: Object overlay showing correct vs. incorrect positions and text

6.6.7. Compound Mapping Markers

Interestingly, much of the appeal of overlays lies in the dependencies of the respective arrangement types. Applying the spatial semantic concept of one arrangement type to another, like ranking a set of collections, is very potent semantically. This way, even new kinds of *compound mapping markers* can be created. A compound mapping marker is an object, composed indivisibly of elements from different types of mapping markers. The example of the time tunnel (Figure 42), discussed in chapter 6.6.2 is such a compound object. A region was created, by mirroring the formula line of a coordinate topography. While the line itself expressed the rise and fall of danger, the tunnel structure increases the visual immediacy of critical situations as bottlenecks in the tunnel. Compound mapping markers are only rarely encountered in semantic spatial arrangements. The reason is the creative effort needed to create one, fitting the specific problem one is facing. Still, it will be interesting to see, what kind of new compound mapping markers people may compose prospectively.

6.6.8. Layer Functions

Previously, we have discussed the notions of *context/evaluation* and *working material* layers. These constitute the basic types of layers in Semantic Positioning. Adding a layer to an overlay arrangement is usually done for a specific purpose, sometimes tied to the specific *function* the layer serves. The following is an exemplary list of layer functions that can be used in scenarios to achieve the described effect:

- ***Personalization Layer***
  By adding this type of layer, all working materials gain a new *personalized* position value, tied to the current user. At the time of creating the layer, the respective values are set to the previously perceivable working material layer. Any active or indirect changes to object position will probably result in attributes, other than that of position, being written. The respective attributes will also record the values as personal values in relation to the personalization layer and current user. Restricting a user to a single personalization layer, can be sensible in some scenarios of use.
- ***Privacy Layer***
  A privacy layer is a specific type of personalization layer that is only visible to authorized users. This privacy extends to the personalized object attributes and manipulations of these values.

- ***Presentation Layer***
  A presentation layer is a specific kind of personalization layer, where a number of selected objects, on the level of context and working materials, have locked personalized positions and attributes. The respective objects need to be selected and keep all position values they visibly had at the time of adding the layer.
- ***Aggregation Layer***
  Adding this type of personalization layer automatically applies a chosen formula (e.g. *average*) to object position and/or dependent attributes of all selected, relevant and/or personalized media object instances in space. An "aggregation attribute" is defined for position and all other corresponding object attributes. The layer should automatically update the average values, in the case of changes to the underlying arrangement.
- ***Opacity Layer***
  Adding this type of layer means that lower layers are displayed at less opacity (e.g. 70% opacity) or grayed out in order to emphasize the status of the previously selected objects, displayed with full opacity on this layer. This can be sensibly combined with an aggregation layer, showing only the new "aggregated" objects.
- ***Filter Layer***
  Adding this kind of layer, on top of object layers, means that based on specified criteria on the layer, a subset of the objects positioned in space become 'blanked out', i.e. removed from perception. Thus the hidden objects cannot be addressed and manipulated on the filter layer. Still, the objects remain in space and can be displayed again by removing the layer or changing its filtering parameters accordingly.

6.7. Responsiveness

Responsive functionality in overlay arrangements may affect both working material and context objects (e.g. mapping markers) on the level of their *contents*, *system status*, *system position* (e.g. published on a web server), *access rights, manipulability* or *attributes,* including *appearance* (markup dimensions). Responsiveness is bound to processing user actions and thus starts when objects are moved and/or attribute values changed. It can affect the changed object(s), spatially and/or semantically related object(s) or even unrelated objects. Additionally, responsive behavior may influence the users *view* on the space (e.g. filtering or zooming) or cause a reaction beyond the confines of the arrangement, such as popup messages, writing reminders/tasks into a calendar, sending messages to users, opening or closing applications etc. Responsiveness is unique to each working scenario and hence will not be analyzed in any more depth here.

6.8. Action Schemes

One point we haven't touched so far is that of *action schemes*. The term is a literal translation of the German term "Handlungsschema" used by (Wettler 1979) in the realm of philosophical sciences. He defines it as the result of the construction of a representation schema, storing the typical characteristics (actor, prerequisite, corpus, result) of actions. In contrast, within Semantic Positioning, the term describes the overall goal or function of user actions in the medi@rena space, including the purposeful invocation of responsive behavior. One could thus simply say, they describe the *contextual purpose* of the working environment.

On a very simple level this purpose could, for instance, be "assignment of attribute values"; i.e. a user arranges media objects in front of a context, so that they receive an attribute value that can be derived directly from their position in space. Imagine for instance a space, where six regions show the overall categories of frequently asked questions and by simply dragging a question document to one of the regions, it is respectively tagged.

The following list is meant to provide a short overview of a few principal action schemes and the respectively associated (general) conventions:

- ***Assignment***
  An object's attribute value, system status, access right or content are derived from its position in the arrangement and respectively assigned.
- ***Response***
  One or more attribute values (including that of position), system status, access rights and/or content of objects are evaluated upon positioning them. Defined responsive behavior ensues, based on the evaluation results.

- ***Right/Wrong Analysis***
  An object's position and respective attribute values are compared to reference values, either coming from a secondary set of personalized attributes (e.g. provided by a teacher in learning scenarios) or standard values defined in the evaluation model. The goal is to judge if an object was correctly placed.
- ***Pattern Recognition***
  Identifying if a moved object fulfills a pattern or destroys an existing one. Patterns depict inter object relations, like forming a group based on position.
- ***Optimization***
  Objects are (re)positioned in space to reach a desired optimal state or result (e.g. minimizing costs in a delivery graph). The effect of (re)positioning any object is immediately evaluated and a new optional result is represented.
- ***Cooperative Writing/Feedback***
  An object's position in a space governs the configuration of access rights, with at least one position ensuring that authorized users may (exclusively) edit the objects, rate them or provide specific feedback.
- ***Cooperative Construction***
  A number of users position shared objects within a common space. Each object is provided with a single shared position attribute. Each object attribute, including that of position can, at any time, only be manipulated by a single user. Added functionality may be required for this action scheme, for instance in the area of awareness, like visualizing the users' mouse pointers.
- ***Discussion/Comparison***
  A number of users position a set of objects within a shared space, each providing personalized position attributes (i.e. a single object has *n* positions, each associated with a single one of *n* users). These different object positions express 'opinions' and can be displayed via overlay for comparison and discussion. Goals may differ, for instance, reaching agreement on the position of an object among the participating users.
- ***Aggregation***
  A number of users position a set of objects within a shared space, each providing a defined set of personalized position attributes. These attributes are aggregated through an evaluation formula towards a single value, which can then be assigned to the object as another personalized attribute or even as its final position.

- ***Automated Positioning***
  The position of objects is derived from evaluating existing object attributes relevant to the current context.
- ***Exchange***
  Exchanges of the context layer(s) cause an automated rearrangement of objects, to reflect the new mapping of information to space (extension of the action scheme of *Automated Positioning*). For that purpose, their attributes are evaluated and upon matches with the new context, position is derived from the respective values.

Action schemes can be tied together synchronously or asynchronously, governed by a set of rules. Hence, multi step scenarios with different arrangement types applying on each step can be created, to support longer knowledge work processes. For instance, if we regard pyramid discourses (Blanck 2006, Hampel & Heckmann 2005) as a kind of Semantic Positioning, then the spatial structure of the pyramid is a representation of the stepwise unification process. regarding formulated hypotheses. The associated action scheme on each step is *unification*, meaning that a single hypothesis is derived from two previous ones, based on defined rules.

Generally, action schemes enable the definition of types of medi@rena spaces, that when implemented, can simply be chosen as the starting point for specific knowledge work and learning needs. A teacher, for example, would often chose the *right/wrong analysis* space, in order to formulate arrangement based exercises or exams for students. In the concrete scenarios presented in chapter 7, specific mention will be made of the respectively applying action schemes.

7. Scenarios – Proving the Hypotheses

"I refuse to prove that I exist," says God, "for proof denies faith, and without faith I am nothing." – "But," says Man, "The Babel fish is a dead giveaway, isn't it? It could not have evolved by chance. It proves you exist, and so therefore, by your own arguments, you don't. QED." – "Oh dear," says God, "I hadn't thought of that," and promptly vanished in a puff of logic."

Douglas Adams (1952-2001)

After having gained an understanding of the individual five arrangement types and their specific roles in knowledge structuring with Semantic Positioning, it is necessary to prove their potential worth for problem solving contexts of knowledge work. This will be performed in three individual scenarios within this chapter. The respectively formulated hypotheses from chapter 6.1 will be used here (remember that part of **hypothesis 2** has already been proven in section 6.6.2).

Essentially, the potential of supporting knowledge work, formulated in **hypothesis 1**, can be realized in the two ways:

a) Reducing the necessary actions a user needs to take, to reach a desired effect.
b) Allow gaining differential experience in more sophisticated or efficient ways.

Though both conditions represent alternative forms of support in **hypothesis 1**, at least one example for each of the two options has to be provided in order to prove the hypothesis. The first two of the three knowledge work scenarios presented in this chapter, will show how, in a concrete overlay setting, the described benefits apply and thereby prove the remaining part of **hypothesis 2**. The third scenario presents proof of **hypothesis 3**, which focuses on the unique concept of exchanging evaluation layers within overlays, to realize benefits for supporting knowledge work.

Summarized, the three scenarios present the following situations within knowledge work contexts with a focus on e-learning:

- ***Improving multiple-choice exams***
  Both the processes of creation and filling out multiple choice exams can be enhanced in efficiency, by reducing necessary actions. The scenario focuses on the action scheme of right/wrong analysis.

- ***Improving Differential Experience in Cooperative Discussions***
  To improve argumentations in a discussion process, the personalized positioning of objects by multiple users can easily be compared and evaluated by object overlays. These alternate views go beyond the scope of meta-plan techniques or digital whiteboards. The scenario is based mainly on the action schemes of Discussion/Comparison and Aggregation.
- ***Improving Semester planning and feedback by exchanging contexts***
  Exchanging the context for objects between planning and feedback views supports systematically improving both the course structure and respectively provided materials. The action scheme of exchange is most relevant here, but aggregation and optimization play a role too.

Each scenario will first be introduced and described both textually and with a graphical depiction of the respective arrangements, covering both Semantic Positioning and the traditional implementation. Then, through a direct comparison of the two, the alleged benefits are proven and discussed.

7.1. Multiple Choice Improvement

This first scenario presents a Semantic Positioning arrangement, set up as an e-learning scenario, based on the 2008 American presidential elections. Here, a student has to correctly position media objects, based on his knowledge of the topic and a provided basic context. A respective *solution*, prepared by the teacher, is then used for evaluation. This procedure is compared to a (digital) multiple choice exam, asking questions to address all information represented by positioning in the knowledge structure. Semantic Positioning manages to present an overview of relations that is difficult to reconstruct from answers to the sequential questions of the compared multiple choice exam. In addition, the amount of user actions, for both creating the tests and taking them, is significantly lower in the spatial semantic arrangement.

7.1.1. Description of Scenario

One of the central pillars of general education is evoking an understanding in pupils of their nation's political system. The system of electing parties into the nation's respective government seats (e.g. Congress) and electing the country's main political representative (e.g. President), is one of the most important concepts that a future voter needs to understand.

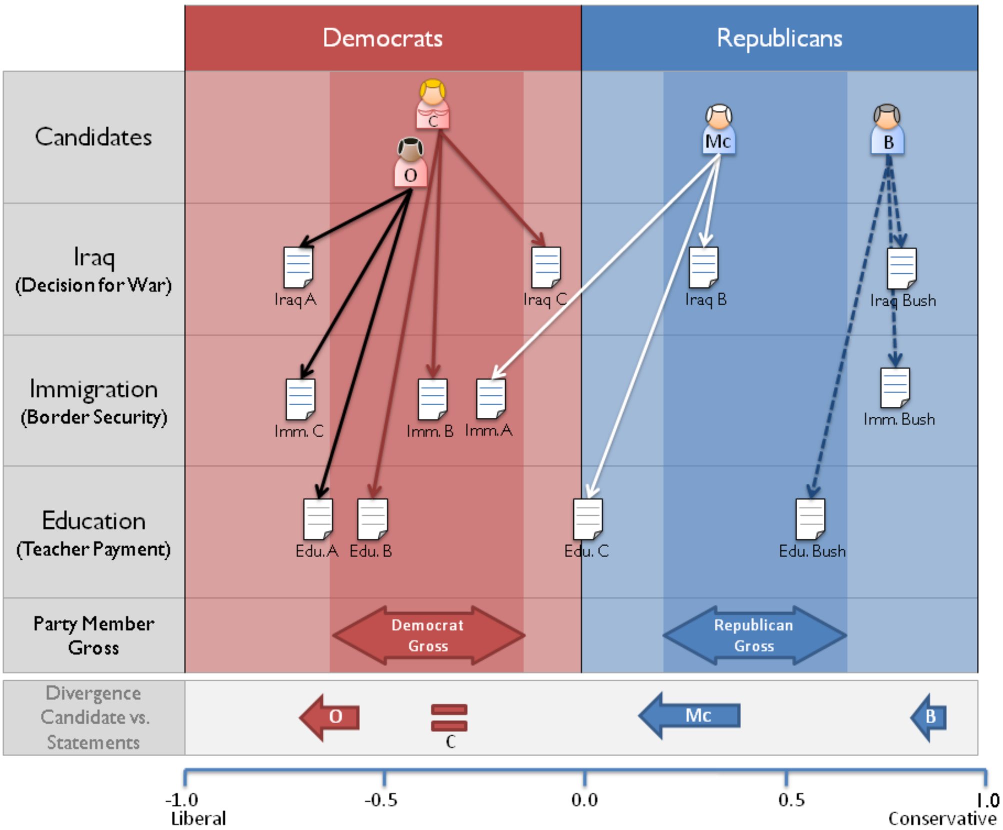

Figure 48: 2008 American presidential election candidates and statements on political spectrum

The following e-learning scenario is nestled within this understanding and focuses mainly on the topic of the political spectrum, between extreme liberal and extreme conservative. It uses the 2008 American presidential elections as its context. On this level, it is important to understand, not only which range of the spectrum the two main parties represent, but also how liberal or conservative the respective candidates are based on their voting behavior in congress. This is put in contrast to the political standing of the candidates' political agendas, represented by statements from campaigning. One should assume that context, candidates and a few of the agendas have been discussed in class previously.

In an exam situation it is expected of students to demonstrate their understanding of the political spectrum, by identifying how liberal or conservative candidate's campaign statements and the politicians are themselves. Within this scenario, the teacher intends to write a multiple choice exam[56], due to the large body of students having to take the test and the possibility of an automated evaluation. Before presenting the classic multiple choice exam, it is necessary to gain a picture of what is required of the students (Figure 48), which is easier with the alternative Semantic Positioning arrangement.

Represented in the knowledge structure are the three presidential candidates of around April 2008, meaning that Senator Hillary Clinton was still campaigning against Senator Barrack Obama and Senator John McCain. Alongside these candidates former US President George W. Bush is positioned for comparisons. Students are asked, to describe these persons' political orientation on the political spectrum, between liberal extreme (-1.0) and conservative extreme (1.0). The judgment is based on the candidates' voting behavior[57] in congress during 2007.

Both Democratic and Republican parties can be represented as mapping markers in relation to that spectrum. Students are asked to adjust the position and width of these regions, to visualize the gross of the parties members voting behavior (cp. Figure 48). Finally, students will have to match twelve political statements[58] to a value[59] on the spectrum, the person who uttered them (3 for each) and one of three topic areas: "Decision for going to war in Iraq", "border security relating to (illegal) immigration" and "teacher payment within the education system". All statements feature a catchy sentence, uttered by one of the candidates, as well as a short summary of the context in which it was uttered, e.g.:

- […] became a vocal critic of Bush's tactics six months into the Iraq war. But last year, he became one of the staunchest defenders of President Bush's current surge strategy: *"The invasion was not a mistake. The handling of the war was a terrible mistake*."[60]

---

56 Among other advantages of multiple choice tests one has to list grading objectivity and consistence, easier preparation for both teachers and test takers, timely feedback as well as efficiency for large numbers of students, because the tests are machine gradable (cp. Kuechler & Simkin).

57 Positions are based on Carroll, R., Lewis, J., Lo, J., McCarty, N., Poole, K. Rosenthal, H. (2008): "Who is more liberal, Senator Obama or Senator Clinton", web article that can be found at (last access 1st of April 2010): http://voteview.org/Clinton_and_Obama.htm

58 Statements reflect campaigning speeches, except those of President Bush, which have been taken from speeches during his term explaining his politics.

59 Political orientation inferred from the statement and respective agenda alone.

60 Source (last accessed on 1st of April 2010): http://www.usnews.com/articles/news/campaign-2008/2008/03/28/where-clinton-obama-and-mccain-stand-on-iraq.html

From these value assignments, several bits of information can be derived, for instance, the deviation of a presidential candidate from his/her voting behavior in congress:

- ***Position on the political spectrum***
  - Party (2x)
  - Gross of party (2x)
  - Candidates and president (4x)
  - Statements (12x)
  - Divergence of candidate's political orientation, expressed through voting behavior in congress compared to that of the respective statements (4x)
  - Divergence of candidate to gross of party members (4x)
  - Divergence of current policy (Bush), compared to candidates' announced political agendas (9x)
- ***Additional statement information***
  - Uttered by (12x)
  - Topic area (12x)
- ***Additional candidate information***
  - Represents which party (4x)

Overall, this amounts to 65 relevant bits of information, each of which would (theoretically) have to be addressed as a separate question in a multiple choice exam. The number would increase further, when comparisons of statements, either among one topic area and across chosen candidates or vice versa were included. Naturally, not every bit of information would probably be translated into an exam question.

7.1.2. Comparison of Multiple Choice with Semantic Positioning

Multiple Choice exams present students with the challenge of selecting one or multiple correct answers, to a posed question by ticking respective checkboxes, representing possible choices. Due to the structure of both given question and answer, many multiple choice exams simply test a student's reproduction of learned facts, rather than applying knowledge to complex problems (Kuechler & Simkin 2003). They are not fit for process based problem solving, like discussions or debates, due to their rigid structure. One of the biggest drawbacks of multiple choice exams is that a student might answer a question correctly by simply guessing. On the positive side, multiple choice questions permit a very easy and automated assessment and questions can be reused in another setup.

On this level, e-learning suites like Respondus[61] and Webassign (Brunsmann et al. 1999) offer multiple choice exams with database functionality. Questions can be stored related to a course and then through an algorithm, each student can receive a personalized exam sheet, with questions randomly selected from the database. Also, in mathematical equations, constants can be randomized. The generated exam sheets can be printed or presented digitally.

A digital exam has the advantage that students can receive an immediate feedback regarding their performance. This is just as true for Semantic Positioning, through the defined evaluation models. In the presented scenario, it is of little relevance if a multiple choice exam is analog or digital, due to the equal amount of actions students have to perform. For the teacher the situation is similar, as the benefits of software, like the ones described above, only play a role if the subject area is wider and questions are reused for other exams.

The goal of this analysis is to show, how Semantic Positioning manages to reduce necessary actions, to reach a desired effect within this knowledge work scenario. Two perspectives have to be considered here, that of the teacher and that of the student. The teacher prepares the task(s) and a respective solution space and is then responsible for evaluating the results and grading. Students are asked to fill out the exam, which in multiple choice comes down to ideally answering every question once with a single check[62] and in Semantic Positioning amounts to arranging objects.

Thus, both the creation process and the answering are defined by the number and setup (i.e. one or multiple answers to tick) of questions in the exam. In the following a list of sensible multiple-choice questions is presented, based on the previous list of presentable and deferrable information. A question that was excluded here, for instance, is one regarding the statement's topic area, as this often becomes clear from the respective text, e.g. "Choice and competition is the key to success in *education* in America […] (Senator McCain)".

61 http://www.respondus.com/

62 There may however be multiple choice exams, where up to all of the answers to a question are right, thus requiring multiple checks per question.

1. Please check between which two positions on the political spectrum the gross of the respective party's candidates are located:

   [**Party**]
   From (2 Times)
   ☐ liberal extreme (-1) ☐ strongly liberal (-0,75) ☐ moderately lib. (-0,5)
   ☐ slightly lib. (-0,25) ☐ neutral (0) ☐ slightly conserv. (0,25)
   ☐ mod. cons. (0,5) ☐ strongly cons. (0,75)

   To (2 Times)
   ☐ liberal extreme (-1) ☐ strongly liberal (-0,75) ☐ moderately lib. (-0,5)
   ☐ slightly lib. (-0,25) ☐ neutral (0) ☐ slightly conserv. (0,25)
   ☐ mod. cons. (0,5) ☐ strongly cons. (0,75)

2. Please check the listed party of each candidate[63]

   [**Candidate**] (4 times)
   ☐ Democrat ☐ Republican

3. Please check the most appropriate answer to where the candidates stand on the political spectrum between (liberal extreme = -1 and conservative extreme =1) based on their voting behavior in congress:

   [**Candidate**] (4 times)
   ☐ liberal extreme (-1) ☐ strongly liberal (-0,75) ☐ moderately lib. (-0,5)
   ☐ slightly lib. (-0,25) ☐ neutral (0) ☐ slightly conserv. (0,25)
   ☐ mod. cons. (0,5) ☐ strongly cons. (0,75)

4. Please check how each candidate has voted in congress compared to the gross of party members.

   [**Candidate**] (4 times)
   ☐ liberal beyond gross ☐ more liberal than most ☐ about average
   ☐ more conservative than most ☐ conservative beyond gross

63 The term candidates is used for the three presidential candidates as well as the President

5. [**Statement**]
   a. Please check who uttered the statement (12 times)
      ☐President Bush ☐Senator Clinton ☐ Senator McCain ☐ Senator Obama

   b. Please check how liberal/conservative the proposed policy has to be regarded (12 times)
      ☐ lib. extreme (-1) ☐ strongly lib. (-0,75) ☐ moderately lib. (-0,5)
      ☐ slightly lib. (-0,25) ☐ neutral (0) ☐ slightly cons. (0,25)
      ☐ mod. cons. (0,5) ☐ strongly cons. (0,75)

6. Please check the rough deviation of the candidates election promises in relation to his voting behavior in congress?

   [**Candidate**] (4 times)
   ☐more liberal ☐about the same ☐more conservative

7. Describe the general tendency of the 2008 candidates' announced politics (statements) on the three thematic sectors compared to President Bush's current policy (1 time)

   ☐more liberal ☐about the same ☐more conservative

This makes for a total of *45 questions* that have to be formulated by a teacher, filled out by a student and then evaluated. A teacher constructing the exam has to use about 8000 characters for its formulation (writing out the questions the appropriate number of times with the variables filled), which can be broken down to about 1600 actions[64]. Manual correction is time consuming, but using devices like Scantron™ sheets or multiple choice software, the effort can be severely reduced. So let us assume an overall minimum of *1600 actions* (typing a key, select, copy, paste) for creating the exam and *45 respective actions* for marking checkboxes as a student.

Comparing this to the process in Semantic Positioning, for a teacher creating the arrangement and a student recreating it, will help determine why fewer actions are

64 Using copy pasting for repeating passages and leaving out the actual written statements (equally copied).

required. The general proceeding of an e-learning scenario with Semantic Positioning is depicted in Figure 49.

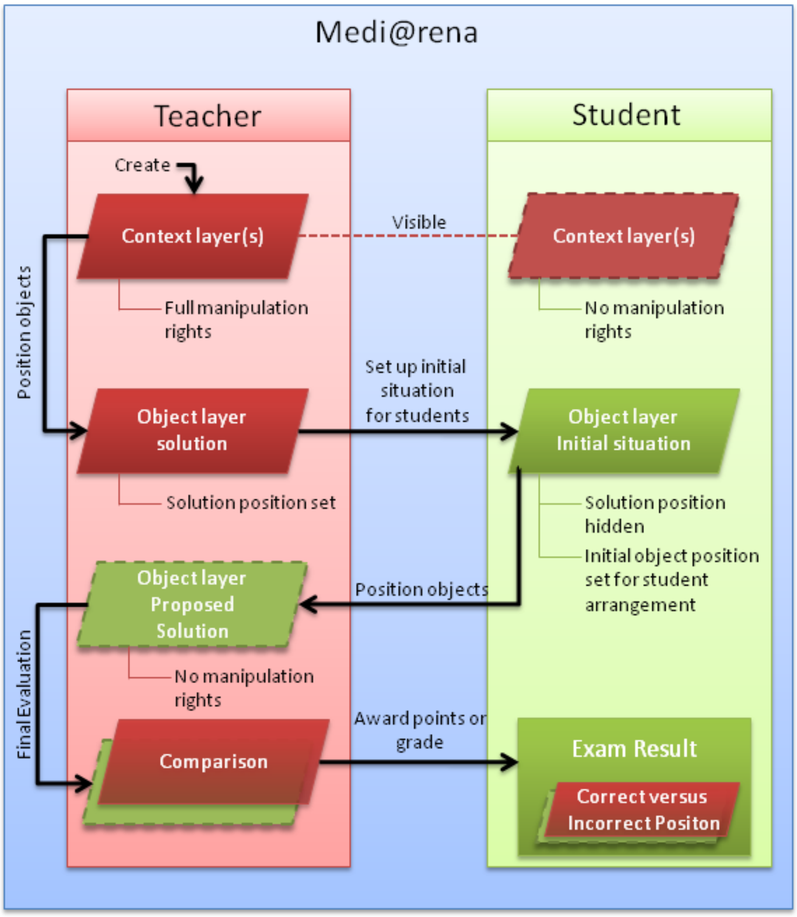

Figure 49: E-Learning process with Semantic Positioning

A formal description of the task, a student has to accomplish, needs to be supplied and takes a total of 446 characters:

Task:

- Show where the Democratic and Conservative parties are positioned (transparent rectangles) in relation to the political spectrum and where the three presidential candidates as well as President Bush stand on that spectrum, based on their voting behavior in Congress.
- Link statements, found in the text objects about three election topics, to the candidate who uttered it and judge where on the political spectrum each specific statement lies.

Then the student is represented with the context space of Figure 50, which is based on the visualization in Figure 48.

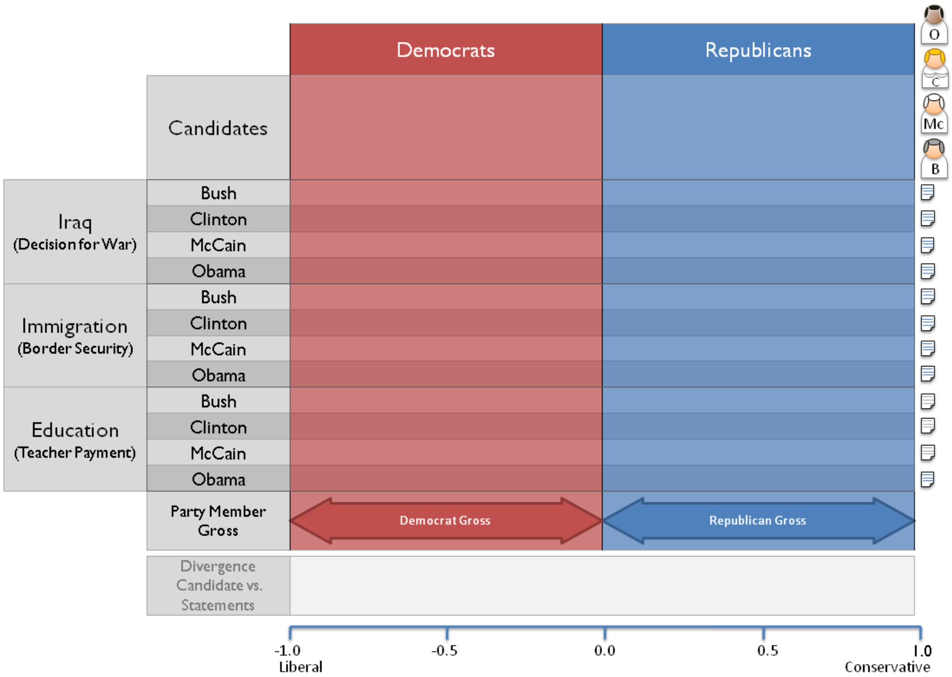

Figure 50: Starting context in front of which a student has to arrange the objects on the right

Note the subtle difference to Figure 48, namely that for each of the topic areas on the left, the matrix was split to incorporate the names of the four candidates. This is in order to save an action that would otherwise be necessary, to connect a statement via arrow to the respective person. Specifically the space is setup as follows:

Context/Evaluation layer(s)

- A two way axis as the mapping marker of the political spectrum, reaching from values of -1 to +1. This Coordinate Topography is the base context of the entire arrangement (i.e. lowest layer)
- A 4x6 Combinatoric Matrix with columns for the two major political parties combined with the rows showcasing the information dimensions that are measured in relation to the axis.
- Two Categorizing Collections as half transparent regions, each linked to a 2-way-arrow. The region represents the voting behavior of the gross of the corresponding party.

Object/Working Material layer

- Four symbols representing the presidential candidates and President Bush
- Twelve icons representing text documents that contain the political statements, adjusted to not reveal the name of the person who uttered them

Assuming that templates exist for the employed shapes, one can assume that without labeling the context can be created with 52 actions:

- *(1x) creating the axis,*
- *(1x) creating the matrix,*
- *(3x) splitting a cell into 4 sub cells,*
- *(2x) creating a 'party gross' arrow,*
- *(2x) creating a 'party gross' region,*
- *(4x) adding 'person' template*
- *(12x) coloring selected objects/cells,*
- *(12x) adding statement text objects*
- *(15x) actions to delete name's in statements (copy-paste replace with "…")*

The respective labeling takes another rough 300 characters, which comes down to 798 actions in total, for creating the space ready for arrangement actions on the working material layer by a student. Creating the final solution space from this basis (see figure H) takes both teacher and students 18 actions:

- (4x) Position candidate
- (12x) Position statement
- (2x) Adjust width of party's gross voting behavior arrow

This leaves the final number of actions for creation at about 816, which equals 51% of the 1600 actions required for the matching multiple choice exam. The 18 movement actions, necessary to arrive at the solution, are only 40% of the actions a student would need to undertake to answer the 45 questions in a multiple choice exam. The respective solution space, with the adjusted rows for candidate placement, looks as depicted in Figure 51.

The reason for the lower amount of actions required by students to express the same amount of information lies in the overlay of matrix, topographic axis and regions, as well as relative position being an automatic derivate. Hence, multiple information dimensions come together at a single coordinate, as the semantic absolute and relative position of candidate and statement objects.

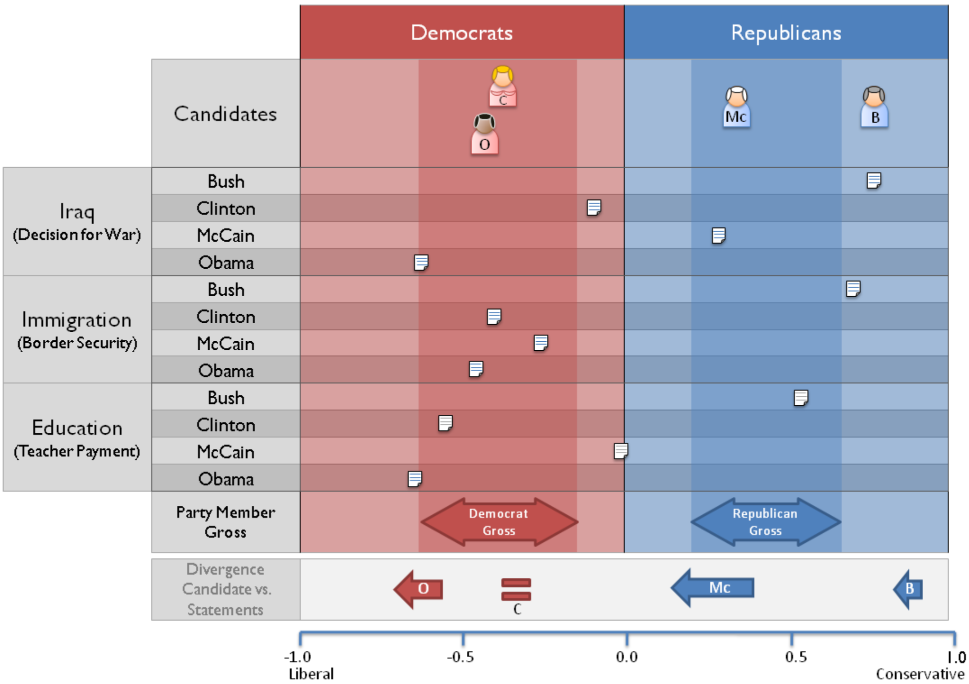

Figure 51: Solution to the arrangement problem

For statement objects, the following list shows the minimal information that can be derived from their absolute and relative positions:

Absolute Position

- Name of person who uttered the statement
- Topic Area the statement is about
- The candidates assumed political position(liberal to conservative) in that issue

Relative Position

- Deviation from average voting behavior in congress
- Deviation from current (President Bush's) politics
- Deviation from other candidates' agenda
- Deviation from candidate's party's gross of representatives (again derived from voting behavior in congress)

This demonstrates how the semantic position of a statement answers at least 6 of the questions from the multiple choice exams. This is the specific strength of Semantic

Positioning and overlay mentioned in hypotheses 1 and 2. The specific benefit is the mentioned reduction of necessary actions (45 to 18) to reach the goal of expressing ones knowledge in the exam. Placing the first object only answers three of these questions based on its absolute position. This changes with further added objects and comparisons of relative position. Part of the respective information may even be inferred from processing (e.g. the “direction of candidate divergence” arrows) and then made perceivable by a responsive reaction. This, in combination with the *overview* of all relevant statements, candidates and information dimensions within a single knowledge structure, supports gaining differential experience. Specifically, comparisons are much easier made than having to turn pages to find related values in the sequential order of a multiple choice exam.

Similarly, the overall assessment can be automated following the *right/wrong analysis* action scheme. Once the teacher has assigned correct positions to the 16 objects and resized the 2 arrows, these values are saved as personalized ‘teacher’ attributes. When a student looks at the same medi@rena space, the teacher’s assigned positions are hidden, because it is a *personalization layer* (chapter 6.6.8). However, in the evaluation stage, the attribute values of teacher and student are compared by changing the respective rules for viewing personalized position attributes. Each correct placement within a defined maximal divergence threshold is awarded a specified number of points. This is demonstrated by a short pseudo code excerpt:

```
▪ Evaluate
  This is the general evaluation mechanism
    ► For all objects
      { if object.teacher.pos-0.1 < object.pos < object.teacher.pos+0.1
       then object.color = green and student.points++
       else object.color = red}
  This is a special evaluation of the 2-way-arrows/gross-regions
    ► For all objects
      {If object = 2-way-arrow then {
      if object.start = object.teacher.start
      and object.end = object.teacher.end
      then object.color = green
      else object.color = red}}
```

Since the evaluation algorithm for multiple choice exams is expected a given, at least the *general evaluation mechanism* (see above), should be too. This means it can be added as a template in a single action. The remaining special evaluation for the 2-way-arrows only takes up 176 characters as a script. Assuming that it would have to be typed, the total amount of creation actions for Semantic Positioning is 977. Even with evaluation, this is only about 61% of the 1600 actions of an equal multiple choice exam. Again, supporting an efficient gaining of differential experience, the evaluation not only calculates the students' scores, but highlights mistakes and correct placements through color markup. This is especially helpful in self studying sessions or in practice exams. As shown in Figure 52, a teacher might even add an explanation of why a statement and person is positioned the way it is in the solution.

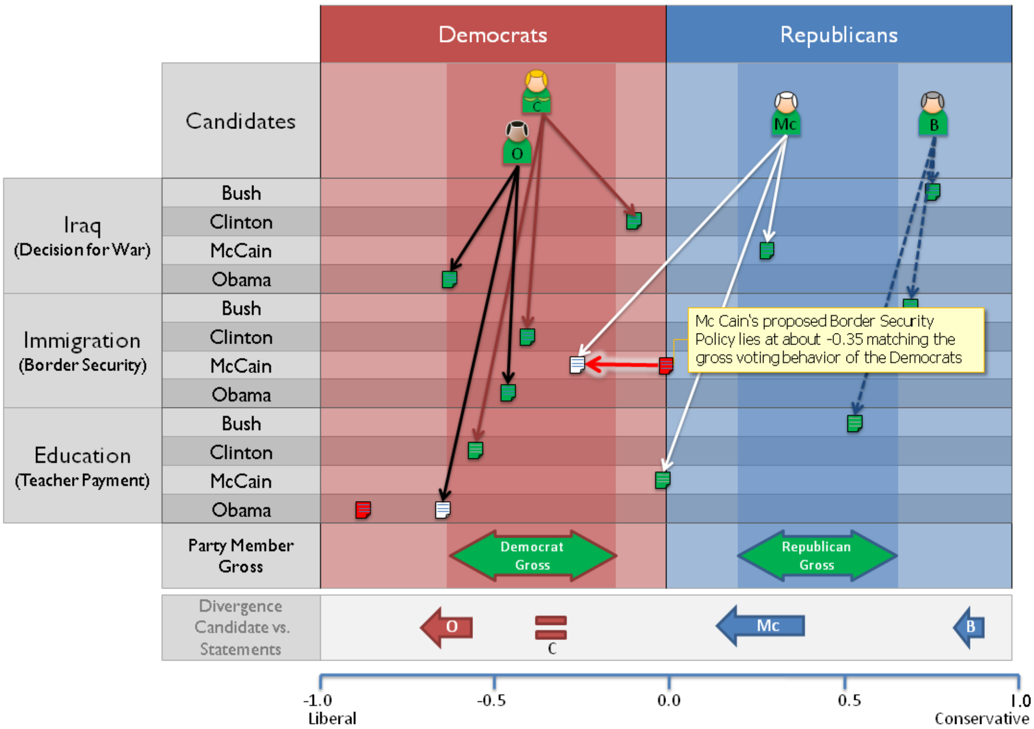

Figure 52: Solution including markups of correct and incorrect object positions

It is possible to add further automated evaluations, though that might increase the number of actions needed for creating the exam. If students can better be enabled to learn in the electronic environment, these additions may however be worth exploring. Differential experience can be increased by calculating the arrows pointing from candidates to their statements, based on the statement's row position (Figure 52). The information supports a quicker recognition of relation. Similarly the color of a candidate's shirt could be adjusted to reflect party affiliation automatically based on position (Figure 53). The "Divergence of candidate vs. statement" arrows can be calculated as the average of the position of all three statements on the political spectrum, compared to the respective candidate's position.

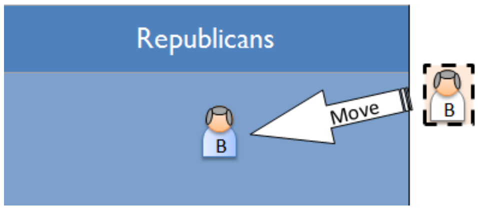

Figure 53: Automated candidate coloring based on position

A comparable kind of spatial evaluation is employed in the so called "Psychopathology Though Online"-project by (Streule et al. 2006). The project uses similarity judgments, to teach students psychopathologic disorders. An expert first judges the similarity of disorders in a pair-wise matrix, from which a two dimensional topographic map is calculated (see Figure 54). On this map disorders appear as labeled dots that are positioned to reflect their similarity on a nine-point-scale by the corresponding relative distances. The expert map can be compared with a student created map visualizing discrepancies. Students can select any two disorders on the map and have the respective similarity matrix displayed, to compare which properties they share. (Streule et al. 2006) report that the scenario has proven highly efficient for student learning.

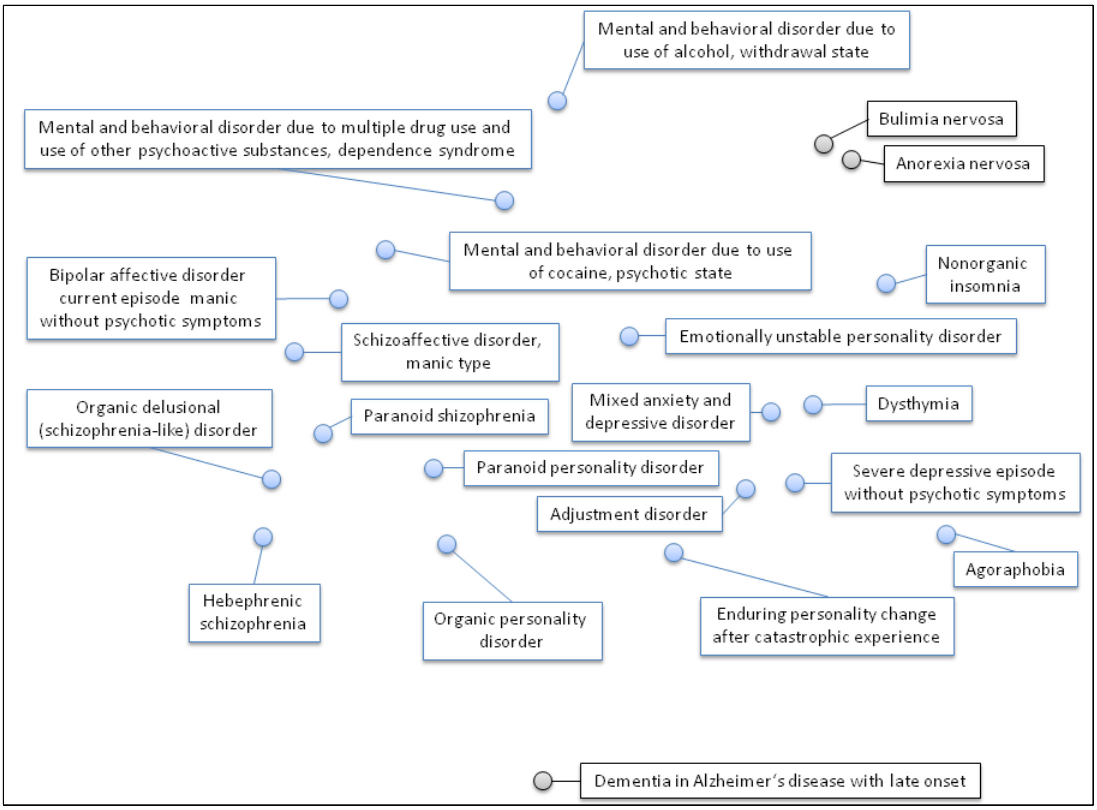

Figure 54: Distance/Similarity map of mental disorders (adapted from Läge et al. 2008)

Semantic Positioning minimally realizes the same benefits and through overlay even surpasses them. There is an indication that through responsiveness differential experience can be gained more efficiently than with multiple choice exams. Learning is supported by an immediate markup of correct and incorrect positioning and provided explanations (cp. Streule et al. 2006, Läge et al. 2008). Compared to multiple choice exams, it was shown that necessary actions for creating, filling-out and evaluating can be reduced in the spatial semantic arrangement.

- Creating took 1600 actions for multiple choice compared to a maximum of 977 for Semantic Positioning.
- Filling-out took 45 actions for multiple choice compared to 18 for Semantic Positioning.

Based on these facts at least the reduced actions have to count as a fact, **proving** the first option of **hypothesis 1** and the second part of **hypothesis 2**.

Hypothesis 1: *"It is possible to support knowledge work and e-learning by Semantic Positioning, as the semantic spatial arrangement of (media) objects in a concrete context. Support can be offered by reducing necessary actions to reach a desired result or expanding differential experience. These benefits are often based on responsive functionality, implemented in specific evaluation models.*

Hypothesis 2: "*[Overlay]…enables the support of knowledge work described in hypothesis 1.*"

Scenario 7.1 already provides some evidence regarding expanded differential experience (the part of **Hypothesis 1** colored grey). However, as the following scenario in chapter 7.2 specifically focuses on added differential experience in cooperative contexts, it is sensible to wait for the respective results before declaring it proven.

7.2. Improving Differential Experience in Cooperative Discussions

The second scenario employs a Semantic Positioning arrangement in order to support and improve differential experience within a cooperative discussion process. Differential experience in Semantic Positioning scenarios can be based on a number of factors, the most common of which are listed here:

Individual

- Discovery of relevant information (media object) that does not fit into current semantic arrangement (i.e. limited *expansion* or *expressiveness*)
  - Information is incompatible with that represented by a related object (e.g. objects with opposed information would share a position)
  - Information cannot be represented in chosen context
- Feedback from evaluation through system response
  - Position of one or more object(s) violates defined condition(s)
  - Object attribute (like media type) violates defined condition(s)
  - Incompatible placement of layer, mapping markers or PicMents

Cooperation - *The above factors for individual users also apply here*

- Feedback by observation of other users' arrangements of the same objects
  - Object overlay – Personalized object position

    Users assign personalized positions to (shared) objects in front of a shared context. Comparison and discussion of differing personal positions of an object or objects representing information not considered before.
  - Object overlay – Personalized parameters influencing position

    Personalized object position depends on set parameters such as weights, whose values are determined by each user individually. Comparison and discussions of differing personal parameters and their effect on object positions.
  - Side by side comparison or overlay of individual contexts

    Each user independently creates an arrangement of a shared set of objects. Differential experience on the level of what information dimensions were selected for the overlay and the respective representation by arrangement. Comparison and discussion of what is/can be semantically expressed by object position and the corresponding effects.
- Direct feedback in the form of information or explanations provided by other users (e.g. comments)

Several of the described ways of gaining differential experience can occur in conjunction in actual scenarios, like finding out by oneself that information is incompatible and then asking for external feedback or ideas on how to better setup the context.

7.2.1. Description of Scenario

This scenario is mainly based on feedback by comparison. It focuses on cooperative object overlay, by comparing the personalized ranking (parameter and position) of pro and contra arguments (position) supplied by users. A discussion process like this is different from the previous scenario, as arguments are rather strong or weak than right or wrong. Position in this kind of scenario, equally, cannot be considered as wrong or right, but simply as an expressed opinion. Typical goals of a discussion process can be reaching an agreement on a provided issue or to convince a person or group to adopt a promoted (personal) opinion. In cooperation one might also aim at improving the overall strength of one's argumentation through feedback. It is this last goal we will examine in this chapter, especially tied to the notion of differential experience. Previously unconsidered information, arguments or questions may result from feedback.

Semantic Positioning in this scenario supports a pro and contra discussion with creative input of a manageable number of five users. When overlaying the personal argument rankings of several users, arguments from other participants, which one may not have considered before, become perceivable. Based on this a user can improve his/her previous argumentation. In addition, similar or equal arguments can be condensed to show how common certain arguments are. Variations of the scenario exist[65].

The process starts by providing an issue for a pro and contra discussion. In this case the topic is related to social media and respective concerns regarding the privacy of user data. People have harshly criticized the behavior of large social media companies gathering, interlinking, evaluating, publishing and selling user information. For instance, a criticism by the Electronic Frontier Foundation (EFF) in April 2010 focused on facebook.com limiting user control over the display of certain items of

65 E.g.: In a seminar two groups can be pitted against each other in a debate with one defending a statement and the other trying to debunk the argumentation. Then the setup is repeated vice versa. A typical question in an economical context might be: "Will the Triad countries remain the dominant force on world markets or will Asian countries take their place?"

personal information[66]. The derived topic of the cooperative discussion process in this scenario is: "Should a world-wide governing body impose unified privacy rules/requirements on social media sites like *facebook.com*?" This question could be discussed within the context of a university course or even on a political level. Similar kinds of questions can be posed in cooperative business contexts, such as discussing product ideas or even potential strategies.

Each user is expected to supply at least five arguments as text objects. An object's name summarizes the respective argument, with a detailed description given in its contents. A user cannot supply a mere pro or contra argumentation, he/she is required to at least submit one argument for either side. Each user individually ranks their arguments, based on perceived strength. The respective *split list* is divided into a pro and a contra side, but is still handled as a single list regarding rank (Figure 55).

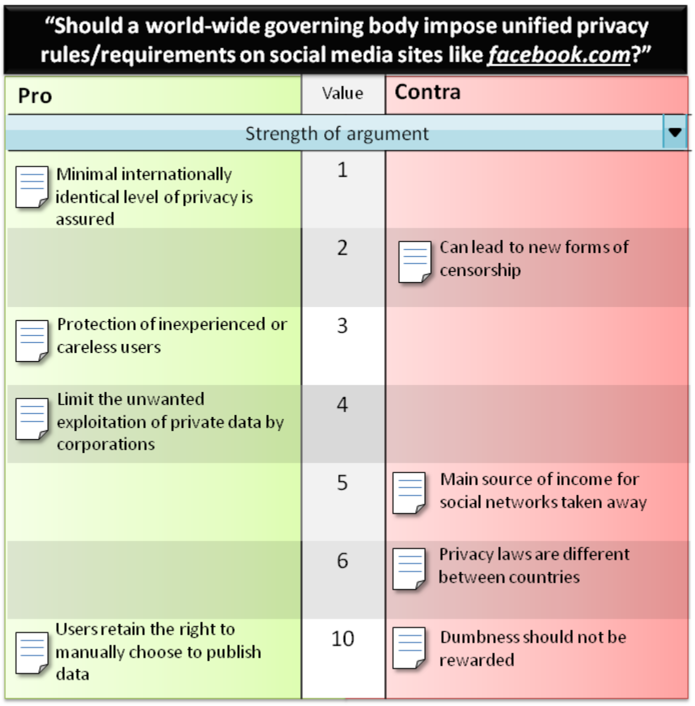

Figure 55: Ranked arguments of a single user

The semantic context of this split list is simple. An Ordered List is overlaid with two regions depicting the pro and contra side of the argument thus 'splitting' the list into two halves. At this stage, the context provides only limited information, namely the strength ranking of an object and if it is pro or contra the provided statement. An

66 http://www.eff.org/deeplinks/2010/04/facebook-further-reduces-control-over-personal-information (last accessed 20/06/2010).

object's name serves as the basis for reasoning, where it needs to be positioned in context. Comparing objects based on their position, reveals which arguments are considered stronger or weaker. Likely, the order hints at a possible argumentation path of the participant.

Arguments are distinguished mainly by a feeling that *A* is stronger (or weaker) than *B*. This makes them an ideal fit for list ranking mechanisms, where the sorting attribute represents strength. Ideally, at this step of the process, there should only be one element on each rank or maximally two, one being pro and the other contra (e.g. rank 10).

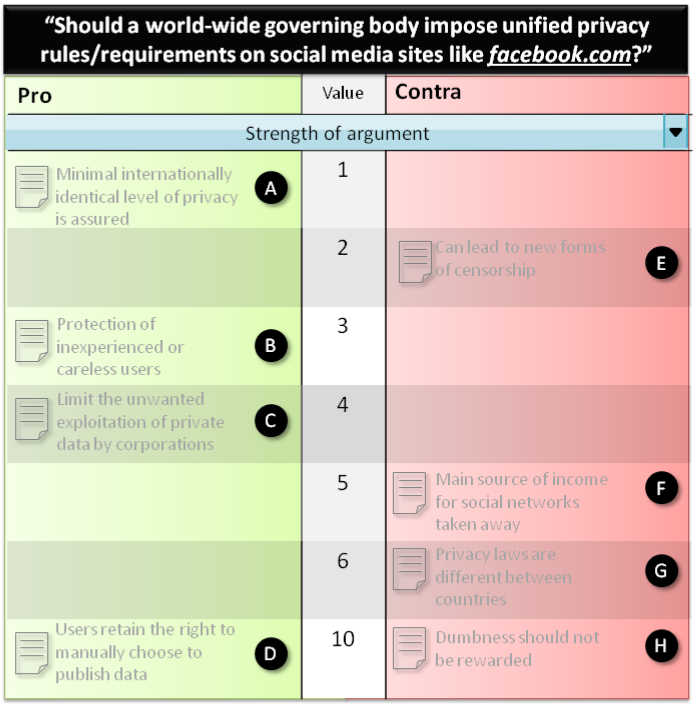

Figure 56: Visual simplification of the scenario for the following overlays

Thus far the process of finding an argumentation for a shared topic has been an individual brainstorming for all participants. Bringing the individual arrangements of the five users together is the next step. In order to save space regarding the depiction of the overall arrangement in this thesis, the media objects will be simplified as depicted in Figure 56.

Overlaying lists is not as simple as stacking the respective material layers. It requires a few calculations to not simply cover objects of the same rank on lower layers. Since the background context is the same for all users, the easiest solution is to keep the vertical position (reflecting rank) of objects intact across layers. Only the assigned horizontal position needs to be set so that each participant has a unique "column" on both the pro and contra sides. This is depicted in Figure 57. In addition to the lanes, each user is associated with a simple color, applied as a markup to his or her arguments. Notice also how the position of arguments D and H automatically shifts three 'steps' downwards in the list, to reflect the now existing values of 7 to 9, leading to fully realized 10 ranks. Differential experience on this level lies in the arguments by other users, that can inspire the formulation of entirely new arguments or at least counter-arguments.

Figure 57: First state after overlay, reflecting each user's individual arguments and assigned ranks

In this first overlay of all the participants' arguments, each object is positioned exactly the way its author ranked it. At first, users will mostly be more interested in what kind of arguments other users have come up with, rather than how they ranked it. Reading arguments that one has not considered previously may spark ideas for entirely new arguments. Still, after the first read-through spatial position begins to play an important role: The rank a user assigned to an argument is not only a sign of strength, but also of his or her qualification at least in the respective judgment. This opens up a lot of additional information for differential experience in comparison to the single user settings:

- Number of arguments each user has supplied
- Relative "standing" of the user (pro or contra) based on his or her arguments
- What arguments each user supplied in comparison:
    - Arguments that are similar/equal and respective differences in rank assigned by the corresponding users (differences on the level of contents might also be highly interesting)
    - Arguments that are unique
    - Arguments that are semantically opposed and respective differences in rank both between users and on the two sides of the argumentation
    - Argument(ation) quality including flawed or irrelevant arguments
    - Which arguments a user considers his/her strongest (and weakest)

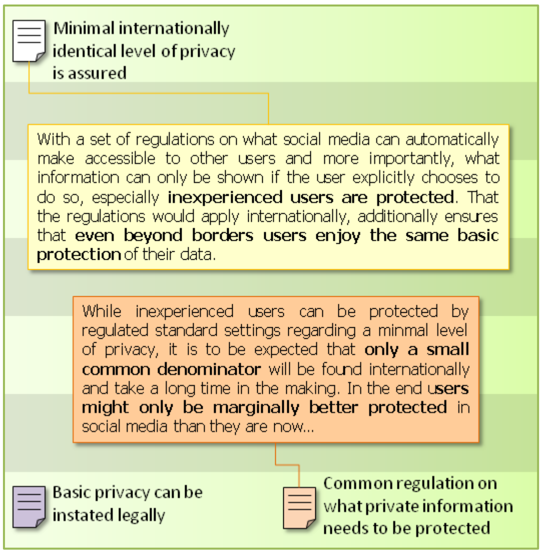

Figure 58: Comparison of similar arguments with different ranks

In relation to Figure 57 one can for instance quickly see that User I supplied the most arguments (10) and User II is most clearly "pro" in his argumentation, with four arguments versus two. Based on the gained differential experience, participants may adjust the ranking of some of their own arguments. Seeing that two other users came up with a similar argument as oneself, but ranked it much higher, one will look at the respective contents in comparison to understand the difference (see Figure 58). The gained differential experience provides incentive to rethink one's previous judgment.

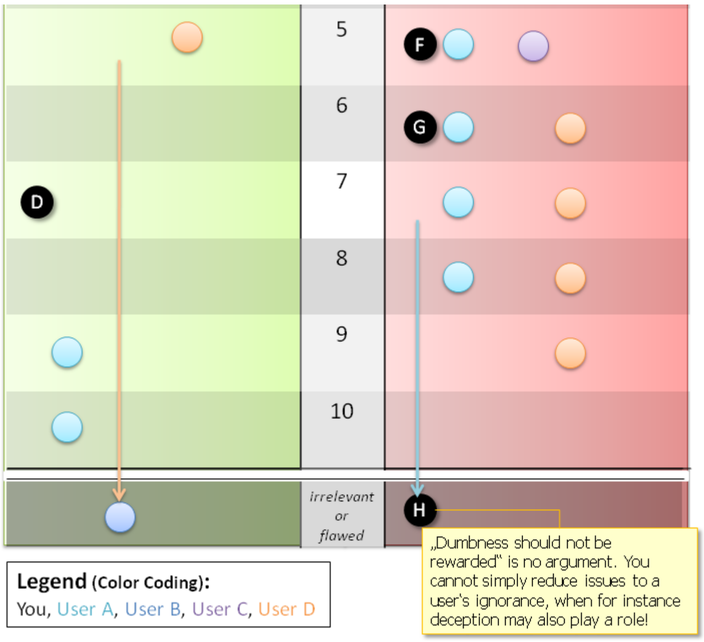

Figure 59: Moving an argument to the 'flawed' or 'irrelevant' section with explanation

Interaction wise, things can be kept simple, even with multiple users: Generally, users can change the position of any objects regarding rank, but logically not change the side of the argument. Special handling can be defined for similar, opposed, unique or flawed arguments, for which further cooperative options exist. Arguments considered flawed can be moved to a designated region by any user (see bottom of Figure 59). By supplying a short comment as an object attribute, the respective author receives an immediate feedback concerning the reason for the repositioning. This is demonstrated in Figure 59. User A has moved our original user's contra argument *H*, "*Dumbness should not be rewarded*", into the 'flawed' region. He/she even provided an explanation. Generally for objects moved by users, colored arrows show from what position they were moved and by whom. They are a simple responsive awareness feature and disappear after a set amount of time or when the object is moved again.

Often, participants of an argumentation process will come up with a number of similar or dependent arguments that can be grouped or consolidated. Consolidation is required, if two arguments can be seen as parts of a larger argument. The process of grouping is depicted in Figure 60. Users can group arguments by creating a collection, into which similar arguments are dragged. Respective actions provide direct feedback through position that may be discussed between participants[67]. For

67 In case the participants do not meet at a shared physical location, it should be assumed communication channels (text chat, audio or video) are available.

instance, grouping provides information about where other users see similarities between arguments and where they don't. If a user removes a document from a collection, this means he/she sees specific differences, which should be clarified by discussion or altering the argument's description and/or contents.

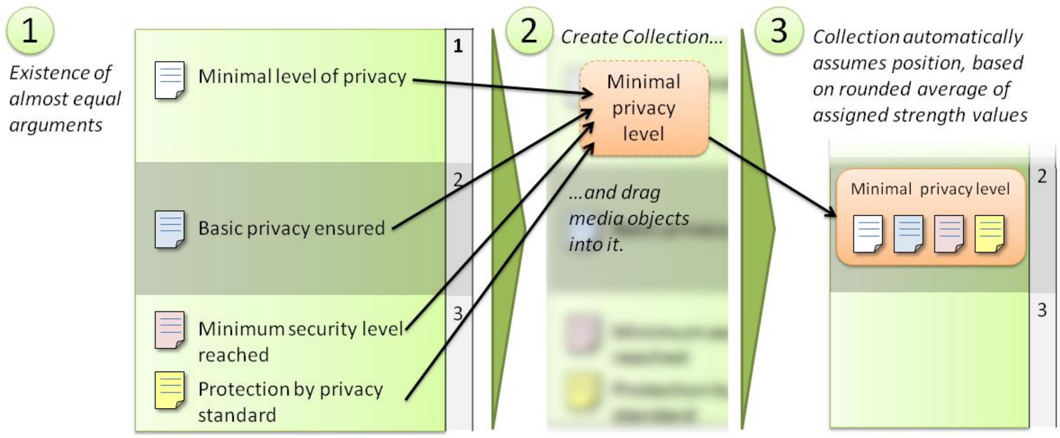

Figure 60: Argument unification process grouping similar or equal arguments

Semantic Positioning provides more direct feedback and differential experience, than typical blackboard discussions. For example, an argument on a blackboard that seems similar to an own, will less likely be questioned. Even in electronic forums where a user provides a post with comments, similar arguments cannot simply be grouped once posted. It is only possible to create a new post with direct links or quotes to the arguments perceived as similar. The original posts remain unaffected, meaning the groupings are ineffective, adding further redundancy and may even go unnoticed. By contrast in a medi@rena setting, other users can and will reposition objects, changing their spatial context and thus their meaning. As the media objects personal positioning changed, the respective author immediately notices divergences. This can be further enhanced by evaluations and responsive behavior, like the colored arrows from Figure 59. Grouping and ungrouping support gaining differential experience: It is immediately apparent which arguments are similar (cp. Figure 61). Also, it can be logically deduced how many unique arguments exist. Grouping reduces the mass of supplied arguments to unique ones. The size of a group is hardly a good indicator of rank, but it makes the commonness of an argument immediately perceivable.

The region mapping marker acquires a calculated rank from the average rank of the included objects. Respective results are illustrated in Figure 61. The depicted arrows indicate from which author assigned position the objects have been moved, to become included in a collection. For instance, argument *A* retains its assigned strength value of '1', but as long as it is contained in a region with an average rank of '2' it is displayed at the respective position.

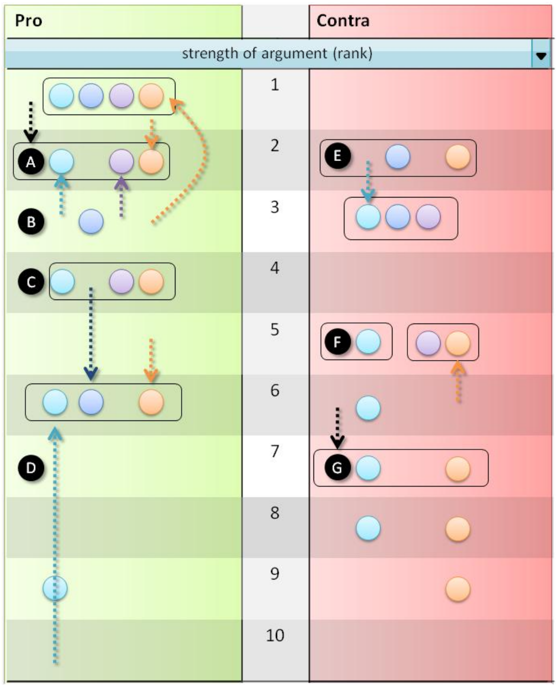

Figure 61: Similar arguments grouped with arrows visualizing rank shifts of respective objects

Even at this stage users can continue to change the strength value of arguments. Any such change requires an evaluation of the region(s) the object is contained in, as the corresponding average rank may change. Similarly arguments removed from a region trigger an automated repositioning operation. Changing strength values can be done by manually editing the attribute value or by dragging an object to a specific rank. There, it assumes a currently associated value. Regions in contrast cannot be moved actively and are logically split between pro and contra side.

Multiple users, collaborating on a Semantic Positioning environment provide enhanced spatial-semantic feedback. One can draw logic conclusions based on the inclusion of objects in regions. E.g., if each argument of a user appears in a group with a similar argument by the same other user, the two basically lead the same argumentation. Similarly, if two arguments of a user are included in the same group, one is likely redundant. Further complexity can be introduced by the use of paths to depict argumentation flows or even just single relational edges, to connect directly opposed arguments independent of their respective rank (cp. Figure 62).

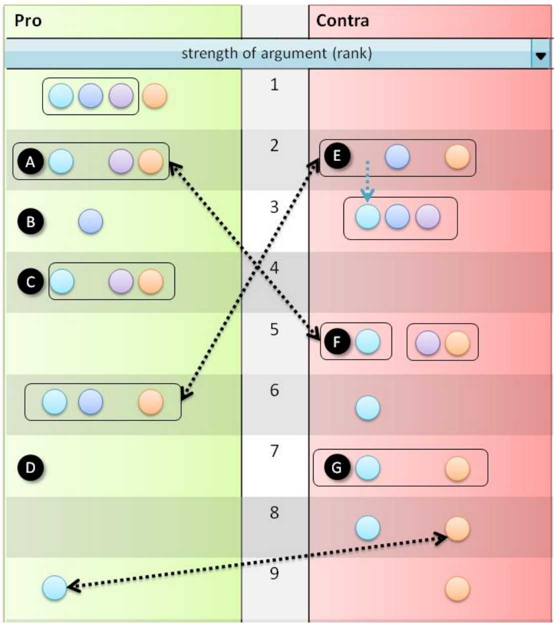

Figure 62: Directly opposed arguments easily visualized by relational edges

This provides additional information, by relational graph positioning:

- Which arguments are opposed
- How opposed arguments compare in rank
- If opposed arguments have been brought up by the same user(s)
- The number of opposed versus independent arguments

Essentially, almost each pro or contra argument can be directly argued against, meaning that in Figure 62 there is large potential for further counter arguments. Relational Graphs can also be used to let users represent their chosen argumentation paths spatially (see Figure 63). A legend is enough to explain what edges express. Color markup was used to associate each path with a user. Users can choose their own and others' arguments. While the overall number of paths looks a little chaotic, it is still easy to follow a path from beginning to end and draw conclusions:

- How a chosen argumentation path incorporates own and other users' arguments (comparable by rank, pro/contra and number)
- The order of argumentation in relation to the rank of the connected arguments and respective experience of users (e.g. User III argues contrary to the usual suggested order)
- Specific intents (e.g. User II focuses on only a few strong arguments, while User IV always compares opposed arguments)

- If a user intends to lead a pro or contra argumentation
- Argument popularity in argumentation

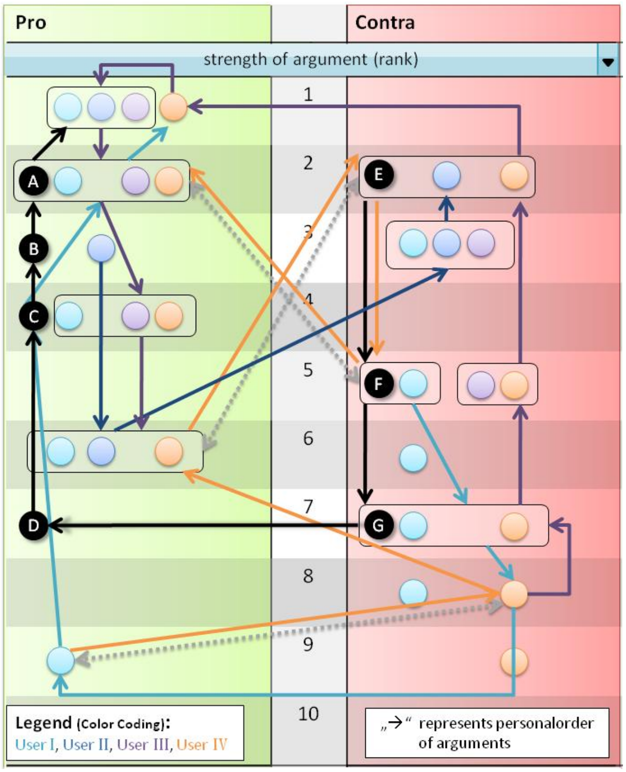

Figure 63: Argumentation paths of participants

Highlighting can be used to help comparing specific paths. This is the case of the paths of User I and II in Figure 64. While User I leads an argument for imposed privacy regulations regarding social media, User II is ultimately opposed to the concept. Both users start with a strong argument of the side contrary to their intended argumentation, then work in a 'u'-shape towards the strongest argument that reflects their actual opinion. If the participants try to prepare for one side of a debate, Semantic Positioning supports them in quickly identifying possible (strong) defenses against arguments that might come from the opposition. The commonness of opposite arguments is an indicator of the likelihood of it appearing in the other group's repertoire. In turn, one might try to choose arguments that are considered strong and stand by themselves, to hit the opposition with an argument they have not previously considered. This of course depends on the previous brainstorming process and the quality of delivered arguments.

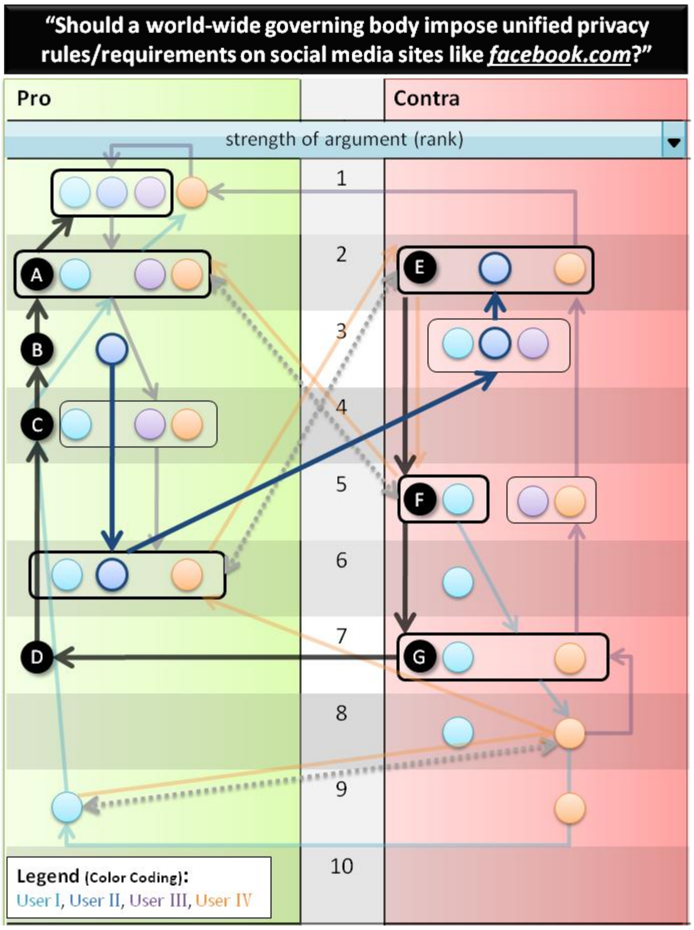

Figure 64: Path highlighting supports users in comparing specific argumentation paths

Users ranking arguments cause a more realistic strength distribution by processing and showing the average strength value and possibly a quality rating of arguments. This is accomplished by an aggregation layer. Rank and quality can be considered distinct, seeing that an argument can be potentially very strong, yet lack a good explanation. In this way not only the arguments perceived as best by the group, but also argumentation paths, can be identified efficiently. With provided comments regarding arguments or paths, even individual users can be asynchronously supported by feedback in improving their formulation of arguments or even their debating skills. Figure 65 demonstrates an example of a rating process in this setting, with a slight expansion of the semantic context. Here, each user provides an argumentation path with the best one(s) identified by rating, for the whole group to use. Comments on these paths help quickly gain an understanding of why other users rated an argument the way they did.

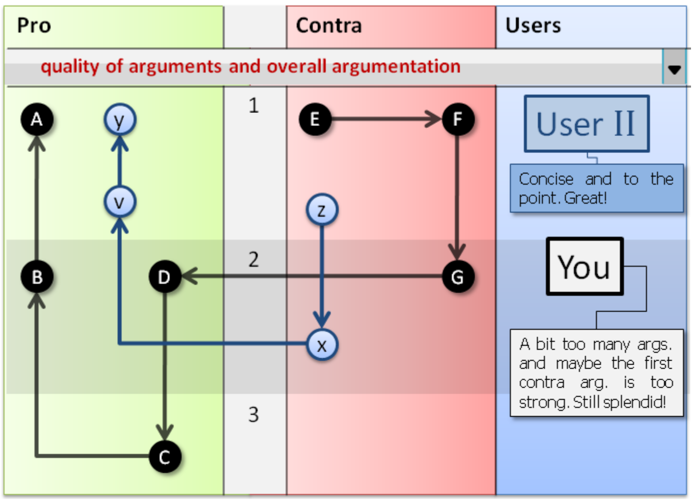

Figure 65: New sorting criterion of 'quality' and enhanced context with user column

An evaluation of the quality rating might highlight only those arguments with a quality rating of 1 or 2 or even suggest 'optimal' argumentation paths for both a pro or contra argumentation (Figure 66). This responsive feedback is directly dependent on the current state of user arrangement; it adjusts dynamically to any changes. Seeing how higher ranked arguments exist for a pro argumentation, the suggestion might even indicate that currently 'pro' seems to have a stronger case. It would prove difficult to manually read through each argument in a forum, to find out which arguments are considered strong and of high quality and how an argumentation can be built from them.

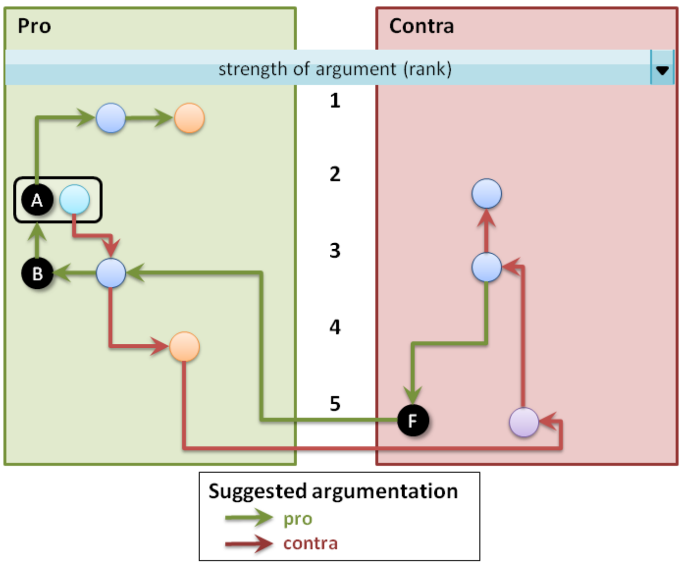

Figure 66: Responsive suggestion of argumentations derived from cooperative positioning alone

7.2.2. Comparison with Discussion Forums and Classic Blackboards

Debates are usually held at a common location, where the participants, usually two persons or groups, meet. The respective preparation processes, take place separately for each participant. Depending on the importance of the respective debate, a lot of time may be spent on this process: E.g. formulating strong, well defendable arguments, while also trying to anticipate the opposition's arguments and how to best counter them. Formal debates are different from informal ones in so far as they often have multiple issues that are each discussed within a limited time frame. Each contestant has to clearly define their position and explain it by argumentation. Often a winner of the debate is declared, even if the argumentation wasn't just clear pro or contra. Informal debates or discussions are more open ended. Participants might simply try to gather a convincing and fair body of arguments both for and against an issue, for instance to be able to take a well informed decision.

The presented Semantic Positioning scenario best compares with informal debates. A comparison with media supporting this process, should consider analog black- or whiteboards, card techniques and digital (discussion) forums. Argumentation at a black- or whiteboard relies mainly on verbal formulations and explanations of arguments. A summary of an introduced argument is written down on the board. Similar to the Semantic Positioning scenario, participants can be given private preparation time before the actual debate. These private argument lists are not visible to other users. This can inhibit creativity to a degree, because it limits the scope of 'publicly' perceivable arguments. People will often agree that they had written down the same argument that another person presented. Without the provided argumentation in context, this is easily said, but actual differences can hardly be identified, leaving little room for improvements.

The available arguments can be ranked, but on the public board a personal user ranking cannot be represented, again limiting differential experience. Any re-sorting is a manual effort of erasing and rewriting affected text. By comparison, in Semantic Positioning choosing a new search criterion, changes order with a single action, while also making new attribute values perceivable. On black- and whiteboards necessary user actions increase for these kinds of operations, though writing down arguments is the same effort in spatial semantic arrangements. Moreover, differential experience is limited, as the objects of perception are not objects of manipulation.

Some of these disadvantages can be remedied by working with moderating cards. Individual arguments noted on moderating cards can be easily pinned on a board, even in the form of a split list like in the Semantic Positioning scenario. Thereby the amount of instantly perceivable arguments would essentially be the same as in the Semantic Positioning variant. Cards are not usually large enough to provide longer descriptions or explanations of an argument (short notes are possible). Grouping, however, is possible by drawing around objects to be included or sticking them on a larger card. The aggregated rank of the group, as well as the necessary individual repositioning have to be performed manually though. Connections between argument-cards can only be established temporarily by drawing, giving up on the convenience and dynamic changeability of the Semantic Positioning. Markups on the other hand can be achieved by using cards of different color or even stickers. Neither the boards nor card techniques are easily kept in an editable state over longer timeframes. Photo documentations are possible, but require painful recreation of earlier arrangement states, if the process is to be continued.

Digital discussion forums (cp. Lau 2007) do not typically exhibit that problem. Here, user postings are digital objects that can be stored, reproduced and rated. Most commonly forums employ a simple time based order of posts or indent comments and replies under an original post. Textual quotes and links can be used, to point to contents stated elsewhere in the current thread or even outside of the forum. Expression-wise forums allow the same use of text, emoticons, pictures and sometimes even attachable media objects as Semantic Positioning. Modern forums allow editing personal posts at any point in time, for instance to update it with newly gained information. Still, it is not commonly possible to sort posts or influence their order otherwise. The only option to visually divide pro and contra arguments is to create individual threads for each. Similarly, similar arguments can only be aggregated within the text of a new argument and/or deleting redundant arguments. The sequential forum setup provides little overview over long user posts and may make it difficult to follow discussions. Authors like (Raleigh 2000) propose, having a moderator summarize the forum activity in dedicated posts in steady intervals. Such a summary might for instance be presented in the first post of a thread. Arguments can be connected by quotes or sometimes hyperlinks on the level of an individual post, where one might also provide an intended order. Having to read and compare individual posts, possibly positioned on different pages of a thread, gathering differential experience in discussion forums can be very time consuming, especially compared to the overview provided in the Semantic Positioning arrangement.

	Semantic Positioning	Black- and Whiteboards	Card Techniques	Digital Forums
Influence on order of arguments (positioning)	YES	NO	YES	NO
Pro/Contra immediately visible	YES	YES	YES	NO
All arguments from the individual brainstorming phase are perceivable and manipulable	YES	NO	YES	DEPENDS Users could post all their arguments, not typical though
Sorting criterion can be chosen and automatically updates list	YES	NO	NO	NO
Similar arguments can be aggregated leaving the original objects perceivable	YES	NO Doubles are usually eliminated	YES Drawing or larger cards as regions	NO Only within posts' free text
Immediate feedback from other users actions	YES	YES	YES	DEPENDS typically requires refresh
Automated Collection rank based on included arguments	YES	NO	NO	NO
Discussion channels (text, voice)	YES	YES	YES	YES
Arguments can be rated	YES	YES	YES	YES
Directly opposed arguments are perceivable	YES	DEPENDS Draw or markup	DEPENDS Draw or markup	YES Hyperlinks
User allocation to argument side (pro/contra) perceivable	YES	NO	DEPENDS If each user has unique card color	DEPENDS difficult to derive, but might say in post
(Number of) arguments a user chooses are immediately perceivable	YES	NO	NO not in the same arrangement	DEPENDS might say in post
(Number of) arguments a user brought into the discussion are immediately perceivable	YES	NO	DEPENDS If each user has unique card color	NO
Side by side comparison of arguments possible	YES	NO	YES	YES Quoting/Windows
Unique arguments can be easily distinguished from grouped ones	YES	NO	YES	NO
Rank differences of similar arguments are directly perceivable before aggregation	YES	NO	YES	NO
Quality of arguments or argumentation can be made perceivable and manipulable	YES	NO	NO not in the same arrangement	YES
User representations can be used as objects for positioning	YES	NO	DEPENDS If unique objects exist for each user	NO
Detail (e.g. contents) on demand	YES	NO	NO only what is 'there'	YES file attachements
Positional changes affecting the arrangement leave immediately perceivable trails	YES Shadow arrows	NO	NO	NO
Object markup is possible	YES	DEPENDS	YES	YES
Comments as object attributes	YES	NO	NO	DEPENDS
Responsiveness enabling differential experience	YES Group ranking; suggested pro/con.	NO	NO	NO
Overview over all available information is presented	YES	NO	YES	NO

Table 5: Available information and feedback for differential experience

Table 5 presents an overview of how efficiently each type of discussion media or technique supports gaining differential experience. This includes the amount of provided information, the available overview, as well as how immediately feedback is available to users. The concept of overlay, again, proves highly efficient for knowledge work scenarios, where a lot of information has to be condensed in a given context, while at the same time providing overview and potential for later extensions. Semantic Positioning arrangements are stored persistently as medi@rena spaces, meaning that an argumentation process can easily be picked up again, at a later point in time. Even a new set of users could immediately start working on the arrangement and arguments, due to the provided binding. New arguments can be supplied and outdated ones removed. As the table details, Semantic Positioning is better fit at supporting cooperative discussions, regarding the amount and efficiency of gaining differential experience.

Both the cooperative arrangement with feedback from other users and from responsiveness serves as very immediate and informative differential experience, proving the second option of **hypothesis 1**: "*…Support can be offered by (…) expanding differential experience. These benefits are often based on responsive functionality, implemented in specific evaluation models.*"

Semantic Positioning not only enables gaining immediate feedback by other user's positioning and commenting, but by evaluation makes even the calculation of optimal argumentation paths, based on information provided through arrangement possible. In addition, features like the automated sorting after a chosen criterion (e.g. quality or strength of argument) once more reduce necessary actions to reach a desired result.

7.3. Improving Semester Planning by Exchanging Contexts

This scenario utilizes the action scheme of exchange. Most basically this means, exchanging one or more evaluation layers that build the interpretational context of a space. The concept of using transparencies in comic animation, to layer characters onto backgrounds, is useful to explain what this means: Imagine that the little frog in Figure 67 is on a transparency layer, placed on top of the drawn underwater scene in the background. The frog looks happy in his natural habitat. Exchanging the context to an outer space setting, in the second frame, puts the frog in a different context. Generally, such an exchange represents a new chance for differential experience. For instance by simply changing the background transparency, we have *semantically positioned* the frog in deadly peril, even though it is still at the same coordinate position. Though, it still looks happy in frame 2, technically the frog should not be able to breathe in space. This is depicted in frame 3 by a simple markup. In order to 'resolve' the situation, we either have to exchange the context again for a more suitable environment for our little frog, or for instance add yet another layer that puts the frog in a space suit (frame 4).

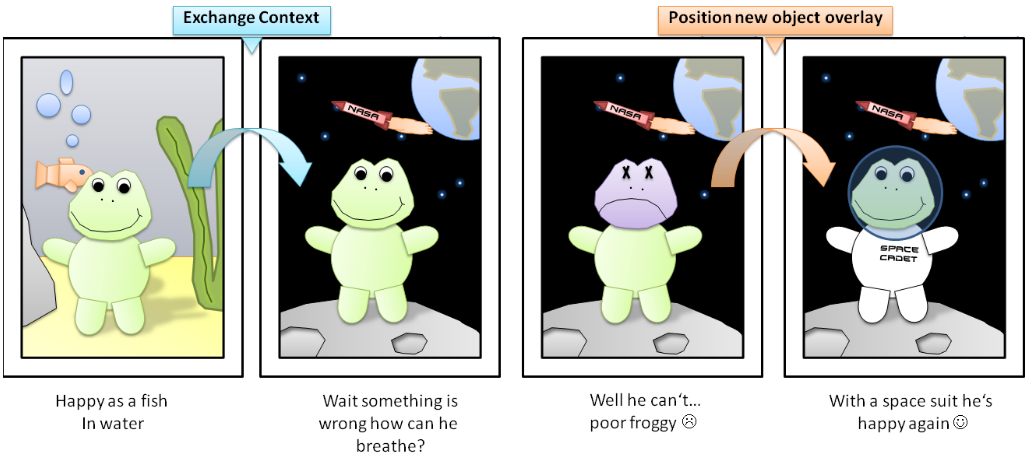

Figure 67: Exchanging a context may lead to differential experience requiring actions or responses

As we have seen, exchanging a context has semantic effects on an arrangement and is sometimes necessary in a working environment. One reason may be that one is not able to find a fitting position for a new relevant piece of information, because at any possible location wrong information or relations would be associated with the object. Another reason for exchanging a context is to achieve a desired effect, in relation to the existing objects in the medi@rena space. Typically, such a new context layer has an associated action scheme, which becomes operative immediately upon exchange. When the context changes and objects remain at their coordinate position, they automatically become associated with new information dimensions, evaluations and conventions. Simply said, the media objects receive a new *semantic position* due to the exchange. For instance: A new context with the associated action scheme of *automated positioning*, will assign a new (coordinate) position to objects, based on their existing attribute values. Either type of exchange and its effects should serve a purpose in a concrete working context to be a sensible tool. The following example, will explore such a beneficial exchange of context.

Whether object attributes are reused between contexts has strong influence on the type of 'exchange' scenario. For instance, to achieve a different arrangement, when using a context with the exact same attributes as the previous one, the mapping of information dimensions would have to be majorly different. This is however the most unlikely scenario; it is far more likely that only a few attributes and related information dimensions are retained between contexts. The three principle cases are:

- New context uses none of the object attributes related to position in the former context
- New context uses some (but not all) of the object attributes related to position in the former context and may or may not utilize further specific attributes
- New context uses all of the object attributes of the former context and may expand this set with further specific attributes

Having considered what a change of context logically means, we have not yet discussed possible reasons or benefits of exchange actions. With no guarantee for completeness the following list summarizes a few of the typical reasons:

- To apply a new action scheme or convention to objects for example to achieve batch processing of responsive behavior applied to objects with specific attributes and/or positions.
- To work on a different set of object attributes by positioning, if the effort to do so in the current context would be disproportionately high.
- To allow for continuous processes that repeat over time, with objects 'copied' into the new time context. For instance a professor may use the same basic materials for a course, when it repeats in a following semester.

- To change one's role in relation to the objects e.g. by a context that realizes different access rights (cp. scenario 7.1 – student and teacher view).
- To gain differential experience from other users, where overlay will not work, e.g. when trying to see how media objects were arranged in relation to a different problem than the one faced currently.

The following scenario will present a combination of several of the above reasons and associated benefits for exchanging a context. Based on the example of providing course materials to students at a university, the scenario will investigate semantic arrangements used for course management. Time based context exchanges are sensible to cover for the constant 'problem' of managing a course, repeating every two semesters. Here, previously provided materials will often be reused. Quality feedback on materials and performance by students, coupled to the context exchange, can increase differential experience and save necessary actions through batch processing and automated positioning.

7.3.1. Description of Scenario

Students have come to expect a fair amount of electronic services from their universities. Often these expectations manifest towards a course's organization, with a minimum demand that lecture slides are made accessible online. Incorporating typical features from social media, like commenting and rating students can deliver very immediate feedback regarding provided materials. If tutors and professors take feedback seriously, they can continuously improve lectures, exercises and materials.

Often, feedback is still only provided by an anonymous questionnaire at the end of a semester and in my personal experience, sometimes does not extend to specific lectures or respective materials. This may be firmly founded in the belief that learning materials are never optimal, that many other sources of information are available and that students just have to live with that. Even modern course management software like *koala* (Roth et al. 2007), while offering comments on a media object basis (materials), as well as blogs, forums and wikis for communication, does not feature rating. Direct feedback loops may still take place in the face to face situation of a lecture, but with the informal nature of such a situation, comments and constructive criticism may easily be forgotten.

Semantic Positioning can easily change between the more organization oriented contexts (including different semesters) and a rating overview that quickly allows determining how materials and lectures are perceived by students. One can work with the same set of media objects over several related or even unrelated work contexts in the same medi@rena space. This keeps media discontinuities to a minimum and allows for complex knowledge work situations to benefit from knowledge structures, again by reducing actions and increased differential experience through direct feedback.

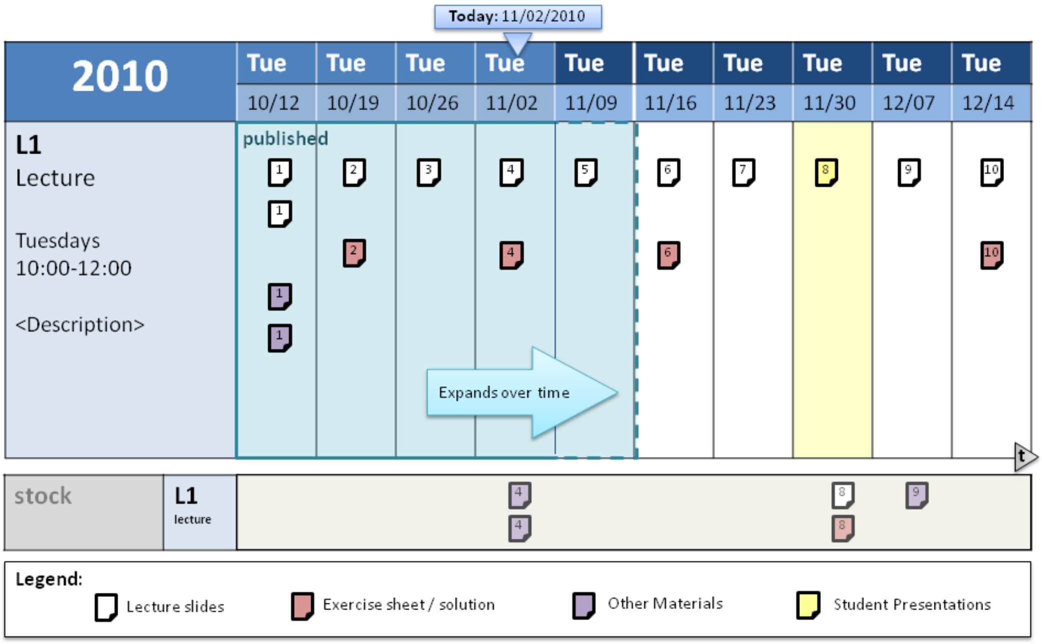

Figure 68: Standard tutor view of a single course, with publishing region automatically expanding

The first working context in this scenario, represented by Figure 68, is the tutor or teacher perspective of a single University course. A few simplifications will be used in this and following mock-up illustrations, like not including media object names and only distinguishing four basic types of files. The space can be roughly parted into two regions. A course schedule is represented by an overlay of a time axis and tabular list. Beneath it a region represents a material stock. Objects positioned on the course schedule are made available to students automatically, when they become included in the expanding 'published'-region. The region's attribute of width is influenced by time, a *response action scheme*, meaning that it grows step by step at set intervals, in this case a week. The region expands a day before a course is held, so that students gain access to the respective materials before the lecture. In turn, objects positioned in the material stock will not be published. Moving an object from the stock to the schedule not only allows its association with a certain date, but also implicitly sets its publishing status and date. When the region reaches a new object, all the necessary operations (e.g. setting access rules etc.) are carried out automatically, saving the user a lot of effort.

The numbers displayed on the objects are a visualization of an object attribute. It represents the number of the associated lecture in the course's sequence. An object associated with the first lecture, can automatically be assigned a new position, in a different semester (Figure 69). The associated specific semester's date can still be saved as a personalized attribute-value to the object. The associated number of a media object in the course's sequence, can be assigned by manually positioning it.

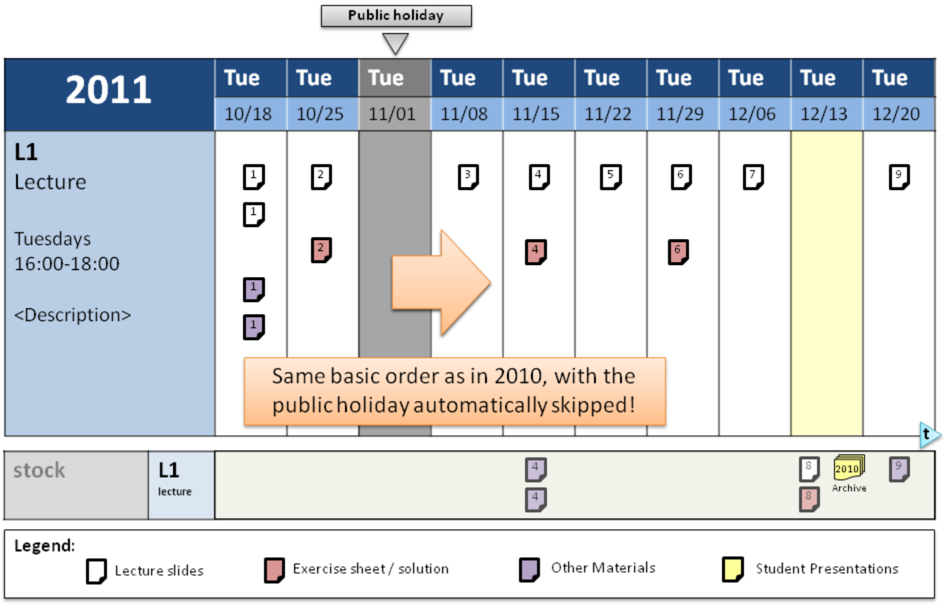

Figure 69: On exchanging the schedule context for a new year, objects are automatically rearranged

The logic order of objects remains the same in the 2011 schedule, however, it does automatically reflect changes. For instance, in Figure 69, the lecture is still held on Tuesdays, but one of these is a public holiday in 2011. This does not affect the list order of objects, but it does have an effect on the coordinate position of media objects: All objects carrying a lecture attribute number of 3 or larger simply move one 'slot' to the right in the list. Equally, the yellow marked column, indicating a planned student presentation, means that the date is skipped regarding regular lectures. Hence, instead of having to manually drag all 14 elements from a copied folder or the stock into the right place on the schedule, they automatically assume sensible positions. The automated publishing procedure through the expanding region, combined with the 'simple' exchange of context *saves at least 27 actions*, which would otherwise have to flow into a recreation of the entire arrangement. Only where problems with scheduling appear, like having one week less this semester compared to the last (e.g. due to a holiday), manual handling may be required, regarding those objects that could not be positioned. A simple solution would be to move these kind of objects to the stock.

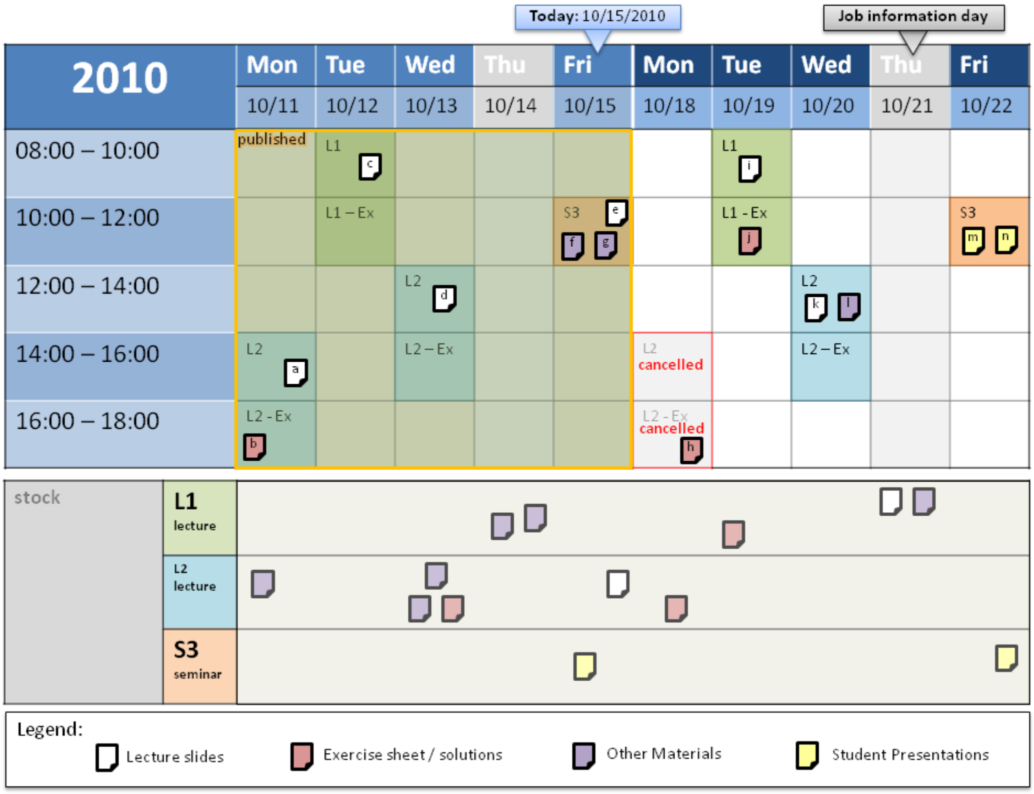

Figure 70: Complete two-week schedule of a tutor or teacher with three courses

While the situation might still be manageable manually for a single course, it is also possible to visualize a tutor's full course schedule for a semester, as demonstrated by Figure 70. Using this more complex context, the same benefits still apply, for each of the three courses modeled here. Objects are now automatically assigned positions not only along the time axis, but also reflecting their time slot displayed in the enhanced list-matrix structure. Due to the cellular nature of this arrangement, individual cells have been colored to make it clear to which lecture an object belongs.

Naturally, a teacher can also exchange the tutor context for a student context, temporarily changing his 'role', which mainly affects access rights (Figure 71). The basic structure is the same as the teacher context, but there are little differences: Only objects that have already been published are represented in the schedule, but still even in this new context automatically assume their correct position. Several Mondays are shown as defined deadlines for submitting answers to exercise sheets. A Semantic Positioning hand-in-process simply requires students to drag the answer object to the respective region (marked up at the bottom of the deadline column). Students can edit and exchange the document there, until the respective deadline has passed and the region is automatically locked. The respective evaluation layer only has to be defined once. It could for instance detect a deadline attribute on an exercise object and then automatically re-create the arrangement setup.

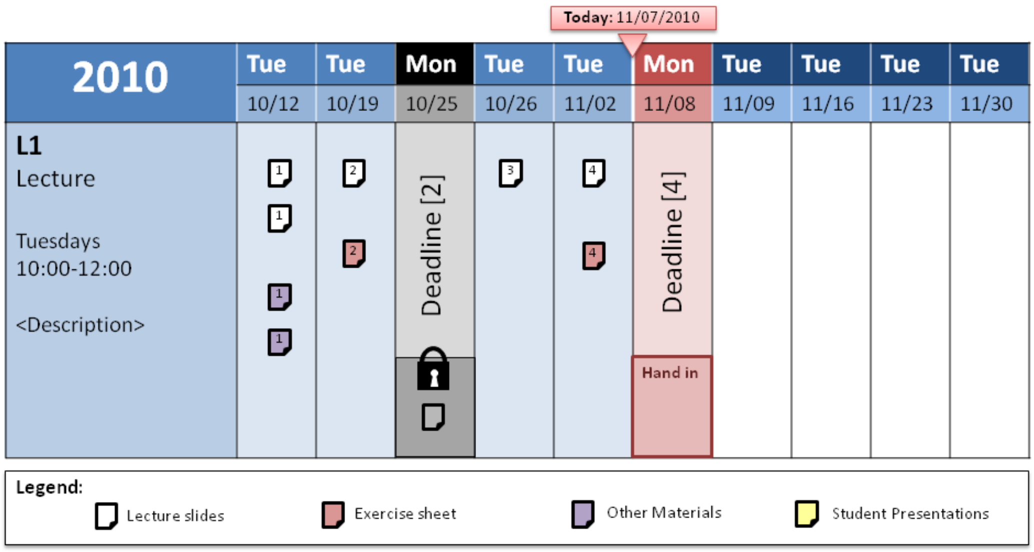

Figure 71: Student context, as a separate view for a user group

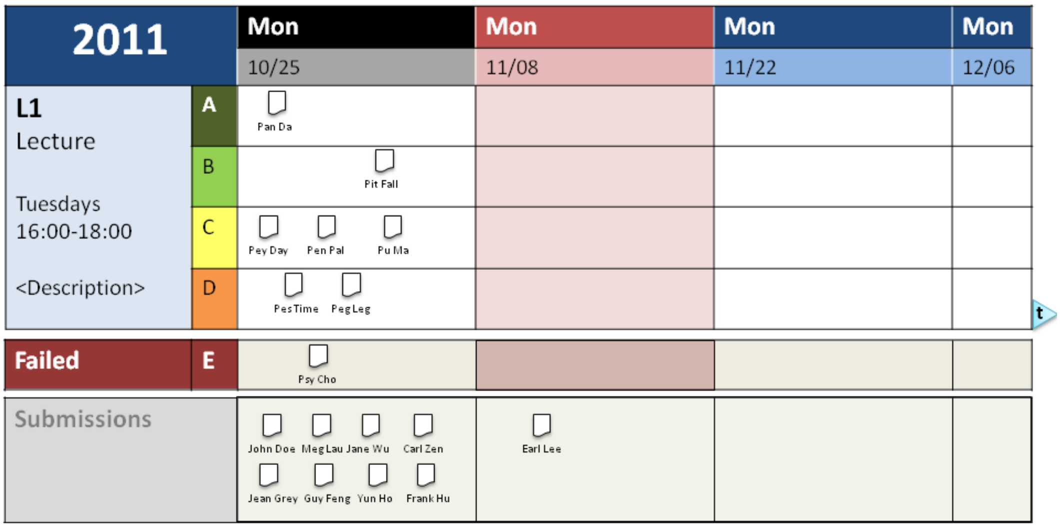

Figure 72: Example of a context for grading student submitted exercises.

Thus, with a single action, a personal document (author attribute can be evaluated) can be submitted and a collection of all the exercise sheets automatically gathered for the teacher. The collected objects could either be shown within a separate region of the tutor's standard view or the working environment can be transformed for the grading purpose, with yet another single action of a background exchange (e.g. Figure 72). Here, positioning an object, vertically assigns it a grade. Rules can control that an object is not horizontally dragged to an obviously wrong date.

A similar exchangeable context (see Figure 73) can be employed for students to rate objects. A teacher can at any point in time receive an overview over the current ratings of materials, stored as an aggregated object attribute. Even lectures and how the professor held them can be rated if respective objects exist in space. Logically, this context will not let the teacher himself move and thus rate objects, because, his role is that of a recipient of student feedback. Without a lot of explanative text the simple structure of this context provides overview over the semantically positioned objects (course, date, rating, type of file and comments).

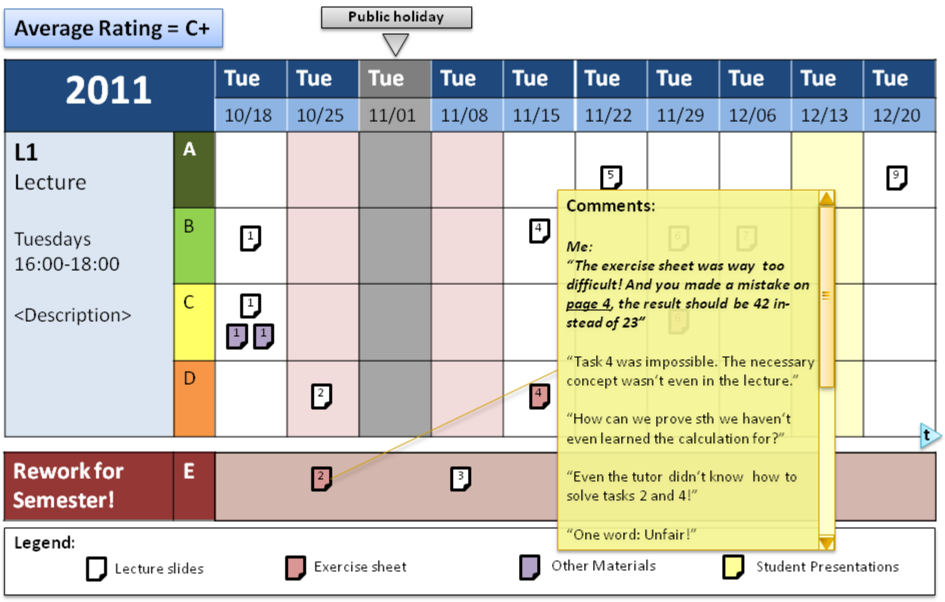

Figure 73: Overview of student feedback at semester end

Instead of looking at an object's contents, tool-tips can provide detail on demand such as student comments. Even hyperlinks can be provided that point to specific parts of a document. A supplied average rating (top left of Figure 73) over all rated objects in the course provides a quick feedback of the overall perceived quality. Within this scenario, it is possible to couple a process, involving both the roles of student and teacher to the semantic arrangement and ratings in particular. For instance, materials that have been ranked "E" by the students, have not lived up to expected standards. These will not be automatically positioned on the exchanged schedule for the next semester. Instead they are moved to a specific region of the stock (see Figure 74). Essentially, the respectively contained objects cannot be moved to any place but the trash, until they have been edited. After an editing procedure, the document can automatically move to a fitting position, based on the assigned lecture number. Technically, the tutor might get away by just editing a single character, but the spatial convention at least forces them to notice and perform some change for every "E" rated object.

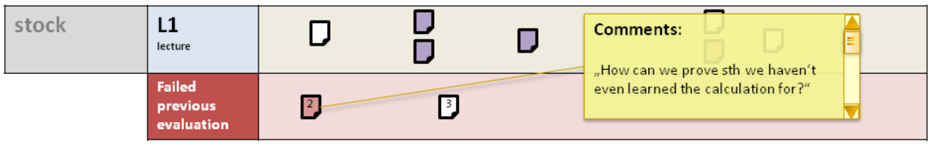

Figure 74: Object attributes obtained by feedback in one context are evaluated in another

Similar semantic spatial conventions can be visualized as exchangeable contexts, like an "assignment graph". E.g. only students who have completed a certain number of successful assignments are permitted to take the respective exam. Objects are filtered by a layer, so that only personal assignment papers are shown. The exam pass becomes accessible to students, once the criterion of having passed 4 assignments is met, allowing them to register for an exam (see Figure 75).

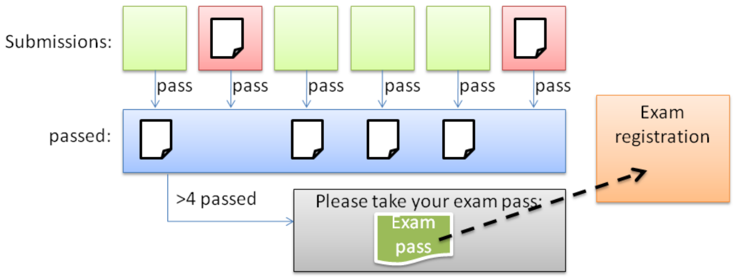

Figure 75: Context used to represent process rules through semantic arrangement

With a context exchange, a student can also integrate objects from a course, setup by a tutor, into (parts of) his/her own working context. In conjunction with the concept of *personalized object attributes*, this gives users freedom in organizing and structuring information the way they can best work with.

It was shown with a number of examples, how creating specific contexts for specific tasks and then exchanging them when needed allows for dealing with complexity in knowledge work related tasks. The two major benefits of Semantic Positioning basically apply for each such context, allowing a reduction of necessary actions to reach desired results and enhancing differential experience. Contexts can be created from scratch or theoretically even simply from objects with defined attributes. In our example a 'course' object with the required attributes could be used to automatically register the course for the next semester and generate a respective schedule. All these arguments indicate that exchanging contexts is a valid scenario for handling the diversity of object operations and evaluations that may be necessary in complex (knowledge) work environments. Based on the chosen example, a comparison of the benefits offered by Semantic Positioning by exchanging context, has to focus on other course management tools and their concept of views.

7.3.2. Comparison with Views

Overlay makes Semantic Positioning different from traditional views or working spaces. Essentially, one is free to create any kind of context and then exchange it with the current one. The exchange itself becomes an arrangement action, since it does not affect the contents of media objects (working materials) or their attributes directly, but only their *semantic position*. There might be evaluations and responsive behavior tied to the new context, though. Complex working contexts that act as a hub for several exchangeable contexts, aggregating and connecting them might fittingly be called a *meta-context*. This concept will not be discussed any further, here, but might be another starting point for further research.

In course management systems, exchanging a context can reduce the number of actions necessary to create a new schedule with a sensible publishing structure and retained materials from the previous semester placed at correct positions. In comparison[68], the course management systems of the University of Tennessee, Northwestern University, the University of Paderborn = "koala") and even "moodle" only allow copying course materials to a new folder. Essentially all the precious work of arranging objects in the last semester is destroyed with such a method. In case, the tool supports setting a publishing policy, the one associated with the previous course likewise is not copied.

68 Chosen because being well documented in the internet - in order of appearance:

NWU:	http://course-management.northwestern.edu/display/cms/Copy+a+Course
UT:	http://online.utk.edu/howto/ca_copyentsite/default.shtml
moodle:	http://docs.moodle.org/de/Kursdaten_importieren
koala:	koala.upb.de

As demonstrated, contexts can simply display information, but often enable its manipulation by exchange. The switching between contexts to reach certain goals or be able to manipulate certain attributes of existing objects is reminiscent of another common and simple feature of digital media, *views*. Changing a view allows presenting a defined set of objects in a different context and/or provide specific manipulation tools. The apparent similarity, however, ends when it comes to functions being automatically bound to an exchanged context, that go beyond reordering objects. For instance, switching a context to delete objects marked as obsolete. Views do not provide the flexibility and customization possible with the concept of exchanging context in Semantic Positioning. Views have to be programmed, before a system is used and can only be customized to a certain degree. For instance a user in “moodle” or “koala” can setup their home page to include a calendar, but defining conventions or even macros is not possible.

By contrast, in Semantic Positioning *any* existing background context can be substituted for another, This openness to changes through rearrangement on the level of context fosters playful testing, since the original background and respective object arrangement can in most cases be restored by a single exchange (or if necessary an “undo”) action. The concept can reduce actions and supports gaining differential experience by actively experimenting with context exchanges, beyond anything preconceived views can provide.

Hence we have proven **hypothesis 3**: “*There are scenarios, where the exchange of the arrangement context, including the evaluation model, is sensible in Semantic Positioning. In those cases, there is an associated benefit other than the necessity of abolishing a previously constructed context, because it has become obsolete under the most recently gained understanding of the problem (area).*”

8. Related Research

"In garden arrangement, as in all other kinds of decorative work, one has not only to acquire a knowledge of what to do, but also to gain some wisdom in perceiving what it is well to let alone."

Gertrude Jekyll (1843-1932)

On the following pages, the concept of Semantic Positioning, introduced in this thesis, will be examined in the context of related research disciplines. This is meant as a differentiation effort, in order to show that Semantic Positioning is composed of a unique combination of elements from four existing research areas:

- Classifications of visualization types
- Semantics research in computing
- Information/knowledge maps
- Support of knowledge work

Semantic Positioning focuses on mapping meaning to space in arrangement processes, which are existing and necessary parts of knowledge work. On this basis, support can be offered to knowledge workers, by first enabling complex meaningful arrangements of media objects and by evaluations tied to responsive behavior.

8.1. Classifications of Visualization Types

Classifications of types of visualization, typically focus on *static* illustrations (Burkhard 2005), grouping them by either *functional* or *structural* similarity. This is also stated by (Lohse et al. 1990, Lohse et al. 1994), who agree that there are mainly functional (e.g. Macdonald-Ross 1977) and structural taxonomies for classifying visualizations. Functional classifications concentrate on the purpose for which visualizations are used, but typically ignore their physical structure (cp. Barsalou 1991). Structural classifications, like the ones presented by (Rankin 1990, Lohse et al. 1994), in contrast focus on the form of visualizations, while neglecting the respective content or purpose.

Under both viewpoints, illustrations are regarded as a whole, rather than as having been constructed from specifically arranged elements or components. A purposeful *construction viewpoint* (cp. Tufte 1983, Tufte 1990, Wood 1992, Eppler & Burkhard 2004, Judelman 2004, chapters 2.1 and 3) allows for a sensible connection of functional and structural perspectives, as demonstrated by (Alexander 1964) with his concept of *constructive diagrams*. Constructive diagrams are defined as (static) illustrations that graphically describe both a problem and its potential solution. Semantic Positioning can replicate this effect, but will make use of spatial arrangement in order to not only represent a solution, but test it and dynamically improve it.

In this thesis, the identified five arrangement types of Semantic Positioning are derived from classical desks, as spatial working environments for knowledge work and respective problem solving processes (cp. Malone 1983). Problem solving in my understanding requires *differential experience* and external artifacts (see chapters 2.1 and 2.2), like media objects. These function as an *external memory* not just on the level of their contents, but also in their *arrangement*. By accessing several artifacts relevant to a problem, relations are identified over time. To keep relevant objects in range and to be able to quickly access related artifacts, knowledge workers automatically and often sub-consciously arrange them on their desks or digital media. This way, identified semantic relations[69] of artifacts become expressed by their position. In effect, the spatial arrangement of artifacts becomes a representation of personal progress (see chapter 4.1). This is the reason why one destroys actual work when cleaning up another person's desk.

Research on how humans may recognize structures in arrangements includes the so called Gestalt principles, like those defined by (Wertheimer 1923) or (Metzger 1966). Among these *closeness*, *similarity* and *enclosure* are the ones most similar to the spatial relations expressed in Semantic Positioning, but only refer to the recognition of elements as groups. Gestalt principles are not functional for describing semantic relations between knowledge artifacts by spatial positioning and are not useful for distinguishing types of arrangement.

Only a space opens up the possibility of placing and arranging objects. Under the assumption that the overall arrangement in space is sensible, an interpretation function needs to make sense of it. Why, for instance, does a selected element of an arrangement appear at a specific position, in relation to other elements? Considering

69 Minimally it is expressed that a believed relation exists between objects or in turn that there is no relation at all.

the concept of *virtual space*[70], (Wexelblat 1991) describes a *semantic space* as a concept different from physical or constructed spaces, which gives meaning to arrangement and location. While this idea principally suits Semantic Positioning arrangements, Wexelblat does not elaborate sufficiently on how such a space could be configured or how meaning can be expressed. (Engelhardt 1998, 1999) is more concrete, talking of *meaningful graphic spaces* in which position expresses a concept or relation. By changing an object's position, the associated meaning changes too. Engelhardt elaborates that on a technical level, the association of meaning with position is based on an interpretation function. Such a function maps information values from one or more information domains to spatial positions. This is almost a perfect description of the underlying mapping procedure in Semantic Positioning. Still, this doctoral thesis expands on Engelhardt's more general idea of mapping information to space, by introducing the concept of arrangement types and respective mapping markers. Semantic Positioning even provides indications of what kind of information can best be expressed by which spatial relation. Finally it enhances arrangements with technical evaluations and responsiveness, something Engelhardt specifically excludes from his research (Engelhardt 2002: p.9)

Spatial relations have also been featured in research by (Engelhardt 2002) and (Horton 1994). Despite the authors' focus on static illustrations, instead of dynamic arrangements, both arrive largely at the same distinct types of spatial object-to-object relations as Semantic Positioning: These are *distance*, *order*, *inclusion*, *connection overlay* and *separation*. Missing from both Engelhardt and Horton is the spatial relation of *combination*. Instead they present the relation of *separation*, which is expressed by placing a visible separator, like a line, between objects. In my opinion, this is not really a separate concept from *inclusion*: A space parted into two regions is separated into two parts as well. By contrast, the relation of combination introduced in this thesis, represents a distinct spatial-semantic dimension, employed in many arrangements of digital knowledge artifacts (cp. sections 5.2.3 and 6.5.4). In addition, the research of (Engelhardt 2002, Horton 1994) lacks definitions of the precise semantic connotations of the identified spatial inter-object relations and their interpretation. Both are central results of this thesis. While overlay is mentioned by both authors, it is not the same as in Semantic Positioning. Describing illustrations, both authors only refer to elements of a graphic that *appear* to be in front of other elements instead of as included. This can, for instance, be achieved by drop shadows.

70 Space presented and utilized in digital media.

In Semantic Positioning, overlay instead describes the complex composition of multiple arrangement types on layers, as a context for equally layered media objects.

(Engelhardt 2007) and (Card et al. 1999) also discuss *building blocks* of illustrations, similar to the ones described in the Semantic Positioning Framework: Objects, their visual properties and the mentioned meaningful space. Visual properties of objects are perceivable attributes beside that of position, e.g. color or size. (Bertin 1967, Hansen 2000, Wilkinson 2005, Zaitsev & Lupandin 2000) present a wide range of these properties. It is difficult, if not impossible to name all possible kinds of visual properties[71], which is why chapter 6.3.2 on Markups only provided a few typical examples. Essentially, any visually distinguishable property can be used to represent information as long as a legend is provided. The respective properties are independent of position and highlight special objects or groups. Their potential expressive power makes them and their influence on semantic spatial arrangements a potential candidate for further research.

The notion of *context* featured in (Burkhard 2005, Eppler & Burkhard 2004, Sauermann et al. 2005) plays an important role for Semantic Positioning arrangements, too. For instance, in Burkhard's "knowledge map"-illustrations a background provides contextual information to graphical objects displayed on top. Since knowledge maps are static (and flattened) illustrations, the distinction of fore- and background objects is only based on perception, representing the *visual overlay* mentioned in (Engelhardt 2002). Still, Semantic Positioning employs a similar understanding of context as explanative 'background' layers for working materials. The multiple layers in Semantic Positioning, however, are not just visual fore- and backgrounds. Each 'layer' groups a number of digital objects, including mapping markers with a multitude of associated attributes and an evaluation model. Here, context has to be understood both thematically[72] and technically, as descriptive elements that allow mapping information and expressing relations in arrangements and illustrations. Hence, the meaning of object position can be analyzed and enhanced with responsiveness and media objects in Semantic Positioning are accessible on the level of contents and attributes. In a semantic arrangement of Burkhard's tube map (described at the beginning of chapter 6), a station as an object could be clicked to reveal contents, like a documentation. Semantic Positioning

71 A very extensive listing of object properties and all kinds of spatial configurations or manipulations can be found in the book "Visual Grammar" by (Leborg 2006).

72 Thematic context describes the topical area or type of visualizations e.g. "medical chart".

arrangements are *active* working environments: they provide as much overview as knowledge maps, with a higher complexity and offer more details on demand. Furthermore, the Semantic Positioning framework describes how overlays can be employed to condense information spatially and offers a construction-oriented framework down to the context level.

An understanding of context, closer to the one used in this thesis, can be found in (Sauermann et al. 2005) in relation to *semantic desktop* research, as a derivate of the concept of spatial hypertext: Working materials are introduced to a personal working environment for specific reasons and purposes, based on respective background information. The common reason for bringing these documents together into a shared space forms a *working context*. It is adapted to reflect progress of work through manipulations, minimally amounting to adding or removing objects. Following this understanding, media objects may be relevant to more than one working context. The specific goal of a semantic desktop is to support knowledge workers in gathering media resources that support one's work. By running text-analyses in the background of the working context, ontologies are formed that are used to cluster and classify resources on the computer. With this mechanism researchers hope to provide better search results, suggesting relevant materials related to the current work effort. This (singular) support function differs from the broader evaluation concept in Semantic Positioning, adaptable to given scenarios. The sole focus on text content processing may ignore equally important spatial relations, expressed in the manual arrangement of objects. As shown in this thesis positioning can express a wide range of information.

The term "semantic graphical arrangement", originally used to describe Semantic Positioning, is most often cited in relation to *concept maps* (Cañas et al. 2005, Tergan et al. 2006, Coffey et al. 2006, Novak & Cañas 2008), *topic maps* (Park et al. 2002, Auillans et al. 2002, Dong & Li 2004) or *mind maps* (Buzan 2005, Willis & Miertschin 2006). Concept and topic maps are graphs depicting concepts or topics as nodes connected by named relations. Relations can be freely named and assigned, giving a lot of freedom to what kind of information can be depicted. However, usually only a single relation can exist between two nodes. Complex or multiple relations between any two nodes are therefore difficult to express. Mind maps are less explicit graphs where connections with labels, representing concepts or ideas, are drawn as branches without nodes. They basically replicate the structure of an index, but spread entries circularly around a central concept. By the connections, any concept is related to the central concept and can have any number of child concepts. Thereby a simple *hierarchy* is depicted. Semantically, the visualization is not necessarily consistent on a given level of depth. For instance, both “milk” and “grass” can be represented on the first level, despite quite different semantic connections to the central concept of “cow”. Concept, topic and mind maps depict relations based on logic, as in relational graphs, but do not feature overlays. When incorporating a large number of nodes or relations, overview may be sacrificed, a common problem of graphs. Semantic Positioning by contrast allows better managing complexity of spatial arrangement and semantic expression up to a certain degree, through its distinct arrangement types and the concept of overlay. Most basically, a single coordinate position in space can have several information dimensions mapped to it, which is very easy visually.

In summary, the distinction of five unique arrangement types within Semantic Positioning is based on an analysis of analog and digital working environments, but is strongly related to research in the area of classifying or categorizing visualizations. The most basic difference lies in the focus of Semantic Positioning on active work with media objects in dynamic arrangements, while classification research typically concentrates on static illustrations. On this level, research, focusing on the process of building illustrations, is thematically closer to Semantic Positioning. In arrangements, spatial inter-object relations are the base means of expressing meaning. Researchers have identified sets of these relations for illustrations, but this thesis enhances the respective scope: it carefully distinguishes how semantic information can be mapped to space in ways that can be technically evaluated. Additionally, interpretational guidelines are offered for expressed spatial relations, not only for later analysis, but for supporting the process of composing meaningful arrangements. A high degree of expressive complexity can be reached, through employing spatial overlays. Lastly, arranged media objects offer any desired level of additional detail through their attributes and contents, beyond what is possible in mere illustrations.

8.2. Semantics Research in Computing

Traditionally, evaluations of meaning in computing have not been tied to *position* or *visual arrangement*. Rather, a system of identified semantic relations in digital media is typically associated with *verbal representations*.

The term *semantic* within the research area of information sciences, e.g. in *Semantic Desktop* (Sauermann et al. 2005) or *Semantic Web* (Berners-Lee 1999), commonly involves the use of *ontologies*. The term originated in philosophy as the discussion of the concept of existence. In their technical interpretation, ontologies describe features of and relationships between abstract concepts, which omit reference to concrete instances (Gruber 1993). Ontologies are intended as verbal and/or mathematical depictions of understood factual relations (knowledge), not of assumed ones (cp. W3C 2004, Munn & Smith 2009). Logic connections are defined formally between these concepts, based on a defined system of terms, relations and rules (W3C 2004, Gómez-Pérez et al. 2004, Dumontier & Villanueva-Rosales 2008). Ontologies are expandable with added concepts or relations, but actual changes only become necessary, when new insights overrule previous knowledge. It is even possible to express spatial relations in the form of (mathematical) axioms, as demonstrated by (Bittner and Goldberg 2007).

Since ontologies model factual knowledge, their creation usually requires highly skilled experts to correctly form and test relations. Hence, they are *end state* descriptions of *factual knowledge*, rather than a helpful tool for active perception to gain understanding in early phases of problem solving processes. Instead, ontologies are intended for making automated deduction processes more efficient (cp. Berners-Lee 1999), like supporting text mining (cp. Weiss et al. 2005, Kao & Poteet 2007). It can be questioned, in how far these automated deduction processes may better enable gaining differential experience. In my opinion ontologies are no replacement for Semantic Positioning, but may best complement it, for instance by helping with the identification of relevant media objects in the current context.

Refinement is at the core of the concept of *semantic zooming* (Frank & Timpf 1994, Bederson et al. 2000) and the related *zoomable user interfaces*, mentioned in (Perlin & Fox 1993). The premise is the so called "Visual Information Seeking Mantra" coined by (Shneiderman 1996): "overview first, zoom and filter, then details-on-demand". In information visualizations, large amounts of data are represented graphically by some form of algorithm. Here, it is first necessary to understand the grand picture, filter out unnecessary information and finally receive further details on presented figures. Typically, some of the added detail is hidden in the overview. The same basic idea is replicated in *refinement* in Semantic Positioning (chapters 6.5 and 6.6.3). On this level, the difference is that arrangements are manually composed from digital media objects, whose contents can be accessed to gain details.

Regarding the evaluation of spatial arrangements, based on an existing set of spatial relation types and objects, Semantic Positioning might share similarities with *visual programming languages*. Here, a program is constructed of an arrangement of programming language functions, represented as graphical elements (Burnett 1995). Typical instructions, like if/then-conditions or for/while-loops, can be modeled actively by arranging visual objects. Visual programming languages often employ graph and container based syntax and semantics and can feature responsive actions and active elements (cp. Bottoni et al. 2007). In most cases, not all parts of a program can be visualized and thus textual program code is also present. Visual programming aims at providing overview over the structure of a program and help newcomers learn how programs run. To that end, each object and their connections are parts of the program and have to be evaluated within the program flow. Only programs that keep a proper syntax and semantic structure are sound and can run. Hence, in visual programming all objects form parts of a program and are arranged (in sequence) to reach one specific system state as a result. By contrast, in Semantic Positioning, individual media objects are evaluated based on their attributes and position, for a great variety of possible effects applying to those same objects.

Overall, spatial arrangement is not typically considered for evaluating semantics in computing, making Semantic Positioning a unique concept, under this perspective.

8.3. Supporting Knowledge Work

This brings us to tools or scenarios that have been devised specifically to support knowledge work through visual and/or arrangement means. On the most basic level Vannevar Bush's Memex (Bush 1945) and Ted Nelson's Xanadu[73] (Nelson 1983) already describe mechanisms of bringing information from different sources into physical relation. However, they do not consider spatial arrangement or a specific handling of different types of relations or media objects.

A different solution is described by (Agarawala & Balakrishnan 2006), who try to emulated the experience of working on a real desk on a 2.5 dimensional digital desktop, called "BumpTop". It is supposed to better reflect creating arrangements of media objects than the digital desktops of most modern operating systems allow, by implementing physical properties like gravity and weight. File icons have a certain

73 http://www.xanadu.net/

weight dependent on their displayed size and can for example 'bump' into other documents, pushing them. The environment also allows for the creation of stacks. It offers a multitude of ways to explore respectively contained objects e.g. flipping through previews of included documents like pages of a book. Other objects on the desktop are not affected by these exploration techniques, because the actual stack remains on its 'physical' position on the desk. Piles can be manipulated while spread like changing the order of documents or adding and removing items. The other typical concept associated with real world desks and offices (cp. chapter 4) 'filing', is also supported by including system folders in arrangements. In comparison, Semantic Positioning has a different paradigm: It does not try to emulate a physical working environment. Instead it clearly defines five spatial concepts (arrangement types) and overlays to structure and not just organize knowledge artifacts, as filing and piling do.

Tools like the Visual Knowledge Builder[74] (Shipman et al. 2001), Tinderbox[75] (Bernstein 2003) or Visuos[76] (Lango 2008) are based mainly on the paradigm of arranging textual notes and/or hyperlinks in space. Tinderbox and Visual Knowledge Builder (VKB) enable free and dynamic arrangements of text notes. Visuos is meant mainly as a support tool for search queries. Each tool provides the ability to form collections. Collections, representing concepts or categories, are visualized either as bubbles (Visuos) or boxes (Tinderbox, VKB) that can aggregate a number of note objects. This depicts the spatial relation of inclusion from this thesis. However, there are no formal criteria or rules to the inclusion of objects. All three tools can depict sub-sections, but only Visuos allows for actual intersections. Tinderbox and Visuos additionally allow for the definition of edges between objects to form simple graphs. The edges are, basically, unlabeled and represent either conceptual connections or hyperlinks between objects. Labeling can be achieved by creating a text box and manually positioning it next to an edge in Tinderbox. Entering a search query in either Visual Knowledge Builder or Visuos creates a new collection of identified (fitting) hyperlinks. Any evaluation of the arrangement itself, however, is not part of the three tools. They are also limited to a maximum of two spatial arrangement types, with only very limited overlay capabilities. Still, research by (Shipman et al. 2004) shows benefits associated with arrangements constructed in knowledge builder. Users felt better able to organize information as an arrangement of notes, compared to just using operating system folders. They also found that the respective arrangement

74 http://www.csdl.tamu.edu/vkb/
75 http://www.eastgate.com/Tinderbox/
76 http://www.visuos.com

made it easier, to explain their organization or structuring of information to others. Shipman et al. conclude that the reason behind both benefits is the ability to spatially manipulate documents in relation to one another. This principle allowed users to create more complex structures, while at the same time emphasizing overview. The same benefits apply to Semantic Positioning scenarios, which offer even more variety and capability of relating objects spatially.

So far all the related work considered only single user arrangements, which may be employed for successfully communicating information to others. (Roschelle et al. 2007) in contrast focus on collaborative arrangements of at least one type of media object with “Group Scribbles”. This tool is designed to add new and interesting learning scenarios to the context of early school education. It is designed for tablet PCs, where pupils may simply write or draw sticky notes, at first in a private area. These notes can be dragged to a public board, visible to all other students. Here, the notes have to be arranged according to given tasks. Contextual information regarding these tasks can be provided by simply drawing or writing on the background of the public board. For this reason, there are no defined templates, since (Roschelle et al. 2007) say writing and drawing is more immediate and easier than handling predefined objects with tablet PCs. Maybe due to this openness the authors do not consider semantic capabilities or respective evaluations of the enabled arrangements. With a teacher present as a coordinator of the collaboration effort, however, advanced evaluation capabilities may actually not be necessary. He/she can instantly provide feedback and information, where and when needed.

8.4. Conclusion

We have seen that Semantic Positioning as a research discipline is distinct from all of the related fields by themselves. This is based on the following features that only in combination make up the concept:

- Enhanced differential experience,
- the dynamic nature of arrangements,
- with five distinct arrangement types,
    - their defined semantic interpretation,
    - their associated information types,
    - their combination in overlays,
- evaluation capabilities and responsiveness

- and the goal of supporting knowledge work.

The following chapter 9 provides a short overview of how the concept of Semantic Positioning was developed and summarizes the main points of this thesis. An analysis of the accomplishments and shortcomings of the respective research is presented and an outlook on future research needs given. A final look at the potential of Semantic Positioning concludes the thesis.

9. Summary and Conclusion

"Most species do their own evolving, making it up as they go along, which is the way Nature intended. And this is all very natural and organic and in tune with mysterious cycles of the cosmos, which believes that there's nothing like millions of years of really frustrating trial and error to give a species moral fiber and, in some cases, backbone."

Terry Pratchett (*1948)

My research began with the realization that desks, even in the age of digital media, are still the typical working environment of knowledge workers. It quickly became clear that the reason goes beyond the ability to sit down and place stuff on them. Both are important reasons though: sitting is more comfortable and less tiring than standing, while also keeping one's hands free for working with knowledge artifacts. The comfort of sitting in my experience, however, means that many people do not like to get up to move around in space, if it is not absolutely necessary. For that reason, relevant artifacts are often placed in direct range of one's hands. The insight that respective working materials were not just *randomly placed* on the desk, resulted from personal experience. When people ask me for certain documents, I am mostly able to find these within approximately 10 seconds, no matter if they are in stacks or drawers. In fact, media artifacts are often carefully and specifically *positioned* at certain spatial locations, with which I have a specific semantic association, like "due tasks". Colleagues in my working environments, as a research assistant at University and an executive assistant in the insurance business, employ the same kind of (informal) spatial semantic mappings. Asked why they do it, people's answers in my experience reflect the results of (Malone 1983), detailed in chapter 4. They want to be able to quickly find objects, but also to remember information learned from the knowledge artifacts individually or in relation. Arranging artifacts on peoples' desks, thus, is a sensible and conscious act *necessary for problem solving* and thus any kind of *knowledge work* (see chapter 2).

Arranging artifacts first enables *active perception* and *differential experience*, which in turn are necessary for the *problem solving* required in knowledge work and learning (chapter 2). Knowledge artifacts act as an *external memory*, representing and containing information content-wise, by their perceivable attributes and position. Most problems cannot be solved quickly, by referring to a single information source. Semantic relations over multiple sources need to be established and tested with any progress stored. Arrangements allow this, as an external memory that reflects the current progress by a meaningful positioning of artifacts over any desired timeframe.

My interest sparked, I continued to investigate, if this kind of semantic arrangement extended to digital media. As described in chapter 5, my findings show that here too, spatial arrangement of knowledge artifacts is performed, because it is necessary for knowledge work. The reasons and even spatial means employed to express meaning are the same as the ones stated in relation to analog media. Limited screen size, the necessity of opening media objects to see their contents and the less comfortable 'physical' handling of objects are restrictions, one has either to accept or work around in digital media. Faster interaction cycles and much larger (physical) storage space for knowledge artifacts can be seen as a general advantage over analog media. Their main advantage is, however, that of making objects of perception also objects of manipulation (cp. chapter 3 and 5). Effectively, this applies to any kind of object, down to individual text characters. The conclusion is that digital media also support arrangement types that are actively used to organize (and rarely structure) knowledge artifacts (see chapter 5).

The final trigger for the foundation of Semantic Positioning was, coming in direct contact with the Paderborner Jour Fixe concept (Hampel et al. 2003), a precursor of the Medi@Thing concept. Instead of writing a seminar thesis on an assigned topic, students are asked to prepare a spatial arrangement of relevant literature, as accessible objects. Within this arrangement the students are required to visually and/or textually provide explanations about identified relations between objects by simple graphical and text elements. Analyzing this type of assignments, both as a student and later a tutor, allowed the insight that very simple means, like a rectangle with a label in front of which users can position knowledge artifacts, already allow knowledge organization. While not every arrangement created within the Jour Fixe or Medi@Thing concepts had great expressive potential, others proved a lot more sophisticated and expressive. In essence, arrangements of media artifacts on desks have a hard time matching some of the respective visual-spatial arrangements. One of the things that quickly became clear was that students tended to reuse a set of basic objects that helped enhance spatial position with meaning – later called *mapping markers* (chapter 6.2.2). These were axes, lists, regions, matrices and graph relations. More complex and semantically interesting arrangements, created by students, featured not just a single of these mapping markers, but multiple of them overlaid (cp. chapter 6.6). Materials were no longer just organized spatially, but skillfully structured as parts of complex and meaningful semantic spaces.

What interested me foremost was how the space became meaningful in arrangements and which role the ever reappearing mapping markers played in that context. For this reason the study of both analog and digital spaces, described in chapters 4 and 5, was undertaken to safely distinguish spatial relations used in knowledge work to represent (relational) information. On this basis actual research started (Erren & Keil 2006, Erren 2007, Erren & Keil 2007a, Erren & Keil 2007b), with the final result of a *constructive framework* for *semantic spatial arrangements*. The idea behind this framework is not to enable an analysis of existing arrangements, but to actually support building and creating information rich layered spatial knowledge structures. Following this framework, a meaningful context can be provided by *mapping markers*, enabling any object in space to gain decipherable semantic meaning by its position alone. Since mapping markers are distinct, it is possible to use them in combination within an arrangement by *overlay*. This enables a greater degree of complexity in expression, which also became apparent in better arrangements delivered by students in the Medi@Thing seminars.

Comparing my ideas with existing research, it seemed that most researchers focused on *graphical* arrangements (i.e. illustrations) and how they aided *knowledge transfer*, while little attention was given to *spatial* arrangements (chapter 8). Still, any day people express *semantic conventions* and *information* by *positioning* artifacts, which made it important at least to me. At first, I also thought simply about using semantic arrangements as communication tools, to improve knowledge transfer. However, it quickly became clear that semantic spatial arrangements (chapter 6), offer more than just benefits to communicating knowledge (chapter 7). Arranging knowledge objects in relation to mapping markers made it possible to infer information about their meaning and relevance in the presented context, by their position alone. Here, the research focus shifted. If mapping markers can be defined clearly and distinctly, it becomes possible to process and evaluate the semantic information associated with the attribute of position. This insight, applied to digital media, opened the possibility of realizing secondary media functions (chapter 3.2), based on the attribute of position. Responsive functions would be tied directly to spatial arrangements to support users and especially knowledge workers. This proved to be a combination with specific benefits that had not yet been explored extensively in research. *Semantic Positioning*, establishes a new field of research that is a distinct from verbal or mathematical ontologies, visualization techniques and typical media object organization in digital media (chapter 8).

Achievements and contributions

The two main achievements of this thesis are first, the Semantic Positioning framework that supports the construction of complex semantic arrangements by overlay and second showing the potential of evaluations in that context. Spatial arrangements have been thoroughly analyzed in this thesis regarding how semantic relations are expressed by the absolute and/or relative positioning of objects and how what kind of information is mapped to space. On this level the discussion of five distinct arrangement types with respective mapping markers and the concept of overlay stand out, as summarized in Table 6.

Arrangement Type	Semantic Concept	Suited for Type of Information	Mapping markers (excluding labels)
Coordinate Topography	Closeness by distance	Relevant numeric information that can be expressed by a formula allowing comparison based on values	**Main:** Axes **Additional:** Formula lines
Ordered List	Rank/Order by sorting	Alpha-numeric information indicating rank or order that can be expressed as short values of a single sorting attribute	**Main:** Tabular lists **Additional:** Sorting criteria, indention levels
Categorizing Collection	Categorization or Classification by inclusion	Factual information on properties and conditions that in specific constellation express category/class	**Main:** Regions **Additional:** None
Combinatoric Matrix	Combination by crossing	Information on two sets of factors that allow a cross-wise combination of each factor from set one with each of set 2 with specific results	**Main:** Matrix **Additional:** Extended cells. blocked cells
Relational Graphs	Specific Relation by edges	Information on existing relations between a set of defined objects, connecting them semantically in complex ways	**Main:** Edges **Additional:** Paths, graph, types of nodes

Table 6: Summary of the five arrangement types of the Semantic Positioning Framework

The five arrangement types were derived exclusively from analyses of actual working environments, both analog and digital. This bears the danger of missing types of arrangement, but has the advantage of remaining close to the basic arrangement skills and competences of knowledge workers. Based on the comparison with inter-object relations presented by (Horton 1994, Engelhardt 2002), it seems that no specific type of arrangement has been left out, as separation can be represented by categorizing collections. Personally, I have been able to describe almost all kinds of arrangement, visualizations, diagram and illustrations, meant to communicate information (excluding pictures or art), in terms of the Semantic Positioning Framework. It can be concluded, that the identified arrangement types are a proper base for representing relations spatially.

In other research (chapter 8.1), semantic concepts were not directly associated with spatial arrangement types, something I have accomplished in the Semantic Positioning framework. *Mapping markers* are versatile tools regarding the semantic information they can express, both perceivably and in a way that allows their evaluation. While super-imposition is a known concept in visualization (Engelhardt 2002), the concept of *overlay* in this thesis is specific. It explores the capability of condensing multiple information dimensions at a given position, an idea derived from illustration research (Tufte 1983: p.40, Tufte 1990: p.24, Larkin and Simon 1987). A unique feature is, that even with the added complexity, evaluation remains possible, due to an association of evaluation models with layers and a unifying bottom layer.

Naturally, it is difficult to prove a general concept like Semantic Positioning without reference to concrete scenarios. It may be criticized that I have chosen to prove all three hypotheses (chapter 6.1) logically (chapter 6.6.2) and by example (chapter 7), rather than by quantifiable data. Still, in the examples, I have thoroughly shown how necessary actions to reach a desired goal can be reduced (chapter 7.1) and that more differential experience can be derived in semantic arrangements (chapter 7.2) compared to using regular tools. In addition the evaluation mechanic, responsive behavior and how exchanging evaluation layers (chapter 7.3) can have benefits was shown throughout chapters 6 and 7. In all of these cases, *overlay* arrangements were used, because of their higher information density, despite the added complexity. If cleverly arranged, inconsistencies between layers can be kept to a minimum, just as presented in the scenarios. Further research might try to provide quantifiable proof of the hypotheses and examine scenarios closer to typical business work contexts.

Still, as explained above, the scenarios 7.1, 7.2 and 7.3 prove the carefully formulated hypotheses sufficiently: "It is possible to support…" essentially is a weak statement, but a necessary one. Not every semantic arrangement will prove successful in supporting knowledge work, but it is necessary to arrange anyways, so using sensible arrangement techniques that can be evaluated will not hurt a knowledge worker either. In effect, I consider the following hypotheses as proven:

Hypothesis 1: *It is possible to support knowledge work and e-learning by Semantic Positioning, as the semantic spatial arrangement of (media) objects in a concrete context. Support can be offered by reducing necessary actions to reach a desired result or expanding differential experience. These benefits are often based on responsive functionality, implemented in specific evaluation models.* → **True, proven in chapters 7.1 and 7.2 and though not mentioned separately also in 7.3.**

Hypothesis 2: *Overlays of mapping markers and the respective information dimensions, in semantic spatial arrangements, may deliver a higher complexity of expressible semantic meaning, than the sum of their individual interpretations. This enables the support of knowledge work described in hypothesis 1.* → **True, proven in chapters 6.6.2, 7.1 and though not mentioned separately also in 7.2 and 7.3.**

Hypothesis 3: *There are scenarios, where the exchange of the arrangement context, including the evaluation model, is sensible in Semantic Positioning. In those cases, there is an associated benefit other than the necessity, of abolishing a previously constructed context, because it has become obsolete under the most recently gained understanding of the problem (area).* → **True, proven in chapter 7.3.**

The comparisons of scenarios with related tools or implementations within chapter 7 showed that Semantic Positioning offers potential to define new kinds of support for knowledge workers. It remains to be shown, however, if knowledge workers will actually appreciate the support in day to day work situations. My own belief in Semantic Positioning as a viable tool for active perception is intensified through personal experience. At the University of Paderborn I tutored Medi@Thing courses (Erren and Keil 2006, Erren 2007, Erren & Keil 2007a, Erren & Keil 2007b) over a four year period. During my time as a research assistant, semantic spatial arrangements were created by more than 60 groups of 2-3 students, based on simple means, but at least communication wise with great effects. A further indication to that effect is given by (Shipman et al. 2004), who show users felt benefits from working with arrangements in "virtual knowledge builder". In this context, another critique might be that despite the emphasis I put on supporting knowledge work with Semantic Positioning, all the scenarios presented in chapter 7 have a learning and University context. While that might not present a large case for a business use of semantic arrangements yet, it is a context with which I am familiar. In addition, learning is an essential part of any knowledge work context (cp. chapter 2.2) and University students are in most cases taught to become knowledge workers. Finally, it may be necessary to specifically investigate an actual implementation of Semantic Positioning arrangements in digital media that can either be used in everyday knowledge work or in specific scenarios of use. This potential future research may bring up new issues that have not been clarified in this thesis, regarding for instance the difficulty of an implementation and a semantic evaluation of position. Action schemes and layer types were mentioned and defined in the end of chapter 6 and applied in the scenarios of chapter 7. As stated in those chapters, neither list of provided schemes and types is complete. Further research might extend those lists and provide data, about how these types of schemes can be setup as basic configurations for medi@rena spaces and thus may find other application areas for Semantic Positioning.

In relation to the mentioned Medi@Thing seminars, a first implementation of a tool for collaboratively creating overlay arrangements of simple graphical shapes, images and media objects – the Medi@rena Composer (Niehues et al. 2007) – was created[77]. It was enhanced by a student project group over the course of a year, for so called “semantic tagging”. The goal was to allow for basic tagging of media objects, through assigning them semantic positions (Erren et al. 2008). This included the development of template mapping markers for axes, regions and matrices. These objects evaluate any media object positioned on their surface. It is checked, if objects have compatible values, at which point they can automatically assume a respective position or else be assigned a respective value. An overlay of mapping markers is not possible. The evaluation implemented is mapping marker and not (yet) layer based. Still, a first few lessons learned on how to evaluate the position of objects exist and were integrated into the description of the three matching arrangement types. It has proven difficult to implement digital objects that have multiple position values and associated attributes. Future implementations also need to evaluate, if the proposed layer based evaluation or an evaluation tied to mapping markers is technically more

77 The respective development process and the tools’ advancement over a course of five years offers insights into the challenges of designing cooperative environments for (semantic) spatial arrangements.

sensible. Logically, however, the latter perspective is more prone to conflicts in overlay situations and may additionally make evaluations over multiple of the information dimensions, regarding an object's position, impossible.

Outlook and Conclusion

Future research in the field of Semantic Positioning needs to concentrate on closing the gaps of missing implementations, either for specific scenarios or more ambitiously an implementation of the whole framework. Even on the level of PicMents, markups and mapping marker stencils, this is a complex and difficult effort. A specific challenge is an implementation of the basic action schemes, described in section 6.8, and evaluation capabilities with responsiveness, which even users without programming skills can create. A research into potential standard building blocks, like in visual programming languages, for evaluation and responsiveness might be worthwhile. Another direction of potential future research lies in a better analysis of the dimension of markups and how these may be used to specifically express semantic relations.

Overall I believe Semantic Positioning is an interesting new concept that puts the meaning found in arrangements of media objects before that expressed in their contents. The concept emphasizes the need of knowledge workers to efficiently gain differential experience through arrangement processes. It offers potential for defining new kinds of learning and knowledge work scenarios (like "context exchange" in chapter 7.3) based on evaluation and responsiveness (cp. chapter 7, Erren & Keil 2006, Erren 2007, Erren & Keil 2007a, Erren & Keil 2007b).

My hope is that this thesis helps establish the capability of spatial arrangements – parallel to that of verbal ontologies – for semantic and practical knowledge work purposes. Semantic Positioning is a digital media enabled evolution of the semantic arrangements of media objects, we have used for centuries to learn and improve our knowledge. Now, Semantic Positioning itself needs to stand the test of survival, to see if it will only help communicating knowledge or if it will actually be picked up to develop new kinds of desktop interactions in digital media. As far as I am concerned, I successfully apply what I have learned regarding semantic spatial arrangements in my job and, surprising or not, it works.

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