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Personal Cross-Media Information Management

Graduation thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Applied Sciences and Engineering: Applied Computer Science

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Abstract

For a long time people consume large amounts of information for personal purposes. We receive, store and re-use information on a daily basis. While current technologies such as laptops or tablets are well developed to provide the necessary storage capacity, the ease of information organisation is still an open issue. In digital space, we are used to the tree structure of file systems and the desktop screen whereas in physical space we use file cabinets and a desk. Already in the sixties, researchers mentioned the lack of information organisation by users, since it is a time consuming and cognitively loaded task. Due to the lacking organisation, we often retrieve information in an ineffective way. The improvement of the organisation and re-finding of personal information is addressed by *Personal Information Management* (PIM).

Several researchers introduced systems to organise and retrieve personal information by allowing users to find the needed information in the way the human memory does. Nevertheless, we still work with our digital file system and most of us face information retrieval issues in physical space. As part of this thesis, we conducted a user case study to gain more insights about this observed information behaviour. In contrast to previous behavioural studies, our study covers the digital as well as the physical space and investigates their coherencies and dependencies. The results of the study lead to the definition of design principles and provide a behavioural matrix with concrete interaction requirements for each observed behaviour in a cross-media information space. The fundamental outcome of these design principles further enabled the definition of a theoretical model for cross-media PIM activities.

Besides the descriptive and theoretical contribution of this thesis, the Information Linking and Interaction (ILI) framework is presented. ILI is based on the Resource-Selector-Link (RSL) hypermedia metamodel and provides the necessary functionality for organising personal information, including digital media and physical artefacts, by linking objects to each other or to semantically defined concepts. A major contribution is the ability to define the relevance of an information piece in a given context. We also provide users the possibility to express how relevant several information pieces are for each other. In addition to the linking functionality, an interaction layer is introduced to serve as a basis for different user interfaces, finally leading to an extensible user-centric framework. A proof of concept is provided by two ubiquitous user interfaces, including context-aware desktops and an augmented bookshelf making use of LEDs. In addition, we provide a developer user interface for testing purposes. The presented work identifies new fundamental research questions on the descriptive as well as the theoretical level and provides a basis for a new generation of cross-media PIM system design.

Samenvatting

Reeds lange tijd consumeren mensen een grote hoeveelheid aan informatie voor persoonlijke doeleinden. Dagelijks ontvangen we informatie, slaan deze op en hergebruiken we deze in andere taken. Desondanks de goed ontwikkelde opslagcapaciteit van veel gebruikte technologieën zoals laptops, ontbreekt het ons om gemakkelijk informatie te organiseren. Digitaal zijn we het gebruik van hiërarchische boom structuren in bestandssystemen en het bureaublad gewoon. Daarnaast, wordt er gebruik gemaakt van gelijkaardige organisatie structuren in de fysieke wereld zoals archiefkasten en bureaus. Al sinds de jaren zestig is er erkent dat gebruikers regelmatig weinig of geen moeite doen om informatie te organiseren doordat het enige cognitieve belasting en tijd vergt. Hierdoor vinden we geregeld niet de juiste informatie terug en wordt terugvinden een hele opgave. Het verbeteren van organisatie activiteiten en het terugvinden van persoonlijke informatie is het onderzoeksonderwerp van Persoonlijk Informatie Beheer (PIB).

Verschillende onderzoekers hebben reeds prototypes ontwikkeld die het toestaan de gebruiker informatie te organiseren en terug te vinden op eenzelfde manier als het menselijk geheugen. Toch gebruiken we nog steeds het digitale bestandssysteem en vele onder ons ondervinden nog steeds moeilijkheden bij het terugvinden van fysieke voorwerpen. Om meer inzicht te verkrijgen in deze observatie van huidig informatie gedrag, is er in dit afstudeerwerk een gebruikersstudie gedaan. Tegengesteld aan voorafgaande gebruikersstudies wordt er in onze studie vooral gekeken naar de verschillen en afhankelijkheden tussen de digitale en fysieke informatie omgeving. De resultaten leiden tot ontwerp principes en geven een gedragsmatrix weer met specifieke interactie criteria voor ieder geobserveerd organisatie gedrag in crossmediale informatie omgevingen. De fundamentele uitkom van deze ontwerp principes hebben het mogelijk gemaakt om een theoretisch model te beschrijven omtrent crossmediale PIB activiteiten.

Naast de descriptieve en theoretische bijdragen presenteren we het Informatie Linking en Interactie raamwerk (ILI). ILI is gebaseerd op het Resource-Selector-Link (RSL) hypermedia metamodel en biedt de mogelijkheid om digitale alsook fysieke media maar eveneens geselecteerde gebieden in deze media te organiseren door het aanmaken van links tussen media elementen en semantisch gedefinieerde concepten. De voornaamste bijdrage bevindt zich in het toestaan van het uitdrukken van een zekere context relevantie voor ieder informatie fragment. Ook geven we de gebruiker de mogelijkheid om de relevantie van de relatie tussen twee informatie fragmenten te laten definiëren voor verscheidene contexten. Naast de functionaliteit om informatie deeltjes te linken voorzien we ook een interactie laag. Deze laag voorziet een basis

voor de vele gebruikersinterfaces. Dit leidt ons naar een uitbreidbaar en gebruikersgericht raamwerk in plaats van een geïsoleerd systeem. Als bewijs van toepassing werden er twee gebruikersinterfaces geïmplementeerd namelijk digitale context-aware bureaubladen en een geaugmenteerde boekenkast door het gebruik van LEDs. Het gepresenteerde werk opent vele nieuwe fundamentele onderzoeksvragen in zowel descriptief als theoretisch onderzoek en voorziet een mogelijke basis voor een nieuwe generatie PIB systemen.

Résumé

Durant les dernières décennies, les gens on consommé de grandes quantités d'informations à des fins personnelles. On reçoit, enregistre et réutilise de l'information tous les jours. Malgré la constante augmentation de la capacité en mémoire des ordinateurs actuels, il nous manque la possibilité d'organiser l'information d'une manière efficace. Les structures hiérarchiques des systèmes de fichiers et du bureau dans l'espace digital nous sont familières. A côté de l'espace digital, nous faisons usage de structures similaires dans le monde physique tels que dossiers et surfaces de travail. Depuis les années soixante, il est reconnu que les utilisateurs font peu ou pas d'efforts pour organiser l'information du fait de la charge cognitive et du temps requis. En conséquence, l'information trouvée est rarement celle recherchée, lorsque quelque chose est trouvé. Améliorer l'organisation et la récupération de l'information personnelle est le sujet de recherche de la Gestion de l'Information Personnelle (*Personal Information Management – PIM*).

Plusieurs chercheurs ont déjà développé des prototypes qui permettent à l'utilisateur d'organiser et trouver l'information personnelle de la même manière que la mémoire humaine. Pourtant, nous utilisons toujours un système de fichiers et beaucoup d'entre nous éprouvent toujours des difficultés pour retrouver des objets dans le monde physique. Pour mieux comprendre le comportement des utilisateurs, nous avons effectué une étude utilisateur dans le cadre de cette thèse. Contrairement aux études précédentes, le sujet de notre étude est axé sur les différences et les corrélations entre les environnements physiques et numériques. Ces résultats nous conduisent à concevoir des principes de conception ainsi qu'une matrice comportementale avec des critères d'interaction spécifiques pour chaque comportement organisationnel observé dans des environnements d'information cross-média. La nature fondamentale de ces principes de conception nous permettent de décrire un modèle théorique concernant les activités PIM cross-média.

En plus des contributions descriptive et théorique, nous présentons le système *Information Linking and Interaction* (ILI). ILI est basé sur le métamodèle hypermédia Resource-Selector-Link (RSL) et offre la possibilité d'organiser les médias numériques et physiques ainsi que des fragments de ce media d'une manière similaire à la mémoire humaine. La contribution principale de cette thèse est de permettre de déterminer la pertinence de fragments d'information par rapport à un contexte donné. De plus, nous donnons à l'utilisateur la possibilité de définir une pertinence pour plusieurs contextes sur la relation entre deux éléments d'information. Au delà de la fonctionnalité de lier des fragments d'information, nous avons créé une couche d'interaction. Cette couche forme une base pour les nombreuses in-

terfaces utilisateur. Cela nous amène à proposer un système extensible et orienté vers l'utilisateur au lieu d'un système isolé. Comme démonstration de l'application, deux interfaces ont été implémentées, à savoir des bureaux sensibles au contexte et une bibliothèque augmentée avec des LEDs. Le travail présenté ouvre des nouvelles opportunités pour la recherche fondamentale à la fois descriptive et théorique et offre une base pour une nouvelle génération de systèmes de PIM.

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First of all, I want to thank my promoter and supervisor Prof. Beat Signer for his incredible interest and guidance in the project. He gave me a lot of freedom and he was always there when I needed some help. All this work started after reading his PhD thesis where I discovered the beauty of the RSL metamodel which hit me in the heart. Besides the intellectual support, he introduced me to the world of research and that it is not wrong at all to sometimes live on your own planet. A lesson I will keep for life is that you need to do things in a way you think it is the best way to do them, even if that means that you walk in the opposite direction than all the other people. Finally, I hope he will stay my mentor for a lifetime.

A special person to thank is my son Vince. Daily, he gave me the spirit, motivation and reason to successfully fulfil this work. Without his patience and understanding of the concept "Wait Vince mom is thinking" over the last two years, I would have had a much more difficult time to graduate. Therefore my little prince, I promise to spend some more quality time with you and only you and thank you so much for being such a good boy, you are the best gift in my life.

Furthermore, I would like to thank all WISE members for their unlimited collegiality and friendship over the last year. It was very pleasant to graduate in such a nice group. Of course, I hope that I can stay a member of this family for the coming years and that we will have many more nice moments.

Last but not least, I want to thank all people who have messy desks, bookcases and digital desktops. Without this mess, my research would have been needless. Therefore, please keep on making a mess with a lot of paper and post-it notes in order that I can keep myself busy for the rest of my academic career.

Contents

Is your fridge full of post-it notes, outdated notes or a messy calendar? Are you keeping documents everywhere or are they all on a stack on your desk? Is the organisation of your photos a chaos and are they spread over your laptop, smartphone, social network sites or even hidden in a closet? Do you blame yourself for forgetting the name of the so nice restaurant of last week? Do you sometimes spend minutes or even hours to search for a particular piece of information, even if you saved it or looked it up a while ago? Then this thesis might give you some hope for the future.

Sandra Trullemans, 2013

1 Introduction

Since the beginning of the human evolution, information is needed in daily activities. Information is often used to solve problems or to gain new knowledge. The five senses (i.e. hearing, sight, touch, smell, taste) are the main input mechanisms of the human brain to capture information [13]. Once the information is received, the brain handles the conceived signals and produces an output such as storing new knowledge. In a psychological system perspective, human memory is defined as a subsystem of the brain. This subsystem is responsible for processing the archive of information and for the retrieval of information. The memory organises and manages information by creating associations between information items [75]. This feature of organising, managing and the ability to retrieve information, makes human beings smart but also has well-known shortcomings. The main limitations of the human memory is the storage capacity and the loss of associations needed for the recall function. People forget things, since this is the nature of our memory.

Already in ancient times people started to store information on physical artefacts in the form of writing glyphs on cave walls to compensate these limitations. From the fifteenth century on, paper has taken a main place in our lives by providing a storage surface for information. Paper has not only been used for information storage but also for moving information, placing information in context or reminding the owner of a paper document [65]. In the last three decades, technologies such as personal computers, tablets, flash drives or compact disks are used more and more to store information aside of paper.

1.1 Information Overload

The evolution of the ability to store information externally to the human memory imposed the problem of *information overload*. The overabundance of information makes it more difficult to find the right information satisfying a specific information need. This is caused by the fact that the human memory may only handle a fixed amount of information at a time. Nowadays, information is widely available and easy to access but it also limits us to judge which information is of actual relevance for the current need. The more information one encounters, the harder it is to skip non-relevant parts and to find the best suited information. Researchers in particular are more and more confronted with the fact that too much information is out there. Besides scientific conferences where researchers present their latest findings, other ways of publications such as on-line journals are raising. Also the easier access to published material via large databases provided by domain-specific organisations are giving us all the needed information. For example, the ACM CHI 2013 conference had more than two hundred accepted papers. It is a hard task to determine which papers are really relevant to ones research without skimming through all published papers. Even more challenging is to not miss any relevant information because it may be "hidden" in a paper with a less related topic. Also for non-knowledge workers too much information may lead to frustration. The evolution of the Web and the Semantic Web will even increase amount of accessible information but more often then desired users will not find the information they are looking for.

Information overload does not only appear in finding information in public available data such as the Web. It may also occur in our own *personal information space*. This space contains all information we kept after finding it; all information we receive from other people or instances and all information we produce ourself. When taking a look around in an office, we may see a lot of papers, books, post-its, pictures, file cabinets and so on. But also the digital information (e.g. digital documents, emails or saved) is included in our personal information space. Within this often large amount of personal information, users may not retrieve the best suited information when searching for information in a given context. For example, a user may want to retrieve information about a meeting's attendees. In their search process, they encounter an email with the meeting's rapport which has listed the attendees. Nevertheless, another previously received email includes all the attendees with their profession and contact information. For the initial search problem (i.e. attendee's information) the second email would better fit than the first one where they stopped the search process. If one would have received less emails, they would have been reminded to the second email and stop the search there instead of being satisfied with the first one.

1.2 Personal Information Management

Issues regarding to information overload go hand-in-hand with the observed *classification* and *fragmentation problem* in the *Personal Information Management* (PIM) research field. For a long time, people started to classify information items (e.g. papers or books) to be able to retrieve them later. Filing information in file systems is still well used in today's office environments. More formal, filing means classifying any information item, which needs to be labelled, in a systematic order (e.g. alphabetically or chronologically) [51]. An example is a doctors file cabinet shown in Figure 1.1 where every file is titled with the name of a patient and the whole file system is ordered alphabetically.

Figure 1.1: File cabinet

This well-used information organisation structure imposes the *classification problem*. Among others, Dumais and Landaeur [29] separate the classification problem in two major problems. The first problem arises at the point where users need to label an information item. Later in this thesis it will become clear that users want to augment the information item with as much extra information as possible in order to help them later in the retrieval process. An implication of such a labelling strategy is the appearance of unclear and fuzzy labels. Because of this construction of long and often complex labels, cognitive overload is required and time must be spent when an item needs to be classified. As Cole [20] concludes, users do not want to spend this time and only apply classification if the benefit goes beyond the initial effort. Besides the label issue, a more pragmatic problem is identified in physical classification systems. An information item can only be in one category in the physical environment without duplicating it. This limitation of the physical space has consequences when the same information item is needed in another category. To compensate this problem, people have developed ingenious strategies. For example, a professor at the Vrije Universiteit Brussel had a filing structure where for each publication which was written, there was a separate folder with all referred papers. As we know, a lot of references come back in publications of the same author. Therefore, the classification structure contained a large amount of duplicated printed papers with sometimes the same annotations and annotations specific for the publication itself. However, for the professor the problem was solved and they did not care about the physical space needed to store these duplicated items. Nevertheless, the digital space is currently encountering the same classification problem since the filing organisational strategy is copied from the physical space. The filing organisational strategy in the digital space is observed at the time of saving a document where one needs to name the document and has to place it in a folder in the file system. Although the digital space does not have the spatial and physical restriction of the physical environment, most of today's folder hierarchy structures do not support multi-classification.

Already in 1945, Vannevar Bush argued that that the filing or indexing of information is not the best way to organise information. Users need to remember the file system schema and the path to the information item. Often they recall a part of the path which implies that they encounter difficulties to find the item in a first attempt.

> *"When data of any sort are placed in storage, they are filed alphabetically or numerically, and information is found (when it is) by tracing it down from subclass to subclass. It can be only in one place, unless duplicates are used; one has to have rules as to which path will locate it, and the rules are cumbersome. [...] The human mind does not work that way. It operates by association. [...] Man cannot hope fully to duplicate this mental process artificially, but he certainly ought to be able to learn from it. [...] Selection by association, rather than by indexing, may yet be mechanized. One cannot hope thus to equal the speed and flexibility with which the mind follows an associative trail, but it should be possible to beat the mind decisively in regard to the permanence and clarity of the items resurrected from storage."*

Vannevar Bush, 1945 [17]

Furthermore, Bush envisioned a mechanical device, the Memex, which would make it possible to define links between information items. By creating associative links, users may do selection or retrieving by associations instead of the currently used indexing strategy. Note that Bush's work was of great inspiration for many current state-of-the-art prototypes. Nevertheless, these prototypes omit that human memory is much more complex than only organising information by associations. In Chapter 2 we therefore give a brief introduction to the human memory whereas further in the reading the prototypes will be discussed.

Figure 1.2: Fragmentation of information over multiple devices

A second problem concerning PIM is the *fragmentation problem.* The problem may be approached through several perspectives. A straightforward perspective is the fragmentation of information on different devices. In the current digital era, one may have different devices supporting different functionality which are desired for different tasks. The same phenomena is observed in the physical space where paper and post-its may be used for different purposes. However, a more important issue in the fragmentation is the spread of information in both digital and physical environments. Information might be duplicated on different information carriers in both spaces with their own affordances as illustrated in Figure 1.2. A researcher may have notes, books, a laptop, a smartphone and a camera, all these objects are carrying information related to their functionality. The notes and books offer the affordance of paper such as easy to carry, annotate or group the notes in the book. Furthermore, a user can easily browse through the group of papers to be reminded about several information concepts. The laptop in its turn allows a user to be connected to the Web and to retrieve additional information needed at a particular time or to browse through previously stored digital information. The smartphone contains all the contacts, email functionality for on the way and some photos taken by its owner which can be sent by email or text message. At last, many users have a camera to take good quality pictures which will be transferred to the laptop at some point. The problem lies in the fact that a user needs to remember *where which information is stored* in order to be able to retrieve it later on. Another instance of the fragmentation problem is the project fragmentation described by Bergman [7]. In his descriptive study, Bergman shows that users use different tools and information formats when working on a project. The main finding is the undesired interruption of switching between these formats. A project may contain information needs out of documents stored in the folder hierarchy, out of emails which are stored in the inbox, outbox or email hierarchy and out of websites which are stored in the bookmarks hierarchy. The extra cognitive effort that a user needs to conduct to switch between these hierarchies and integrate them in another final format is a burden. Even if Bergman [7] does not talk about formats other than documents, email and bookmarks, his insights may be generalised to a broader perspective such as switching between the physical filing system and its digital counterparts. In general, one may synchronise all devices and organisation structures but this seems even a harder burden as the effort to maintain such an approach is high.

The three introduced problems, namely information overload, the classification problem and the fragmentation problem, are the main concerns of the research field of Personal Information Management. A formal definition of Personal Information Management is given by Jones [42].

> *"Personal information management (PIM) refers to both the practice and the study of the activities a person performs in order to acquire or create, store, organize, maintain, retrieve, use and distribute the information needed to meet life's many goals (everyday and long-term, work-related and not) and to fulfill life's many roles and responsibilities (as parent, spouse, friend, employee, member of community, etc.). PIM places special emphasis on the organization and maintenance of personal information collections in which information items, such as paper documents, electronic documents, email messages, web references or handwritten notes are stored for later use and repeated re-use.*

> *[...] But PIM is also about finding answers to this question: How can I get smarter about the way I manage my information so that I have more time for my family, friends and the things I really care about in life?"*

Jones William, 2008 [42]

This definition shows that PIM is a combination of descriptive research as well as technical system design. The descriptive research places emphasis on describing user behaviour in personal information spaces. In addition, the technical side is concerned with the system design of tools supporting a user's needs. Nevertheless, PIM researchers often stay in one of these research subfields where they are specialist in [25]. In this thesis, we overcome this community problem by including both subfields and approaching PIM system design out of a user-centric perspective.

Furthermore, the final sentence of Jones' definition makes the main goal of PIM clear. We need to find a way to augment the human memory so that we do not need to spend precious lifetime on managing information but more enjoying the life in its own right. How would it be like if all information is taken care by a system disappearing in our daily life? Users would not aware of the presence of all technological support but they would just use it as we now use a pencil to write on paper. Weiser described this view in 1991 in his publication entitled *The Computer for the 21st Century* [77] under the term *Ubiquitous Computing.*

> *Most important, ubiquitous computing will help overcome the problem of information overload. There is more information available at our fingertips during a walk in the woods than in any computer system, yet people find a walk among trees relaxing and computers frustrating. Machines that fit the human environment instead of forcing humans to enter theirs will make using a computer as refreshing as taking a walk in the woods.*

Weiser Mark, 1991 [77]

The aim is not to digitise the physical environment but to enhance it with additional functionality offered by digital systems in such a way that the user experiences a minimal cognitive overload by using the technological enhancements. Accomplishing this vision would result in a world where *computers* would be vanished to the background and more emphasis could be placed again to the daily activities instead of burden oneself with the frustration of using the available technologies. In this view, the augmented human memory would not be noticed in our real world but just give us the necessary support to beat the information overload, classification problem and fragmentation problem.

1.3 Contribution of This Thesis

In the context of Personal Information Management (PIM), the information storage to compensate the limitation of the human memory is well developed via the use of personal computers, external hard disks, flash drives and other storage devices. The pitfall lies in the way people organise and access the stored information, where the aspect of consulting the stored information *in exceed speed and flexibility*, as mentioned by Bush [17], is still an unachieved goal. This goal is a major focus of previous system design in the PIM research field by making attempts to organise the personal information in the way the human memory does. Nonetheless, users have adopted their own organising and re-finding behaviour over their life-time. As known in behavioural psychology, it takes a lot of effort and is time consuming to change users behaviour. Hereby, PIM systems should also support augmentations for the current performed users behaviour. Following this research line, the research question of this thesis is formulated as follows:

How may we design a PIM system which allows users to organise and re-find their personal information in the same way the human memory does?

- How do users currently organise and re-find their personal information?
- What are the current interaction issues with the available technologies and physical storage artefacts?
- What are the affordances of the physical and digital space in organising and re-finding personal information?
- How does the human memory organise personal information?
- Can we provide an abstraction of the human memory storage structure as a guideline for future PIM systems?
- Is it possible to implement a PIM system which augments the current organisational and re-find behaviours and in the meanwhile organises the personal information in a similar way human memory does?

Please note that in this thesis we see PIM in a much broader perspective than only organising digital information in an effective way for later retrieval. Our aim is to approach the personal information space as a *Personal*

Cross-Media Information Space covering the digital as well as the physical space. Since personal information crosses the boundaries of both environments (e.g. written information, emails or documents), the broader view will give better insights concerning the design of a *Personal Cross-Media Information Management System.* A second goal at this thesis is the combination of several insights from different related research fields to Personal Cross-Media Information Management as illustrated in Figure 1.3. By considering different points of view to the research subject, additional value can be given to the research area. In particular, in this thesis, the implementation hypotheses are built on four perspectives. The descriptive research area of PIM and the system design research to PIM are combined with additional insights from the Hypertext Community and Ubiquitous Computing.

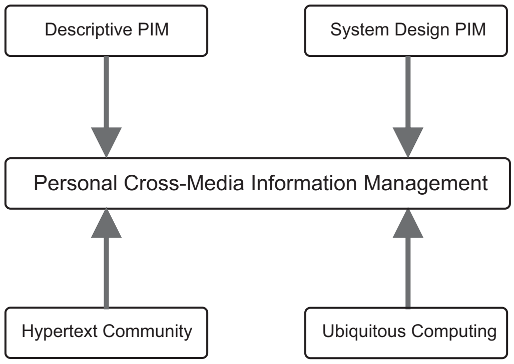


Figure 1.3: Insights to Personal Cross-Media Information Management

The user-centric system design approach will provide user criteria in terms of the affordances of the physical and digital information space. Out of these affordances the best of the two worlds concerning PIM will be combined to be able to augment the physical world with digital information without duplicating the physical restrictions. As we show in the next chapters, there is a lack of descriptive research and system design which include the cross-media part of *Personal Cross-Media Information Management.*

The contribution of this thesis goes further than providing new insights in the PIM research field. The presented work makes three main contributions in the research field of PIM. First, we conducted a user study which is directed to the digital as well as the physical space and to their coherency and dependency in terms of organising and re-finding personal information. The results of this study define design principles and provide a behavioural matrix with concrete interaction requirements for each observed behaviour in a cross-media information space. The fundamental outcome of these design principles made it possible to define a theoretical model with respect to PIM activities. Besides the general formulation of PIM activities, the model also reflects a high abstraction of the human memory storage structure. Furthermore, the theoretical model does not have any concerns about implementation strategies or user study guidance but is seen as a fundamental contribution to the area of theoretical PIM research. Secondly, the thesis also provides the use of the formulated design guidelines and theory in PIM system design. On one side, the presented PIM system framework implements the theory by first translating the high abstraction of the human memory structure to a more concrete metamodel followed by a concrete implementation. On the other side, the PIM system framework includes an interaction layer between the storage structure imposed by the model and the user interfaces following the design guidelines. Further in the reading it will be clarified that we do not provide an isolated PIM tool but a framework which is extensible and adaptive to support any user needed interactions concerning the organisation and re-finding of information. Besides a general developer user interface, a proof of concept of two user interfaces has been implemented supporting some of the guidelines of the conducted user study. This thesis has some limitations in the implementation of all needed user interfaces by providing only two of them. Due to the fact that the functionality provided by our PIM system framework is fundamentally different from the current way of organising and re-finding interactions, it opens new opportunities to investigate innovative interactions and user interfaces. Note that the conducted user study represents an initial investigation but much more research needs to be done on the complexity and introduction of new interaction paradigms for our PIM system framework as mentioned when discussing future work in Section 8.3.

1.4 Thesis Structure

The thesis is structured in three parts. The first part provides the necessary introduction of several concepts to be able to follow the further contributions. It is of important value to understand how the human memory storage structure works and how users currently struggle with the organisation and re-finding of personal information. Therefore, the second chapter provides a literature review on the descriptive research fields including Cognitive Psychology, Human Information Interaction and the younger descriptive part of PIM.

In the second part we present the three main contributions consisting of the user study, the theoretical model and the PIM system framework. Chapter 3 discusses the hypothesis, methodology and results of the user study. The results are used to define design principles concerning the affordance of the physical and digital information space and the user information behaviour in both spaces. In Chapter 4 we formulate the theoretical model and discuss the shortcomings of current PIM systems by reflecting on the given design principles and the theory. Due to the separation of the storage layer and the interaction indirection layer, the two layers are discussed in depth in the next chapters. Thereby, Chapter 5 first provides the overall architecture and goes deeper in on the storage layer. After an introduction of the basic concepts of the *Resource Selector Link* (RSL) metamodel by Signer and Norrie [69], our extensions of the model which where necessary to support the design principles and theoretical model are introduced. The implementation of the RSL metamodel and its extended version are briefly discussed since we made changes regarding the associations. The PIM interaction layer is described in Chapter 6.

Finally, the third part concerns a proof of concept application. Two user interfaces are presented in Chapter 8 which are based on the user study findings. A developers user interface with some guidelines is provided to deal with the new functionality offered by our PIM system. Some further ideas for new forms of user interactions for organising and re-finding personal information as well as future work are discussed in Chapter 9. Last but not least, we provide some conclusions about the presented research on Personal Cross-Media Information Systems.

I'm in a very good mood today, and
my System 2 is weaker than usual.
I should be extra careful.

Daniel Kahneman, 2011 [44]

2 A Human as a "Human"

The user-centric perspective on system design places the user in a central role. Since we take such an approach for developing a personal information management system, a brief introduction to the user information behaviour has to be provided. Section 2.1 introduces some basic insights about the human memory in order to better understand the user information behaviour and to be familiar with the used terminology in this thesis. Next, the focus is turned to the field of information management where several concepts related to information are introduced including the difference between *data*, *information* and *knowledge*. Finally, the more specific research subject of personal information management is explored by outlining the most widely used strategies concerning *organising* and *managing* as well as *re-finding* information. Throughout the whole chapter, only the main paradigms and currently most important views are discussed since it is out of the scope of this thesis to provide a detailed discussion of human science.

2.1 The Human Memory

In the introductory chapter, the augmented human memory vision was briefly introduced. If we speak of human memory, do we really know what human memory is? In the field of psychology, a lot of work has been done to answer this question. The human memory actually concerns the information storage and retrieval process as mentioned by Tulving [75]. First, a short overview of the human memory is given followed by the focus on the long-term memory because our interest lies in the long-term storage and not in the human capacity to encode this information. Second, the attention is turned to the most accepted theory concerning the semantic memory namely the *Quillian Theory* [58]. Although research in psychology gives a lot of interesting views on the user information behaviour, in this thesis only the individual is analysed and group interaction as well as the non-declarative memory insights focussing on the general human behaviour are not addressed.

2.1.1 Memory Storage Structures

In the mid-twentieth century, the view of a dual storage system of the memory became accepted by several psychologists. One of the first researchers who aimed for such a dichotomy was Brown [14]. In his study, he points out that there is evidence to take a step away from the unary view of the memory system. He defines the dichotomy as short-term and long-term memory. These memories for information storage are interdependent. In the late sixties, Atkinson and Shiffrin [2] proposed a three subsystem model which is an extension of Brown's dichotomy, including the sensory memory as a third lower-level memory as shown in Figure 2.1. Today, this separation into memory subsystems is still well accepted by the community.

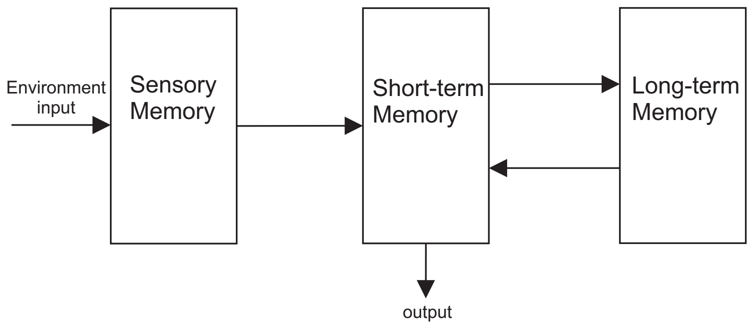


Figure 2.1: The memory model by Atkinson and Shiffrin [2]

The sensory memory is seen as the *entrance* of information into the memory system. At the sensory level, information which is not transferred to the short-term or long-term memory is kept. This information is highly detailed and stays in the sensory storage for only a few seconds. Humans are mostly not aware of this low-level information input. By invoking the process of attention, a small amount of this sensory information is transferred to the short-term memory. In this sense, the sensory memory acts as a buffer where only relevant information is presented to the consciousness of the human mind. An example of this buffer mechanism can be seen in the usage of the breathing technique in aiding natural birth where a woman needs to focus on the respiration frequency so that the pain signals are less captured by the consciousness. Next, the short-term memory which is limited in storage capacity stores encoded information during an average of thirty seconds. The limitation in memory span is shown by Miller in his publication entitled *The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information* [54]. The results show that the short-term memory can only store five to nine chunks of information items after presentation. A well misunderstanding in the field is the interpretation of the short-term memory span. As the study mentions, the span is not representing the size of the total short-term memory. Moreover, it is an indication to express that the short-term memory can only handle seven different chunks which might be seen as boxes. In its turn, each chunk may contain any amount of information. The storage capacity of the short-term memory is therefore defined by the ability to form seven information chunks and not the total amount of stored information. The amount of information items which can be stored depends on how well the person can place the information item into chunks. This classification depends on several factors such as a semantic relation or words with the same start letters. An experiment cited in Miller's works clearly show the distinction between the limited amount of chunks and the unlimited amount of information bits. The respondents were presented several different monosyllable three letter words and could retain five words. In a second experiment, they could retain seven numbers of length one. The difference between the amount of words (i.e. five words) and the amount of numbers (i.e. seven numbers) is not significant in this study. More importantly it shows that although the words contain more information bits (three letters) there was no significant difference in the amount of retained information items. To remember these chunks for more than the limited time interval of about thirty seconds, rehearsal can be applied [13]. Often people apply rehearsal when they need to remember a short list of digits such as a phone number.

The next stage of the memory storage process is the long-term memory. In the well studied long-term memory with its unlimited capacity, information is stored for a long time. Two major contributions have been made by Squire and Tulving. Squire [72] provides a framework distinguishing declarative and non-declarative long-term memory as shown in Figure 2.2. The non-declarative long-term memory contains the priming, procedural, associative learning and non-associative learning memories. Priming happens when

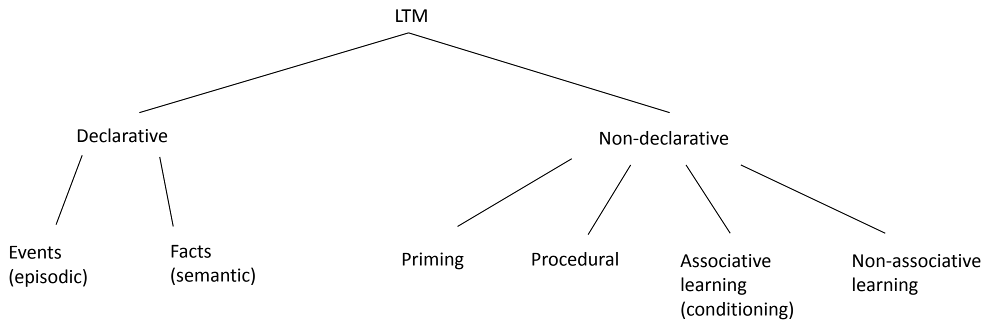


Figure 2.2: Declarative and non-declarative memory by Squire [72]

people are for example presented the word 'table' and after a time period they are presented with the sequence 'tab_'. By priming, they will complete the 'tab_' sequence as 'table'. Procedural on its turn concerns learned skills and habits. Associative learning includes the classic and operant conditioning. Classic conditioning has been nicely illustrated in the well-known Pavlov experiment. In this experiment, Pavlov rings a bell before a dog is presented with food. As a reaction to the presented food, the dog starts to salivate. After some repetitions, the dog already starts to salivate when Pavlov rings the bell without presenting the food. The second associative learning, operant conditioning, is for instance reinforcement learning where a behaviour is rewarded. Non-associative learning concerns learning including non-procedural habits. These are habits where no condition is set to learn the habit and where no procedural pattern can be determined. An example can be seen in the fact that some people always use the same stopping words in a conversation.

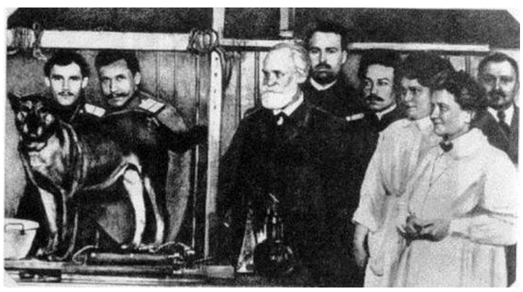


Figure 2.3: Pavlov and the dog experiment

In contrast to the non-declarative memory, the declarative memory provides people with storage for events and facts. The event factor in Squire's model can be seen as the episodic memory in the model by Schacter and Tulving [76] whereas the fact memory is seen as the semantic memory. The episodic memory involves the process of receiving and storing temporal-spatial information about events and their autobiographical reference with other events. The information about an event which is stored in the episodic storage also contains the perceptible properties of the event. Figure 2.4 shows the storage structure of the episodic memory represented by a chronologically ordered list of events.

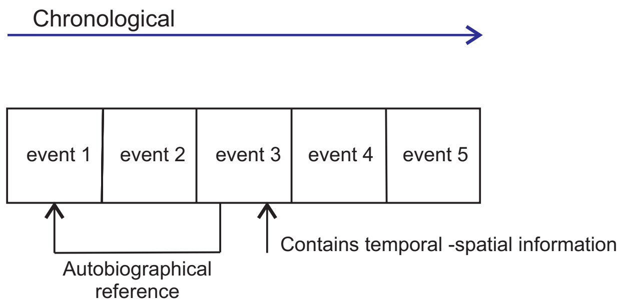


Figure 2.4: Episodic memory storage structure

In contrast to the episodic memory storage structure, the semantic memory storage structure is constructed of associative linked information as shown in Figure 2.5. Furthermore, an event always occurs at a spatial location and always has an autobiographical reference to a previously experienced event stored in the episodic memory. An example of the use of the episodic memory can be found in the notion of *‘I remember having a coffee before class yesterday’*. But also retaining a short list of words with no semantic relationship is the responsibility of the episodic memory. In this case, an autobiographical reference is made to the previous word in the list. When one recalls the words, they usually follow these autobiographical references.

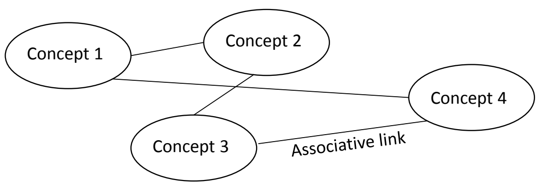


Figure 2.5: Semantic memory storage structure

One of the main differences between the episodic and semantic memory is the degree of complexity. As mentioned by Tulving in his book entitled *Organization of Memory* [76], the semantic memory is far more complex.

> *It is a mental thesaurus, organized knowledge a person possesses about words and other verbal symbols, their meaning and referents, about relations among them, about rules, formulas and algorithms for the manipulation of these symbols, concepts and relations. Semantic memory does not register perceptible properties of inputs but rather cognitive referents of input signals.*

Endel Tulving, 1972 [76]

A cause of this complexity may be found in the fact that the semantic memory does not need new information to expand its knowledge. It is possible that people start to reason on their own semantic graph and thereby creating new associations without an external event invocation. This is in strong contrast to the episodic memory where every added event in the memory is an event which happened in the real world. The reasoning functionality of the semantic memory imposes that recording and maintenance of its internal structure can be independent from the episodic memory as well as independent from the retrieval activity. Furthermore, the retrieval activity out of the semantic memory will always transform the episodic memory by inducing the creation of a new event concerning the retrieval activity. Nevertheless, the semantic memory does not necessarily change its storage structure when retrieving information. This is in contrast to the episodic memory where every retrieving activity creates a new event and therefore changes its structure. Thereby, the episodic memory has a much larger transformation speed than the semantic memory. This interaction between the two memories are subject to research and a lot of discussion is set in the community of cognitive psychology [13]. The interplay is enlightened by the following example. Let us assume that a holidaymaker is reading a folder about a museum which contains information about the history of Montmeyan. The reading takes place on a Friday at 14:00 while the holidaymaker lies on a comfortable chair situated at the poolside. Furthermore, the holidaymaker's wife is swimming and the sun is shining. During this activity, the memory is encoding more than only the information out of the folder of the museum. The episodic memory first stores a new event of this activity in its chronologically ordered list of events and makes an autobiographical reference to a previously related event (e.g. having lunch at 12:00). Together with the storage process, contextual parameters are stored along the event. In this example the contextual parameters are given by Friday 14:00, his wife is swimming, the sun is shining and he sits on a comfortable chair at the poolside. At the same time, the content information is stored in the semantic memory making associations with the previously gathered knowledge. Also the holidaymaker starts to reason about the history of Montmeyan and expands his semantic memory with concepts and associative links as a result of the reasoning. This example illustrates the interaction between the semantic memory and episodic memory at encoding time shown in Figure 2.6.

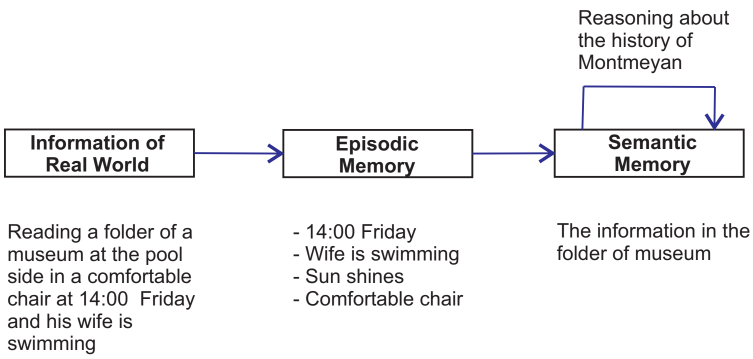


Figure 2.6: Example of the encoding activity

As mentioned before, the encoding of ‘real world’ semantic information (e.g. the content of the folder) implies the extension of the episodic memory and a change of the episodic memory structure. In contrast, the encoding of the result of the reasoning activity does not invoke the creation of an episodic event as it is not invoked by the ‘real world’ but by the semantic memory itself. Once the information is stored in both memories, the holidaymaker can retrieve two kinds of information. They may retrieve the information about the event or the information about the content of the folder of the museum. Figure 2.7 gives an overview of the retrieval process applied to the current example. First, consider the remembering activity of what the holidaymaker did on Friday 14:00 shown by the red arrow in Figure 2.7. This remember activity takes place later the same day at 19:00 while the holidaymaker has a conversation with his wife about their memories of the vacation. In the meantime they have dinner in a restaurant called ‘Sur Verdon’. This event creates a new event in the episodic memory with the contextual information such as the conversation with his wife, Friday 19:00 and the restaurant ‘Sur Verdon’. During this event encoding which is illustrated by (A) in Figure 2.7, an autobiographical reference is set to the event which occurred at 14:00 because the event concerns the remember activity of the previously experienced event (B). By following this autobiographical referential link, the information of the event of reading a folder of the museum might be retrieved (C). The blue arrow in Figure 2.7 displays the information output of the event at 14:00. The same evening, a second activity took place at 20:00. This activity consists of a conversation with a friend about the history of Montmeyan. At its turn, the activity invokes a new event in the episodic memory with the contextual information such as the holidaymaker's friend and Friday 20:00 (D). Nevertheless, the retrieval of information about the history of Montmeyan activates the semantic memory concept 'history of Montmeyan' instead of following the autobiographical referential link to a previous event (E). Finally, the blue arrow (F) in Figure 2.7 shows the information output as a result of the activation of the 'history of Montmeyan' concept stored in the semantic memory.

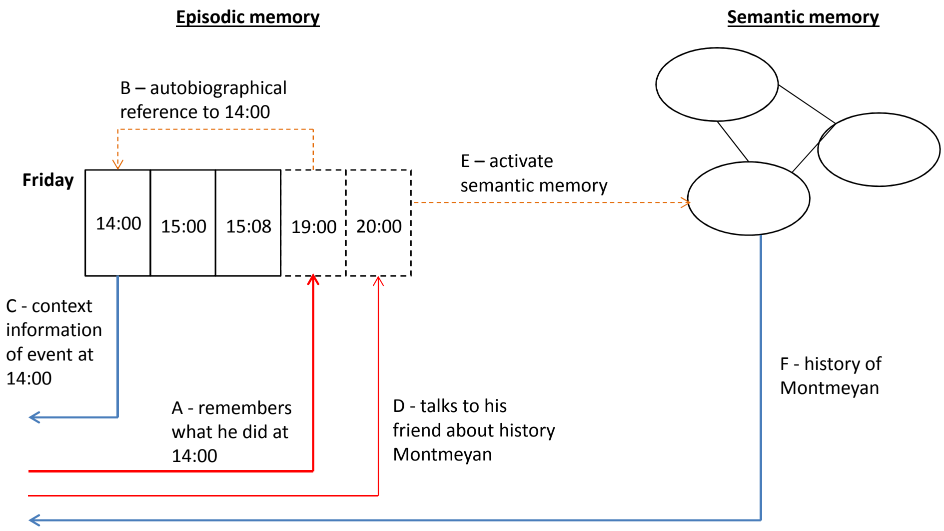


Figure 2.7: Example of the retrieval activity

The example demonstrates that every retrieval from the episodic memory as well as the semantic memory creates a new event in the episodic memory. A consequence of the creation of an event for every retrieval activity is a continuously transformed episodic memory storage structure. In contrast, the retrieval activity from the semantic memory does not necessary change the content of the semantic memory itself. The next subsection introduces the *Quillian Theory* which is one of the most accepted conceptual models concerning the storage structure of the semantic memory.

2.1.2 The Quillian Theory

Before an explanation of the Quillian Theory can be given, some concepts needs to be introduced. Out of the previous sentence one might understand that first some concepts will be introduced but what do we mean by 'some concepts'? Concepts are general ideas formed in the mind to abstract the complexity of the real world. On the other hand, categories concern the things in the real world that the concept is about. Therefore, concepts are internal to the mind where categories are external to the mind. An example is given by *'Rosie is a cat'*. *'Rosie'* is member of the category which contains the real things of the concept *'cat'*. By the composition of real world things in a category the meaning of a concept is clarified. A notion to take is that often people confuse words with concepts. In a psychological interpretation of the concept, the meaning needs to be unique for each concept. In contrast to words which can have multiple meanings and a meaning can refer to different words such as synonyms. Concepts are unique and people classify real world things in categories referring to a concept. Bruner [16] points out that human behaviour to certain real things such as objects, events or people depends on the category these things are member of. For example, they behave in a certain way to a dog but in a different way to a human. In everyday life, humans classify a lot of things in different ways. When opening a food closet, mostly the food is grouped together such as cookies on one side of the closet and spices on the other half. Several studies have shown that the classification process is quite complex. Barsalou [5] gives the insight that the classification depends on the goal or the purpose people have in mind. In his enquiry, respondents where asked which elements they would classify in the concept *'things to take in case of fire'* where most respondents answered with very different non-associative elements such as photos and my pet. On the other hand, a study by Ross and Murphy [59] about food categorisation gives evidence of cross-classification. An example from their study is the classification of eggs. Sometimes eggs where grouped together with bacon and bread referring to the concept of breakfast and sometimes eggs where classified with butter and milk which refers to a concept of the food pyramid. Therefore, an information item which is present in the real world can be classified in more than one concept called cross-classification or multi-classification in the more technical research fields. Furthermore, classification can depend on the context where the real world information item is placed in. The previous example shows that talking about breakfast or the food pyramid results in different classification categories. The context dependency comes from the linguistic view where people place concepts in a certain context which defines the circumstances in which the meaning of a concept is comprehensible [60].

The notion of the semantic memory storage constructed out of associatively linked concepts as mentioned previously, was already described by earlier researchers. Nevertheless, the mostly accepted theory about this no-

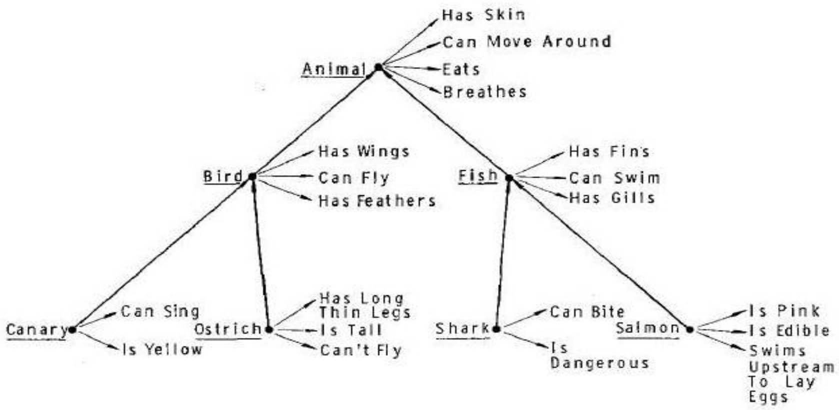


Figure 2.8: Illustration of the hypothetical memory structure for a 3-level hierarchy. Adapted from Collins and Quillian (1969) [22]

tion is the *Quillian Theory* which was later extended and retitled as the *Spreading-Activation Theory* [58]. Quillian first describes the concept of concepts where concepts may be constructed out of any word sequence such as nouns, verbs or whole sentences. Furthermore, semantic associative links are constructed between the concepts in a networked hierarchical structure. On its turn, every concept may contain properties specific to the unique concept and may be a specialisation or generalisation of another concept. Figure 2.8 shows an example of this semantic memory structure. In the example, a canary is a bird with properties such as *'can sing'* and *'is yellow'*. Also the canary concept inherits the properties of the bird which are more general such as *'has wings'*, *'can fly'* and *'has feathers'*. Going to the concept of an ostrich, it inherits also the properties of the bird but a problem arises because in the real world an ostrich cannot fly and in the basic model a property *'can't fly'* should be added to the concept of an ostrich.

The strength of this theory lies in the proposed five distinct link definitions and the fact that links between two concepts are bidirectional. A link between two concepts can be of one of the following five type:

- superordinate or subordinate: one concept is more general or more specific than the other one.
- modifier: also seen as a property link where a concept links to another concept by means of 'is property'.
- conjunction: because the concepts may be labelled out of multiple words or even sentences, the concept may be a conjunction of two or

more other concepts. To derive the meaning of the conjunction in the labelled concept, a conjunction link may be defined to the individual concepts.

- disjunction: a disjunctive link defines that a concept is not in relation to the other concept.
- residual: a link between two concepts may be used by another concept.

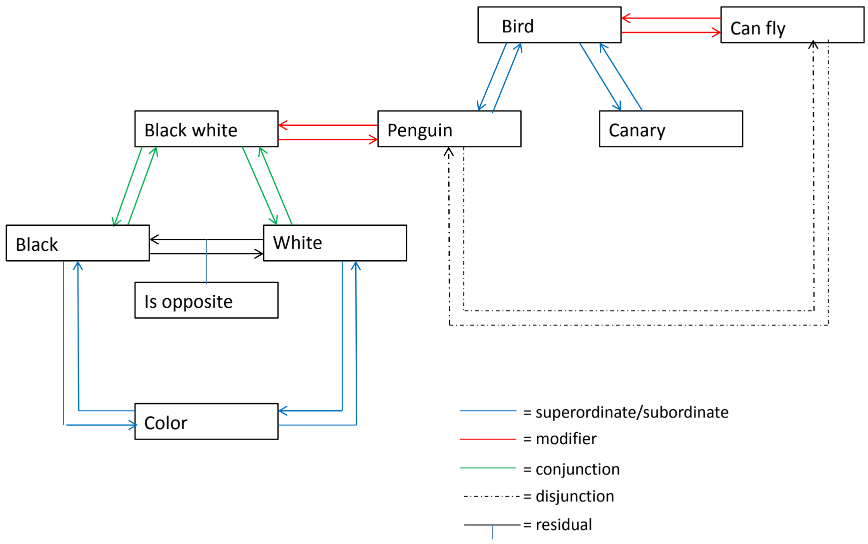


Figure 2.9: Illustration of the five links proposed by Quillian [58]

An example of applying these link definitions is given in Figure 2.9. For clarity purposes, the ostrich out of the previous example is modified to a penguin. The canary and the penguin concepts are linked through subordinated links to the concept of the bird where they inherit the concept of *‘can fly’* which is linked by a modifier link to the bird concept. But a penguin can not fly so a disjunctive link is constructed between the concept *‘penguin’* and the concept *‘can fly’*. Furthermore, a penguin is black and white which implies a modifier concept *‘black white’* which indicates the colour of a penguin. Now no direct link is made to the colour concept because the concept *‘black white’* is not a colour in its own right. Therefore, an intermediated link is constructed between the concept *‘black white’* to the concept *‘black’* and the concept *‘white’*, namely a conjunction link. This is followed by the subordinate link to the concept of *‘colour’* because black and white are colours in their own right. Quillian further states that any piece of text, any description of a real world object or any event may be formulated in terms of associative semantic links using the bidirectional approach and the five link definitions. The context and meaning of all concepts might be derived from the activation of the network. To derive the context and the meaning of a concept, a degree of relevance to the linked concept is set. The degree of relevance is called the threshold of a link between two concepts. This threshold can defer between the directions of the bidirectional link between two concepts since one direction may be of more importance than the other direction. As shown in Figure 2.9, the link from *'penguin'* to *'black white'* may be of more importance than the other way around because the concept *'black white'* may put more emphasis on another related concept such as the concept *'black'* instead of the concept *'penguin'*. Increased use of a link and therefore frequently activated concept links, increase the threshold in time. The resulting semantic memory storage structure also needs to be able to retrieve the concepts and their context and meaning. Quillian described for this reason a process of spreading-activation. This process involves the activation of several nodes which are given by the external environment such as a sentence or a stimuli. When concepts are activated, a strategy of spreading is used to determine which node will be activated next. The spreading takes one level at a time, where a concept will activate its linked concepts and on their turn they will activate their linked concepts. At each level, the concepts are tagged to store the information that the node is already activated. The spreading goes further until an intersection with a tagged concept is met. Both paths are then evaluated based on the links thresholds and if satisfied, the spreading activation stops. For more details and extensions of the Quillian Theory following references may be consulted [57, 58, 22, 21].

2.2 Talking About Information

The introduction to the human memory mentioned concepts as the main building blocks of the semantic memory. These concepts are an abstraction of the real world things with the purpose to be able to understand, to communicate and to reason on daily encountered things. We still talk about things at this stage but why? Can we call the things we encounter in daily life data, information or even knowledge? No.

People talk about information as if it is a clearly defined item. Nevertheless, the distinction between data, information and knowledge is a topic for discussion in the information science research field. In this thesis, the ecological approach of Thomas Davenport is followed to define these concepts. In his book entitled *Information Ecology: Mastering the Information and Knowledge Environment* [23], the distinction between data, information

Data	Information	Knowledge
Simple observation of states of the world	Data endowed with relevance and purpose	Valuable information from the human mind - includes reflection, synthesis and context

Table 2.1: Definition of data, information and knowledge as cited in [23]

and knowledge is defined with a perspective on the development of information management systems. Table 2.1 gives an overview of these definitions. Data are the raw facts which people observe from the real world such as the amount of books in a closet or detecting a movement of an object by sensors. This data is easily structured, captured from machines (e.g. sensors) and easily transferred. Once a human processes the data by enhancing it with relevance and a purpose, the data becomes information. An example is the price of a good. For someone the price might be data because it is not relevant to them. On the other side, the price may be information to a second person who is interested to buy the good. Furthermore, information becomes knowledge when it gets valuable to the human mind. Information which becomes valuable to the human mind has given a context, meaning and an interpretation. The process of searching on the Web for relevant information to solve a problem is a good example to demonstrate the three level distinction. A user may have a problem and needs relevant information to fill the gap between the current knowledge and the desired knowledge state. By navigating through different websites, the user captures data. It is only when they give relevance to the website that it becomes information. Commonly, they will process this information when the information answers the information need. This processing makes the information available on the website to knowledge. The user places meaning to the saved information and interprets the information in the context of his problem which was the invoker of the search.

The importance of context is already given by the episodic memory storage structure aside of its descriptive variable function in the definition of knowledge. Nevertheless, the definition of context is a subject to discussion in several research fields. Because of the user-centric system design, the choice is made to agree with Dervin's description of context.

> *"Context constitutes necessary conditions for sufficient understanding of phenomena"*
>
> Dervin, 1997 [24]

The main difference between information and knowledge is the application of context to the information. In the view of the definition of context by Dervin [24], knowledge is information which is enhanced with necessary conditions or variables to understand the information. Furthermore, context is fluid and dynamic in a user-centric system design [30]. Fluid in the sense that not all context variables may be described and observed. The most important argument is the user dependency to which emphasis is set on a real world variable. In other words, a user may set more or less emphasis on the different conditions out of the definition of context by Dervin [24]. On the other hand, context is dynamic which is seen by the fact that the context variables describing the context may change over time for a certain contextual concept.

The Personal Information Management research field concerns both information and knowledge. Jones [42] points out that actually a personal information space contains more knowledge fragments than information. PIM could easily have been called Personal Knowledge Management but this would create fuzziness because the Knowledge Management research is more focused on digitising and automatically transforming information to knowledge without the participation of a human. Therefore, personal information contains the information items as well as the knowledge items which people store in the physical and digital space. In this writing, both information and knowledge items are called information items for consistency within the PIM community. Furthermore, information items are seen as first class objects which means that the information or knowledge stored is independent from the carrier. In the coming sections, it will become clear why this approach has been chosen. The main reason is given by the fact that people duplicate a lot of information items to different carriers. For example, a journal article may be stored digitally, on paper or in both formats but it concerns the same information item namely the content of the article. Such an approach has major advantages in PIM system design. It allows the user to interact with the information itself and not with a certain format in which it is stored. Nevertheless, the information carrier may provide extra information to the user or may play the role of a context variable to identify a contextual concept. A second advantage is that we can talk about information on three granularity levels namely the organisation structure (e.g. folder hierarchy), the document and unstructured fragments (e.g. post-it notes). A PIM system needs to be able to manage all granularity levels.

Jones [42] also provides the understanding of the *personal* factor in PIM. The *Personal Information Space* contains all information items related and owned by the person. An important aspect is the notion of *all* information items. Most enquiries include work related to limited information formats (e.g. email or documents) and are mostly restricted to the digital information space. In this thesis, a lot of emphasis is set to the right interpretation of *all* information items.

2.3 Organising and Managing Information

A PIM perspective with respect to the organisation and management of personal information is outlined in this section. Organising and managing information are important activities because they allow the user to re-find an information item. Nevertheless, as the information overload is increasing, neglected or badly supported organisation of information may impose even larger issues in retrieving activities than the current encountered problems. Following the approach of Personal Cross-Media Information Management both environments – the *physical* and *digital* spaces – are considered as well as the organisation and management of information at the three granularity level such as organisation structures (e.g. folder hierarchy), documents and unstructured fragments (e.g. post-it notes).

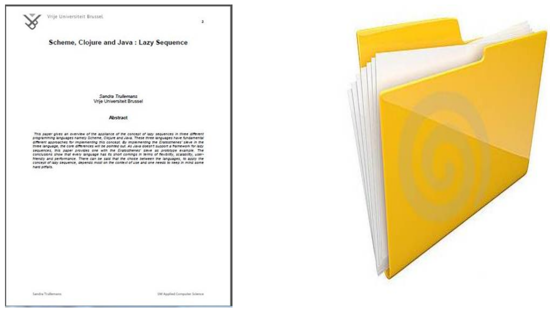
2.3.1 Two Strategies and the Classification Problem

A pioneer in the research on how people organise their desks is Thomas Malone. In his publication from 1983 [51], Malone defines two strategies of information organisation including *filing* and *piling*. Later on, his view is integrated in the research on how people organise information in the digital environment in the form of email [83, 10], files and bookmarks [10]. Nevertheless, there are differences in applying his definition of those two strategies across both environments. The next sections will clarify these differences in terms of the properties of each environment.

	Elements titled	Elements ordered	Groups titled	Groups ordered
Files	Yes	Yes	?	?
Piles	?	No	No	?

Table 2.2: Definition of files and piles as cited in [51]

In Malone’s approach, individual elements are seen as information carriers (e.g. paper) or they can be larger objects which are composed of elements (e.g. folder). Furthermore, groups are defined as grouped individual elements (e.g. grouped folders). Figure 2.10 shows some examples of those concepts. These elements can be explicitly titled and systematically ordered in a user-specific way, mostly alphabetically or chronologically. Table 2.2 shows the definition of both strategies in terms of the elements and their property.

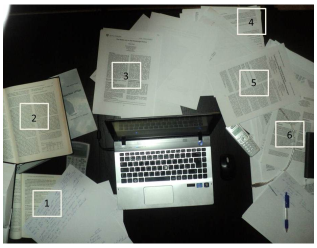


(a) Paper as an element (b) Folder as an element

Figure 2.10: Elements by Malone [51]

Files are elements which are titled and ordered by the user. Also grouped elements can be seen as a file as long as the whole group is ordered in a systematic order and the group is titled. An example are the old file cabinets where files are ordered and titled but at the same time the entire file cabinet can be titled and being a part of a bigger file system containing ordered file cabinets as shown in Figure 2.11b.

Already in the mid-1800s, people where filing their information items mostly books in filing systems with explicitly labelling and order. This behaviour of organising the personal information items in private offices inspired Otlet and Lafontaine to unify the organisation of the large amount of knowledge in libraries. Their work lead to the well used *Universal Decimal Classification Model* which is a model where categories are labelled by decimals and the order is fixed [52]. Due to the decimal approach, subclasses may be defined depending on the desired concepts. The example of the file cabinet is reflected in the digital space where each document needs to be labelled and placed in a folder. Also all folders and their documents are alphabetically ordered. Nevertheless, in the personal information space it is not always desired to be restricted to the filing requirements of labelling and ordering the information items. Therefore, people started to pile information items. Piles are untitled and unordered elements forming a pile as illustrated in Figure 2.11a. Piles can be ordered in some way but the containing elements cannot be explicitly ordered. Elements forming part of the pile can be titled but the entire pile cannot. This implies that it is impossible to have a



(a) Desk pile

(b) File cabinet

(c) Neither file nor pile

Figure 2.11: Piling and filing

titled pile of documents. Of course those two strategies are not covering all organisation behaviour. An element can be neither a file nor a pile (e.g. a titled folder which contains unordered papers) as shown in Figure 2.11c. The further reading will show the lack on research covering the strategy of neither file nor pile which is the mostly used organising strategy in our daily information organisation.

One of the forces that leads to piling is the *classification problem.* The classification problem has been described in earlier research of Malone [51]. He points out the fact that people have difficulties to decide on a classification structure which will be the most easiest for later retrieval (e.g. alphabetical, contextual or chronological). A second difficulty is the challenge to label an item with enough information about the item itself but that still fits in the context of the classification structure. This issue has to do with the cognitive overload at the moment of describing the element [48]. Furthermore, the cognitive overload can refer to the mismatch with the human memory in terms of the organisation structure. The organisation structure of the memory namely the chronological event list of the episodic memory and the graph-based associative link structure of the semantic memory are fundamentally different from the filing and piling strategies. As stated by Cole [20], users tend to have the vision of the less time they spent on filing the better. At the same time that Malone's research took place, Dumais and Landaeur [29] formulated two major problems inspired by the menu-based retrieval systems. Because menu-based activities at that time where constructed out of tree structures, a similarity can be seen to the file strategy. Joining Malone's findings, they identified that users do not always tend to use descriptive labels for the titles. This problem also implies the mismatch between the system designer and the user concerning the perception of the used concept in the label. Although, personal information management is restricted to the user themselves and we can see the user in the case of a file system as the system designer, there can still be a mismatch problem. As highlighted by several researchers [20, 51, 50] a mismatch between the moment of filing and the later retrieval can be identified. This mismatch appears when the item is needed in a different context than the filing moment and at retrieval time the user is not aware anymore of the file label used in a previous context. Lansdale [50] enhanced this view with the difficulty of using words for formal classification. Words may have many meanings and a description may be referred to in many distinct words. For example, one may have a folder with a label *'WIS course'* where all the study material of the Web Information System (WIS) course is placed and a folder labelled *'Thesis'* where all thesis material is stored. The 'WIS course' folder contains a file named *'memex.pdf'* since it was used in the context of a lecture about the history of the internet. After some time, the user needs to re-find the *'memex.pdf'* file for a new project they are working on. By the fact that the Memex is referenced in the thesis, they first search for the file in the folder labelled *'Thesis'*. Nevertheless, they do not find it in that folder because at the moment of classification, they saw the paper in the context of the WIS course and so not in the context of the thesis.

The second major problem described by Dumais and Landaeur [29] concerns the classification paradigma. The appearance of overlapping and fuzzy categories makes unambigious partition impossible or in other words a multi-classification system is desired. Let us go back to the previous example. Once the user had found the *'memex.pdf'* file in the *'WIS course'*, they will need to classify it again later on. Now the question raises under which category they need to classify the item to be able to retrieve it later namely 'WIS course' or 'Thesis'. In the next section we go deeper in on the two strategies in the context of the physical environment.

2.3.2 The Physical Space

The physical environment still represents an important part of our information space. Although technologies are well used, paper has affordances which are hard to digitise. It is well suited for reading, annotating and flexible navigation through documents is possible [65]. Whittaker and Hirschberg [80] agree with Sellen [65] and confirm that knowledge workers keep large paper archives. Nevertheless, the study shows that only 48% of the archive contains uniquely processed documents. The remaining part consists of copies of public data and even unprocessed information. Joining Malone’s [51] findings, evidence is given for the use of files and piles. Furthermore, the study marks people as filers or pilers based on the most used strategy. People who tend to file, collect more information but access it less frequently than people who tend to use more piles. A reason for this can be found in the premature filing where filers file information to clear their desks but afterwards the filed information seems to be of no value. In this case, a user would file away all the received information during the preparation of a task. They would store all the information found on the Web and their notes, the public data respectively unique data. When they will resume the task, they will only process a part of this filed information where a significant amount of information would be left unprocessed. In contrast to Kidd [47], the study of Whittaker and Hirschberg found that researchers do archive lot of information as a support for the long-term memory. Reasons are the availibility, the mistrust of public information and the reminding function of paper. Another perspective is given by Kaye [46] where the study results give other causes for filing such as building a legacy, sharing information, fear of loss of information and the file system is used as an identity construction.

Besides the classification problem as a force to pile information, the lack of time to process all incoming information due to the information overload and the uncertainty about the future use and value of the gathered information are other forces to pile information [80]. Piles have advantages in these situations but they also provide a much better reminding function than archives as described by [20, 51, 19, 50, 80]. This reminding function comes alone when the user looks up an information element in the pile. Because of the properties of a pile, the elements are not ordered which means that the user needs to browse through the pile. By being confronted with other information elements in the pile a reminder may be triggered. This reminding function is one of the affordance of paper in a general context [65]. A second function of piles is the preservation of the context of the information. This in contrast to files where at the time of filing the context of the label is not preserved [50]. By ordering piles in a contextual way, the context can be used as a cue for retrieval. Several researcher share these findings and point out that the context cue is one of the main advantages of the human memory for recall [51, 50, 47, 12]. A last function of piles is the spatial property they provide. Already in early research by Miller [53] their is shown interest in the special property of the 3D physical environment. The retrieval of information is supported by the natural action of the spatial memory. An illustration of the natural spatial behaviour is given in his work. A chimpanzee is sitting in front of two boxes, one white box which is at his left side and one black box which is at his right side. The guardian places food in the white box and switches the two boxes so that the white box is at the right side of the chimpanzee. Knowing that chimpanzees can be trained to notice colours, he will choose the black box when searching for food. These findings show that users have the intention to ask where the information is in the space as a natural behaviour. The importance of spatial reference is supported by Cole [20] in his research on human aspects in office filing. A file system in a 3D space has spatial reference points which minimally compensates the classification problem. Nevertheless, piles provide much more spatial references than a file system and therefore the recall of an information item in a pile is more based on the spatial information.

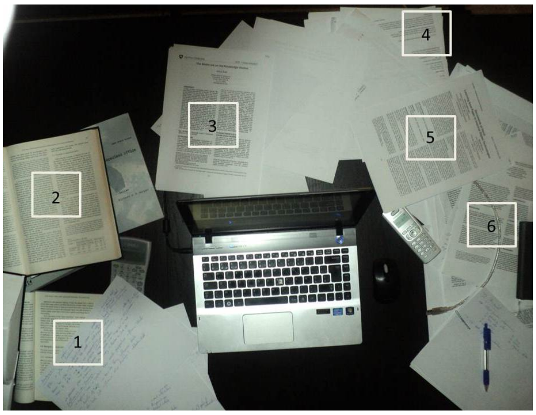


Figure 2.12: Context and spatial advantages of piles

An example is given by analysing a desk surface while working on this thesis with piles consisting of books, research papers, personal notes, drafts and post-it notes which is shown in Figure 2.12. Six piles are made around the central working place (i.e. the laptop). Nevertheless, each of these piles contain information about different concepts related to PIM. One pile is used for the information about filing and piling, another one contains information about finding and re-finding and one is piled with information about research on system design. Out of this pile structure the context of writing a thesis about PIM is kept. The figure also shows that piles are not always clearly separated. This fuzziness comes from the classification problem where some items could belong to more then one concept. A compensating strategy is used here by ordering the piles in such a way that the papers belonging to two related piles are just sliding somewhat out of one pile pointing to the other related pile. This can be observed in pile three, four, five and six in Figure 2.12. Furthermore, this structure lets us also see the spatial property of piles. By being aware of the context and the spatial ordering of piles, the user will re-find a paper without the need of a label or other properties of the required paper. Enhancing previous findings, the conclusions of Jones and Dumais [39] from their observation study on the spatial metaphor for user interfaces show that the location alone is not the best way to re-find information in the long-term such as in a file system. In this case, a label joining the spatial references is the best way. In contrast, for short-term retrieval the location aspect is a major advantage to re-find the information item even when the item is labelled. This confirms the findings by previous research [19, 4, 80] where piles are used for short-term activities or working information. Paradoxically, all advantages of piling described earlier will reduce when the amount of information increases. Table 2.3 gives an overview of the most important concepts introduced till now. The next paragraph goes deeper in on the different influences on both strategies defined by Malone [51]. Those influences contribute to the application of the degree of filing and piling.

Files	Piles
Users collect more information but access less it less frequently	Users collect less information but access it more frequently
Support long-term storage	Support for short-term storage
Loss of context in classification	Preservation of context
Small amount of spatial references	Large amount of spatial references
Location and label used in the retrieval process	More emphasis on location in the retrieval process
Need a lot physical space	Restricted use of the physical space
No reminding function	Good reminding function
Stable in time	Less functionality supported when increasing the amount of piles

Table 2.3: File and pile properties

Separating the short-term and long-term use of information is defined in several studies. First, Cole [20] defined three information categories namely action, personal and archived information. The degree of the used organisational strategy (i.e. piling or filing) and the access frequency determines to which category an information item belongs. Next, Sellen [65] also defines three information levels as hot, warm and cold. The definition provides a categorisation based upon the level of activity the user applies on the information item. For cold information which is not often accessed and most often filed away, paper has a disadvantage in a sense that it takes place in the physical environment. Piles are often used for warm and hot information. The affordance of paper like reminding and grouping of papers gives additional advantages to the pile strategy. Besides the level of information usage, Cole [20] defines other factors which may contribute to determine which strategy is used. These factors are the type of information, the form, the volume, the complexity and the function of the received information item. Later, Case [19] concluded in his study on the information use by research workers, three factors influencing the way they organised their information namely spatial constraints, the form and the topic of information. Table 2.4 provides an overview of these main influences on the used strategy.

Cole [20]	Case [19]	Sellen [65]
Information levels: archived, personal and action	-	Information levels: cold, warm and hot
Form	Form	-
Volume	Spatial constraints	-
Function	Topic	-
Complexity	-	-

Table 2.4: Main influences on the used strategy

2.3.3 The Digital Space

Going to the digital environment the two strategies defined by Malone [51] files and piles are present. In the seventies, Xerox Parc introduced the *Desktop Metaphor* for personal computers. The folder hierarchy is an application of the file strategy where the documents are titled and ordered. Even more, each folder is again titled and ordered so that the whole hierarchy is a file system compared to a file cabinet in the physical space. Figure 2.13 gives an example of a folder hierarchy with labelled folders and files which are alphabetically ordered.

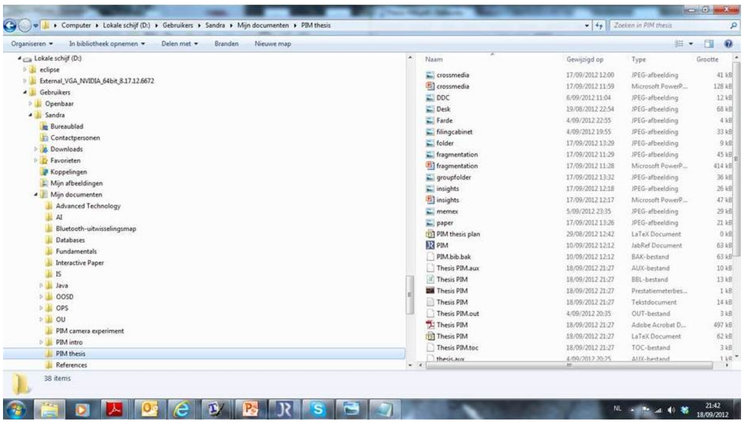


Figure 2.13: A folder hierarchy

Through this approach the classification issues clarified in the physical space stay and the opportunities of multi-classification provided by the affordance of the digital space is neglected [41]. Additional issues to the classification problem in the digital space are observed. Due to the non-spatial restrictions compared to the physical environment, the naming and overall structure of the file system is much more complex [12]. There are less restrictions on the name length (e.g. 255 characters in NTFS) whereas in the physical environment the length is limited to the spatial property of the label. Furthermore, the breadth and depth of a hierarchy is not restricted by spatial limitations. Because of the loss of context about the information item when naming the document or folder, users tend to construct complex labels and squeeze in the current context into the folder hierarchy [40]. This naming strategy compensates the loss of context but at the same time the filing activity comes with more cognitive overload and takes more time. Also the variety of used naming strategies imposes problems in re-finding filed information. The same user may apply different contextual granularity in different situations or tasks [3]. Let us assume that we take a look at the file hierarchy of a researcher. They could have a folder structure about a vacation to the George du Verdon. Furthermore, they could have a folder structure about a research project on the descriptive research of PIM. Of course for the research project they will have a folder structure with quite some levels of sub-folders and files. These folders and files will be labelled with as much contextual information as possible due to the complexity of a research project. On the other hand, the folder structure of the vacation will have one or two levels of sub-folders and the naming of files will be less rich in contextual information. The problem appears when a researcher is working in the vacation project and wants to retrieve information about the research project. The research project has a finer granularity and greater complexity so they will experience cognitive overload when switching from one structure to the other one. At a certain level the folders structure may become too wide. The user may then easily break down the folder into sub-folders. Nevertheless, breaking the folders down into too many levels, the depth of the hierarchy becomes too deep to re-find the information item [12]. Barreau's [3] explanation goes back to the psychology view where a user needs to have a previous knowledge of the schema of the constructed hierarchy to be able to navigate in an efficient way. As this schema becomes more complex when the hierarchy grows vertically, it is more difficult to memorise this schema.

Some researchers have defined more specific used strategies to file documents in the folder hierarchy. Boardmann and Sasse [10] categorised users filing behaviour in three categories. Total filers are people who file the majority at the moment of creation. Some users leave a little amount of files untitled and are called extensive filers. More exceptional are the occasional filers where the participants left most files untitled. In addition, Henderson and Srinivasan [35] found an average of 16% of the participants who where piling files. Usually piles are created at the desktop or the root of the hierarchy. A disadvantage of the digital pile strategy is the impossibility of easy grouping different formats of files [12]. Besides their support for the filing strategy described by [51], a third strategy namely structuring is perceived. This strategy points out the effort users do in keeping the context of the file. Before or at creation time different folder structures are created and named for the current activity. A consequence of the structuring strategy is a file system which is very narrow and deep. The structuring strategy fits the functionality of a file system imposed by the users. The file system is not only used for re-finding the information item but also as a meta tool and a problem decomposition tool [40]. Trade-offs need to be made in this case. By the extensive use of the structuring strategy, the file system becomes very narrow and deep. A consequence is that user need to spend more cognitive overload and time accordingly to the re-find activity. Table 2.5 gives the different strategies of organising information used in the digital space.

Problems of the current file hierarchy are given by several researchers [3, 11, 40]. The main problem is the classification problem described previously. Furthermore, lot of files have overlaps in different folders. This factor has also been observed in the physical classification system [11]. In the digital space, a lot of duplication and overlaps are being noticed between different types of files such as between email and the file system. Another issue is

Malone [20]	Boardmann and Sasse [10]
Files	Total filers Extensive filers Occasional filers
Piles	-
-	Structuring

Table 2.5: Used strategies in digital space

the additional functionality users tend to add to the file system. Previous research indicates that users use the file system for problem and project decomposition. The problem in this additional functionality is the dynamic approach of those decompositions. What is now seen as a good decomposition may have no relevance later in time [43, 15]. Besides these problems there are also issues concerning the missing support for desired ordering, the tension between current use and later use and the lack of support in re-using organizational structures which cannot be neglected in the analysis of file strategies [43]. Bondarenko [12] concludes that the current structure of the file system and the user behaviour is good suited for cold information storage. This is in contrast to warm and hot information where the spatial property and the contextual cue are one of the main used cues to organise and re-find information. The above described problems are illustrated by an example. A user has a folder structure concerning a vacation project in the file system. When receiving an email from a friend with some touristic information, they want to save this somewhere in the digital space. As we will see later on, they want to keep not only the email attachment but the whole email. Now for their convenience they will just copy/paste the folder structure used in the file system or a part of it to the email hierarchical structure. In this way, they have the same or partly the same structure in both formats. The overload of this strategy is to maintain the consistency or partly consistency of the folder structures in both formats. While working on the vacation project, the folder structure in the file system will grow in breadth and depth depending on the decomposition of the project. Later on, they are going back on vacation so they have a second vacation project. Because there is time past by, they may want to have another decomposition of the project. This means they need to re-organise the folder structure to fit their mental model of the vacation project.

Looking at email, users tend to experience more information overload [42]. Therefore, they use email tools with other purposes than the ones they have been designed for. In the core, email tools are developed for asynchronous communication but today they are used for several distinct functionalities [79]. This is also referred to as email overload. Users use email for task management joined by a reminding function [12, 79]. The reminding function will decline when the size of the inbox increases which implies that the inbox is not suited for this functionality. Even for task management users get stuck in many folder structures with the same problems as described for the folder hierarchy. Although the time stamp is saved and provides a time cue, the context of the conversation could be lost when filing the email away. A second functionality which contributes to email overload is the personal archive of attachments [79, 12]. Users keep files in attachments for the extra information the email provides and to not be concerned about the classification problem. Nevertheless, because of the integration of these functionalities in email, fragmentation becomes even a bigger problem. Organizational strategies are therefore very diverse depending on which additional functionality the user integrates. A close relationship is found between email and the hierarchical file structure namely duplicating the file structure and keeping copies of files in both systems [10]. As the last research is done by Whittaker in 2006 [79], a current view and the functionality provided by current email tools are not known.

2.4 Re-finding Personal Information

The next step followed by organising information is re-finding the information. Because the purpose of information management is to retrieve the stored information in an easy and flexible manner, this paragraph considers user behaviour and criteria for that purpose. A distinction is made between *finding* and *re-finding* information. Finding information is characterised by the search for certain unprocessed information and where the information target is usually unknown. On the other hand, re-finding information appears after the information is stored and organised by the same user. The main difference between finding and re-finding is that for re-finding the user has much more knowledge about the information target because the information item has already been processed before. In the context of this thesis we only handle the re-finding information since its importance to PIM.

2.4.1 The Best Search Engine is Not Enough

In Human Computer Interaction there are two perspectives concerning the future of search engine tools. A group of researchers belief that when search engines are improved to better fit the users information need, all problems of re-finding the information element would be solved. Nevertheless, this perspective gets quite some criticism from other researchers. Teevan [73] describes in her paper entitled *“The Perfect Search Engine Is Not Enough: A Study Of Orienteering Behavior in Directed Search”* that users actually do not often use search engines to re-find personal information. Amplifying this statement by the study of Bergman [8], users only use the search engine as a last resort when the location of a file is forgotten. This situation appears only in 25% of the total re-find activities which shows that other re-finding strategies are practised. One main strategy is referred to as *orienteering*. Orienteering comes from the game where players need to find a target by navigating through a map of the city. In the digital space, this strategy is seen in starting the search at a certain point in an organisation structure (e.g. folder hierarchy) followed by navigating through the structure in a step-wise manner [73]. Several other researchers [3, 4, 8] support Teevans findings about the use of an orienteering strategy as the main strategy for information retrieval. Nevertheless, why do they all the effort of navigating to the location of an item instead of using the search engine? Several reasons are found for this preference. Out of cognitive psychology, there is a difference between recognition and recall. Recall and therefore formulating the file name or other properties about an information item is more cognitively loaded than the recognition of elements related to an information item [75]. Bergman [8] and Teevan [73] both point to this underlying theory to justify the use of an orienteering strategy which is based on recognition. The consistency of the folder hierarchy unless the user re-organise it, contributes to the recognition of a path which leads to the desired information element. As shown in the organising section, some problems may occur when using deep hierarchies. The schema becomes more complex and the recognition of related information items are harder to recognise than when the schema would be less complex. Additionally, Bergmann’s results on the influence of the depth of the folder hierarchy to the step duration shows that users do not spend more time at each step of the navigation process as the hierarchy increases in depth. This results could be explained by the evidence that when the hierarchy depth increases the folder breadth decreases so that the time spend choosing the next folder stays stable. Another reason to use an orienteering strategy is the way users add additional functionality to the folder hierarchy. The folder hierarchy is used for purposes as keeping the context of the information item and as a project decomposition tool. By using navigation throughout the hierarchy, the “hidden” contextual information of a project is available to the user. This in contrast to the use of the search engine where all this relevant contextual information is lost. Furthermore, the spatial awareness which is a natural human behaviour [20] enhances the use of orienteering. The followed path during the stepwise navigation gives the user spatial reference points in the information space. The spatial awareness is totally neglected in the use of current search engines as they display the results in a list without the full path of the folder hierarchy.

The orienteering strategy is not only used in the folder hierarchy but also in email hierarchies and bookmark hierarchies [11]. Other research by Henderson [35] inspected the relation between the used organisational strategy (i.e. files and piles) and the use of a re-finding strategy. In both organisational strategies, orienteering is the most significantly used re-finding strategy. Even in piles where one would intuitively think that a search engine would provide some advantages, this is not the case. Often the content in the email inbox is already ordered chronologically which is enough to re-find a related email conversation from where the user can navigate to the needed email. This brings us to the additional time cue which is used to re-find information. People remember events which happened at a certain time interval in their life. Even if the exact event of the needed information item is not known, a related event in the same time interval may be a trigger to re-find the exact event [42]. Out of the above outlining, cues used for information retrieving can be defined such as the context cue, spatial cue and time cue. Referring back to the human memory, it is a natural behaviour to use these cues. The episodic memory supports the storage of contextual and spatial information about an event which took place at a specific time at encoding time. This event is linked on its turn to previously encoded events. In this case, the user can indeed access information about an event even if the event itself is not remembered.

2.4.2 Fragmentation is Everywhere

A major issue concerning re-finding is the *fragmentation problem* which can be approached through several perspectives. A straightforward perspective is the fragmentation of information across different devices. In the current digital era, one may have different devices supporting different functionality which are desired for different tasks, resulting in the fragmentation problem illustrated earlier in Figure 1.2. Another approach to the fragmentation problem is the project fragmentation described by Bergman [7]. The main finding is the undesired interruption of switching between formats such as the folder hierarchy, emails and websites which are stored in the bookmarks hierarchy. The extra cognitive effort that a user needs to do to switch between these hierarchies and integrate them in another final format is a burden. Besides the cognitive overload of switching between formats, the re-find activity of information also implies an additional cognitive overload. Re-finding information is mostly based on recognition using the orienteering strategy. This behaviour cannot be applied on the identification of which device or tool contains the information item. The user needs to fall back on the recall function of the memory to identify the location. Because recalling imposes more cognitive effort, the fragmentation problem can be a burden in re-finding information.

2.5 Summary

The human memory storage structure is composed of the interdependent memories namely the episodic and semantic memory. The former may be seen as a timeline where every slot stores contextual information of the event, in contrast to the latter where semantic associations are made between concepts of the real world. The interplay between those two memories are not neglectable because the episodic memory changes when retrieving information from the semantic memory and the semantic memory adapt the thresholds of the associations depending on the information in the slots of the episodic memory. Current organisational strategies such as filing and piling are fundamentally different from the human memory storage structure and therefore impose cognitive overload at the time of re-finding. Two major problems may be highlighted as the cause of this cognitive overload. The classification problem which stands for the cognitive overload of the obligation that people need to label and categorise each stored information item. Additionally, the fragmentation problem gives even more cognitive overload due to the fact that users need to know where which information is stored (e.g. on which device). Because of these issues, users tend to organise their personal information in a badly way. They mostly use three cues to re-find their information, namely time, spatial and contextual cues. These are natural human behaviours because the episodic memory provides this extra information in addition to the semantic memory. Therefore, a search engine is not often used in the digital space. An underlying factor for these findings are the fact that people have an easier time to recognise than to recall which is needed for the interaction with a search engine.

There are so many ways to go wrong. All we've got are metaphors, and they're never exactly right. You can never just Say. The. Thing.

Jennifer Egan

3 User Behaviour in the Desktop Metaphor

In the previous chapter we introduced the current user organisational behaviour in a cross-media environment. The current work identified two organisation strategies (i.e. piling and filing) which are used in the physical as well as the digital information space. Each of these strategies have their own issues and users apply different cues to re-find information when a strategy is used. By the everyday aspect of the research matter, we could easily apply the state of the art findings in our own workplace. This resulted in the determination of another used organisational strategy namely *mixing*. Therefore, our interest directed to perform a user study. The study gave proof for the mixing organisational strategy and induced several other insights in the contemporary user information behaviour in cross-media information spaces. These obtained results led to the specification of design principles for future PIM system development.

3.1 Context of the User Study

In the seventies, the personal computer was born. Researchers at Xerox Parc introduced the file system and the desktop window we are all familiar with. Their inspiration came from the physical space where users have file cabinets and desks. The phenomena of copying interfaces and interactions from the physical space in the digital space is as well observed in other digital concepts (i.e. paper as files). Maybe it is just the easiest way to handle the unknown or new experiences of the digital space which has almost unlimited design possibilities. But it also has consequences since we take over the limitations and issues existing in the physical space to the digital space. Nonetheless, it is impossible to turn the clock back in time. Equally, we may not change the user's current organisational and re-find behaviour in one day. Of course, it is very hard to change the user's behaviour applied in a physical environment but even in the digital opponent it could be a challenge in short-term. An alternative to this changing behaviour challenge is to augment the information spaces. In such a way, systems may provide solutions to help the user better organising and re-finding personal information.

The previous chapter already gave an outline of observed issues concerning the piling and filing of information in digital and physical environments. Nevertheless, research is constrained by the isolated study of piling and filing in one of the two spaces. It may be that these spaces have coherency or dependencies to each other. In cross-media information spaces, we specially look across these boundaries between both spaces. A second concern with current research is the ignorance of mixing. Besides the piling and filing strategies, mixing is present in most of our offices. These two concerns form the starting point of our formulated hypotheses.

3.2 Methodology

The user study may be characterised as exploratory qualitative research. This research choice is made since our main goal is to evaluate how and why people organise personal information across digital and physical environments. An empirical-analytic case study is established by the described research design. The full case study protocol is attached in Appendix A and more information about our used methodology may be found in [86].

Design

The research design is an embedded multi-case case study. Figure 3.1 illustrates the overall design. Our study's context is given by narrowing to descriptive research in Personal Information Management. This means that the study is placed in context of the encountered organising and re-finding issues which users experience on a daily basis. Due to the interest in the organisation and re-finding behaviour of personal information in the digital as well as the physical space, these spaces are selected as individual cases. Case one studies the user's behaviour in physical space whereas case two studies this behaviour in the digital space. Since the comparative nature of the research question, a cross-case analysis is performed to identify any coherency and dependencies of user behaviour in organising and re-finding information applied in both spaces. First, the individual cases are independently investigated where for each case hypotheses are formulated based on the literature elaborated in the previous chapter. Secondly, these individual case findings are used in a cross-case analysis with the purpose to search for differences and relationships of user behaviour between the digital and the physical information space. Furthermore, the units of analysis within each case are defined to the identification of organisational strategies, the access frequency of used organisational strategies and the ease of re-finding information in these organisational strategies.

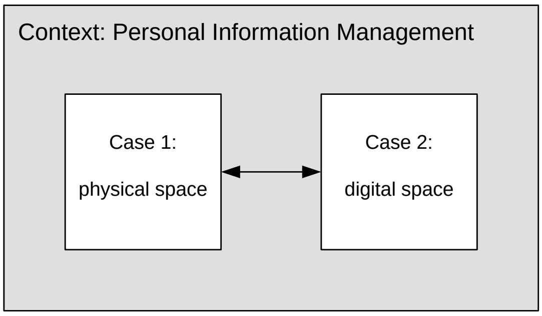


Figure 3.1: The case study design

Validity is given by several design decisions. The use of contradictory logic in multi-case design enhances the external validation of the work. By analysing both information spaces and their coherency, analytic generalisation may be extended to the level of cross-media information spaces. Note that previous research was limited to individual analysis of these spaces which makes the contribution of this study of great informative value. Internal validation is provided by hypotheses formulating and the use of explanation building in the data analysis stage. Additionally, the carried out pilot study contributes to the internal validity. Finally, the practise of a case study protocol and use of centralised data collection increase the reliability.

Research Instruments

To enquire how people organise and re-find personal information, an online survey has been established. This survey includes questions related to the three units of analysis. The organisational strategies (i.e. piling, mixing and filing) where decomposed in several sub-factors such as the use of semi-ordered folders as a factor of mixing. Access frequencies of the organisational strategies where investigated by questions such as how often users accessed piles on a desk. The ease of re-finding is determined by questions such as how easy the user experience the re-finding in the digital file system. A full mapping of the survey questions to the hypotheses of the units of analysis is given in the case study protocol. In addition, some open-ended questions where of an exploratory nature. They concern the investigation of tools to easier re-find information in a file system. To enhance the internal validity, a pilot study was executed with a representative group of nine respondents. Comments where given whereas completion time was measured. The case study protocol includes an elaboration on the pilot study.

After data collection, we have used various non-parametric statistical tests on the survey data. Due to the qualitative nature of the study, all parametrised and normalised statistical tests where not in order. Most survey questions are on ordinal data level (e.g. 5 point Likert scale) and a normal distribution may not be guaranteed. Therefore, the parametrised test conditions are not met and non-parametrised tests are used to analyse correlations and differences in both cases as well as across both cases. To identify correlations between factors, a Spearman's rho (ρ) is used. Instead of applying the correlation analysis on the data itself, a Spearman's rho correlation coefficient is calculated on the ranks of the ordinal data. By the use of these ranks, the data do not need to have a normal distribution [71]. All correlations included in the results discussion are significant (p-value) at a minimal level of 0.05 ($p < 0.05$). Secondly, to identify a significant difference between factors, the Wilcoxon Signed Rank Test (z-value) has been used. This test compares two related samples and identifies if the mean is moved to the positive or negative side of the initial ordinal data distribution [85]. Again a significance level of 0.05 ($p < 0.05$) is defined on the results. Besides these used non-parametrised statistical tests, frequencies and open-ended questions are interpreted by the use of Toulmin argumentation where each statement needs to be argued with facts and references to scientific related work [74].

Participants

A case study must be conducted on a representative group of the global context subjects. Since Personal Information Management is a concern of all participants in the society, the community has agreed on population representativeness by limiting the context of enquiry to knowledge workers. Knowledge workers are seen as a population which uses a large amount of personal information. If the results are significant for this population than they are also significant for less extensive information users. Therefore, we have enquired 170 knowledge workers including professors, postdoctoral researchers, PhD students as well as graduate and undergraduate university students. Figure 3.2 shows the distribution of the respondents. This distribution is a representative population based on the yearly numbers (i.e. academic year 2012-2013) from the Vrije Universiteit Brussel[1].

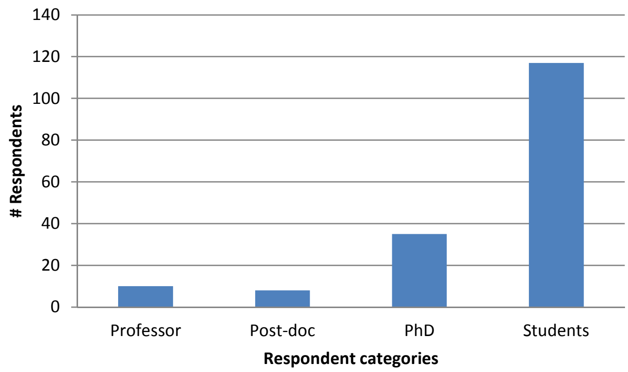


Figure 3.2: Distribution of respondents

3.3 Hypotheses and Results

Because of the extensiveness of this study, only a generalisation of the hypotheses and their results are explicitly given in this report. Nevertheless, the complete hypotheses and can be found in the case study protocol. In this generalisation, the three units of analysis are discussed with the results of the cross-case investigation.

Organisational Strategies

The first unit of analysis in both cases is concerned with organisational strategies. Malone identified two organisational strategies in knowledge workers' offices [51]. The filing of information items appears when people label every item and order them according to an explicit order (i.e. alphabetically or chronologically). In contrast to filing, the piling of information items cannot contain explicit ordered content and the whole pile may not be labelled. These two organisational strategies where also observed in the digital

[1] `http://www.vub.ac.be/home/feiten.html` Last accessed on 03-08-2013

space [83, 10]. Nevertheless, research in PIM ignored the research context limitations of Malone's research. Malone mentions the following about the completeness of the definitions of piling and filing which where introduced in Chapter 2 of this thesis.

> *"The dimensions of Table I can also be used to analyse other types of groupings. For example, a folder in a file drawer may be a group of elements (e.g. paper) that are not ordered, but the group itself (the folder) is explicitly titled. Thus the folder is neither a file nor a pile by these definitions. "*
>
> Malone, 1983 [51]

As mentioned earlier, the classification problem has the effect that users do not always file information items which leads to the creation of piles. However, piling is not well-suited for information retrieval after a longer time period and can become cognitively loaded when the amount of piled information items are increasing. It is of interest to investigate a third strategy which is neither filing nor piling since these introduced issues of both strategies in digital and physical environments. Therefore, we define the third organisational strategy as *mixing* by using Malone's dimensions of titled and ordered elements or groups.

Definition 1 *Mixing is an organisational strategy which is neither filing nor piling. Mixtures may contain titled as well as untitled elements and the elements may be explicitly ordered. A group may be titled and groups may also be explicitly ordered whereas the titling and ordering of elements does not need to be consistent. The dimension values for piling or filing cannot be true in the observed elements constructing a mixtures.*

An example of mixing is the use of a labelled ring binder which contains semi-ordered publications. In this case, the publications are not explicitly titled as elements but the group (i.e. ring binder) is titled. Also the content is semi-ordered which means that some division is made where some partitions may be explicitly ordered whereas another partitions might be unordered. In the digital space, we may encounter the mixing organisational strategy in the use of a labelled folders in the file system where the files of a folder are not given a title by the user and there is no explicit order. One might think of a folder with pictures imported from a camera. Often the pictures have a title created by the camera software and they are randomly placed in the user's labelled folder.

Hypothesis 1 *There exists the organisational strategy of mixing as a third organisational strategy besides piling and filing.*

The first hypothesis in the organisational strategies unit of analysis is the fact that we do use a mixing strategy besides the use of piles and files. People indeed use a mixing organisational strategy next to piling and filing. The three factors were investigated in both cases (i.e. digital and physical space) and the average degree of use is aggregated for each organisational strategy to be able to make statements on the cross-media information space level. In this way, we have now a better understanding on the general degree of use of organisational strategies. Figure 3.3 illustrates the usage of filing, mixing and piling from 'never' to 'a high degree' in use.

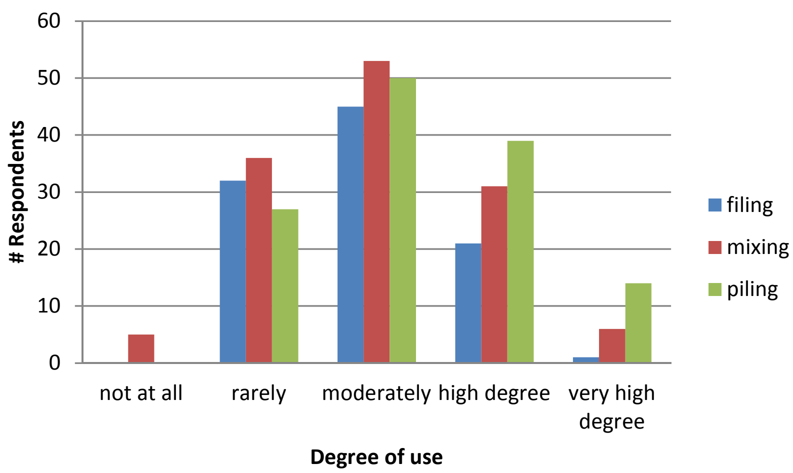


Figure 3.3: General degree of use for the three organisational strategies

For filing and piling, the diagramme reflects the statements made by current research. Due to the classification problem, users will conduct less filing than piling. Furthermore, the normal curve is slightly skewed to the left which means that the overall use of filing does not appear very frequently. Most participants use filing on a rarely to moderate basis. Compared to mixing and piling a significant amount of users even do not use filing at all. This is in contrast to piling where all of the 170 respondents had at least some digital piles, piles on a desk or piles in a bookcase. Additionally, the normal curve is directed to the right-hand side which indicates the higher level of use of piling. A majority of the respondents pile information from a moderate level to a high degree. Although, piles impose re-finding issues when a large amount of information is encountered, they are the main used strategy in the organisation of personal information. Besides the piling and filing, the results show a normal distributed degree of use concerning mixing. Some people do not use the mixing strategy at all whereas some people use it to a very high degree. Frequently, mixing is used from rarely to a high degree but a moderated degree is observed the most. This finding indicates that it is worthwhile to have a better understanding of mixing in the future as it is a heavily-used organisational strategy besides filing and piling.

A second concern we have made in current research is the categorisation of people as pilers or filers [51, 80, 4, 35]. Malone was the first researcher to identify the organisational strategies of piling and filing [51]. Besides of his formal definitions of these two strategies, he observed that users may use more piles than files and vica versa. This observation made him state that people do have neat or messy offices (i.e. filers respectively pilers). After 18 years of classifying people in pilers or filers, Whittaker has observed that people may apply both strategies at the same time [80]. A reason for this long time interval of such an observation may be based on the fact that often qualitative research such as observations are done on extreme cases or with a small number of respondents and therefore miss the observation of average user behaviour. Although Whittaker has observed this coherent use of strategies, they still classified people as pilers and filers. Therefore, they defined a threshold of 40% to distinguish pilers from filers. All respondents who had more than 40% piles on their desk were classified as pilers whereas all the rest were classified as filers. We need to underline that this is quite a shortcut in the research design. To actually be able to classify users in pilers or filers, there needs to be a negative correlation between the degree of use. This leads to our second hypothesis including the mixing organisational strategy.

Hypothesis 2 *All three organisational strategies have a negative correlation.*

The user study provides evidence to reject this hypothesis. In both cases (i.e. digital and physical space), no negative or positive correlations were found between any of the three organisational strategies. This means that people do apply all three strategies independently from each other. For example, users may have a lot of files, mixtures and piles at the same time. Therefore, we may not classify users as pilers, filers or mixing people. These findings have significant consequences for the state of the art research. Since researchers used the classification of pilers and filers, they might have made wrong interpretations of the observed phenomena. For example, the work of Henderson is based on pilers and filers [35]. They used a survey to determine preferences of interactions with the digital file system. Questions were asked concerning a list view versus a tile view or the depth of created folders. The results were analysed with a K-means clustering test to cluster pilers and filers. Respondents are classified in a cluster depending on the answers of six survey questions. One of them is a question on how well the respondent thinks they are organised. If a low score is given, the respondent is seen as a piler otherwise as a filer. Due to our statement that both strategies may occur at the same time and are independent from each other, the question on how well they are organised, is not representative any more to identify pilers. A respondent may think they have a badly organisation because they use extensively the pile strategy but at the same time they also can use an extensive filing strategy. In this case, the K-means clustering analysis would classify the respondent as a piler but in practise their behaviour is extensive piling as well as filing and therefore the internal validity of the study becomes significantly low.

A third hypothesis in organisational strategies is directed to the cross-media aspect of our case study. Previous research recognises the use of piling and filing in physical as well as digital spaces [83, 10]. Nonetheless, there is a lack of research on the coherency and dependency between the three used organisational strategies in both information spaces. Each space offers its own affordance to each organisational strategy. For example, filing might be applied more frequently in digital space due to the spatial restrictions in physical space such as the limited amount of papers a user may place in a file cabinet. On the other hand, piles may be easier to use in the physical space due to the affordance of paper such as easily grouping papers together and modifying the group. Hypothesis three investigates this differences in use of the three strategies in both information spaces.

Hypothesis 3 *There is a significant difference in the degree of use of the strategies in digital and physical information spaces.*

A cross-case analysis is done between the two cases (i.e. digital and physical space). No significant differences which would indicate a different degree of use of each organisational strategy in one of the cases (filing ($z = -0.659,\ \rho = 0.510$), mixing ($z = -1.616,\ \rho = 0.106$), piling ($z = -0.920,\ \rho = 0.357$)) were found. Surprisingly, people do not have significantly less piles, mixtures or files in the digital than in the physical space and vice versa. Figure 3.4 gives the distribution of the degree of use of the three organisational strategies in both spaces.

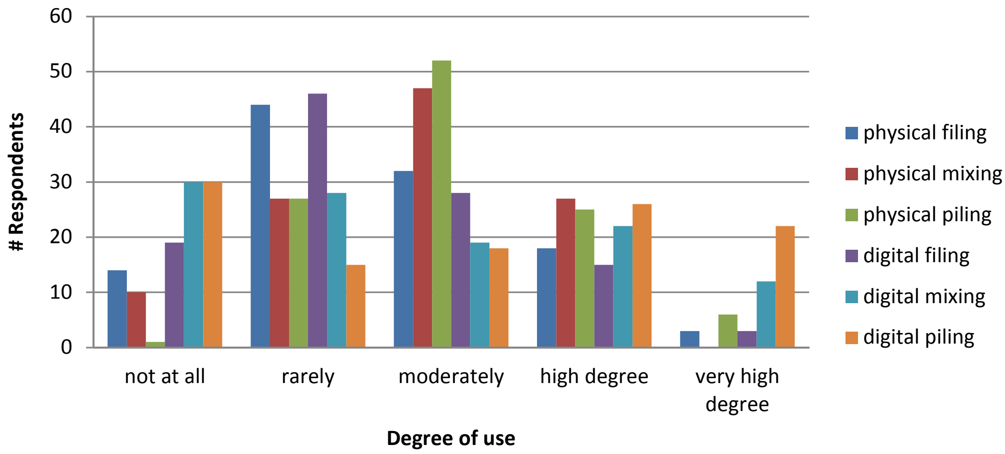


Figure 3.4: Degree of use of the three organisational strategies in the digital and physical space

Although the appropriated Wilcoxon Signed Rank Test does not give any significant difference between the digital and physical space, the diagramme shown in Figure 3.4 indicates some differences to be taken into account. While almost all respondents (110) had some degree of physical piles, 30 respondents did not use digital piles at all. Also physical piling has a more moderate use (52 respondents) whereas the degree of use of digital piles is in average equally spread. The same can be observed for the mixing organisational strategy. The semantic interpretation and explanation building are still more valid than a statistical test in qualitative research and therefore we may state that there are some differences between the two spaces concerning piling and mixing. An additional finding is the use of piles on different artefacts. Digital piles are mostly used on the desktop whereas physical piles may be on a desk or in shelves. Figure 3.5 actually reveals that users construct piles on desks and shelves to a same degree and no significant differences were found. Furthermore, a significant positive correlation is found between the use of piles on a desk and in shelves ($p = 0.431,\ \rho = 0.000$). This means that the more users have piles on their desk the more they have piles in shelves. Besides this findings, we can also indicate that users have at least some piles on the desk or in shelves. As shown in Figure 3.5, only one respondent has no piles at all whereas 15 respondents had no piles on their desk and 24 respondents had no piles in shelves. This illustrates that the users who had no piles on their desks had at least some piles in a shelve and vice versa. Implications of these findings to PIM system design are given in Section 3.4.

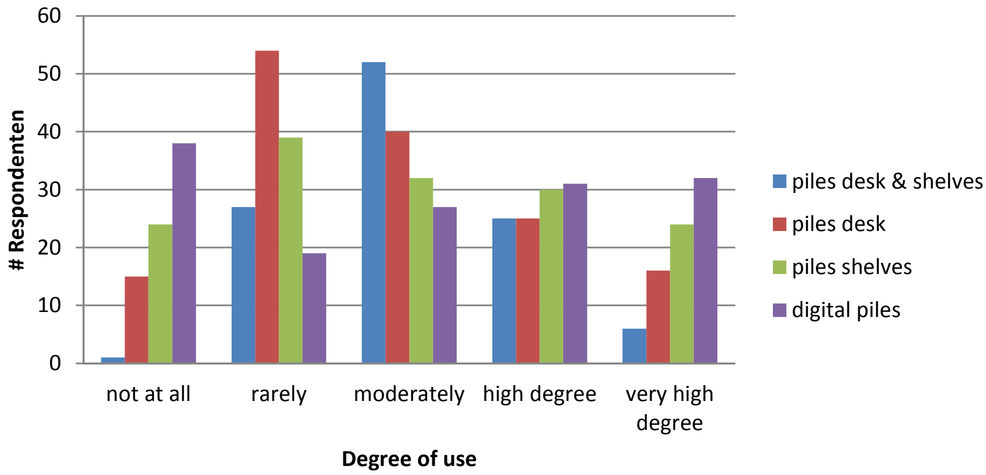


Figure 3.5: Degree of use of the pile strategy in the digital and physical space

Access Frequencies of Used Strategies

In this unit of analysis, the access frequency of organisational strategies is investigated. Previous work identified hot, warm and cold information depending on how often an information item is accessed [65]. For cold information which is not often accessed and mostly filed away, paper has a disadvantage in a sense that it occupies some space in the physical environment. Piles are often used for warm and hot information. The affordance of paper like reminding and grouping of papers gives additional advantages to the pile strategy for warm and hot information. Therefore, the first two hypothesis in this section (i.e. Hypothesis 4 and Hypothesis 5) are the following.

Hypothesis 4 *Piles are more frequently accessed than files.*

Hypothesis 5 *There is no access frequency difference of the three organisational strategies between digital and physical spaces.*

Our results support the literature findings and so these hypothesis are not rejected. In both cases (i.e. digital and physical space), piles are significantly more accessed than files. Digital piles are more frequently accessed than the digital file system ($z = -3.889$, $\rho = 0.000$). This implies that digital piles are well-suited for warm or hot information where the same holds for the physical space ($z = -3.515,\ \rho = 0.000$). Nonetheless, the physical space indicates an additional observation. As elaborated above, users may have a significant amount of piles in shelves besides piles on their desk. The access frequency of piles on a desk is significant higher than the access frequency of piles in shelves ($z = -5.558,\ \rho = 0.000$). Even more valuable is the fact that the access frequency of piles in a shelve is not significantly different from the access frequency of a physical file system ($z = -1.847,\ \rho = 0.063$). This indicates that there is a difference in the purposes of usage of piles on desks and piles in shelves. Whereas piles on a desk are well-suited for hot and warm information, the piles in shelves contain colder information. This statement is of value for further investigation. Since we know now that piles in shelves contain cold information, we may investigate if this is a compensating strategy for the classification problem. Until now research claimed that the pile strategy is introduced because of the classification problem. Nevertheless, their interpretation of piles was directed to piles on desks. Future research may go deeper in this subject matter by investigating if the classification problem has indeed a causal relationship to piles in shelves, which would make sense because they contain cold information. But it is also worthwhile to see whether piles on a desk are indeed caused by the classification problem whereas other relevant causal relationships may be found. It is likely that other causal relationships would be observed since our user study indicates that piles on a desk only contain warm and hot information. For example, when working on a task it could just be more convenient to place the needed artefacts on the desk instead of accessing a file system every time one needs an information item. A last observation is the difference in access frequency of the strategies between both information spaces. Digital piles are not significantly more accessed than physical desk piles ($z = -1.749,\ \rho = 0.080$). This is in contrast to the access frequencies of filing. A physical filing system is less accessed than the digital opponent ($z = -6.455,\ \rho = 0.000$). Nevertheless, it does not indicate that the digital file system is mostly use for hot and warm information. There is still a significant difference between the access frequencies of physical or digital piles and the digital file system ($z = -4.062,\ \rho = 0.000$ respectively $z = -3.889,\ \rho = 0.000$). Future research may clarify these findings by investigating if users have more cold content in their digital file system than in a physical file system. We may reason that if one has more content it is more likely that they would access the file system more frequently although it contains cold information.

Ease of Re-finding

The last unit of analysis investigates how easy users may re-find personal information by the use of previously described organisational strategies. Users need to organise their information to be able to retrieve it later on. Several researchers identified that the use of a classification system enhances the re-finding effectiveness [41]. Accordingly to the state of the art, filing improves the re-finding process because the information is more structured in contrast to piling. On the other hand, piles provide more contextual information and spatial cues to re-find information. Therefore, Hypothesis 6 states that it is easier to re-find in a file system than in piles. Since we introduced the mixing organisational strategy in our work, Hypothesis 7 includes mixing. In mixtures it is more difficult to re-find information than in piles or files because of its complexity and allowed inconsistency. For example, in a pile users may know if an item is on top of the pile or in the middle by the implicit chronological order. In a file system, the user has often an overall knowledge of the file hierarchy's schema. However, in mixtures no consistency is allowed which means that a labelled ring binder may contain a sub-group of totally chaotic paper arrangements and a sub-group with alphabetically ordered papers. Thereby, users may have a lack of extra information to help them re-finding the information item. At last, Hypothesis 8 claims the easier re-finding in a digital file system than in a physical file system. This finds its basis in the fact that the digital space has the affordance of creating easily long labels for files and folders, easily constructing broad and deep hierarchies and allows the user to easily navigate through the files [12]. This affordance of the digital space provides the user with the ability to squeeze more contextual information about the information item into the file system. Because of this extra contextual information, re-finding will be easier [40].

Hypothesis 6 *It is easier to re-find personal information in files than in piles.*

Hypothesis 7 *It is more difficult to re-find information in mixtures than in piles and files.*

Hypothesis 8 *Re-finding in digital file system is easier than in the physical file system.*

The obtained results support Hypothesis 6 and Hypothesis 7 as well as Hypothesis 8. A Friedman test shows a significant difference ($\chi^2 = 151.814, \rho = 0.000$) between the ease of re-finding in digital file systems, physical file systems, mixtures and piles. Figure 3.6 provides the distribution of these findings for each of the organisational strategies. We may observe that filing indeed induces easier retrieval of information than piles. The normal curve skewness is directed to the left-hand side for digital as well as physical file systems. This is in contrast to piling where the normal curve gives a more standard distribution. Secondly, the distribution of mixing shows a strong normal curve skewness to the right-hand side. This means that users have a difficult time to re-find information when they apply the mixing organisational strategy. 27 respondents answered that they found it moderately easy whereas 47 respondents experience a hard time to re-find personal information in mixing. Finally, in the digital file system it is easier to re-find information than in its physical opponent. Most respondents find it very easy to easy (i.e. 37 respectively 39 respondents) to re-find information in the digital file system. A difference is observed with the physical file system where most respondents find it easy to moderately easy (i.e. 44 respectively 26 respondents) to re-find personal information.

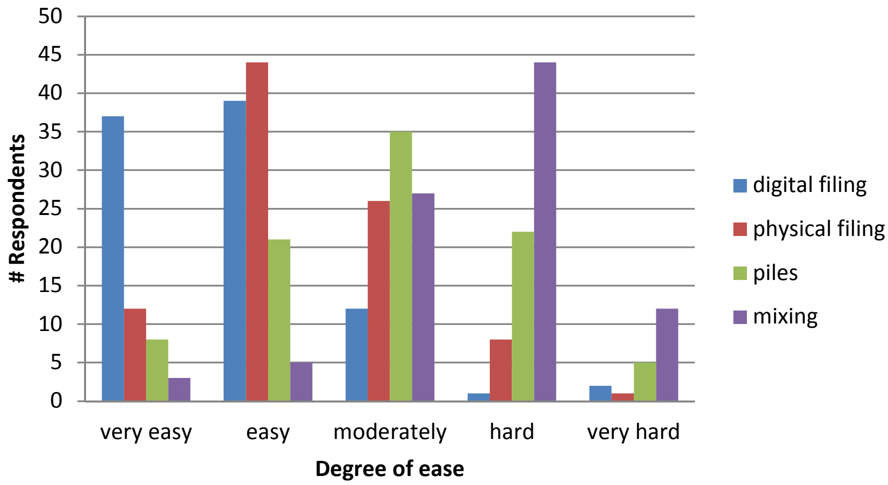


Figure 3.6: The ease of re-finding by use of organisational strategies in the digital and physical space

3.4 Design Principles

In addition to the hypotheses processing, the multi-case study design allows us to expand the enquiry. This would not have been possible if we would have done empirical quantitative research. In the context of this Master thesis in Applied Computer Science, it was a straightforward decision to translate the additional results of the user case study to design principles for future PIM system development. Nevertheless, in such a translation the internal and external validity of the results need to be kept. Therefore, all results included in the following design principles are also included in the case study protocol. The design principles are formulated out of the viewpoint that current organisational and re-finding behaviour may not be changed in one day. It is hard to change a user's behaviour applied in the physical environment but even in the digital space it could be a challenge in short-term. Several researchers have tried to change the desktop metaphor in digital spaces with no success for the common end-user [64]. There is a lack of research on the support for physical organisational behaviour. All provided prototypes are focused on improving and changing the digital organisational behaviour of users. Previously in our own and among others Sellen's [65] work, findings have shown that a user's information space includes physical artefacts for a large part. Prior to this section, results have indicated that almost all respondents use physical piles, most respondents use physical file systems on a moderated basis and a majority have mixtures in the physical space as shown in Figure 3.4. By providing design principles based on the current user behaviour in organising and re-finding personal information in both spaces, we may improve the design of PIM systems augmenting this current behaviour. Until we have found a way to completely release the user from organising and re-finding information, the synergy with the current behaviour needs to be included in PIM systems.

Principle 1 *A PIM system needs to support all three organisational strategies in both information spaces.*

The three organisational behaviours observed in the digital as well as the physical space are independent of each other. Additionally, they are also independent across both information spaces. This implies that we cannot classify people in terms of the most frequently used organisational strategy such as pilers or filers. Proof is given by the rejection of Hypothesis 1, Hypothesis 2 and Hypothesis 3 in this case study. In the context of system design, these findings have consequences on the interaction level. A PIM system therefore needs to support all three organisational strategies in both information spaces. Since the purpose of a PIM system is the overall organisation of *all* personal information, it may not lack the possibility of one organisational strategy in one of the two spaces. Furthermore, customisation is needed for all strategies. By the user specific degree of use of an organisational strategy, a PIM system may provide greater support to the more emphasised strategies. Note that a user behaviour is a combination of the degree of use of all three strategies in both spaces which means it is defined by six dimensions of use. For example, the degree of use is measured on a 5 point Likert scale and thereby a user may have the following profile:

	Not at all	Rarely	Moderated	High	Very high
Digital piling	✓				
Digital mixing			✓		
Digital filing				✓	
Physical piling					✓
Physical mixing				✓	
Physical filing			✓		

Table 3.1: Example of a defined user organisational behaviour in a cross-media information space

Ideally, a PIM system may now provide an adaptive augmentation of the physical space and personalised digital user interfaces supporting the six organisational strategies on the applied level of the user. In the simplest form, each organisational strategy may have its own user interface but this user interface needs to be adaptable to the degree a user applies or uses the strategy. For example, a PIM system has a digital file system user interface. When a user has a high degree of usage in digital filing, the user interface may provide a tooltip which displays the most accessed folders or files when hoovering a digital folder. On the other hand, the tooltip could be seen as overhead for a user who is rarely using the digital file system. For this user it may be more suited to provide a user interface with less functionality or predefined folders. In addition, the PIM system needs to provide augmentation for the physical pile strategy. The above user profile indicates a very high degree of physical pile use. Therefore, the piles may be augmented with a projection which displays extra contextual information of the pile. On the other hand, if a user uses physical piles of a moderate level, some less invasive technologies may be used such as a sound which indicates in which pile a document is. The example further illustrates the practical relevance of our user study findings.

Principle 2 *Physical piles:*

- *Contextual hints need to be provided.*
- *Spatial hints need to be provided.*
- *Context retrieval may be done from the extensive use of post-its notes and spatial arrangements of piles.*
- *Extra re-finding support is needed in digital and physical file systems.*
- *There is a major difference between piles on desks and piles in shelves.*
- *Unlabelled folders are the mainly used piling artefact.*
- *The augmentation of bookcases is less important.*

Some of the most important design principles are the ones for physical piles. The results of our hypotheses show that almost all users have physical piles and they have on average a hard time to re-find information in physical piles. First, a system needs to provide a way that users may use contextual hints in the retrieval process. Besides the reasons to use piles described in Chapter 2, people use piles to preserve the context of the information items [50]. At the same time, they use this extra contextual information when retrieving an item. Several researcher agree that the context cue is one of the main advantages of the human memory for recall [51, 50, 47, 12]. Furthermore, evidence is found for increased use of contextual information when more physical piles are used ($p = 0.272,\ \rho = 0.009$). Since users keep contextual information in the piling strategy, a system may retrieve this contextual information from the piles. More specifically, a positive correlation is found between piling and the use of post-it notes for keeping contextual information ($p = 0.206,\ \rho = 0.032$). Next to the context retrieval from post-it notes, the spatial arrangement of piles may also be of value ($p = 0.221$, $\rho = 0.039$) [39]. This arrangement often reflects categorical information of a pile. For example, papers on a specific topic may be placed in one pile while the pile next to it contains papers on a strongly related topic. Secondly, the more piles a user has, the harder is the re-finding in a digital and physical file system ($p = 0.229,\ \rho = 0.31$ respectively $p = 0.262,\ \rho = 0.013$). A reason may be that users with a significant amount of piles are so used to use contextual hints when re-finding. As mentioned previously, digital as well as physical file systems do not extensively preserve the contextual information of a classified item which then also cannot be used in the retrieval process. It could be worthwhile for future research to investigate this hypothetical causality. Finally, we have to be careful when augmenting physical piles. Piles on desks may have different purposes than piles in shelves. Desk piles mainly contain hot and warm information whereas piles in shelves contain cold information and are therefore less frequently accessed. An elaboration on the differences between these two variants has already been given when processing the hypothesis. Furthermore, in the perspective of an augmented pile strategy, it should be noted that the more piles a users has, the more they have unlabelled folders ($p = 0.310,\ \rho = 0.000$). This indicates that piles are mainly used in combination with these unlabelled folders since no other correlations or coherencies are found with other organisational strategies. Furthermore, the more piling in general the easier users re-find information items in bookcases ($p = 0.315,\ \rho = 0.003$). We are not able to give a causal relationship for this fact but may state that the augmentation of bookcases is not a priority in an augmented physical pile interface.

Principle 3 *Digital piles:*

- *Contextual hints need to be provided.*
- *The labels of the included information items are important for re-finding.*
- *Annotations are a well-used artefact for re-finding and reminding.*
- *Users annotate more digital content more frequently with physical annotations besides digital annotation.*
- *User access more frequently the digital file system.*

Also for digital piles contextual hints are the main retrieval cues. The same reasoning as for physical piles may hold whereas the provision and use of the contextual information is quite different in digital piling. An important difference with physical piles is that elements of digital piles are often labelled. Nevertheless, while this labelling is allowed by the definition of a pile in Malone's work, the whole pile may not be labelled [51]. To preserve the contextual information, these labels are becoming longer with the increased use of digital piles whereas the meaning of the label is more extensively used ($p = 0.457,\ \rho = 0.000$ respectively $p = 0.309,\ \rho = 0.002$). Besides the use of longer labels, annotations of digital content are an important contextual provider for context-awareness functionality in a PIM system. Users increasingly use digital and physical annotations to annotate the included information items if the use of digital piles raise ($p = 0.236,\ \rho = 0.018$ respectively $p = 0.366,\ \rho = 0.000$). On the other hand, they use these annotations to re-find and as a reminder ($p = 0.427,\ \rho = 0.000$ respectively $p = 0.254,\ \rho = 0.012$). Furthermore, annotations are more actively used when the digital pile usage increases ($p = 0.457,\ \rho = 0.000$). This phenomena of annotating digital content, reflects the need to preserve contextual information. Future research could focus on how to release the user from this annotation process. For example, we could implement a digital pile user interface which learns the user's needs of what kind of contextual information they want to keep from this annotation process. In a term, the application may totally or partly provide this contextual information without user interaction in the annotation process. The observation of the use of physical annotations to annotate digital content is a second opportunity for future research. Additionally, a negative correlation is found between the use of digital piles and the annotation of physical content for better understanding the content ($p = -0.214,\ \rho = 0.034$). Research may investigate this finding in more depth but we hypothesise that users may use digital piles for hot and warm information instead of their opponent in the physical space where piles in bookshelves are used for cold information. This interplay between digital content and physical annotations shows the importance of research on cross-media information spaces. Finally, the digital file system is accessed more frequently by digital pile users ($p = 0.231,\ \rho = 0.021$). Therefore, a system may for example provide shortcuts to the digital file system in order to let users work more efficiently.

Principle 4 *Physical mixing:*

- *Time hints need to be provided.*
- *Annotations are used for re-finding purposes.*
- *Easy re-finding in physical file system.*

In contrast to piling, contextual cues are less used to re-find information within mixtures. The mixing strategy implies a time cue for information retrieval. Users first annotate information items with timestamps ($p = 0.265,\ \rho = 0.005$). At the time of re-finding the item, they extensively use these timestamps ($p = 0.271$, $\rho = 0.008$). Besides the timestamps, users look up extra information about the needed information item in their physical agenda ($p = 0.240,\ \rho = 0.019$). Next to the time cue, a positive correlation is observed with the use of physical annotations which are used to re-find content in the mixtures ($p = 0.202,\ \rho = 0.049$). Furthermore, users found it easier to re-find information in the physical classification system when the mixtures increases ($p = 0.258,\ \rho = 0.015$). We may observe that there is no coherency with the digital space whereas this was the case in the piling strategy. PIM systems may augment information items included in mixtures with, for example, time-based search functionality. Since we just defined this mixing organisational strategy in our case study, further research needs to be done to give causal relationships and how/why users apply this time related activities in organising and re-finding information.

Principle 5 *Digital mixing:*

- *Contextual hints need to be provided.*
- *Time hints need to be provided.*
- *Users create and use timestamps to re-find personal information.*

In contrast to the physical mixing, re-finding information in the digital mixing is done by a combination of contextual hints and time hints. Users annotate digital content with reminders ($p = 0.256,\ \rho = 0.047$). Next to this contextual information, they provide the digital content with timestamps and also use these in re-finding information items in digital mixing ($p = 0.234$, $\rho = 0.021$ respectively $p = 0.202,\ \rho = 0.047$). Again more research needs to be conducted to clarify these observations.

Principle 6 *Physical filing:*

- *Contextual hints need to be provided.*

- *Time hints need to be provided.*
- *Spacial hints need to be provided.*
- *Intensive use of annotations on physical artefacts such as paper, books, notes and so on.*
- *Use of labelled classification artefacts (e.g. ring binders, folders, shelves).*
- *Preservation of contextual information by using long file labels and annotations with reminders.*
- *The augmentation of bookcases is necessary.*

Previous research already defined the importance of contextual information to re-find information items when using a filing strategy. Users squeeze this extra information in labels and use the structure of the file system in such a way that it reflects the overall context of use [51, 48]. For example, different structures (e.g. one for student records and one for research publications) may be used in a file cabinet which need to preserve contextual information is one of the issues described in the classification problem. At the time of classification, users experience a cognitive overload and need to spend extra time which is not preferable by the end user [20]. In addition to these findings, we were able to identify more specific ways on how users keep contextual information in physical file systems. Besides the use of contextual information in the labels ($p = 0.345,\ \rho = 0.001$), users extensively annotate physical documents with reminders ($p0 = 0.257,\ \rho = 0.011$). Furthermore, an intensive use of annotations in papers ($p = 0.212,\ \rho = 0.038$), books ($p = 0.208,\ \rho = 0.040$) and the use of post-it notes ($p = 0.295,\ \rho = 0.004$) is observed to keep contextual information. A PIM system may therefore use these annotations to provide contextual hints in the retrieval process. A second finding is the use of timestamps in re-finding information items ($p = 0.337,\ \rho = 0.001$). For example, a user starts their search in the file system by recalling when they had last classified the item. This time-related information provides the starting point for orienteering through the file system. Nevertheless, the more expanded a file system is, the less they use a physical agenda to recall the timestamps ($p = -0.307,\ \rho = 0.002$). For system design this could be applied by augmenting the file system with time-related information such as last accessed or modified date but also references to past and future used information items in the file system. Whereas for small physical file systems, the system may also include some interaction with a user's physical agenda. A last cue to support when augmenting a physical file system is the spatial cue. Spatial awareness as a cue in re-finding information in file systems is already introduced by other researchers [20]. Our results confirm these findings ($p = 0.224,\ \rho = 0.033$). The disquisition of this phenomena was already given in Chapter 2. Finally, file systems are constructed by the use of labelled ring binders ($p = 0.352,\ \rho = 0.000$), labelled folders ($p = 0.306,\ \rho = 0.000$) and labelled shelves ($p = 0.276,\ \rho = 0.002$) besides the classic file cabinets. It is important that a system which augments a physical file system is not restricted to the augmentation of file cabinets but also includes these other organisational artefacts. Next to the augmentation of the physical file system, bookcases need to be augmented with contextual information. With the use of physical file systems users experience more difficulties in re-finding information in chaotic bookcases ($p = -0.230,\ \rho = 0.029$).

		Context cue	Spatial cue	Time cue
Physical space	Piling	✓	✓	
	Mixing	✓		✓
	Filing	✓	✓	✓
Digital space	Piling	✓		
	Mixing	✓		✓
	Filing	✓		

Table 3.2: Overview of the used cues in organisational strategies for cross-media information spaces

Conclusion

The design principles give guidelines for future PIM system design in terms of augmenting the current user organisational behaviour in the digital as well as physical ingformation space. It is mandatory to provide in a PIM system support for all three strategies namely piling, mixing and filing in both information spaces due to their independency. Furthermore, each principle reflects the most important needs of users for a specific strategy. A PIM systems needs to provide contextual hints in the re-finding process for all three strategies in both information spaces whereas time hints are only needed in the augmentation of physical mixing and physical filing. In the augmentation of physical file systems, also a spatial hint needs to be integrated. Table 3.2 gives a short overview of the needed cues in the organisational strategies.

3.5 Summary

In this chapter we have presented the results of the conducted multi-case study. This study was conducted since the restricted research contexts of previous enquiries. Most research is constrained by the isolated study of piling and filing in one of the two information spaces. On the other hand, our study went across these boundaries and investigated the organisational strategies in both spaces. Additionally, we investigated coherency and dependency between these information spaces. Furthermore, a definition of a third strategy namely mixing has been defined and included in the overall study. The results are presented in two parts to enhance the internal validity. First, the hypothesis processing is discussed where we have indicated the independence of the three organisational strategies (e.g. piling, mixing and filing) within the specific information space as well as across the spaces. Since the practical relevance of this multi-case study for the field of Human-Computer Interaction, further results are presented in design principles for future PIM system development. Each principle reflects more concrete guidelines for the design of user interfaces implementing these organisational strategies in a cross-media information space setting.

We are searching for some kind of harmony between two intangibles: a form which we have not yet designed and a context which we cannot properly describe.

Christopher Alexander

4 The Meta-Activity Black Box

The theoretical part of PIM research is not yet well developed compared to other research fields such as Human Information Interaction. The last decade more interest is directed to fundamental research in PIM and it is recognised as a complex and promising field to discover. Nevertheless, because of its complexity and overlaps with a lot of other mature research areas, research is often directed to user studies and system design where generalisation and visionary approaches are neglected. Although the PIM research is still in its infancy, several attempts are made to define PIM activities. This chapter discusses these theoretical contributions and provides a conceptual model which extends one of the most recognised PIM frameworks. To demonstrate the lack of applying fundamental PIM research findings in system design, the chapter ends with an elaboration on this issue.

4.1 Keeping, Organising and Re-finding Theory

In order to be able to design a PIM system, researchers need to understand why users would need such a system. In the previous two chapters we have outlined problems such as information overload as well as the classification and fragmentation problem. Current PIM systems try to solve these issues by providing the functionality to organise the personal information in a semantic or timeline-based manner. Often the focus is set on the organisation activity in system design where the evaluation of these systems is then focused on the improved support for the re-finding activity. The interplay between organising and re-finding of personal information is theoretically defined by Jones in the *"Keeping, Organising and Re-finding Theory"* illustrated in Figure 4.1 [42]. Although, several theoretical frameworks have been published to describe PIM activities in different settings (e.g. digital file system or email), they all identify the three general PIM activities of *keeping*, *organising* and *re-finding* [3, 78, 31, 9].

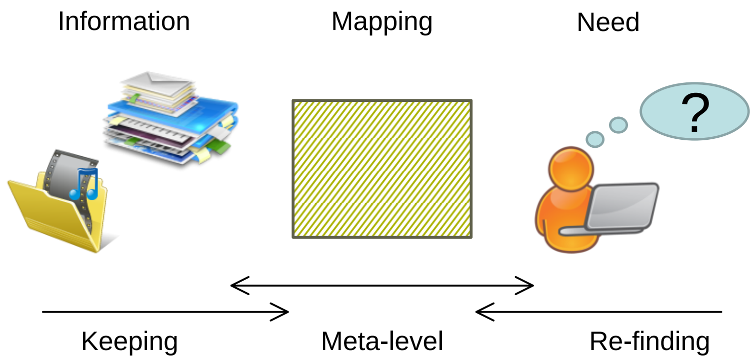


Figure 4.1: Keeping, organising (i.e. meta-level) and re-finding activities

Users keep all kind of information in the digital as well as the physical information space. The information may be stored in different forms such as paper, digital documents, email, videos, voice fragments and so on. Keeping activities concern the decision to integrate encountered public or received information in the personal information space. Information may be consumed immediately during the search or receiving process before storage. Our previously conducted case study indeed illustrates that users annotate information items to better re-find them in digital piles. This annotating activity is an example of consuming the encountered information before storing it in the personal information space. Some information may also be totally ignored. For example, users do not keep every received email since its relevance may be of no value for the future. The decision of consuming the information right away or not is not always so clear or easy. A considerable amount of information that users encounter may have no value at this moment but may be of great value later in time which is called an anticipated need. As a consequence users may have a lot of unprocessed information in their personal information space. At least 73% of the respondents of our case study do not disagree that they have more than 70% unprocessed or unvaluable information in their overall information space. Most people will encounter the issue of receiving an email which they do not want to remove but at the same time they will not processes the content and store the email in a folder. In the physical space, one may encounter a publiction in a journal which may be only of relevance later in the context of another project. In this case we may decide to keep the journal and just place it on a pile which has the context of *'TODO items'*.

The need to re-finding information instantiates re-finding activities. Re-finding activities are those activities which users execute to find a stored information item which they have integrated in their personal information space before. This means that there is a significant difference between finding information and re-finding information. Finding information does not belong to a PIM process as it is done in a public and not in the personal information space. The main difference with re-finding activities is that the user has much more extra information about the needed information item than unexplored public information. Nevertheless, re-finding activities have a broad range. Users may use a search engine on the desktop or they may navigate through a digital file system by orienteering. In Chapter 2 several re-finding strategies have been elaborated.

To be able to re-find an information item in the personal information space, the information item needs to have been stored. After a user made the decision to keep an encountered information item as part of a keeping activity, a meta-level activity is started. The main meta-level activities are organising and maintaining the stored items. Without any organisation of the stored information, the re-finding would be ineffective. Previous work enlightened in the aforgoing chapters indicated three organisational strategies (i.e. piling, mixing and filing) used in digital as well as physical information spaces. Each of these strategies have their issues when adding items to them and imply different re-finding activities. In addition, these differences in re-finding activities are different across both information spaces (i.e. digital and physical space). We refer the reader to the end of Chapter 2 and to the results of the case study in Chapter 3 for more clarification on these issues and different re-finding activities. Conclusive is the fact that at the start of the meta-level activity, the user needs to decide where and how they store each encountered information item. This decision is influenced by several factors where among others the ease of re-finding it later on and the access frequency in the future are the main concerns. The double-directed arrow on meta-level activities in Figure 4.1 illustrates this interplay between keeping activities and re-finding activities. Furthermore, Whittaker has extended the keeping, organising and re-finding theory by the identification that all PIM processes always start with a keeping activity and may be described as a closed cycle [78]. This is of relevance when a user wants to reintegrate personal information in their personal information space after re-finding the information item. A user will again need to make decisions concerning keeping the retrieved information item and concerning which organisational strategy is best suited to effectively and efficiently conduct future re-finding activities.

4.2 Contextual Keeping, Organising and Re-finding Theory

The keeping, organising and re-finding theory may be complemented by our findings of the user case study and by providing a conceptual model of the human memory as shown in Figure 4.2.

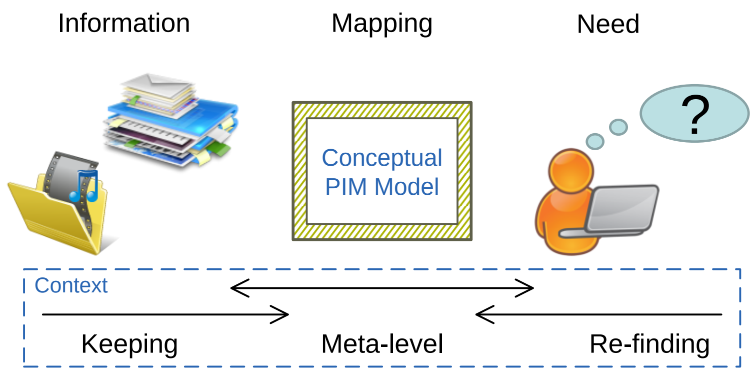


Figure 4.2: Contextual keeping, organising and re-finding activities

The conclusion of our conducted user study indicates the use of contextual hints as a main factor in the retrieving activity for all three organisational strategies in both information spaces (see Table 3.2). In addition, other research also identified the importance of context in keeping activities [41]. For example, an encountered information item may be of no relevance for the current context of the executed task but may be of importance to another task or subject. We may see this as a variant of the anticipated need activity in keeping activities. Although, the keeping, organising and re-finding theory of Jones is well accepted in the PIM community, it ignores the contextual dependency of all three activities. Earlier, Barreau [3] recognised the context dependency when keeping and re-finding information. Although her findings were only valid for digital file systems, we may agree upon this context dependency in a personal cross-media information space. We therefore extend the keeping, organising and re-finding theory of Jones with the following statement:

> *Keeping, organising and re-finding activities are dependent on the context in which the information item is used and includes this context in the activity.*

By the definition of context, given in Dervin's work, it contains any condition which makes a better understanding of a phenomena [24]. In PIM terms this means that any activity a user does contains contextual factors related to that activity. Additionally, the information item included in the activity also contains this contextual information. For example, a user decides to keep a printed publication describing the ideal PIM system. They keep the paper because of the high relevance it has to the thesis writing. At this keeping activity, the paper is augmented with contextual information by means of a post-it note such as the date they received it and the thesis relevancy. Next, they store the paper in a pile on the desk. This pile represents the contextual factor of highly relevant papers for the thesis. Therefore, the organisational activity of piling also happens in the context of writing the thesis which was the user's context at the keeping activity. A day later, the user needs to re-find the paper since they need it to refer to in the thesis. They use the context cue of writing the thesis and highly relevant papers to the thesis to retrieve the paper out of the right pile on their desk. Again the re-finding activity is taking place in the context of writing the thesis and the contextual information of the paper is used in this activity.

Until now we have focussed on supporting users' current organisational and re-find behaviour. Also the described theory only includes current observed behavioural activities. For the organisational activity, we have for example discussed piling, mixing and filing strategies. Nevertheless, a PIM theory also needs to be extensible for newly introduced organisational strategies. Besides the support of the current user organisational behaviour in PIM systems, attempts need to be done to find new ways of organising personal information. Ideally a user may retrieve the information as they do from their memory. By following the theory of keeping, organising and re-finding, this means that the organisation and keeping of personal information also need to provide the functionality of the human memory. To describe this organisational strategy used by the human memory, we introduce a conceptual model which is a high-level abstraction of psychological findings. Figure 4.3 illustrates how users construct a mental model of their personal information space.

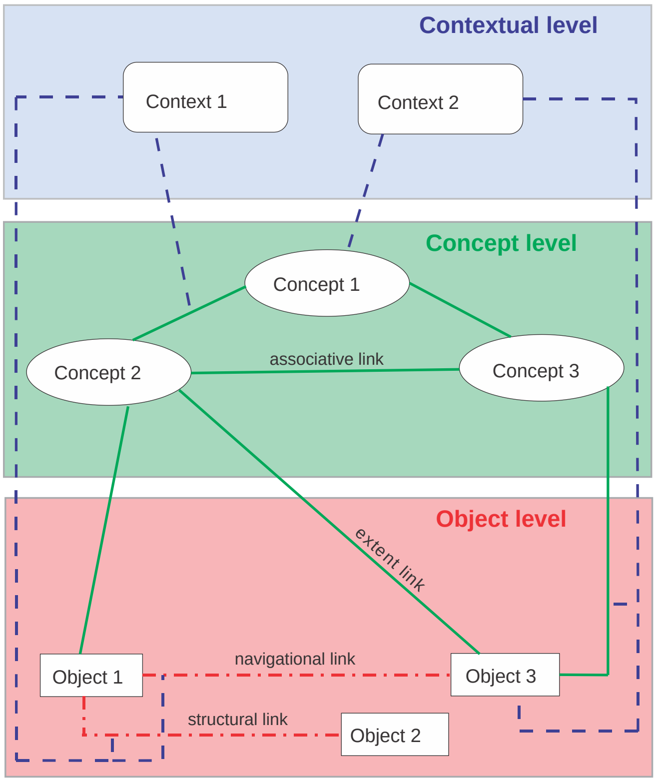


Figure 4.3: Conceptual human memory model

The conceptual human memory model consists of three levels, including the *object*, *concept* and *contextual* level. Each level contains its own specific elements. At the object level (i.e. red box in Figure 4.3), these elements are *objects*. Objects represent any real world element which can be observed in both the physical space as well as the digital space. For example, they may be a physical paper document, a book or a post-it note but also an email, a website or a phone call. Objects are not restricted to observable identities, but they can also form a part of an element such as a highlighted paragraph in a text. Since they are represented in the real world, they need to be uniquely identifiable through a uniform resource identifier. On the other hand, the concept level (i.e. green box in Figure 4.3) contains *concept* elements. Concepts are general ideas formed in the mind to abstract the complexity of the real world. Therefore, concepts are words or sentences which represent the user's conceptualisation of an observation of objects. In the digital space, concepts can be seen as the labels users give to a folder in the digital file system. These labels represent a certain conceptualisation of the containing elements in the folder. At last, the contextual level with its *context* elements is given in the blue box in Figure 4.3. A context element describes a composition of contextual factors. On their turn, a contextual factor can be any condition or observation which makes the objects or concepts more understandable. This is in accordance with Dervin's definition of context [24]. For example, a context *'WISE meeting'* may be composed of the contextual factors such as the meeting date, place, attendees, agenda topics and so on. Nevertheless, the composition of these contextual factors needs to be unique in order to identify the context element.

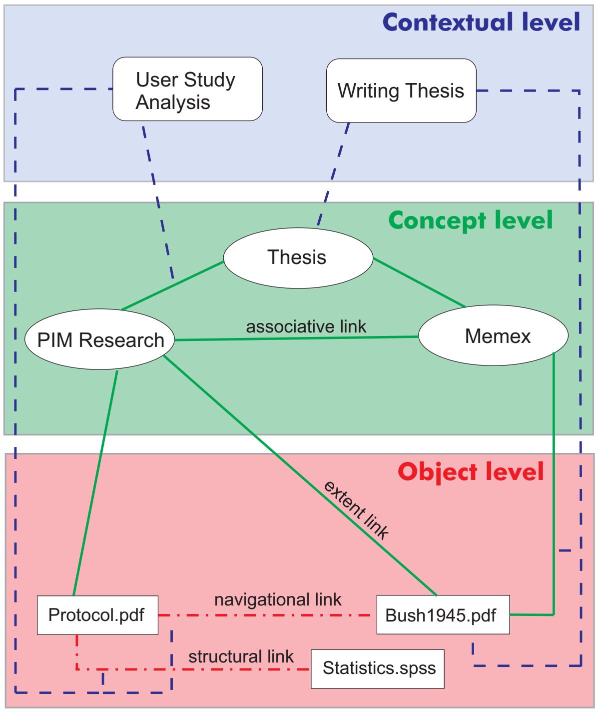


Figure 4.4: An example of applying the conceptual human memory model

The three levels of the conceptual human memory model have consistency between their elements and among each other. At the object level, objects may have relationships to other objects. These relationships are represented by *navigational links* and *structural links* (i.e. red dotted lines in Figure 4.3). Navigational links are relations which have the meaning of navigating from one object to the next one. An example are hyperlinks as we use them to navigate from a webpage to another webpage. Secondly, the structural links represent compositional relationships. An object may be composed of or include other objects. In this way, a digital document can be a composition of text fragments and an image where each of these text fragments and the image are objects in their own right. A level higher in the model, concepts may have *associative links* and *extent links* (i.e. green lines in Figure 4.3). As mentioned in Chapter 2, the human memory makes semantic associations between its elements. These semantic associations are represented by associative links. Along with the human memory findings, these associative links are bidirectional. An example of this and what is following is given in Figure 4.4. One may have concepts such as *'PIM Research'*, *'Thesis'* and *'Memex'*. Associative links may be constructed between these concepts such as between *'PIM Research'* and *'Thesis'* whereas between *'PIM Research'* and *'Memex'*. Furthermore, the concept level includes extent links. They represent any categorical relationship between a concept and objects. Therefore, real world objects or observations are classified in this complex network of concepts by the use of extent links. In this way, the conceptual model represents the psychological theory that concepts are internal to the mind where categories or objects are external to the mind [13]. An example is given by the previously mentioned concepts and the imagined objects *'Bush1945.pdf'* and *'Protocol.pdf'*. The *'Bush1945.pdf'* object is member of the category which contains the real things of the concept *'Memex'*. By the composition of real world things in a category, the meaning of a concept is clarified. Nevertheless, objects may participate in more than one extent link. For example, a user may construct an extent link from the concept *'PIM Research'* to the objects *'Bush1945.pdf'* and *'Protocol.pdf'* where *'Bush1945.pdf'* may also be a member of the extent link constructed from the concept *'Memex'*.

The above modelling may sound familiar from semantic web technologies such as the Resource Description Framework (RDF)[1]. Nevertheless, the human memory has an additional powerful feature to organise information. As enlightened in the elaboration of the human memory, the memory is composed of not only the semantic memory represented by the above modelling but also includes the episodic memory. The episodic memory is responsible to store contextual factors about, among others, changes made in the semantic memory. By preserving these contextual factors, users may search in their semantic memory by using these contextual cues. This is an important fact illustrated by the conducted user study in the previous chapter. Therefore, we enhanced the conceptual human memory model with the inclusion of the contextual level. The contextual level is responsible for keeping the contextual factors of the represented semantic graph induced by the concept and object level. Each concept or object as well as the defined links on both levels may have a relevance to a context element (i.e. blue dotted lines in

[1] `http://www.w3.org/TR/2004/REC-rdf-concepts-20040210/` Last accessed on 23-08-2013

Figure 4.3). The context element therefore represents the preservation of the relevant contextual factors to these elements and links. In practice, a user may define the contexts *'User Study Analysis'* and *'Writing Thesis'*. In the context of *'Writing Thesis'*, the concept *'Thesis'* is of high relevance whereas it has a much lower relevance to the context *'User Study Analysis'*. Besides the concept *'Thesis'*, the object *'Bush1945.pdf'* is also of relevance. Since the user is writing a thesis, the extent link from the concept *'Memex'* to the actual PDF version of the Bush paper is much stronger than in the other context of *'User Study Analysis'*. The same reasoning may hold for associative links between concepts. One associative link may be of higher relevance than another. In the context *'User Study Analysis'*, the *'PIM Research'* concept is less important to the *'Thesis'* than in the context *'Writing Thesis'*. Furthermore, the navigational link between the *'Protocol.pdf'* object and the *'Bush1945.pdf'* object may be of moderate relevance. Nevertheless, in the analysis of the user study, the statistical results included in the *'Protocol.pdf'* by a structural link to the SPSS file will be of very high relevance in contrast to the moderate relevance of the *'Bush1945.pdf'*.

Our approach enables the activation of all elements and links at the concept and object level, resulting in a sub-semantic network that is relevant for a user at a given time. Therefore, the proposed organisational strategy inside the meta-level activities may induce more easier and effective re-finding than the current organisational behaviours in PIM. Furthermore, we need to mention that this is only the organisational aspect of the new strategy based on the human memory. An extensive amount of further research needs to be done to define new keeping and re-finding activities accordingly to this newly defined organisational strategy.

4.3 PIM System Requirements

In this section, system requirements are given which need to form the basis of every PIM system. A note is the difference between these requirements and the previously introduced design principles. The design principles give guidelines to the user interface design for all three organisational behaviours across information spaces. In contrast, the following system requirements translate the minimum needed functionality in a PIM system.

The end goal of each PIM system is the organisation of personal information items via associations. This should reduce the cognitive overload and time effort users experience in their current organisational behaviour. It is the basic component for future research in innovative interaction opportunities. Without the possibility of linking information items, future interaction research within this linked information space may not be done. To push the ideal PIM system development, a PIM system needs to be able to construct such a linked information space.

Requirement 1 *Associative linking needs to be provided.*

It is not sufficient to only provide the possibility to link information items. Our introduced conceptual human memory model also defines a context relevance of these links and its elements. This contextual relevance is also used as a main cue in re-finding activities shown by the user study conclusions. As mentioned previously, a user's context also influences keeping activities. Therefore, it is of high importance that a PIM system includes this contextual relevancy of information items and their constructed links.

Requirement 2 *Elements and links need to have a context relevancy.*

A main concern in current system design is the focus on mostly digital information items. Nevertheless, a user's personal information space includes a large number of physical information carriers. We have to unify all information without the ignorance of either spaces.

Requirement 3 *The full cross-media information space needs to be integrated.*

A second cue in re-finding is the time cue. Users often remember a time interval about a certain event with or related to the needed information item. Note that only providing a time-based organisation is not enough to improve the re-finding effectiveness. Our user study indicates the use of time-based retrieval only in physical mixing and filing organisational strategies. Hereby, time-based organisation needs to be included in a PIM system but may not be the only provided functionality.

Requirement 4 *Episodic time-based organisation needs to be provided.*

This leads us to the support of all current organisational and re-finding behaviour. Since it is hard to change human behaviour in general and users have constructed organisational structures over their lifetime, it is impossible to expect from a user to integrate all their organised information in a new PIM system. Therefore, we need to provide ways to augment the current behaviour or at least to take it into account.

Requirement 5 *Current organisational and re-finding behaviour needs to be supported.*

When all current organisational and re-finding behaviour needs to be supported, there is a need for adaptive user interfaces. First of all, each organisational strategy has its own design principles. This imposes that different user interfaces may be needed to fulfil all functionality required by the design principles. Furthermore, each organisational strategy may need to implement a different user interface depending on the degree of usage.

Requirement 6 *Adaptive user interfaces are needed within each organisational and re-finding behaviour/activity.*

Finally, a PIM system needs to provide the user with all three observed re-finding cues namely contextual cues, time cues and spatial cues. Our user study as well as past research identified the use of these cues for the current organisational strategy.

Requirement 7 *All three re-finding cues need to be integrated based on the organisational strategies.*

4.4 Where Current Systems Fail

Now that we have a more clear view about a user's behaviour and what functionality a PIM system should minimal provide, we may discuss current PIM prototypes. These prototypes can be classified in three major groups. A first group of prototypes are the time-based PIM systems. Their focus is mainly set to capture changes in the personal information space such as importing information items. For re-finding they provide mostly time cues. A second group attempts to organise the personal information by associations. These systems focus on the ability to link information items where less attention is given to the user interaction with these linked information space. Finally, a third group focuses on these interactions with information items and tries to provide user interfaces which improve the effectiveness of re-finding activities. All three groups are discussed in the context of the previously defined system requirements and an overview table is given at the end.

4.4.1 Time Approach

Two well-known prototypes are provides in this first group of time-based information organisation. First, LifeStreams was developed at Yale University by Freeman and Gelernter in 1996 [32]. It is based on the observation that users do not want to label and classify every information item in the hierarchical file system. In their view, the system must be able to automatically

Figure 4.5: A timeline in MyLifeBits as shown in [33]

archive the information in order to prevent that users throw away old information which could be useful in the future. Furthermore, the system should be able to provide a summary of a group of files such as a to-do list if the group contains several future tasks. A reminder function is desired for scheduled tasks and users must be able to access their information items anywhere regarding the used device. LifeStreams integrates all these requirements by storing all created files such as documents, images and email in a chronological list which forms the LifeStream of a user. The LifeStream has also a future line where reminders or future events are stored. By formulating a query, the user is able to retrieve information items. The result of a query is returned in the form of a substream which may be used as a second LifeStream. This substream contains copies of the main LifeStream and is dynamic which means that this substream may be changed automatically. For example, a user may input a query of *'give me the latest received files'* which will return a substream which will store all incoming emails or created files. A second time-based approach to information organisation is MyLifeBits which is developed at the Microsoft research lab in San Francisco and first published in 2002 by Jim Gemmell et al. [33]. Figure 4.5 shows the timeline of a user in MyLifeBits. The system has similarities with the LifeStream system such as the support of collections or substreams of information items, multiple views such as a timeline or a collection of linked resources and the ability to implicitly link information items together based on the timeline. MyLifeBits uses an SQL Server database to store all resources, links and collections. Links are defined as one-to-one bidirectional links which are used to provide the functionality to annotate a resource with another resource.

Some remarks should be made on the use of such time-based PIM systems. By only providing a query functionality to re-find information items, the importance of orienteering through a personal information space is ignored. Although, we did not take this into the system requirements, it is worth a note. As we may see from both systems, they only support a certain degree of providing a context relevance to an information item. By grouping items and labelling this substream, they try to preserve the context relevance. Furthermore, only support for a time cue is given in re-finding activities. No other system requirements are provided which may let us conclude that a time-based system may not be the best solution to future PIM system design.

Nevertheless, the vision of lifelogging is currently a real hype. Lifelogging concerns the recording of all events with personal information on a chronological basis. The previously mentioned systems are the predecessors of lifelogging applications such as the SenseCam developed by Microsoft [36]. The SenseCam goes further than recording only digital information interactions by capturing all events of the users daily life. A major concern with such applications is the large amount of recorded information. Therefore, projects such as the SenseCam and the well-known Google Glasses[2] use artificial intelligence to filter out the less important information.

4.4.2 Network Approach

A second group of PIM systems may be classified as those systems which provide the ability to semantically link information items. In 1991, the Semantic File System (SFS) was introduced by David Gifford at MIT [34]. The SFS linked content of the digital file system by providing a layer on top of the file system which kept all extra link information. It allocated to each file in the file system some attributes where among others the paths to other files where set to introduce implicit links. By the use of a query, a certain file could be retrieved and the links to other files could be followed. A similar system was introduced in 1993 with the Rufus System by IBM [66]. An improvement to the SFS, is the introduction of an object-oriented database to store extra information about the information item whereas these contextual information can be automatically derived from the imported item. Besides information items out of the file system, emails and directories could be linked. These links are still not explicitly stored as defined by our system requirements but implied by the use of collections, composite structures and so on.

A second generation of PIM systems came by the end of the nineties. These systems took into account that it is not only a matter of being able to link information items together but that it needed to be usable by end users. A first attempt was made by the Presto system developed at Xerox Palo Alto

[2] `http://www.google.com/glass/start/` Last accessed on 23-08-2013

Research Center [28, 27]. Presto uses the same implicit way of linking information items and retrieving extra information from the digital file as in the Rufus system. Nevertheless, Presto also allowed users to still use the digital file system as usually but provides the retrieved contextual information to support the re-finding. The most added value is the introduction of several user interfaces on top of the lower level organisation of the information items. For example, Presto has implemented a digital pile interface on top of the desktop. By grouping digital files together they are placed in a collection at the lower organisation layer. When a user now navigates in the digital file system, they may query for the other information items in the constructed pile at the desktop. This shows the adaptive user interfaces depending on the used organisational strategy (i.e. digital piling and digital filing).

By the introduction of the Semantic Web technology Resource Description Framework (RDF) in the early 21st century, the PIM system design gave a bust to new prototypes. Untill then no system had found the right technology to link information items in an explicit way in the context of PIM. This changed by the use of RDF where the predicate can be seen as the link in an explicit form. In RDF, a triple (i.e. link with one source and one target) is defined as `(subject, predicate, object)`. A subject needs to be a Unique Resource Identifier (URI) which points to a "real world" object whereas an object may be a URI or a literal such as a string. By storing this triple in a database and by using SPARQL queries, a user may query for relations between information items. One level higher, ontologies may be defined on top of RDF triples. An ontology models concepts and their relationships on a higher abstraction-level based on the RDF data. In ontologies one may for example introduce a class `Person` and a relation `has name` where the subject or object of a triple may then be a member of the persons class and where the predicate refers to the `has name` relation. It is out of the scope of this thesis to provide a deeper discussion on Semantic Web technologies but this basic notion should be sufficient to understand the prototype discussion.

The first system which uses RDF as a solution to link information items is the HayStack system developed by David Karger at MIT in 2003 [45]. HayStack is the most promising system to date but they still miss some functionality to fulfil all system requirements. First of all, the system does not take the context relevancy on the information items and their relations into account. To provide contextual information in re-finding activities, they use the same principle as previous prototypes namely retrieving contextual information out of the information item. Nevertheless, HayStack provides a modular architecture to import this contextual information from third-party tools into the RDF datastore. It is the responsibility of these modules to translate any information retrieved from the third-party tool to RDF which is then integrated in the central triple store. They have implemented such a module for among others Outlook and the digital file system where for example time related properties (e.g. access date) is exported to RDF as a relation between the information item and this property. More of a fundamental contribution is the partial inclusion of current user organising behaviour. Because the system is seen as a layer on top of all existing applications and the digital file system, a user may still interact with them. The only requirement is that these applications have their importing module which provides the URI of the information item and its contextual information to the datastore. Additionally, HayStack may integrate with physical information items if they are identifiable by a URI. Nevertheless, they never implemented integration with the physical space because the focus was never set to this integration and mostly mentioned as future work. Other missing functionality implied by our system requirements are the lack of the support for current re-finding behaviour and the ability to have adaptive user interfaces for re-finding activities.

From then on several prototypes are presented, each with their own focus on different aspects of a PIM system. The Gnowsis system introduced by Suaermann in 2005 is highly comparable to the HayStack system [63, 62]. Nevertheless, some disadvantage are imposed by their vision on PIM systems. To import RDF triples in the datastore, they provide modules which crawl the third-party application metadata. This implies that only contextual information which is in the RDF format may be imported. In contrast to HayStack, other contextual information, for example from text search, is ignored. We may consider this as a major disadvantage since a user's personal information space is not always structured in RDF. For example, an email may contain much more contextual information such as the attendees of a meeting in the body of the email. In this case, the crawler will not be able to retrieve the attendees whereas a module in HayStack may implement a text search algorithm which extracts this information. Besides the disadvantages in importing, the Gnowsis system provides different user interfaces to navigate and interact with the stored RDF triples. The first user interface is a sidebar which represents the triples in a hierarchical structure whereas the second user interface shows the provided semantic WIKI. The purpose of the semantic WIKI is to let the user construct a personal ontology of their information space besides defining relations between information items. Nevertheless, a user study revealed that the construction of a personal ontology takes some time and effort by the end user. Hereby, users did not model their information space very often whereas the semantic WIKI was mostly used to annotate information items which was intentionally just an additional provided feature [64]. Furthermore, systems such as Semex [18, 26], LiFiDea [38] and FCB [61] where developed. The main difference between them is that LiFiDea focusses on providing a time cue whereas the FCB focusses on the augmentation of the digital file system with extra contextual information. On the other hand, Semex only provides an isolated system to create and navigate through the semantic graph of information items.

4.4.3 Individual Attempts

The last group concerns systems which focus on the interaction with personal information. As mentioned in Chapter 2, users use email clients not only for sending and receiving emails but also to manage contacts. TeleNotes purpose is to help users with this extra functionality [84]. They introduced the concept of communication threads and stickies to manage contacts or to keep track of task related conversations which is integrated in much of the email clients we use nowadays. In a communication thread, previously related emails are grouped where users may access them in TeleNotes in the form of a pile. Furthermore, stickies provide the ability to annotate such a thread or an email. By the use of stickies users may preserve contextual information about the conversation and the email. As shown in our user study, annotations are indeed often used to preserve the context whereas they serve as a support in re-finding activities. A related system to TeleNotes is the Bluemail email client [82]. Besides of communication thread and stickies, Bluemail provides the possibility to tag and organise these threads. Organisation may be done by the use of a hierarchical classification structure where the tags are seen as the folder names in the digital file system. To support re-finding activities, most used tags are displayed in a side panel. Nevertheless, both systems implicitly link emails by grouping or tagging whereas context relevancy is not provided. In contrast to network based systems, they are often restricted to specific media such as email. A positive facet is the provided time cue in organising and re-finding activities whereas the context is partially preserved by allowing annotations in the form of stickies.

Two other systems are examples of visualising linked personal information. First, the ContactMap by Whittaker [81] shows how current organisational strategies such as digital piles may be extended to organise a user contacts. In ContactMap, users may group contacts together in the context of specific tasks. Of course, a contact may be a member of several groups at a time and each contact may give access to the contacts information as well as email threads where they participate in. Although a lot of the system requirements are inapplicable, this system shows how a user interface may bring support for current user organisation behaviour in an application. Contacts are namely organised by constructing digital piles. One issue is the observation that when the amount of groups and contacts in group increase, it gets more difficult to re-find contacts. A second visualisation tool is the Personal Information Dashboard (PiD) [1]. PiD is based on the visualisation technique of dashboards. Figure 4.6 shows the PiD user interface. In a dashboard several views are given to the personal information. For example, a view in the dashboard represents the residence of a user's contacts on a map whereas a second view represents in which application the contact is used (e.g. email, Facebook or Twitter). Such systems allow users to reflect on their personal information which may result in the discovery of relations between information items. Future research may investigate the use of a dashboard on semantically linked personal information introduced by the network approach systems.

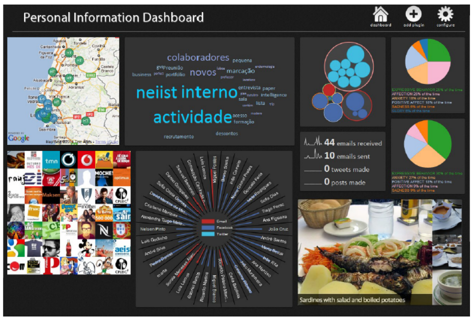


Figure 4.6: PiD dashboard as shown in [1]

4.4.4 An Overview

We may conclude that no system fulfils all our system requirements. Although promising prototypes are developed, they always mainly focus on digital information items whereas the integration with current organisational and re-finding behaviour is often ignored. Table 4.1 shows the observed system requirements for each discussed prototype.

		Organisation						Re-finding		
		Associative Linking	Context Relevancy	Digital Space	Physical Space	Episodic Timeline	Support Current Behaviour	Support Current Behaviour	Adaptive UI	Re-finding Cues
Time-based	LifeStreams [32]		+/-	+		+				T
	MyLifeBits [33]		+/-	+		+				T
Network-based	SFS [34]	+		+/-						C
	Rufus [66]	+		+/-						C
	Presto [28]	+		+			+/-			C
	HayStack [45]	+		+	+/-	+/-	+/-			T/C
	Semex [18]	+		+	+/-					C
	FCB [61]	+		+	+/-		+/-	+/-		C
	LiFiDea [38]	+		+	+/-	+/-				T/C
	Gnowsis [63]	+		+	+/-	+/-				C
Individual Attempts	ContactMap [81]	+/-		+/-		+/-				T/C/S
	BlueMail [82]	+/-		+/-		+/-	+/-	+/-		T/C
	PiD [1]	+		+/-		+				T/C/S
	Telenotes [84]	+/-		+/-		+/-				T/C

Table 4.1: Overview of the used cues in organisational strategies applied in a cross-media information space. (T = time cue, C = contextual cue, S = spatial cue)

4.5 Summary

This chapter has shown the theoretical contribution of this thesis. The KOR theory was introduced as well as our extension to it. We defined a contextual dependency on all three PIM activities namely keeping, organising and re-finding. The observed contextual dependency is based on the current state of the art in descriptive research and moreover on our own user study findings where users indicated a significant use of context in keeping and re-finding personal information. Furthermore, we envisioned the ideal PIM system by the ability to organise the information items in a similar way the human memory does. Where most systems restrict themselves to the functionality of creating associative links between information items, we provide a conceptual human memory model which identifies a context relevancy on these links and the information item itself. Future PIM systems may use this abstracted conceptual model of the human memory as a blueprint. As a summary of all user-centric contributions, we defined a number of system requirements. Last but not least, current prototypes have been evaluated in the context of these requirements and we can conclude that no existing PIM prototype fulfils all our requirements.

Education is our passport to the future, for tomorrow belongs to the people who prepare for it today.

Malcolm X

5 Linking Information in the Information Space

Now that we have elaborated the user side of this thesis, it is time to take a closer look at the provided Information Linking and Interaction Framework (ILI). In the previous chapter we have shown that none of the current prototypes support all system requirements. Therefore, we saw the opportunity to contribute with a framework which includes all of them. First, the framework's overall architecture is given followed by the presentation of the link layer. The next chapter goes in deeper on the second interaction layer. Before we start with a discussion of the implementation, the used Resource-Selector-Link (RSL) metamodel by Signer and Norrie is introduced [69]. Next, our extension of the RSL metamodel and the necessary implementation are explained in more detail. Since we have adapted the new implementation of the RSL metamodel, these changes are also discussed.

5.1 The Information Linking and Interaction Framework

It is known in the PIM community that the unification of user-centric PIM systems design with the observed descriptive findings concerning user organisational and re-finding behaviour is a major challenge. Additionally, researchers face a challenge in designing and implementing entire PIM systems for user interface evaluations. As seen within the existing prototypes presented earlier, a lot of work is done in the facet of providing the functionality to organise the personal information by associations at the lower system level. On the other hand, several prototypes focus on the visualisation and interaction with personal information. This leads to a disjunctive developing process where one part of the community focuses on the low level "organisation" whereas the other part re-invents the wheel or hardcodes this lower level functionality to be able to evaluate new user interfaces. Due to this observation, we have decided to provide the PIM community with the ILI framework. By separating the concerns of lower level functionality such as associative linking and the user interface design which focus on the interaction with personal information, we bridge the gap of this disjunctive design process. Specially for user interface design and evaluation, the framework is well-suited for fast prototyping by the introduction of user interface plug-ins. Two examples of such fast user interface prototyping are given in Chapter 7. In this way, a common base in the form of ILI can be used to experiment with new interactions and there is no need to redesign a whole PIM system for user studies.

The ILI frameworks architecture reflects the above mentioned separation of concerns by its layered design. Figure 5.1 shows the overall ILI architecture. First, the lower level functionality of organising personal information by associations is the concern of the linking layer. This layer's functionality may be compared to systems such as HayStack [45] and Gnowsis [63]. Nevertheless, the linking layer provides much more functionality than only associative linking. It also includes the contextual relevancy of these associative links and the time-based organisation of information items which are both previously defined system requirements. To be able to provide all this functionality, the link layer includes a data model which is based on an extension of the Resource-Selector-Link metamodel. The iServer provided by Signer and Norrie [68] implemented this RSL metamodel and provides the iServer interface to apply CRUD operations on these data elements. The original implementation was done in OMS Java but to be less bundled with a persistence database solution, a new iServer version was introduced. Nevertheless, we have improved this new iServer version besides the extension of the iServer to support the needed functionality given in the conceptual model of the human memory. This lead to the overall architecture of the link layer (i.e. extended iServer). A Façade and Strategy design pattern is included to enhance the independency of the layered architecture and the reusability of iServer in other applications. The iServer Façade Interface provides the interface for client applications. This interface is then provided in two implementation versions. One version includes the new iServer with the implementation of the core RSL metamodel elements. The other version includes our extensions to this iServer implementation and is called the iServerCCO version. Furthermore, we have used db4o[1] as a backend storage technology for the new iServer implementation.

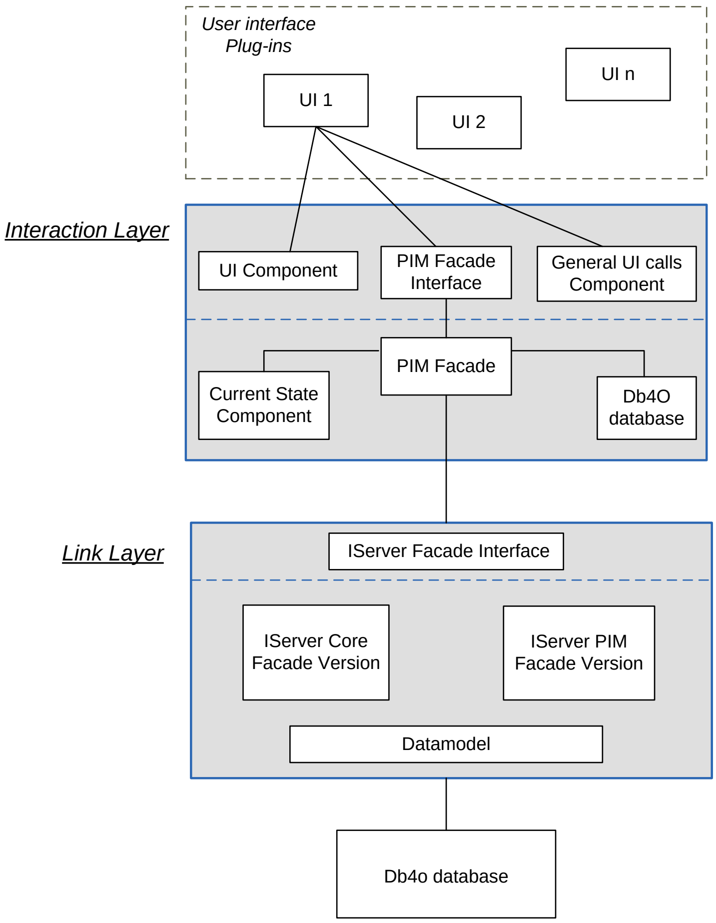


Figure 5.1: Overall ILI architecture

Secondly, the interaction layer concerns the needed functionality for PIM user interface design. This layer is constructed out of three components namely a PIM component, a User Interface (UI) component and a General UI calls component. The UI component provides the functionality to register

[1]http://www.db4o.com Last accessed on 23-08-2013

a user interface which can then be used by other user interfaces. We also provide a plug-in mechanism for these user interfaces. Next, the General UI calls component provides commonly used calls by the user interfaces such as opening documents or scaling of PIM elements icons. The core component of the interaction layer is the PIM component. This component includes the functionality to access the underlying iServer whereas more PIM-specific operations such as ordered lists of elements for a specified context. Besides this, it also provides an abstraction to link elements. It will become clear in the next sections that several types of links may be instantiated but this has the consequence that each user interface needs to have the knowledge of the extended RSL metamodel. Since our aim is to provide the ILI framework for fast prototyping, this issue may become a major concern. Furthermore, the current state of a user's personal information organisation is kept and a database for PIM-specific elements is provided by the PIM component. The following sections elaborate on the link layer whereas the next chapter provides a detailed discussion of the interaction layer.

5.2 Extension of the RSL Model

Before presenting implementation-specific work at the link layer, we first need to introduce the basic concepts of the used RSL metamodel. After this introduction, our extensions made to the RSL metamodel in order to support the previously presented conceptual model of the human memory storage structure are outlined.

5.2.1 Resource-Selector-Link Model

The RSL metamodel was initially defined in the context of research on interactive paper. Several successive projects have been done using the RSL metamodel as a core component for interactive paper [67]. Examples are PaperPoint [70] and EdFest [6]. PaperPoint allows presenters to navigate, annotate and sketch on PowerPoint slides via a printed paper version of the presentation. A more extensive project is EdFest where the Edinburgh Festivals Guide was augmented with additional functionality. Visitors could interact with an augmented version of the normal paper guide. These augmentations included among others the functionality to get extra information of a show or to make reservations for an activity. All these augmentations where done in the paper festival guide itself or in a bookmark. Nevertheless, the RSL metamodel has not only shown its functionality in such interactive paper applications but may be used as a fundamental data model to link information elements in cross-media information spaces. Since a personal information space includes all kinds of media from the full range of different paper-based artefacts (e.g. documents and post-it notes) to all digital media types, we may see it as a cross-media information space. In addition, the presented conceptual model defines the need to link all these media which leads us to the RSL metamodel. Earlier research demonstrated that the RSL metamodel may serve as a base for PIM systems [37]. But how does it work and what is the actual fundamental value of this metamodel? In what is following this will become clear.

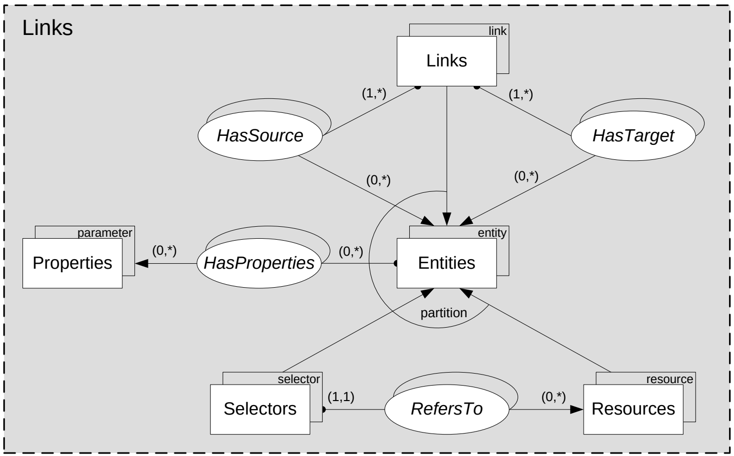


Figure 5.2: Links as cited in [68]

As the name says, it is a way to link resources and selectors as highlighted in Figure 5.2. The model is represented by using the Object-oriented OM data model [56]. OM makes a distinction between a collection of objects and associations. A collection is shown by a white rectangle whereas the type of the included objects is given in the shaded rectangle. A collection may be subtyped by other collections and a partition constraint may be set to indicate that an element can only be in one of the subtyped collections. Associations are illustrate by oval shapes and are defined between elements of collections. Furthermore, cardinality constraints can be set for each participating collection in the association. In this way, the elements in a collection are restricted by their type and by their participation in an association.

Back to the RSL metamodel, a generic collection is given by `Entities`. This generic collection includes the `Links` collection as well as the `Resources` and `Selectors` collections where an entity may only be a member of one of these three collections which is ensured by a `partition` constraint. The

`Resources` collection contains all objects of the type resource. A resource is instantiated for each information item which needs to be linked. We can not only link resources but also specific parts of a resource. This is done by introducing `Selectors`. `Selectors` have an association `RefersTo` with one resource given by the cardinality constrained `(1,1)`. On the other hand, for each resource we may define one or more selector instances indicated by the cardinality constrain `(0,*)`. Via a plug-in mechanism these resources and selectors may be subtyped for media types which contain then media-specific information. Several plug-ins have been implemented such as iPaper, iWeb and iMovie [67]. For example, if the resource is of the subtype video, the selector may be defined by a time span. On the other hand, if the plug-in is for physical paper then the resource is subtyped with a document page and a selector may be defined as a shape. We may provide specific plug-ins for physical as well as digital media. By including only the general concepts of resource and selector at the model level and by using plug-ins for different media types, a maximum extensibility is reached to include all media types.

Besides `Resources` and `Selectors`, also `Links` are a subcollection of the `Entities` collection and are directed many-to-many links between entities. This means that a link can have more than one source as well as more than one target. Nevertheless, each link needs to have at least one source and one target. In terms of the model, a link needs to participate in two associations with a `(1,*)` cardinality constraint. The `HasSource` association contains the associations between a link and its source entities whereas the `HasTarget` association contains the associations to the target entities. On the target side of both associations, a cardinality constraint `(0,*)` indicates that every source and target entity may be the source or target of other links. By defining the source and target of a link on the `Entities` collection, the sources and targets of links may be of the type resource, selector or link. Furthermore, links are directed (i.e. they has sources and targets) in the RSL metamodel. Note that a link instance does not have any knowledge of its sources or targets. The bidirectionality of a link is implied by the fact that associations are bidirectional in OM.

Additionally, an entity may have properties by participating in the association `HasProperties`. The properties include a set of parameters for an entity. These parameters are represented by `(key, value)` pairs but the iServer does not define these pairs. It is up to the application to allocate keys and values to the parameter object. This leads to the possibility to customise the behaviour for a specific entity object. For example in the context of our PIM system, a resource may have a property with the key *'access time'* where the values are the timestamps of accessing the resource.

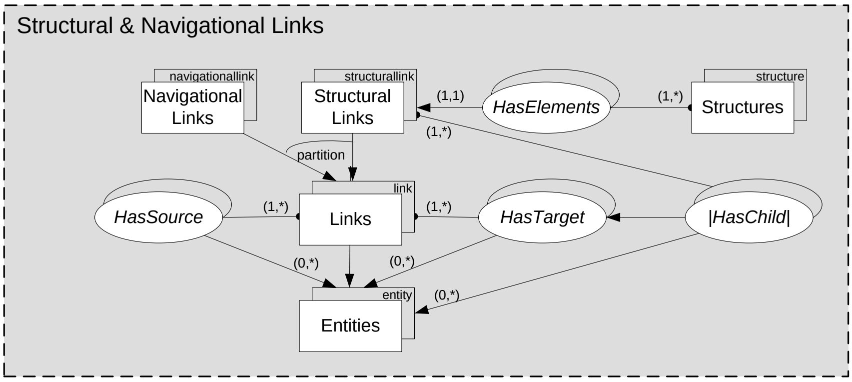


Figure 5.3: Structural and navigational links as cited in [69]

A first extension on this core RSL metamodel is the inclusion of navigational and structural links as shown in Figure 5.3. A distinction is made between navigational links and structural links. Structural links are subtyped from links and they can represent a structure over entities. The structure itself is a member of the structures collection. A structure may include several structural links but a structural link may only be associated with one structure. For example, a book has a structure of chapters and each chapter includes sections. The content of a chapter and section is given by the chapter or section structural links between resources. A resource may of course be the target or source of several structural links which leads to the reuse of data in a document. This is also known as transclusion mentioned by Nelson [55]. Besides the included content, we need to know the order of these chapters in the book and the order of the sections in a chapter. Hereby, a structural link uses an ordered subassociation `HasChild` of the `HasTarget` association. In this way, a structure may be defined over data (i.e. resources), over structures (i.e. chapter and section) and over links. Most relevant for our PIM system is the possibility to define a structure over links. Since finally, all personal information is semantically linked to each other, we may use structures to guide the user through their mental model graph. Note that this is out of the scope of this thesis and is referred to as future work.

Furthermore, the core of the RSL metamodel includes layers and user management which is illustrated in Figure 5.4. The concept of layers concern the ordering of selectors. By this extension, we may define selectors on top of selectors but we are still able to identify the desired selector object. For example, a selector for a paper document may be a rectangle. The problem raises when a user defines two selectors (e.g. two rectangles) within one rectangle forming part of the other rectangles shape. When the user

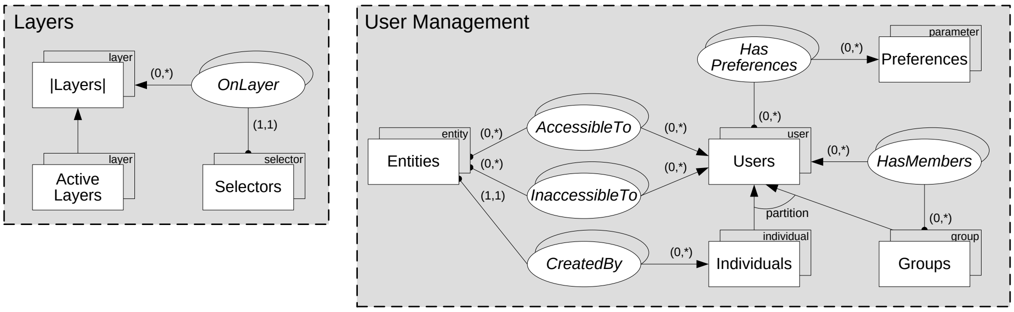


Figure 5.4: Layers and User Management as cited in [68]

now points to the overlapping part, both selectors will be activated. Nevertheless, we often do not want this and may want to choose between these activated overlapping selectors. Therefore, the model introduces the notion of an ordered collection `Layers`. Each selector needs to be related to exactly one layer by the association `OnLayer` whereas each layer may contain multiple selectors but overlapping selectors may not appear on the same layer. Furthermore, a subcollection of `Layers` is defined as `Active Layers`. When a user selects an area in the paper document, the ordered collection of active layers are available where the selector on the top layer is returned. The order of layers may also be dynamically changed, so that the user can choose the selector instance of their need. Besides the layers, user management provides the functionality of defining specific access rights to individuals or groups of individuals. In the context of PIM, this is a major advantage to have the user management at the data level since sharing of personal information items within small groups is often done. First, each entity is created by one individual whereas an individual may create multiple entities. The `Individuals` are a subclass of more general `Users` collection where users can also be groups of users represented by the `HasMembers` association. Note that a group may contain other groups as well as individuals. Additionally, each user (i.e. level of individual or group) may be related to preferences by the `HasPreference` association. Each entity may now specify the relation `AccessibleTo` and `InAccessibleTo` for several users. In this way, we may give access to some pictures to small groups (e.g some friends) or/and just to a single friend.

5.2.2 Matching the Conceptual Memory Model

After the introduction of the RSL metamodel, we may elaborate on the extensions made in the context of this thesis subject matter. The challenge to

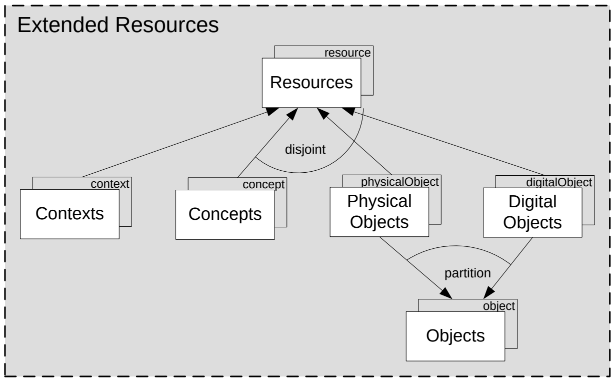


Figure 5.5: Extended resources

enhance the RSL metamodel in order to match with the conceptual human memory model were threefold. The conceptual human memory model makes a distinction between concepts which are internal to the memory and objects which are external to the memory. Additionally, objects may be physical or digital objects. Due to the fact that our memory uses the extra information of the object being a physical or digital as a re-finding cue, this needs to be taken into account in the modelling. Therefore, we have extended the `Resources` collection with `Concepts`, `Physical Objects` and `Digital Objects` subcollections where a disjoint constraint indicates that an information item can only be one of these three types as shown in Figure 5.5. Since `Physical Objects` and `Digital Objects` are also just objects external to the memory, we have introduced a more generic `Object` collection. At any given time `Context` may be represented by concepts or objects. For example, a concept *'thesis'* may also be seen as the context *'thesis'*. By introducing `Context` as a subcollection of `Resources`, a context may also be linked to other entities specially to other context. This allows us to, for example, link the context *'thesis'* with the context *'thesis writing'*.

Secondly, the conceptual human memory model imposes a distinction between associative links and extent links as highlighted in Figure 5.6. `Extent Links` are a subcollection of `Links` because they have the semantics of linking `Objects`. In contrast, `Associative Links` are more seen as a specific type of navigational links since they represent the navigation functionality between `Concepts`. Therefore, they are a subcollection of `Navigational Links` instead of `Links`.

Finally, a more fundamental extension is introduced to provide the context dependency and relevancy of information items and links. To be able

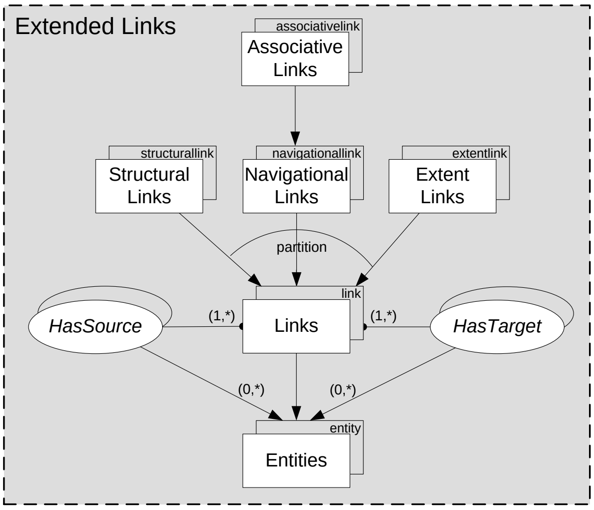


Figure 5.6: Extended Links

to define a weight factor to a certain context, we have defined a new type of association namely the weighted association indicated by a `*` in Figure 5.7. This new type of association provides the possibility to allocate a weight within a range from `0` to `1` to the association itself. In terms of the extended model this means that we can express that an entity relates to a context with a specified weight by the `HasRelevance` weighted association where this weighted association instance includes the specified weight factor. Secondly, we also need to provide this context dependency and relevancy on the associative links and extent links. With a vision for future opportunities, the context dependency and relevancy is included on the links instead of only on associative and extent links. Nevertheless, since the RSL metamodel defines links as many-to-many links, this would indicate that only the link itself could have a contextual dependency and relevancy. A more powerful solution is to allow the contextual dependency and relevancy at the level of `HasSource` and `HasTarget` associations. All sources and targets of a link can now express the importance of their participation in the relationship for each specified context. Therefore, we have introduced the weighted associations `HasSourceRelevance` which has its startpoint at the association `HasSource` and the `HasTargetRelevance` weighted association which has its startpoint at the association `HasTarget`. Both weighted associations have a `Context` instance as targetpoint. In this way, each source and target of a link may have their own relevancy to a context. For example, the concept *'thesis'* is linked by an associative link to the concepts *'rsl'* and *'user study'*. When a user is in the context of *'writing rsl chapter'*, the concept *'rsl'* is much more relevant to the user than the concept *'user study'* but they are both targets of the same associative link. Consequently, the concept *'rsl'* has a higher weighted factor in the `HasTargetRelevance` weighted association. A general overview of the full extended RSL metamodel is given in Figure 5.8.

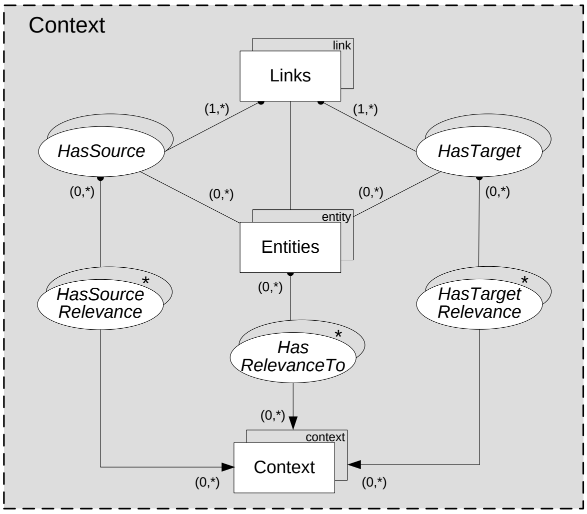


Figure 5.7: Integration of context

5.3 Implementation

After the introduction of the RSL metamodel and our extensions to it, a discussion of the implementation is given. Initially, the iServer implementation was done in OMS Java [49]. Besides this version, the lab was working on new version which is less bundled with a persistence database solution. When working on this thesis, we have encountered some issues according to the unfinished new version's implementation. Therefore, we have taken the opportunity to enhance this new version besides the needed functionality for the ILI framework. First, some issues concerning the architecture of the new version are given followed by the introduction of the OMS Java associations and our introduced weighted associations in this iServer version. Also some other implementation decisions are provided.

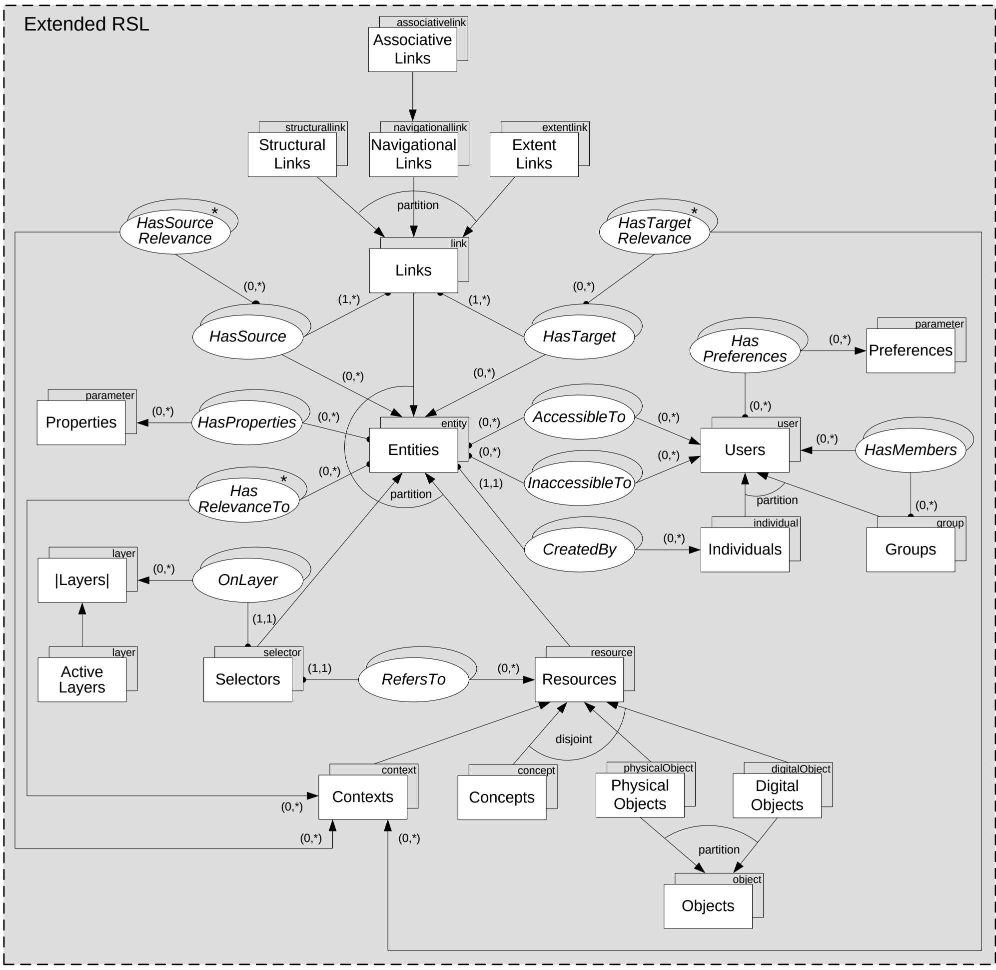


Figure 5.8: Overview Extended Resource Selector Link Metamodel

5.3.1 Contribution of the Improved Software Quality

The iServer façade provides all Create, Read, Update and Delete (CRUD) operations on the data model elements. On an implementation level, the iServer façade was designed as a static class. This has several consequences on the modularity and extensibility of the framework in terms of software quality. First of all, the client application needs to be "aware" of the state of the static class façade. If the façade changes its implementation, the client has no certainty that their application will still compile or run. This is a major concern since iServer is used and will be used in several applications. Furthermore, every extension of the RSL metamodel and its data model implementation needs to be supported in the iServer façade as CRUD operations. By the use of a static class, we need to "open" the class and add the methods for the extension. This means that applications using the iServer need to be recompiled because after an update they are not sure their code will still be faultless.

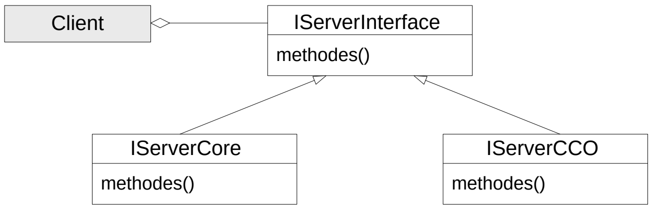


Figure 5.9: Strategy pattern

As a solution to this issue, we have implemented the Strategy design pattern illustrated by the UML diagram in Figure 5.9. The purpose of a Strategy pattern is to decouple the client from the actual implementation of iServer. A second feature of the pattern is the ability to switch between iServer versions without any additional effort required by the client. Since we provide two versions namely the core iServer version and a Context-Concept-Object iServer version (iServerCCO), the client can switch between these provided implementations by only instantiating the new version. The ability to switch between versions is twofold. On one hand, the client may decide dynamically to switch between the versions whereas the iServer may change the actual implementation without consequences for the client. A client can only accesses methods defined in the `iServerInterface`. This interface is then implemented by the two implementation classes `iServerCore` and `iServerCCO`. The forenamed concerns the implementation of the CRUD operations on the core RSL metamodel whereas the later concerns the implementation of the CRUD operations on the extensions done in this work.

Nevertheless, some well-known issues of the Strategy pattern raise in terms of software quality. The solutions are reflected in the adapted Strategy pattern shown in Figure 5.10. Because we do not know beforehand which additional methods for several extensions need to be included in the `iServerInterface`, we need to "open" this interface for each extension. As mentioned before, this may have consequences for client applications. Therefore, only the CRUD operations on the core RSL metamodel are provided by the `iServerInterface`. To assure the client that there will be no changes in this interface, we supertype the `iServerInterface` with an additional interface for each extension on the RSL metamodel. Hereby, the

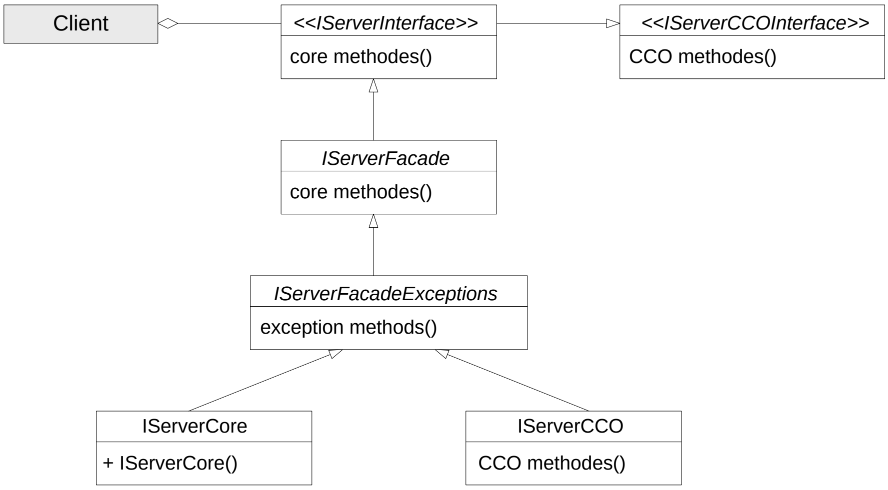


Figure 5.10: Adapted Strategy pattern

`iServerInterface` inherits these additional methods where the client does not have to be aware of these inherited methods only if they want to use them. For the iServerCCO version, we have supertyped the `iServerInterface` with the `iServerCCOInterface`. A consequence of the use of inheritance on the interface level, is that all implementation classes need to implement all methods from the additional interfaces. This leads to duplicated code of the CRUD operations on the core RSL metamodel for each extended iServer version. Of course, it is never good in terms of software quality to have this duplicated code. The problem is that if we change the implementation of one method concerning a CRUD operation, this needs to be done in every single extended iServer version. To overcome this problem, we have adapted the Strategy pattern with two classes. Since a version of iServer is mostly an extension of the core RSL metamodel, we can introduce an abstract class namely `iServerFacade` between the interface an its versions' implementation classes. This abstract class only implements the CRUD operations on the core RSL metamodel. All extensions need to inherit from this abstract `iServerFacade` and need to provide the implementation of the CRUD operations of their own extensions of the core RSL metamodel. In this way, when there is a change needed in one of the core CRUD operations, we simply need to change the implementation in the abstract `iServerFacade` and by inheritance it will be reflected in all implemented iServer versions. It is straightforward that the implementation class of the core iServer version (i.e. `iServerCore`) only contains a constructor. Nevertheless, an improvement needed to be done to let this design work. Because the introduced way of extending the interface by inheritance, these interfaces methods are pushed down to all versions. Every extension introduces the required implementation of these extensions in every implementation class of each version. But the purpose is to have only the version's-specific implementation in the relevant version class. When a client instantiates a specific iServer version, there is no need to provide access to all other versions-specific methods. That is why we use versions after all. By the introduction of the abstract `iServerFacadeException` class, we provide a way to prevent the mandatory implementation across versions whereby an exception is thrown to the client application when a non-included method is called in a specific instantiated version. It is only required by every extension of the core RSL metamodel to expand the `iServerFacadeException` class with its own methods throwing a unsupported exception.

5.3.2 Introduction of Model Elements

The adaptations in the new iServer version and its extension goes further than only architectural improvements. The new implementation of the RSL metamodel was unfinished on several aspects. Most CRUD operations where copied from the OMS Java version whereas at the data model implementation the identification of objects was done by defining a name field and OM associations where implicitly implemented by using object references. As we have seen in the RSL metamodel discussion, associations are language elements. These OM associations are bidirectional which is of importance in the context of links since the bidirectionality of links in RSL is imposed by the bidirectionality of the `HasSource` and `HasTarget` associations. This bidirectionally was missing in the new implementation of the RSL metamodel due to the fact that implicit associations in object references were used.

First, we have provided a persistent unique resource identifier for each instantiated element in the data model. By the use of a name attribute in the new implementation of the RSL metamodel, no guarantee could be given that two or more iServer versions would always provide a unique name for each object. Therefore, we have implemented a unique identifier in terms of a `long` attribute which is automatically set by every creation of each RSL metamodel object and the objects of its extensions. To accomplish this, a general abstract `AbstractRSLElement` class needed to be introduced where each stored data object need to be subtyped from. Nevertheless, several options where investigated but no cleaner solution was found to provide client applications of the iServer with a unique identifier for entities.

Secondly, we provide iServerCCO listeners for client applications. All methods concerning CRUD operations in the iServerCCO version fire notifications to the registered listeners. A client can listen to any specific CRUD operation on individual RSL metamodel elements or to CRUD operations on the whole iServer including all RSL metamodel elements. These listeners are also implemented for the iServerCCO version.

An iServerCCO-specific issue was the multiple inheritance of `Physical Objects` and `Digital Objects` by the `Resources` and `Object` collections. Multiple inheritance is allowed by OM and supported in OMS Java but not in Java. Therefore, we have implemented the `Object` collection as a subtype of `Resources` followed by subtyping `Objects` with `Physical Objects` and `Digital Objects`. An additional equivalent issue is raised at the non-included disjoint constraint between `Context` and other `Resources` subcollections. In the semantics of the model, a context may be defined by a concept, physical or digital object but it may also be defined in terms of a context itself. Additionally, a resource may be both context and one of the other three subtypes. Nevertheless, Java does not allow multi-typing of objects so we needed to adapt the mapping of the model with the implementation. First, a `onlyContext` type is introduced which represents the context when no other object (i.e. one of the three resource subtypes) is referred to as context. Next, to overcome multi-typing, an object reference to the referred object is included in the context object. We admit that this is not the best or nicest way to have the model implemented but Java does not provide an elegant way to use multi-typing.

Last but not least, we have introduced explicit associations and weighted associations in the new RSL metamodel implementation. The associations needed to be implemented as a first class object type in this new version since they are language elements in OM and where required for the introduction of weighted associations. To be able to do this we have adapted the existing odiCollection library by Signer which included the implementation of OM associations. By some small adaptations, these associations are now available in pure Java. Since associations are bidirectional, the Java version contains two hashtables namely the `domainCollection` and the `rangeCollection`. As seen in the modelling, an association has a startpoint (i.e. domain object) and a target (i.e. range object). When an association is made between these two objects, the `domainCollection` as well as `rangeCollection` are included with this new association to provide the bidirectional facet of the association. The `domainCollection` is expanded by the pair `(domain object, range object)` whereas the `rangeCollection` is expanded with the pair `(range object, domain object)`. If the hashtable already contains the key object, the value is added to this key. Note that it are the associations which provide the bidirectionality and that associations can only be made between members of participating collections in the model. The given code illustrates the signature of both hashtables.

```
domainCollection = new Hashtable<Object,Object>();
rangeCollection = new Hashtable<Object,Object>();
```

Nevertheless, this implementation of associations needed to be adapted for our introduced weighted associations in the extended RSL metamodel. A weighted association needs to define a weight between `0` and `1` on the relation between the domain object and the range object. A significant difference with normal associations is the notion that the startpoint (i.e. domain) can be another association. Therefore, a new type is introduced namely an `AssociationInstance`. This type includes two attributes, a domain and a range. We may see the similarity with normal associations where an instance of the association has a domain object and a range object. These objects are referenced by the `AssociationInstance` relevant attributes. Hereby, the weighted association may now have a normal association instance as its domain object. Nevertheless, when the domain object is not an association, the value of the range object in the `AssociationInstance` is set to null. A second challenge to be implemented is the introduction of a weight to the range object. This is done by interchanging the use of a hashtable in the parameters of `domainCollection` and `rangeCollection` which are similar to normal associations. The following code shows this interchange of a hashtable.

```
domainCollection = new Hashtable<AssociationInstance,Hashtable<Object,Double
    >>();
rangeCollection = new Hashtable<Object,Hashtable<AssociationInstance,Double
    >>();
```

In the `domainCollection`, the domain object is given as a key value which needs to be of the type `AssociationInstance` to allow normal associations as domain objects. To preserve the weight to a given range object, the value of the key becomes a hashtable with the range object as a key and the weight as a value. In this way, a domain object of a weighted association may have several range objects with each their weight factor. On the other hand, we could not just inverse the domain and range objects of a weighted association as done in normal associations to provide the bidirectionality. This would lead to a `rangeCollection` where each key is a hashtable of the range object with its weight to a domain object. In contrast, what we want is a `rangeCollection` where the range object itself is the key and that for each domain object the weight is given. This is done by setting the value type to a hashtable of `AssociationInstance` (i.e. domain) and the weight as value for the key range object.

Because of its complexity, we have provided the functionality of getting an ordered list of range objects with their weight for a specific domain object whereas getting an ordered list of domain objects with their weight for a given range object. To retrieve an ordered list of range objects with their weight of a specified domain object, the values of the domain object are retrieved from the `domainCollection`. Then this hashtable is ordered on the weight factor of each range from high to low by the use of a comparator object provided by Java. The code below illustrates this logic.

```
public LinkedHashMap<Object,Double> getOrderedRange(AssociationInstance
    domainObject){
     if(domainCollection.containsKey(domainObject)){
      Hashtable<Object,Double> x = (Hashtable<Object,Double>)
          domainCollection.get(domainObject);
      List<Entry<Object, Double>> list = new LinkedList<Entry<Object, Double
          >>(x.entrySet());
         Collections.sort(list, new Comparator<Entry<Object, Double>>(){
              public int compare(Entry<Object, Double> o1, Entry<Object,
                  Double> o2){
                  if (o1.getValue().compareTo(o2.getValue()) < 0){
                      return 1;
                  }
                  else{
                   if(o1.getValue().compareTo(o2.getValue()) > 0 || o1.
                       getValue().compareTo(o2.getValue()) == 0 ){
                    return -1;
                   } else{
                    return 0;
                   }
                  }
              }
         });
         LinkedHashMap<Object, Double> sortedMap = new LinkedHashMap<Object
              , Double>();
         for (Entry<Object, Double> entry : list){
              sortedMap.put(entry.getKey(), entry.getValue());
         }
         return sortedMap;
     }
     else{
      return null;
     }
    }
```

5.4 Summary

In this chapter, the ILI frameworks architecture has been elaborated. By introducing a layered architecture there is a separation of concerns imposed between the lower level “organisation” of the personal information space and the higher level of interactions with these stored information items in the personal information space. By providing both, the possibility to organise information items by associations and the possibility to rapid prototype user interfaces on these linked items, we overcome the gap between the communities in system design. Next, the first layer is discussed namely the link layer. This layer concerns the lower level functionality of linking all information items included in our personal information space which crosses the boundaries of physical and digital information items. This linking is based on the RSL metamodel which was elaborated together with the necessary extensions in order to fully implement the conceptual human memory model. In addition, some architectural improvements are provided for the new RSL metamodel implementation. Of course, our own extensions to the RSL metamodel are implemented besides the core RSL metamodel implementation. In order to be able to implement the extensions on the RSL metamodel, we also had to introduce weighted associations.

If a cluttered desk is a sign of a cluttered mind, of what, then, is an empty desk a sign?

Albert Einstein

6 Support for the Ubiquity of Information

After the introduction of the link layer, a closer look at the interaction layer can be taken. At the link layer information is everywhere and nowhere but how can we access this personal information? In this chapter we go deeper in on the provided interaction layer of ILI. An introduction is given followed by the architecture of this layer. Subsequently, additional features are presented and some developer guidelines are given.

6.1 The PIM Indirection Layer

As we have seen in the system requirements, it is not sufficient to provide only the ability to link information items. Although, our contribution at the link layer is of significant value for system design by introducing context relevancy on the level of information items and their relations to other items, it is not sufficient to fulfil the overall system requirements. Therefore, we have implemented an additional interaction layer on top of the link layer. The interaction layer makes several contributions as outlined in this chapter.

Due to the need to support all users' current behaviour in organisational and re-finding activities, we need to handle several user interfaces. In this chapter user interfaces are seen in a very broad perspective. A user interface serves as an access point to our personal information space. Our personal information space includes digital information items but also physical items. This imposes that user interfaces are not only digital but may be physical. For example, we may provide a digital user interface to interact with digital piles containing digital files. In the physical space, the user interface for physical piles is given by the pile itself. Since the pile provides us with access to its information items. The same may hold for digital and physical file systems. While the digital file system often has a user interface with a tree composed of folders and digital files, a physical file system's user interface is provided by a file cabinet with its physical folders and documents. In addition, the access to our personal information may be provided by augmented or virtual user interfaces. For example, we may augment a physical pile with a projection representing its contextual information or we may virtually walk through our information space by the use of a head-mounted display. Besides the categorisation of digital, physical, augmented and virtual user interfaces, we can categorise PIM user interfaces by their provided activity support. A user interface can be used for keeping, organising/navigating and retrieving personal information. Therefore, a PIM user interface may be one of the four first categories and provide support for one or several activities. It is of importance to see the opportunities of this variety of different user interfaces in the context of PIM. Our previously defined design principles give guidelines in the support for the current user organisational and re-finding behaviour. For example, in the support for digital piles, we may provide a tooltip for the containing digital files which give feedback on the annotations made in the file. This because of the observation that users use these annotations to re-find a file in the digital pile which is given by the design principle. Such a user interface may now be categorised as a digital user interface supporting a re-finding activity. Nevertheless, it may become much more complex when we take a look at an augmented user interface supporting both the navigation and re-finding activities. An augmented user interface may augment a physical pile. Here, the design guidelines for physical piles need to be considered.

We have observed that the main artefact to construct piles are unlabelled folders whereas contextual information is used to better re-find items in the piles. An augmented user interface may augment each containing physical document of an unlabelled folder with a projection of the contextual information. Besides the extra support for the re-finding activity, it also needs to provide a way to support the navigation activity. One could imagine that a user points to an unlabelled folder where then a projected version of the content in the form of a pile is given on top of the physical folder. By a slide gesture, the user may now navigate through the projected version of the papers forming part of the pile.

As illustrated above, a PIM system needs to provide the functionality to handle all these different user interfaces. Additionally, our contextual keeping, organising and re-finding theory, indicates that all activities performed in a personal information space are context dependent. Therefore, we provide the ability to define a context relevance factor for information items and their relations. This context relevancy and the context dependency of all three activities gives even more opportunities on the user interface level of a PIM system. A PIM system may include different user interfaces for a given context and one user interface may represent different information depending on the users current context. For example, the augmented physical pile user interface may be adapted for a specific context. If the unlabelled folder contains confidential personal information and the navigation activity takes place in the context of a meeting, the projected version of the folders content may not be the best solution. An adapted version could be provided where the user is guided through the folder with a displayed digital version on their smartphone. On the other hand, an augmented user interface of the physical folder may change its representation based on a user's current context. Since we provide context relevancy on information items and their relationships to other items, we may reflect this in the augmentation process. While the projection was initially just a copy of the physical folder as a pile, we may now first display the most relevant papers included in the projected pile for the users current context. Besides the previously introduced categories of different user interfaces and their support for PIM activities, a PIM system also needs to offer the context-awareness of these user interfaces.

Furthermore, the personal information space may include copies of the same information item which may be organised in different organisation strategies (i.e. pile, mixtures, files). To make it even more complex, by the introduction of concepts in the link layer, several information items could be needed out of different organisational strategies. The above examples illustrated possible user interfaces to interact with these organisational strategies (i.e. augmentation of physical piles). Often users may want to be reminded of these duplicated information items. An example might be that we are reading a book paragraph with a quote out of a paper which we have stored in an unlabelled folder. It could be convenient to indicate this to the reader by projecting an arrow to the folder. But also when one is navigating via a digital user interface in the presented linked graph of the personal information space, the user may want to be reminded where the information item really is across the different organisational strategies.

All these user interfaces and their need to support the PIM activities, lead to the extension of the link layer with an interaction layer. This interaction layers major concerns are the following:

- Providing the possibility to integrate an unlimited amount of user interfaces.
- Handle the contextual state of a user and inform all user interfaces about this state.
- Identify a user's imposed PIM activity (i.e. keeping, organising/navigating or re-finding).
- Coordinate the use of an information item across user interfaces to reflect the use in different organisational strategies.
- Abstract the complexity of the link layer for fast prototyping.

The first four concerns are already introduced by the above examples. Nevertheless, we have experienced the complexity of the presented link layer when implementing proof of concept user interfaces (see Chapter 7). Due to all the distinctions between link types and resources, the implementation of applications using the link layer may become time consuming and complex. The link layer's interface assumes the knowledge of the RSL metamodel and its extensions. In the context of our future PIM research which would use the ILI framework as a basis for user studies, this complexity and the need for knowledge of the underlying link layer is not the best solution. Therefore, the interaction layer also provides an abstraction of all the link layer's concepts where a developer does not need to be fully familiar with the underlying introduced concepts of the RSL metamodel. A detailed discussion of this abstraction is given in the next section on the implementation of the interaction layer.

6.2 Implementation

After an elaboration on the purpose of our interaction layer, implementation-specific decisions are now discussed. The challenge we have faced is to include all the above mentioned concerns by keeping the interaction layer's functionality as general as possible. We aspired generality because of future extensive use of the ILI framework in several interaction evaluations and specific directed user studies. If we would have hardcoded all the necessary functionality for the proof of concept implementations, we would have thus thrown out the good with the bad.

6.2.1 Interaction Layer Architecture

To achieve all previous concerns, we have used the notion of individual components each with their responsibility and a plug-in mechanism for the user interfaces. The interaction layer's architecture is shown in Figure 6.1. This layer is constructed out of three components including a `PIM` component, a `UI` component and a `General UI calls` component.

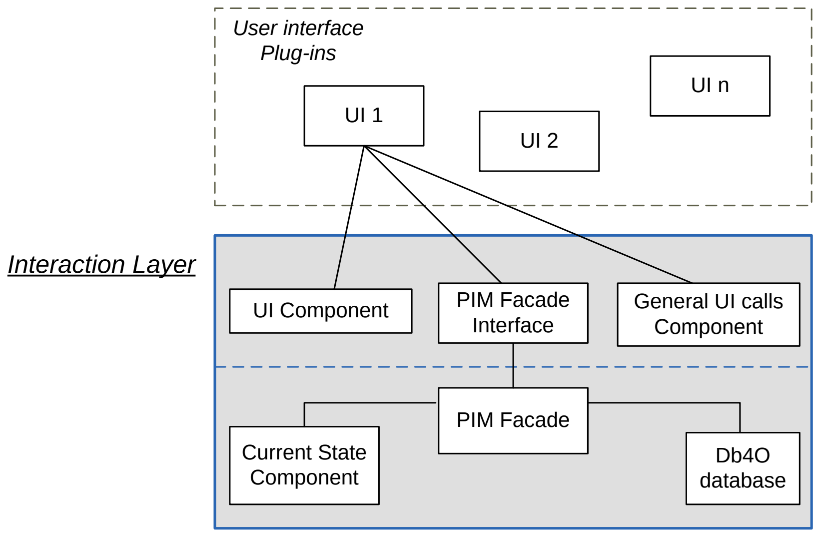


Figure 6.1: Interaction layer architecture

The core component of the interaction layer is the `PIM` component. This component includes the functionality to access the underlying iServer and more PIM specific operations such as ordered lists of elements for a specified context. Besides this, it also provides an abstraction for linking elements. The `PIM` component uses a `Current State` component to provide current state information to the UI plug-ins. The `Current State` component is responsible for keeping the state of the users invoked PIM activity (i.e. keeping, navigating/organising or re-finding) and its current context. This was necessary because of the need to provide different user interfaces for these PIM activities and for different users contexts. Although the user's current state is provided via the `PIM` component to the UI plug-ins, in terms of software quality it is better to decouple the `PIM` component and the `Current State` component. In this way, the `Current State` component may be easily replaced or extended in the future. Furthermore, persistence is provided for this `Current State` Component as well as for UI plug-ins. On the implementation level, the `PIM` component is designed with a Strategy pattern to provide future reusability and easier maintenance. The `IPimCore` interface also acts as a façade to the functionality of the underlying iServer and to the `Current State` component. To provide data consistency between all UI plug-ins, several listeners are implemented. Each UI plug-in may listen to state updates in the `Current State` component, to CRUD operations on the underlying iServer and to focus events on iServer objects. These three listeners make it possible that each UI plug-in can adapt itself for a given context, a switch in PIM activities and may update their feedback to the user when a CRUD operation is invoked by other UI plug-ins. Also by providing a focus listener, each UI plug-in may set its focus to the object which has focussed by another UI plug-in. For example, the user may set the focus to a digital file in the file system where all other UI plug-ins are notified of this focus. Now a UI plug-in which provides the navigation via a graph may set the focus on the digital file node so that the user does not need to search for it when switching from the digital file system to the graph interface.

The `UI` component provides the functionality to register a user interface which can then be used by other user interfaces. By registering the user interfaces, a user or developer has the freedom to select active user interfaces in certain situations. As shown in the previous section, a PIM system may include an extensible amount of user interfaces. Different users may need different user interfaces because their current behaviour is defined by the degree of use of the three organisational strategies in both spaces (i.e. digital and physical). Hereby, a PIM system needs to provide different user interfaces for each of these strategies whereas at the same time different user interfaces for the degree of use in a strategy. Nevertheless, the system needs to allow a user to configure the user's current organisational behaviour (this can also be done automatically). Besides the customisation, it is also responsible for the plug-in mechanism for all user interfaces. Note that the concept of a user interface is very broad. This means that plug-ins are components which allow users to interact with the underlying linked personal information space whereas they may be modules which automatically apply CRUD operations on this information space. For example, a plug-in may be just a digital user interface to navigate through the linked graph of personal information. A second plug-in may be monitoring a physical desk which creates a resource when a new paper document is detected. We make no distinction between these plug-ins as they all apply CRUD operations on the personal information space. In this way, a user or developer gets all the freedom to determine which user interfaces (automatic or visual components) are being used at a given time. Implementation-wise, all UI plug-ins need to extend from the `Frame` class. The `Frame` class requires to give the UI plug-in a name and requires the implementation of the three PIM listeners. Furthermore, the registration of the UI plug-in is programmatically done for each UI plug-in whereas a reference to the `PIM` component is given for all subclasses. Now the UI plug-in may use the `IPimCore` interface to access its the functionality as explained above. In addition, the `General UI calls` component provides commonly used calls by UI plug-ins such as opening documents or scaling of PIM elements icons.

6.2.2 Additional Functionality

We have observed that only forwarding the link layers functionality to UI plug-ins via the `PIM` component is not the most efficient way for developers. The underlying iServer interface namely imposes good knowledge of the used RSL metamodel. Also our extensions made to this RSL metamodel, impose a detailed understanding of all different link types and the context integration via weighted associations when implementing UI plug-ins. This may not be developers friendly, in particular for the fast prototyping of PIM user interfaces. Therefore, we provide an abstraction of this complexity to the UI plug-ins via the `IPimCore` interface. UI plug-ins may just use the `linkResourceTo()` method to link the specified resource to other information items in a specific context. The method signature looks as follows:

```
public void linkResourceTo(Resource entitySource, Context context, HashMap<
    Context,Double> contextTargets, HashMap<Concept,Double> conceptTargets,
    HashMap<org.st.iserver.Object,Double> objectTargets, double linkWeight,
    String linkName) throws CardinalityConstraintException
```

The `resource` parameter includes the resource which need to be linked whereas the `context` parameter indicates the context in which the link has relevance to. Note that there is a difference between the `context` parameter and the `contextTarget` parameter. The `context` parameter determines the context of all links which will be created between the resource and its targets whereas the `contextTargets` define to which other contexts the resource item has a relevance. Because of the distinction of associative links and extent links, a distinction between targets of the type `Concept` and `Object` needs to be set. All target concepts and objects need to be placed in the relevant hashmap with their relevance weight to the `context` parameter instance. Besides the relevance weight of the associations between the target item and the link, the link itself may also have a specified relevance to the `context` parameter instance. Note that it is not mandatory to define relevance weights to a context for all targets and the link. In this case, the relevance weight will be set by default to a value of 0.5. Since we provide this abstraction method, a UI plug-in just needs to construct the needed parameters but does not need to create the different link types itself.

In addition, the `UI` component provides a `PimFile` type. This object type may be used in the same way as the normal `File` type in Java. A major difference is that the `PimFile` contains an object reference to a resource object stored by iServer. By providing such a `PimFile`, developers may easily integrate all resource subtypes in the digital file system or desktop. For example, concepts and physical objects may be integrated in the digital file system by drag and drop from another user interface.

A last important feature is the possibility to define context relevancies to a person's perception. By allowing the user to define how important a specific context is to their daily work, we may provide an ordered list of defined contexts with always the most relevant ones on at the top. This is done by introducing a root context where each created context needs to set its weight or importance relevance to this root context. A specific usage of such daily importance may be seen in providing the user with only the relevant context objects and their subgraph of weighted linked information items based on their scheduled activities. Each activity would then be defined as a context and may be ordered by importance or the weight to the root context may indicate the order in which these contexts need to appear.

6.3 Summary

In this chapter, we have elaborated on the interaction layer of the ILI framework. The interaction layer serves as an indirection between the underlying iServer and the user interfaces. First of all, we gave a brief explanation of the purpose of this layer. A PIM system needs to handle several interfaces for each current organisational behaviour. These user interfaces may each support all or partially keeping, navigation/organisation or re-finding activities. Besides the need to handle an unlimited amount of user interfaces, a user's current context and PIM activity needs to be reflected in all these user interfaces. Additionally, users need to be able to configure these user interfaces by their current organisational behaviour profile. To make all this possible, a user interface is seen as plug-ins which is registered to the `UI` component. The PIM component then takes care of all notifications when current state events or iServer events are invoked. Also focus notifications on iServer objects are provided across UI plug-ins. Furthermore, UI plug-ins may use the PIM component to apply CRUD operations to the underlying link layer. Nevertheless, linking resources may become complex and knowledge of the underlying RSL metamodel is required. Therefore, an abstraction method is provided which simplifies the rapid prototyping of new instances.

Good books don't give up all their secrets at once.

Stephen King

7

Examples of PIM User Interfaces

Last but not least, in this chapter we present a developer user interface and two examples of augmented current organisational behaviour strategies. These user interfaces give a proof of concept for the ILI framework. They also provide an example on how a developer may apply our design principles and integrate the contextual dependency of keeping, organising and re-finding activities introduced by our theoretical model in user interfaces. A developer user interface is implemented which should make it easier for developers to explore the data in iServer and to apply CRUD operations on these objects. After a demonstration of the provided developer user interface, both additional user interfaces are further discussed. We have implemented a context-aware desktop to augment the digital piling organisational strategy. Secondly, an augmentation of physical piles in bookcases is implemented via the use of LEDs. Note that we do not provide an evaluation of these user interfaces. The common evaluation technique for PIM system prototypes is a longitudinal user study over a time period of a few months. We may not evaluate an organisational strategy in terms of a single observation since the evolving nature of these organisational strategies. Due to the limited time span of this thesis, it was not possible to conduct such longitudinal user evaluations.

7.1 Developer User Interface

In the ILI interaction layer we already introduced a method (i.e. general link method) which hides the complexity of the extended iServer version and may be used instead of the explicit creation of different link types. Nevertheless, debugging a UI plug-in can be hard. Developers may want to explore the iServer database to verify the CRUD operations on iServer objects. For example, if the developer has written a user interface which invokes CRUD operations, they may want to check the stored instances. By the broad view on user interfaces, a user interface may also only provide a reflection on iServer objects. In this case, the developer needs to be able to apply CRUD operation via another user interface or hardcode them for testing. Our own experience shows that there was a need for a developer-friendly environment which makes verification, debugging and isolated user interface development easier. Specially in rapid prototyping, it can be an overhead for a developer to manually create different links and so on. Therefore, we have implemented a developers environment where a developer may navigate throughout the whole iServer database including information items and different link types. In addition, the environment allows developers to apply CRUD operations on this data.

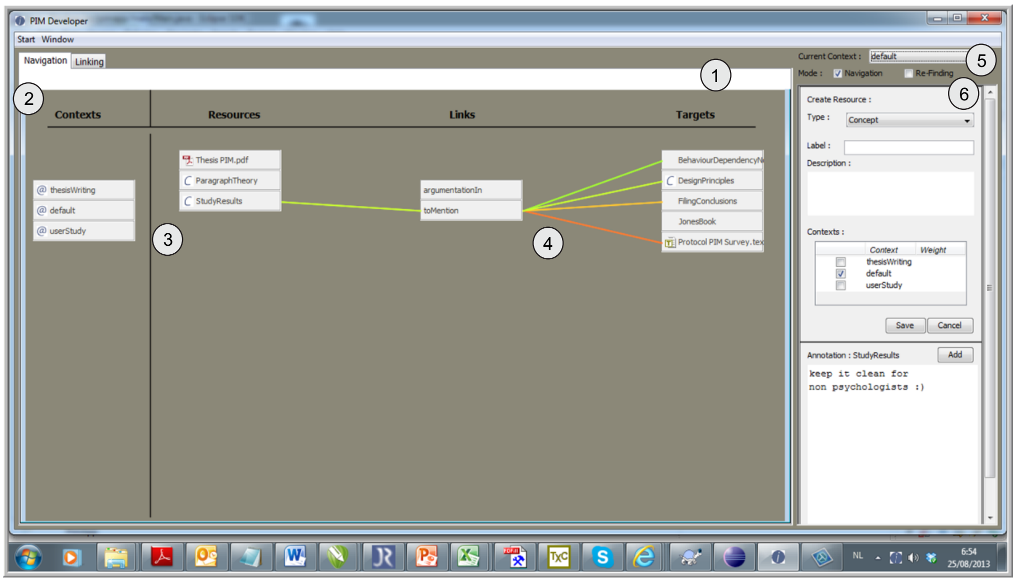


Figure 7.1: Navigation window of the developer user interface

The navigation window allows developers to explore the iServer database. Figure 7.1 (1) shows the navigation tab in our developer environment. The navigation tab consists of four columns (2). On the left-hand side, all defined contexts are given where the focus is set on the current context when opening the environment. All contexts are decreasingly ordered by their relevance weight to the root context. Next to the contexts, resources are given which have a relevance in the selected context. Note that in our extended RSL metamodel resources may have a relevance weight for a specific context as well as links and their associations. Therefore, the resource column also includes the source objects of links which are of relevance in this context. These links are then given in the next column with all target objects in the target column. Resources, links and targets are all decreasingly ordered by their relevance weight in the selected context except for those source objects of relevant links with no explicit relevance weight. These source objects are appended at the end of the list of resources which have an explicit relevance weight in the specified context. Furthermore, each entity type has its own icon. Digital objects have their format icon as used by the operating system. Context, physical objects and concepts have each an icon to indicate their resource type. To navigate between the four columns and inside a column keyboard arrows may be used. When a context is selected, the relevant resources, links and their targets are displayed together with all associations. On the left-side of each link, all `HasSource` associations are drawn by a line whereas at the right side of a link all `HasTarget` associations are explicitly shown (4). Nevertheless, both associations may have a weight factor for the context where we are navigating in. This weight factor is indicated by colouring the associations from green to red (i.e. high to low weight). When a user selects a resource, all `HasSource` associations are displayed with the relevant links as sourcepoint and the `HasTarget` associations are drawn for these links (3). Thereby, if the resource is not a source of a link, no associations are displayed. Next, when selecting a specific link, all associations between the selected link and its sources as well as its targets are drawn with their appropriate weight colour. At last, one may select a target object. In this case, all associations to links which have the target object as target are drawn whereas all `HasSource` associations of these links to their source objects.

External to the navigation tab other functionality is provided. In the right upper corner, the current context may manually be changed and the PIM activity (i.e. navigation or re-finding) can be chosen (5). Figure 7.3 (1) shows the switch from the *'default'* context to a *'thesis writing'* context. By allowing the developer to set the current user's context and selecting a PIM activity, they may verify if their UI plug-in reflects these changes. A second feature are dynamic panels shown in Figure 7.1 (6). Since developers often implement independent components or functionality, it is useful to provide the ability to design small visual panels which provide some specific functionality. Our developer environment includes three such panels namely a create resource panel, an annotation panel and an info panel. Panels can be set visible on the right-hand side by selecting them in the window menu shown in Figure 7.2 (1). An annotation panel provides the functionality to annotate any resource object managed by iServer (2). When an annotated resource is selected, the previously added annotation is shown. We have used this annotation panel in the context-aware desktop interface to provide annotations on resources. Secondly, the info panel shown in Figure 7.3 (2) displays additional information about a selected resource such as its id, type and in which other contexts the resource is relevant.

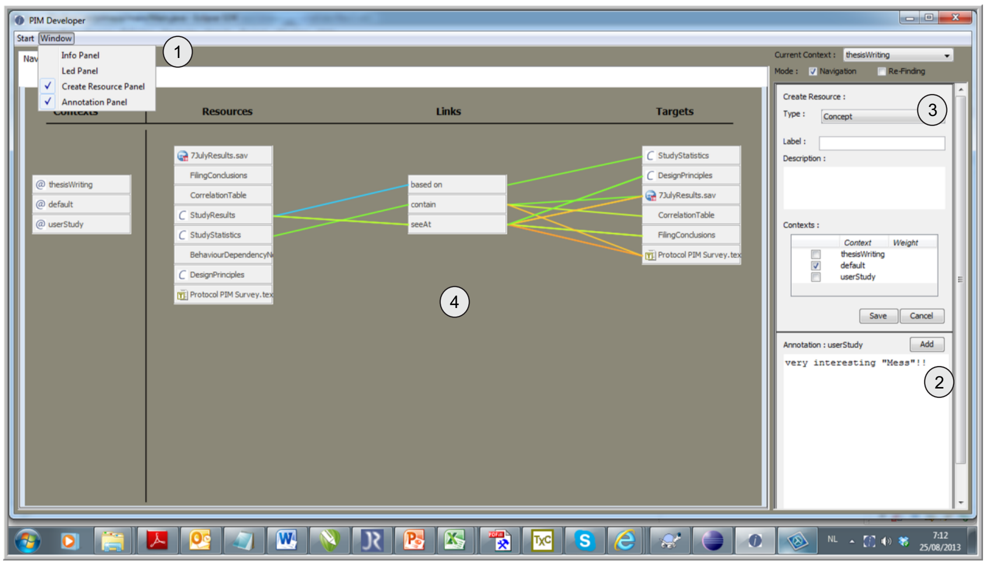


Figure 7.2: Dynamic panels

The create resource panel as illustrated in Figure 7.2 (3) is of more importance to the developer environment. In this panel, developers may create objects of the type context, concept, physical objects as well as digital objects. By selecting the desired type, the panel adapts itself and shows the needed information to create the object. To create a concept, physical object and digital object, one needs to enter a label and needs to select the contexts to which this new resource has a relevance with a weight between 0 and 1 for the selected contexts. By default a new resource is given a relevance of 0.5 to the default context. This default context allows users to create resources and link them without having to explicitly classify them in a specific context. Users do not always know the relevance of an information item for a future task or context in a keeping activity. Hereby, this default context can be used as temporal storage for resources or linked resources. Nevertheless, to import a digital object in iServer, we provide a file system view where specific digital files may be selected. The label of the new digital object will be set to the digital file's short path name. In order to create a context, a different panel view is given which is illustrated in Figure 7.3 (3). In addition to the view of other resources, the possibility is given to set the relevance of a new context to the root context. Note that our navigation view is not the best way to visualise a large amount of linked resources let alone linked links. As shown in Figure 7.2 (4), displaying all `HasSource` and `HasTarget` associations may result in a chaos. Future research needs to be done in the direction of visualising a large semantic graph where associations are explicitly carrying a relevance factor to a specific context or more contexts. It is out of the scope of this thesis to come with a user-friendly visualisation solution.

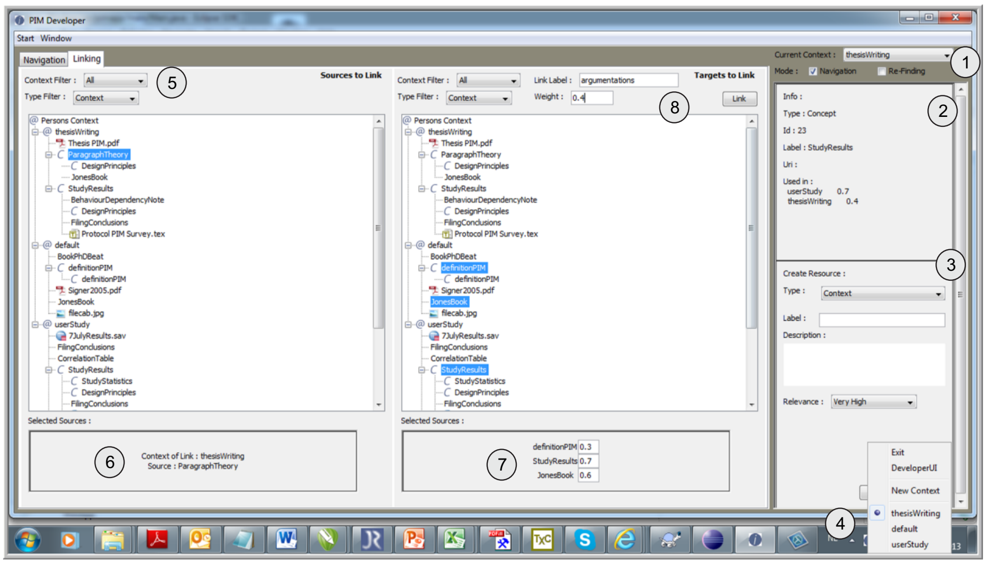


Figure 7.3: Linking resources in the developer user interface

Besides a navigation interface, we also provide a link tab which allows to link information items or resources in a visual manner. Figure 7.3 shows the link interface. The link tab is divided into two compartments namely a source panel (5) and a target panel (8). Both panels display all linked resources in a tree-like structure with the root context as root followed by all contexts in a decreasing order. Each context has its relevant resources as children whereas each child has its linked resources as children. To provide a user with more flexibility in finding the desired resources, two filters are implemented. A context filter allows a user to display only a subtree by selecting a specific predefined context. The second filter allows to filter the general tree or a context subtree by the type of a resource. In this way, a user may already filter out all irrelevant resources in their search process. In order to create a link, a user first needs to select a resource in the source panel tree where then the selected resource is shown in the selected resource area (6). Next, targets may be selected in the target panel on the right-hand side and are displayed in the target selected area (7). In this area, each resource may be given a weight between `0` and `1`. This weight is the relevance weight of the `HasTarget` association between a link and its target object to the current context object (i.e. in this case *'thesis writing'*). At last, a link may be given a label and its own relevance weight to the current context (8). Note that it is not mandatory to give a link a label. When a label is left out, a developer may always retrieve the link object out of the iServer by its id. In the background, the appropriate links are created according to their type by the use of the abstract `linkResourceTo()` method in the `IPimCore` interface (see Chapter 6).

Additionally, a system tray is provided to exit the PIM system and to show/hide the developer environment (4). A user may also create and select a current context in this tray. Some implementation remarks should be mentioned. First, we had a hard time to translate the graph of linked resources to a tree-like structure. Due to the occurrence of infinite loops between linked resources, it is not possible to create a tree data model in advance. Consequently, each CRUD operation on resources and links implies the instantiation of a new tree data model which is restricted to two levels of depth. Each time a user selects a node in the tree, the next two levels are instantiated. Unfortunately, this approach results in a slow rendering of the `JTree`. Secondly, we have used layered panels as offered by Java for the navigation tab in order to be able to overlay the content panel with a glass panel to draw the associations. This has forced us to place an undecorated `JFrame` in the tab as main panel which may be not the best option.

7.2 Example One: Context-Aware Desktops

Now that the underlying technology of our ILI framework is introduced, we can present a first application. Context-aware desktops augment the digital piling organisational strategy. Let us first take a look at issues which users encounter on a digital desktop. Often users have a desktop full of digital files with some contextual grouping as shown in Figure 7.4. We may identify several groups of digital files as indicated by different colours. For example, the green area contains files related to our extended RSL model, the orange area includes files related to our user study, the purple area covers digital files concerning the theoretical model and the uncoloured areas indicate non-associated digital files. Nevertheless, after a while, we may forget the constructed contextual groups on a desktop.

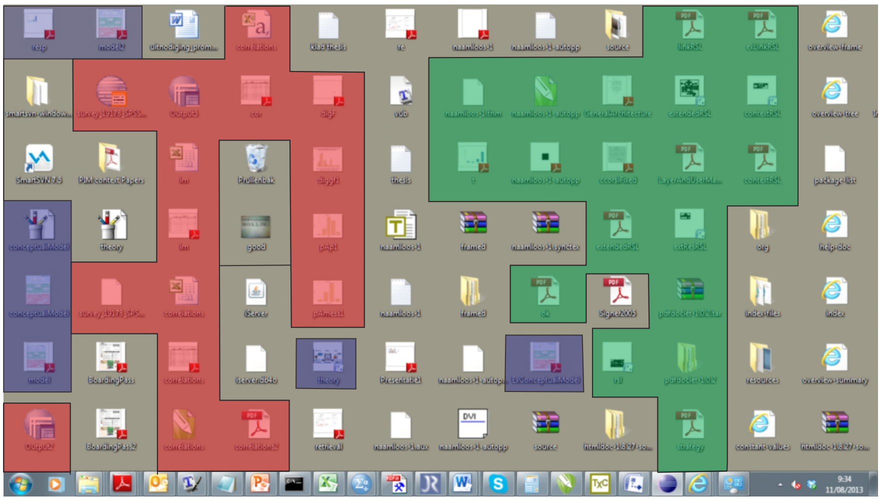


Figure 7.4: Organisation of a digital desktop

To augment digital piles, we first need to recapitulate on our design principles. The principles show five observed behaviour elements which serve as a guideline in the design of our context-aware desktops.

- Contextual hints need to be provided.
- The labels of the included information items are important in re-finding.
- Annotations are a well-used artefact for re-finding and reminding.
- Users annotate more frequently digital content with physical annotations besides digital annotation.
- Frequent access of the digital file system.

As seen in the above illustrated desktop, contextual groups are created. Our design principles indicate that users actively use this contextual information in re-finding a digital file. Context-aware Desktops is mostly based on this principle. The overall concept is to allow users to switch between desktops depending on their current context. Each desktop contains its relevant digital files. For example, each identified group in the above desktop can be placed in its relevant context of *'extended RSL model'*, *'user study'* or *'theoretical model'*. Furthermore, we need to keep the possibility to label a digital file and annotations may need to be integrated in the search functionality. Furthermore, we need to take into account that users often access the digital file system. Finally, digital as well as physical annotations are extensively used when using digital piles. This last principle is not included in the overall design because of its extensive implementation effort with third-party applications.

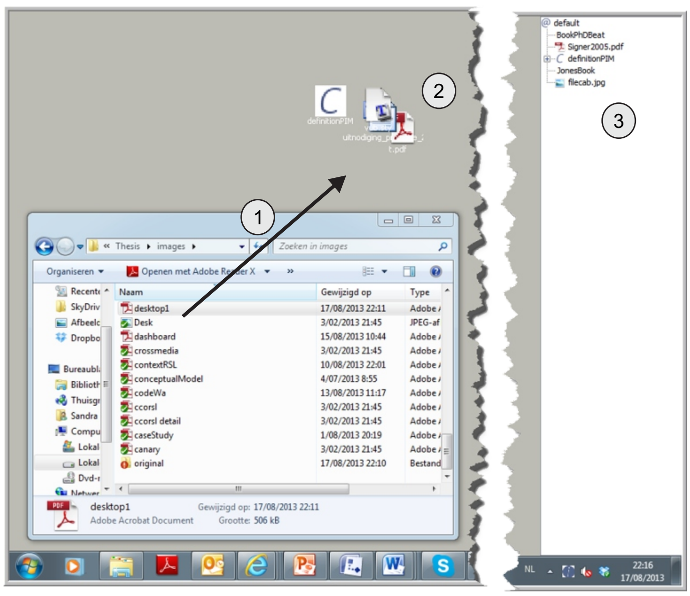


Figure 7.5: Drag and drop on a context-aware desktop

Our context-aware desktops replace the old desktop screen with dynamic context-aware desktop transparent frames. For each defined context in the developer environment or via the system tray, a new desktop is instantiated. Note that a user may only interact with the desktop related to their current context and only one desktop is shown at a time. Furthermore, each desktop has a sidebar with the context subtree as previously elaborated in our developer environment and which is shown in Figure 7.5 (3). This sidebar allows to easily drag and drop any resource type which is relevant to this context in the desktop. Additionally, users may drag and drop digital files from a digital file system on the displayed desktop shown in Figure 7.5 (1). The inverse can also be applied where digital objects may be dropped back into the file system. Since the frequent access of the file system indicated by our design principles, a user may now easily interact with both organisational strategies by just dragging and dropping digital files in both ways. To provide annotations in the re-finding activity, a user may right click any resource on the desktop which will then show the previously created annotation and the possibility is given to update or delete an annotation. Finally, users may easily group resources together and construct digital piles (2). In a lot of current operating systems such virtual piling is not allowed by their implied grid layout and leads to the grouping behaviour illustrated above.

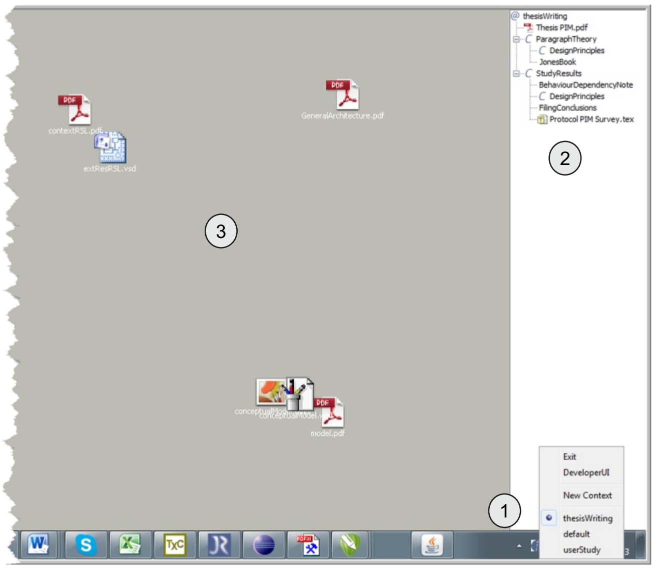


Figure 7.6: Spatial arrangement of digital piles

When switching the current context in the tray shown in Figure 7.6 (1), the desktop of the new context is given with the previously dropped resources in it. The sidebar is also adjusted to the new current context subtree (2). In contrast to current desktop use, a user may also construct a spatial arrangement of digital piles (3). The idea to provide the functionality of such a spatial arrangement comes from the use of spatial cues in the physical piling organisational strategy. In physical space, users use spatial cues to re-find information items in piles. By providing the same functionality in digital space, a user may improve the effectiveness of re-finding activities by using spatial cues.

Implementation-wise, we have faced some challenges to provide dynamic desktop frames and drag and drop functionality. Java provides a Swing library for normal standard user interface development. Nevertheless, our desktop frames do not fall in this category of user interfaces. To accomplish the undecorated transparent frame, we had to set the opacity to almost zero (but not to zero as expected). Swing does not allow full opacity on undecorated frames since it implies an invisible frame. This security mechanism costed us quite some overhead to discover. Furthermore, one of our goals was to provide virtual digital piles by placing one resource on top of another. Therefore, the frame could not have one of the predefined layouts provided by Swing. Due to this empty layout, a lot of trivial rendering mechanisms such as repainting a component did not work anymore. For example, we had to reimplement the painting method for our `JLabels` used to visualise the dropped resources in the desktop frame and repaint them manually after every change in the container. Furthermore, we needed to extend the provided drag and drop mechanism because of the use of `PimFile` types which contain an object reference to the resource object. In this drag and drop extension, labels for the imported resources need to be manually positioned and repainted due to the use of empty layouts in desktop frames.

7.3 Example Two: Re-Finding Books by the Use of LEDs

A second example of a PIM user interface is the augmentation of physical piles in a bookcase. Out of our user study it turned out that users have a significant amount of physical piles in bookcases. Nevertheless, the design principles indicate the use of a spatial cue as one of the most applied cue in re-finding activities. This spatial cue may not be applied for physical piles in bookcases due to the limited space of a bookcase. Often piles are placed next to each other in a linear way. Additionally, the results mention a rare access time of these bookcase piles in contrast to desk piles which are accessed on a frequent basis. Based on the finding that cold information is stored in file systems whereas hot information is be stored in piles, we may say that the less users access information items, the more organisation there need to be. We observe an issue in re-finding information items in such bookcase piles as they are used for cold information and lack the spatial arrangement of desk piles. Therefore, we augmented a bookcase with LEDs. Each LED is allocated to a pile in our bookcase as illustrated in Figure 7.7.

For an proof of concept implementation, we left out the actual document tracking with which the PIM system could automatically allocate an LED to a physical document. At the moment the user needs to explicitly allocate

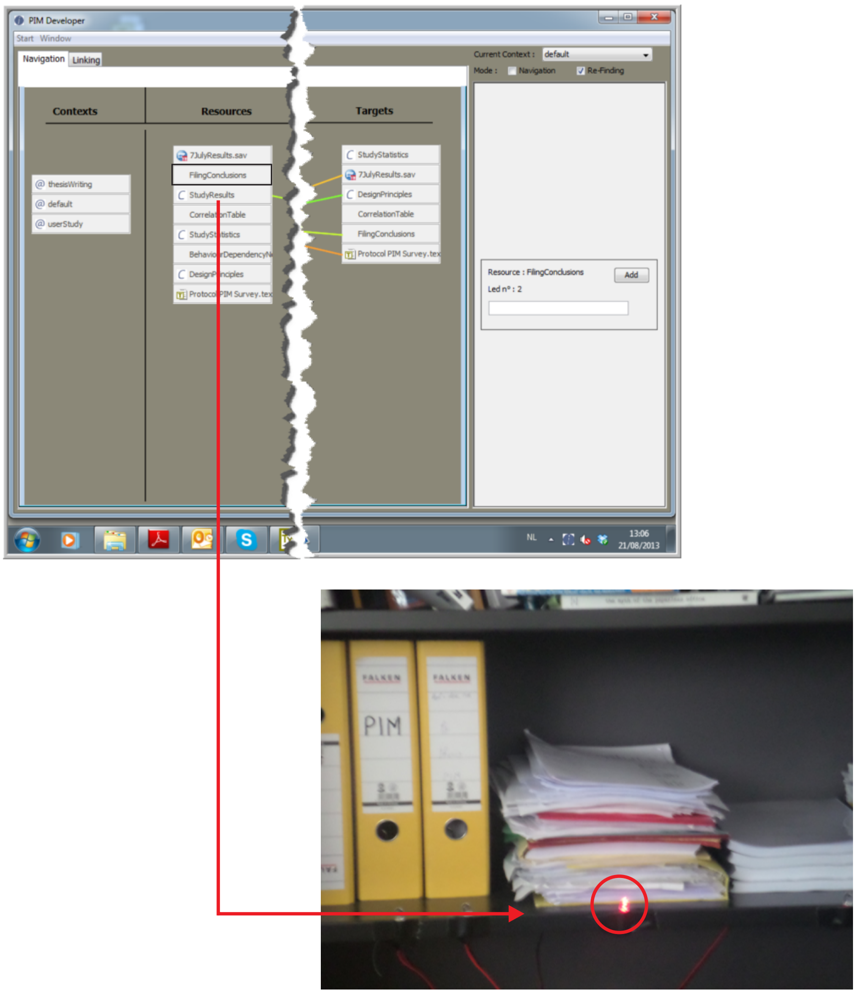


Figure 7.7: Augmented bookshelves with LEDs

the pile LED to the physical document via the LED panel in our developer environment. Once a physical resource is made and the resource is allocated to the LED, a user may place the physical document in the relevant pile. By selecting the physical resource in the navigation or link interface in our developer environment, the LED in the bookcase will be enlighten. Nevertheless, it will only be illuminated if the user is performing a re-finding activity but not if they are just navigating. Otherwise, the bookcase would light up too many and to often LEDs with no purpose if the user is not searching for the physical document at first.

7.4 Summary

We have provided a developer visual environment and two user interfaces as a proof of concept. The developer environment's goal was to allow developers to easily verify, debug and apply CRUD operations on iServer objects. We have implemented a navigation and link interface with their respectively functionality. Besides these interfaces, developers may implement small GUI panels for specific needs and add them to the dynamic panel area. Furthermore, we have presented the context-aware desktops application where desktops are changed when switching a users current context. Additionally, users may easily drag and drop between the context desktop and the file system as well as between the context desktop and the context subtree in the sidebar. Last but not least, a bookcase has been augmented with LEDs to improve re-finding activities in physical piles stored in a bookshelf.

Have you figured out the head fake?
It is not how to achieve your dreams,
it is how to live your life!
–The "Last Lecture", Randy Pausch

8 Conclusions

We started with a brief introduction to the human memory from a psychological viewpoint followed by an elaboration of past descriptive research in Personal Information Management. In a next chapter we presented our user study resulting in the definition of mixing as a third organisational strategy besides piling and filing. In addition, we defined a number of design principles for each organisational strategy in the digital as well as the physical information space. By combining the previously gained knowledge, we extended the keeping, organising and re-finding theory with a contextual factor and a conceptual model for an organisational structure imposed by the human memory. Furthermore, current PIM prototypes were evaluated based on our obtained implementation requirements. We then introduced our Information Linking and Interaction (ILI) framework which successfully implements all the requirements. Last but not least, a proof of concept implementation of two user interfaces dealing with the augmentation of digital and physical piling was provided. After all these contributions, we now provide a discussion of the presented work and conclude with some future opportunities regarding PIM system design in cross-media information spaces.

8.1 Discussion

After a better understanding of current organisational and re-finding behaviour, we have identified an additional organisational behaviour strategy that we call mixing. Past descriptive research in physical as well as digital information spaces enquired the two organisational strategies of piling and filing defined by Malone [51]. In a filing strategy, information items need to be explicitly labelled and ordered (e.g. file cabinet). A disadvantage of filing is the fact that users experience cognitive overload, they need to do some extra effort and they have to spend time when filling away an item. On the other hand, piling is constructing piles of information items. In contrast to filing, the information items in a pile may not be explicitly ordered and the pile itself may not be labelled (e.g. pile on a desk). Piles have a disadvantage in re-finding when the amount of piled information increases or when the piled information items are not used for a long time. Nevertheless, our user study showed the existence of mixing which we defined as an organisational strategy leading to mixed structures. A mixture includes everything else than piles and files. An example of a mixture are labelled ring binders where the content is not explicitly ordered or partly ordered. According to our user study findings, users apply this mixing strategy on a moderate level in both information spaces in addition to the use of piles and filing systems. Our findings also illustrate the independency of all three organisational strategies (i.e. piling, mixing and filing) within an information space and no dependencies have been found between the digital and physical information space. Hereby, a user's organisational behaviour is identified by the combination of the degree of use of each organisational strategy in both information spaces. This is in contrast to previous research findings where researchers classified users as pilers or filers depending on the mainly used organisational strategy. Because of the independence of all organisational strategies, it is reasonable to argue that not all users can be classified in these two categories. For example, users might have a lot of piles and a lot of files at the same time. By defining a third organisational strategy and by proofing their independence, new opportunities are given to descriptive research to better understand a user's current organisational behaviour. Nevertheless, this might also have consequences for some earlier research findings. The internal validity of some descriptive enquiries might decrease to a significantly lower level. This can, for example, be observed in the study of Henderson [35] where a K-means cluster analysis is done with six questions which resulted in clusters of pilers and filers. However, we have now shown that this clustering might not be valid for some users. Finally, we have translated additional study results in design principles to bridge the gap between descriptive research and PIM system design. By the independence of organisational strategies within and across digital and physical information spaces, each organisational strategy in digital and physical space can be seen as a separated subject matter. Therefore, we defined individual design principles for each of these subjects. By doing so, developers of PIM systems have a clear understanding of which elements need to be included to support and aid current user behaviour. The scientific contribution of our design principles is the better understanding on how users pile, mix and file information items and which hints they use to re-find this information when using a specific strategy. Additionally, the broad research context which crosses the boundaries of digital and physical information spaces significantly contributes to the descriptive PIM research field. The generalisation to cross-media information spaces has not yet been observed by previous related descriptive research in organisational and re-finding behaviour.

A second contribution is more directed to theoretical PIM research. A well-accepted theoretical PIM framework is the Keeping, Organising and Re-finding theory (KOR) by Jones [42]. This theoretical framework identifies a PIM behaviour cycle by the linear keeping, organising and re-finding activities. Keeping activities concern decisions about including public information item in the personal information space. When an information item is kept, it needs to be stored. Hereby, an organising activity is invoked which concerns the storage process. In this process a user determines which organisational strategy is best-suited depending on several factors such as the estimated access frequency of the information item or the available time they have to apply an organisational strategy. For example, filing an information item takes more time than piling. Nevertheless, the used organisational strategy in organising activity has consequences for the re-finding activities. Users use different hints (e.g. spatial, time or contextual hints) in the re-finding activity for a given organisational strategy. By means of our user study analysis and the findings of previous enquiries, we observed a commonly used contextual factor in the way users keep, organise and re-find personal information. Related enquiries recognise the importance of contextual factors in keeping activities where among others the relevancy to the current need and the relevancy to future needs are influencing the decision to add an information item to the personal information space. In organising activities, we might see the context dependency in the fact that users create complex and long labels in file systems (i.e. digital and physical) to preserve the contextual factors. At last, our user study revealed that users mainly use these contextual factors provided by the keeping and organising activities to re-find information items. Therefore, we may extend the previously elaborated KOR theory by the statement that all keeping, organising and re-finding activities are context dependent. Although, this context dependency is highly used in all three activities, current PIM prototypes do not reflect this factor to support the keeping activity, to support users in organising activities or to help them re-finding personal information in digital and physical information spaces.

The work discussed so far concerns the current users' organisational behaviour. It is well known in behavioural psychology that changing peoples' behaviour might take a lot of effort and time. Indeed, users have been familiar with their own information organisation in piles, mixtures and files over a lifetime. Even if we could provide the ideal PIM system which could keep, organise and re-find personal information in a similar way the human memory does and which would be highly personalised, users might still use their ongoing organised information space. Therefore, a PIM system should augment the currently observed activities besides of providing the ideal solution. Nevertheless, no PIM research or prototypes have been found which provide both visions. Even though interesting attempts have been made to provide the ideal organisation of personal information, they ignore the context dependent aspect. Therefore, we provide a conceptual model of the human memory which may serve as a blueprint for the ideal PIM system design.

Because none of the investigated PIM prototypes fulfils our implementation requirements, we provide the Information Linking and Interaction (ILI) framework. The general architecture of our framework is composed of two independent layers and a plug-in mechanism for user interfaces. The lowest layer is responsible for linking all information items where each association may have a specific relevance weight for a specified context. Information items are also defined in a broad perspective. According to the given conceptual model, information items or resources in the metamodel may be of the types context, concepts and physical/digital objects. Each of these resources may be linked by many-to-many bidirectional links whereby a distinction is made between associative links (between concepts), extent links (between a concept and categorised objects), navigational links (between objects with the purpose to navigate) and structural links (between objects to compose a larger object). Each of these many-to-many bidirectional links offer for each link association the functionality to contain a relevance factor for different contexts. Each resource can also define its relevance in a specified context. In this way, the PIM system has a large graph of all context-dependent linked personal information which can now serve as a basis for the interaction layer. Most provided PIM prototypes use semantic web technologies such as the Resource Description Framework (RDF). Nevertheless, technologies such as RDF have implicit associations which makes the integration of context relevancies hard without hacking the general concept and purpose. In contrast, our metamodel provides weighted associations which allows us to specify a relevance factor on the association between an entity and a context.

At this point, current prototypes stop and just provide an isolated user interface to interact with the constructed graph of information items. However, as we mentioned before, a PIM system should provide the augmentation of current organisational and re-finding behaviour and not only focus on the ideal solution. Therefore, the interaction layer provides the functionality to plug-in several user interfaces on top of the context-dependent associative graph of the personal information space. This approach to PIM system design is novel due to the awareness of the need for multiple user interfaces for different organisational strategies. By the introduction of an intermediate interaction layer, a separation of concerns is introduced between the user interfaces (i.e. information interaction) and the storage of context dependent links. The PIM community might use our framework to implement and evaluate keeping, organisational and re-finding user interfaces without having to concern about the lower-level storage of linked cross-media information.

Last but not least, two examples of user interfaces are given as a proof of concept. We have augmented digital piles with the notion of context-aware desktops where users may construct a different desktop arrangement depending on their current context. Next, physical piles on shelves have been augmented with an LED interface. Due to time constraints, we were not able to evaluate these user interfaces since longitudinal evaluation techniques need to be used in PIM system evaluation enquiries. Nevertheless, they provide a proof of concept that we indeed can augment the current user organisational and re-finding behaviour based on the ILI framework. The vision of the ideal PIM system which keeps, organises and re-finds personal information similar to our human memory is integrated in the ILI framework by providing the implementation of the conceptual human memory model at the link layer. Major challenges raise on the aspect of introducing user interfaces to support all three activities in this ideal viewpoint. Future research needs to be conducted to see how users might interact with their mental model of the personal information space.

8.2 Conclusion

In this thesis we found new insights for future PIM system design. A user study identified a third organisational strategy as mixing besides the well-known piling and filing strategies. We also found that the degree of use of these organisational strategies is independent from each other as well as independent across the digital and physical information space. These insights gave us a first answer in how users currently organise and re-find personal information. Secondly, we have seen that each organisational strategy has different issues and consequences for keeping and re-finding activities across information spaces. Our identified mixing organisational strategy needs to be more enquired to determine such issues and consequence as well as further enquiries are needed to investigate causal relationships and how/why users apply the mixing organisational strategy. Furthermore, the observed independence of organisational strategies concludes that each information space has its own affordances in organising and re-finding strategies and gave the opportunity to define design principles for each individual organisational strategy. Next, we have encountered a common contextual factor which influences the way users keep, organise and re-find personal information. Thereby, we extended the KOR theory with this context dependency. The contextual factor goes hand in hand with the observed context integration applied by the human memory. This ascertainment led to a conceptual model of the human memory which is needed to be able to develop PIM systems in the idealistic viewpoint as an extension of the human memory. Nevertheless, it is hard to change the current organisational and re-finding behaviour of users. In this perspective, we have argued that the ideal PIM system should provide the possibility to augment current users' behavioural strategies and in the meanwhile allow new innovative user interfaces to interact with the context-dependent associative linked graph of a user's mental model. We have proposed an architecture and framework which offers this functionality. By separating the concerns of storage and interactions, the PIM community may use the ILI framework for fast prototyping of different user interfaces to enquire the augmentation of current user behaviour as well as new user interfaces concerning the interaction with a user's mental model. We have presented a novel approach to PIM system design where the ideal organisation viewpoint of the human memory is implemented and which in addition supports the augmentation of current users' organisational and re-finding behaviour. Finally, our presented work raises a lot of new fundamental research questions in descriptive and theoretical PIM research. On the other hand, the ILI framework opens new opportunities for PIM system design and may serve as a basis for a new generation of PIM systems.

8.3 Future Work and Vision

The presented work raises a lot of new opportunities in both descriptive research and PIM system design. Future work may be categorised in four packages. The first package concerns the improvement of storage-level functionality whereas the other three packages focus on the information interaction level. For the first package, a unique resource identification (URI) across devices and information spaces is needed. We also need to take into account that information items may have duplicates and versions with their own extra contextual information such as annotations. A second opportunity is the possibility to automatically share subparts of the large context-dependent associative graph. One should be able to define a subpart and share it with another user and at the same time be able to integrate received graphs from other users. Finally, we may introduce reasoning on the constructed unified personal information graph. By using metadata provided by third-party tools where the information item is stored or tasks are done, we may start to semi-automatically define type classes and relations between these classes. In addition, the context relevance factor of information items may, for example, be deduced from text processing. In this way, links might be automatically created or lead to a recommendation system which could improve the interaction level keeping, organising and re-finding activities.

The second package concerns the interaction possibilities in keeping activities. The previously mentioned recommendation system could be one of the aids to decide which information is best integrated in the personal information space. To help users to determine the value of the encountered information item, we could think of integrating a component in the storage layer which compares the value of the encountered item against the already stored items and across contexts. This could then be used as a feedback to the user where the relevance of the encountered item is given to each context. A second vision is to provide extra user interfaces to enhance the keeping activity. We have seen that users make extensive use of annotations to keep the contextual factors in physical piles and mix. In this case, we may provide a projection on the physical paper with a summarise of the current contextual factors or even deduce extra contextual information from previous made annotations on other papers in the current users context.

Opportunities in organising activities are the focus of the third package. An augmentation of the currently used organisational strategies is necessary to aid the user in their current organisation of their information space. First, we need to find solutions to make the decision of which strategy is best-suited for the information item. Depending on a user's defined organisational behaviour profile and the information item properties such as size, context relevancy and the estimated access frequency, the system may guide the user to apply a piling, mixing or filing strategy. For example, if a user's profile indicates a high use of mixture in bookcases and we know that books are mostly stored in the bookcase, we may provide a projection such as an arrow which indicates free space in a bookcase to place a received book. This place may be identified by the system not only from the fact that there is a free space but also other factors might be taken into account. Factors such as the current ordering of other books, the estimated access frequency of the book or the average contextual relevance to the user's defined context may be included in the guidance of deciding where to place the book. Nevertheless, we also need to provide new innovative organisational strategies to reflect the organisation of information in the way the human memory does. Our presented ILI framework implements this human memory organisational structure but we have faced challenges at the interaction level. How do we visually represent this immense graph of linked information items across information spaces and across information granularities (e.g. concepts and objects)? An option is to experiment with zoomable interfaces and to introduce abstractions of composed links. On the other hand, how do we include the physical space in such a navigational interface? Even if we come up with a good visualisation of the personal information graph, the physical space needs to be represented either by a digital representation or by an augmentation of the physical artefact.

Finally, the fourth package includes opportunities for re-finding activities. Our user study's design principles already gave an initial guidance to augment digital and physical re-finding activities for each used organisational strategy. For example, we might provide tooltips in a digital file system to indicate in which other contexts the digital file is used and what its relevance is to these contexts and the current user's context. In this way, the user may use these contextual hints to improve the search. In the physical mixing strategy, a system may augment the content of ring binders by an indication of time hints such as last accessed or indicate documents which where accessed before and after the current visible document in the ring binder. Since we observed the use of a physical agenda to look up extra time cues, we can, for example, provide a LED to each ring binder and when the user navigates through their agenda, the LED of the ring binder which includes content within the same time interval may light up. In addition, one organisational strategy might include more than one user interface so that the user interface can be adapted to the degree of use of the organisational strategy. For example, a system may include two user interfaces to help users re-finding items in a physical pile. One interface is used when the pile has reached a certain height whereas the other one is used when the desk includes several low piles which are spread out. The first user interface may provide the functionality to virtually navigate through the pile in thin air without really needing to navigate through the physical version of the pile. Nevertheless, this augmentation would not be the best-suited for small piles as users do not experience any issue with traversing small piles. Therefore, the second user interface may provide a sound under each low pile on the desk. When a user searches an item forming part of one of the desk piles, the sound may indicate the pile to navigate through in order to re-find the information item.

These opportunities represent only a start for future research. By the fact that the piling, mixing and filing organisational strategies are independent from each other within and across digital and physical information spaces, a user's organisational behaviour needs to be described in terms of the degree all three organisational strategies are used in both information spaces. As a consequence, we step away from the categorical organisational behaviour paradigm where users are categorised in pilers and filers. We even went a step further and identified that all PIM activities, including the organisational strategies, are influenced by the surrounding contextual factors in which these activities take place. This is of fundamental value for understanding users' current organisational and re-finding behaviour in personal cross-media information spaces. Such an understanding is needed in order to develop innovative PIM systems which provide support for current organisational behaviour in organising and re-finding personal information. At the same time, PIM system design needs to strive for the ideal vision of organising personal information in a similar way as our human memory. Our new conceptual human memory model can be used as a blueprint for future descriptive enquiries and PIM system design within this ideal research vision. Besides the descriptive and theoretical contributions, our presented ILI framework might serve as a basis for a new generation of PIM systems for personal cross-media information spaces. Last but not least, our unified perspective on personal information management resulted in new fundamental research challenges which we are planning to address in the near future.

A
Case Study Protocol

A.1 Research Goal

Previous descriptive enquiries in PIM research identified two organisational strategies (i.e. piling and filing) which are used in digital as well as physical information spaces. Each organisational strategy has its consequences for users behaviour in re-finding activities. Besides the relation between the used organisational strategy and applied re-finding activity, a moderate factor of frequency access may be identified. Nevertheless, all descriptive enquiries are conducted within a narrow research context. The research contexts of previous enquires are only including digital or physical information spaces or place focus on a single organisational strategy. This case study will look for generalisation by combining both information spaces in one research context and investigating each organisational strategy inside each information space as well as looking for cross-case coherency and dependencies. The research goal is to determine and validate the affordances of the physical and digital information spaces concerning organising and re-finding personal information.

The research questions are as follow :

- To which degree are the organisation strategies used in both information spaces?

- What are their influences on the degree of re-finding in both information spaces?
- Is there coherency and dependency between both information spaces?
- To which degree is metadata, multi-classification and task management used and desired in both information spaces?

A.2 Literature Review

A.2.1 Organisation Strategies

A pioneer in the research on how people organise their desks is Thomas Malone. In his publication from 1983 [51] he defines two strategies of information organisation namely *filing* and *piling*. Later on, his view is integrated in the research on how people organise information in the digital environment in the form of email [83, 10], files and bookmarks [10].

	Elements titled	Elements ordered	Groups titled	Groups ordered
Files	Yes	Yes	?	?
Piles	?	No	No	?

Table A.1: Definition of files and piles as cited in [51]

In Malone's approach individual elements are seen as information carriers (e.g. paper) or they can be a larger object which could contain elements (e.g. folder). Furthermore, groups are defined as grouped individual elements (e.g. grouped folders). These elements can be explicitly titled and systematically ordered in a user-specific way, mostly alphabetically or chronologically. Table A.1 gives the definition of both strategies in terms of the elements and their property. Files are elements which are titled and ordered by the user. Also grouped elements can be seen as a file as long as the whole group is ordered in a systematic order and the group is titled. An example are the old file cabinets where files are ordered and titled but at the same time the entire file cabinet can be titled and being a part of a bigger file system containing ordered file cabinets. In the personal information space it is not always desired to be restricted to filing requirements. In contrast to files, piles are untitled and unordered elements forming a pile. Piles can be ordered in some way but the containing elements cannot. On their turn, elements forming part of the pile can be titled but the whole pile cannot. This implies that a titled pile of documents is not allowed and therefore a filing strategy needs to be constructed of file elements which are at there turn files. Out of this implication, a file cabinet containing labelled and ordered files, these files need to be again containing labelled and ordered papers. Of course those two strategies are not covering all organisation behaviour. An element can be neither a file nor a pile given the example of a titled folder which contains unordered papers. The physical environment represents still an important information space. Although technologies are well-used, paper has affordances which are hard to digitise as it is well suited for reading, annotating, quick and flexible navigation through documents and grouping of papers together [65]. Whittaker and Hirschberg [80] agree with Sellen [65] and confirm that knowledge workers keep large paper archives. Nevertheless, the study shows that only 48% of the archive contains unique documents, the remaining part consists of copies of public data and even unprocessed information. Joining Malone's [51] findings, evidence is given for the use of files and piles. Furthermore, the study marks people as filers or pilers based on the most used strategy. People who tend to file (i.e. filers), collect more information but access it less frequent than people who tend to use more piles (i.e. pilers). A reason for this can be found in the premature filing where filers file information to clear their desks but afterwards the filed information seems to be of no value. In contrast to Kidd [47], the study of Whittaker and Hirschberg found that researchers do archive a lot of information to support the long-term memory. Reasons are the availability, the mistrust of public information and the reminding function of paper. Another perspective is given by Kaye [46] where the study results in other reasons for filing like building a legancy, sharing information, fear of loss of information and the file system is used as an identity construction. Piles are used for several purposes such as the lack of time to process all incoming information due to the information overload and the uncertainty about the future use and value of the gathered information [80]. Piles have advantages in these situations but they also provide a much better reminding function than archives as described by [20, 51, 19, 50, 80]. This reminding function comes alone when the user looks up an information element in the pile. Because of the properties of a pile, the elements are not ordered which means that the user needs to browse through the pile. By being confronted with other information elements in the pile a reminder can be triggered. As mentioned by Sellen [65], this remainding function is one of the affordance of paper in a general context.

Going to the digital environment the piling and filing strategies defined by Malone [51] are also present. The folder hierarchy is an application of the file strategy as the documents are titled and ordered. Even more, each folder is again titled and ordered so that the whole hierarchy is a file system similar to a file cabinet in the physical space. As an extension of Malone's strategies, some researchers have defined more specific used strategies to file documents in the folder hierarchy. Boardmann and Sasse [10] categorised users' filing behaviour in three categories. Total filers file the majority at the moment of creation. Some users leave a little amount of files untitled and are called extensive filers. More exceptional observed organisational behaviour are occasional filers where only 7% of the participants left most files untitled. Additionly, Henderson and Srinivasan [35] found an average of 16% of the participants who where piling files which can be seen as occasional filers in Boardmann and Sasse point of view. Usually piles are created at the desktop or the root of the hierarchy. A disadvantage of the digital pile strategy is the impossibility of easy grouping different formats of files [12]. Besides their support for the filing strategy described by [51], a third strategy namely structuring is perceived. This strategy points out the effort users do in keeping the context of the file. Before or at creation time different folder structures are created and named for the current activity. A consequence of the structuring strategy is a file system which is very narrow and deep. The structuring strategy fits the functionality of a file system imposed by the users. As the file system is not only used for finding back the information item but also as a meta tool and a problem decomposition tool [40]. The meta tool can be seen in the folder hierarchy as the user constructs complex labels and squeeze in the current context of an information item in the folder structure. On the other hand, the decomposition of a problem or project by using the folder hierarchy can be seen as a compensation strategy to preserve the context of the problem/project and their related information items [40]. Looking at the email side users tend more to experience information overload [42]. Therefore, users use email tools with other purpose to which they are designed for. In the core, email tools are developed for asynchonious communication but today they are used for several distinct functionalities [79]. This is referred to as email overload. Users use email as task management joined by a reminding function [12, 79]. The reminding function will decrease when the inbox increases which implies that the inbox is not suited for this functionality. This observation is in agreement with the findings of a piles strategy as the inbox is in its fundamental approach a pile of emails. Even for task management users get stock in many folder structures with the same problems as described for the folder hierarchy although the time stamp is saved and provides a time cue the context of the conversation could be lost when filing the email away. A second additional functionality which contributes to email overload is the personal archive of attachments [79, 12]. Users tend to keep files in attachments for the extra information the email provided and to not be concerned about the classification problem in the folder hierarchy. Nevertheless, because of the integration of these functionalities in the email, fragmentation becomes even a bigger problem. The degree of the used organisational strategy is therefore very diverse depending on which additional functionality the user integrates. A close relationship is found between email and the hierarchical file structure namely duplicating the file structure and keeping copies of files in both systems [10]. As the last research is done by Whittaker in 2006 [79] a current view and the functionality provided by current email tools are not known.

A.2.2 Re-finding

The next step followed after organising information is re-finding the information. Since the purpose of information management is to retrieve the stored information in an easy and flexible manner, this paragraph considers users behaviour and criteria for this purpose. A distinction is made between *finding* and *re-finding* information. Finding information is characterised by the search for certain unprocessed information and where the information target is usually unknown. On the other hand, re-finding information appears after the information is stored and organised by the same user. As the information item has already been processed before, the user has much more meta-data and knowledge about the information target.

In the Human-Computer Interaction community there are two perspectives concerning the future of search engine tools. A group of researchers belief that when search engines are improved to better fit the users information need, all problems of re-finding the information element would be solved. Nevertheless, this perspective has quite some criticism out of other research concerning the re-find behaviour of users. Teevan [73] describes in his paper *The Perfect Search Engine Is Not Enough: A Study Of Orienteering Behavior in Directed Search* that users actually do not use search engines often in their personal information space. Amplifying this statement by the study of Bergman [8] where the findings point out that users only use the search engine as last resort when not remembering the file location. This situation appears only in 25% of the total re-find activities which shows that other re-find strategies are practised. One main strategy is referred to as *orienteering*. Orienteering comes from the game where players need to find a target by navigating through a map of the city. In the digital space this strategy is seen as starting the search at a certain point in an organisation structure (e.g. folder hierarchy) followed by navigating through the structure in a step-wise manner [73]. Teevan's findings about the use of an orienteering strategy as the main used re-finding stratrgy for information retrieval is supported by several other researchers [3, 4, 8]. Nevertheless, why does he all the effort of navigating to the location of the map instead of using the search engine? Several reasons are found for this preference. In cognitive psychology there is a difference between recognition and recall. Recall (i.e. formulating the file name or meta-data about an information item) is more cognitive loaded than the recognition of elements related to a certain information element [75]. Bergman [8] and Teevan [73] both point to this underlying element in the use of an orienteering strategy which is based on recognition. The consistency of the folder hierarchy is stable unless the user re-organise it, contributes to the recognition of a path that leads to the desired information element. Furthermore, the spatial awareness as a natural human behaviour [20] enhances the use of orienteering as the followed path during the step-wise navigation gives the user spatial reference points in the information space. The spatial awareness is totally neglected in the use of current search engines as they display the results in a list without the full path of the folder hierarchy. Also in the use of search engines the consistency is very low as the returned list can give the information items in a random order. A last reason to use an orienteering strategy lies in the way users add additional functionality to the folder hierarchy. As seen before, the folder hierarchy is used for purposes such as keeping the context of the information item and as a project decomposition tool. By using navigation throughout the hierarchy, the hidden information of the context and project choices are available to the user. This in contrast to the use of the search engine where all this relevant metadata is lost. The orienteering strategy is not only used in the file hierarchy. Boardmann [11] conducted a descriptive research in cross-tool environments concluding the use of the orienteering strategy in as well as the file system as the email and bookmark structures. Other research by Henderson [35] inspected the relation between the used organising strategy as files versus piles and the use of a re-find strategy. In both organisation strategies orienteering is the most significantly used re-find strategy. Even in piles where one would intuitively think that a search engine would give advantages, this is not the case. Often the use of piles in the email inbox are already ordered chronologically which is often enough to re-find a related email conversation from where the user can navigate to the needed email.

A.2.3 Cues

Out of the previous literature, three main cues can be derived namely *spatial*, *contextual* and *time* cues. The spatial cue is based on the fact that people use the spatial memory to retrieve information. Even more in the study of Miller [53] there is shown interest in the special property of the 3D physical environment. In his study he points out that the retrieval of information is supported by the natural action of the spatial memory. As cited in [53] an illustration of the natural spatial behaviour is given. A chimpanzee is sitting in front of two boxes, one white box which is at his left side and one black box which is at his right side. The guardian places food in the white box and switches the two boxes so that the white box is at the right side of the chimpanzee. Knowing that chimpanzees can be trained to notice colours, he will choose the black box when searching for food. These findings show that users have the intention to ask where the information is in the space as a natural behaviour. Enhancing previous findings, Jones and Dumais [39] conclusions of their observation study on the spatial metaphor for user interfaces show that for short term retrieval the location aspect is a major advantage to re-find the information item even when the item is labelled. A second cue is the contextual cue that users show to use out of the why they organise information. As mentioned earlier the opportunity to construct complex and large file structures in the folder hierarchy is well used to preserve the context of the information item. The effort that users do to keep the context and the use of the orienteering re-find strategy implies that user put emphasis on a contextual cue. Furthermore, the time cue is reached as shown in the use of the chronologically ordered inbox of email.

A.3 Methodology

The user study may be characterised as an exploratory qualitative research. This research choice is made because our main goal is to evaluate how and why people organise personal information across digital and physical environments. An empirical-analytic case study is established by the described research design.

Design

The research design is an embedded multi-case case study. Figure A.1 illustrates the overall design. Our study's context is given by narrowing to descriptive research in Personal Information Management. This means that the study is placed in context of organising and re-finding issues which users

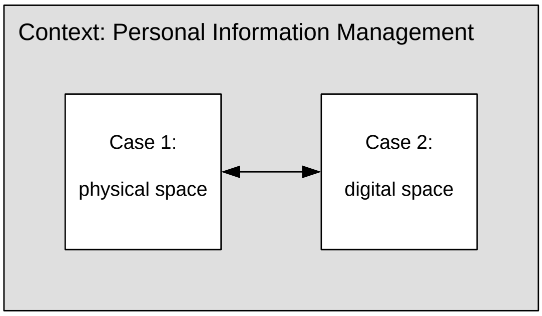


Figure A.1: The case study design

experience on a daily basis. Due to our interest in the organisation and re-finding behaviour of personal information in the digital as well as the physical space, these two spaces are selected as individual cases. The first case (Case 1) studies the user behaviour in physical space whereas case two studies this behaviour in the digital space. By the comparative nature of the research question, a cross-case analysis is performed to identify any coherency and dependencies of user behaviour in organising and re-finding information applied in both spaces. First, the individual cases are investigated independently where for each case a number of hypotheses are formulated based on literature elaborated in the previous section. Secondly, these individual case findings are used in a cross-case analysis. This analysis has the purpose to search for differences and relationships of user behaviour between the digital and the physical information space. Furthermore, the units of analysis within each case are the following:

- The degree of use in piling, mess and filing strategies.
- The degree of use of metadata in organisational and re-finding activities.
- The degree of applied decomposition behaviour.
- The degree of applied orienteering search strategy.
- The degree of use of time, contextual and spatial cues in re-finding activities.

Validity is given by several design decisions. The use of contradictory logic in multi-case design enhances the external validation of the work. By analysing both information spaces and their coherency, analytic generalisation may be enlarged to the level of cross-media information spaces. Note that previous research was limited to the level of individual analysis of these spaces which makes the contribution of this study of great informative value. Internal validation is provided by inducting hypotheses processing and the use of explanation building in the data analysis phases. Additionally, the carried out pilot study contributes to the internal validity. At last, the practice of a case study protocol and use of centralised data collection provide a greater reliability.

Research Agenda

Date	Activity
Nov-Dec '12	Defining hypotheses
Jan-Feb '13	Defining survey questions
4-10 Feb '13	Pilot survey
28 Feb '13	First send-out
2 Mar '13	Published on WISE website
5 Mar '13	Published VUB newsletter
28-31 Apr '13	Flyers at CHI 2013 conference
26 Jun '13	Last call sent out
07 Jul '13	Survey off-line
8-24 Jul '13	Data analysis
5-8 Aug '13	Report in thesis
18-19 Aug '13	Updated protocol

Table A.2: Research agenda until August 2013

Research Instruments: Phase 1

In a first phase, we will determine to which degree users apply organisational strategies and which re-finding cues are used by the different organisational strategies. With the results of our individual case analysis, a cross-case analysis is done. In this first phase, we have chosen for an online survey. This survey includes questions related to all units of analysis. In addition, some open-ended questions where of an exploratory nature. They concern including the investigation of tools for easier re-finding information in a file system. To enhance the internal validity, a pilot study was executed with a representative group of nine respondents. Comments where given whereas completion time was measured.

After data collection, we have used various non-parametric statistical tests on the survey data. Because of the qualitative nature of the study, all parametrised and normalised statistical tests where not applicable. Most survey questions are on ordinal data level (e.g. on a 5 point Likert scale) and therefore do not fulfil parametrised tests conditions. To identify correlations between factors, Spearman's rho (ρ) is used because of the ordinal factors [71]. All correlations included in the discussion of the results are significant in terms of the p-value at a minimal level of 0.05 ($p < 0.05$). Secondly, to identify a significant difference between factors, the Wilcoxon Signed Rank Test (z-value) is being used because of the ordinal data [85]. This test compares two related samples and identifies if the mean is moved to the positive or negative side of the initial ordinal data distribution. Again a significance level of 0.05 ($p < 0.05$) is defined on the results. Besides these used non-parametrised statistical tests, frequencies and open-ended questions are interpreted by the use of Toulmin argumentation [74].

A.4 Hypotheses

A.4.1 Degree of Re-finding

Miller [53] points out the use of a spatial cue as a natural behaviour to retrieve information. His findings are supported by Cole [20] where the spatial reference is found to be used in the information retrieval process in office settings. Therefore the hypothesis can be made that the use of a spatial cue will improve the degree of re-finding.

H8 : The use of spatial cues will positively influence the degree of re-finding.

Several researchers in the previously literature point to the use of contextual cues to retrieve information. Their enquiries show that users put a lot of effort in the preservation of the context for easier retrieval of information besides the reason of a better understanding of re-found information [51, 50, 47, 12].

H9 : The use of contextual cues will positively influence the degree of re-finding.

People remember events which happened at a certain time interval in their life. Even if the exact event related to the needed information item is not known, a related event in the same time interval may be a trigger to re-find the exact event [42]. This results in the hypothesis that users apply time cues which increases the degree of successfully refound information.

H10 : The use of time cues will positively influence the degree of re-finding.

A.4.2 In-Case Hypotheses

By the affordances of paper, paper is easy to group together and to move in physical space [65]. Following the pile definition [51], piles are constructed out of elements such as paper documents and these elements are not specifically labelled or ordered. Therefore, the affordances of paper will contribute to the use of piles and the neither file nor pile strategy as this strategy is just a titled pile which is titled.

H1a : The affordances of paper will positively influence the use of piles.
H1b : The affordances of paper will positively influence the use of neither files nor piles.

The importance of spatial references is supported by Cole [20] in his research on human aspects in office filing. A file system in a 3D space has spatial reference points which compensate the categorical classification problem. In contrast, piles provide much more spatial references than a file system and therefore the recall of an information item in a pile is stronger based on the spatial information. Also given by [29] spatial references are not enough to retrieve long-term information which is stored in file systems. Support is also given to the statement of the importance of the spatial references for information retrieval from piles. The use of a spatial cue will be increased by the use of a neither file nor pile strategy because of the combination of a pile label with the spatial reference contributions of piles. Going to the digital space the same argumentation can be found as the concept of a pile and files do not change. Nevertheless, the spatial restriction of a two-dimensional space will decrease the spatial reference points of piles where the use of a spatial cue will be less. The same can be seen for the neither file nor pile strategy. On the other hand, the file system provides more spatial references as seen in the physical space and the digital piles. A user can easily navigate through the structure of labelled elements and the path which is followed can be displayed.

H2a : The use of piles will positively influence the use of spatial cues.
H3a : The use of neither file nor piles will positively influence the use of spatial cues.
H4a : The use of files will negatively influence the use of spatial cues.
H5a : The use of digital piles will negatively influence the use of spatial cues.
H6a : The use of digital neither file nor piles will negatively influence the use of spatial cues.
H7a : The use of digital files will positively influence the use of spatial cues.

As highlighted by several researchers [20, 51, 50], a mismatch between the moment of filing and the later retrieval can be identified. This mismatch appears when the item is needed in a different context than at the filing moment and at retrieval time the user is not aware of the file label used in a previous context. Lansdale [50] enhanced this view with the difficulty of using words for formal classification stated by the fact that a word can have many meanings and a description may be referred to in many distinct words. In contrast, piles can be used for the preservation of the context of the information compared to files where the context of the label created at the time of filing is not preserved [50]. By ordering a group of unordered elements in a contextual way, the context can be used as a cue for retrieval. Several researchers share these findings and point out that the context cue is one of the main advantages of the human memory for recall [51, 50, 47, 12]. Out of this, there can be seen that the use of piles and the strategy of neither file nor pile give an increased use of the contextual cues. This compared to the file strategy where the context is not preserved and so it will have a negative influence on the use of the contextual cue. Going to the digital space, the non-spatial restrictions compared with the physical environment are an advantage for the filing strategy. The naming and overall structure of the file system is more complex than in the physical space [12]. Indeed there are less restrictions on the name length (e.g. 255 characters in NTFS) as in the physical environment where the length is limited by the spatial property of the label and the breath and depth of a hierarchy is not restricted by spatial limitations. Due to the loss of context by simply naming a document or folder, users tend to construct complex labels and squeeze the current context into the folder hierarchy [40]. It can be stated that in the digital space the use of piles, the use of the neither file nor pile strategy and the use of the filing strategy increases the use of the contextual cue.

H2b : The use of piles will positively influence the use of contextual cues.
H3b : The use of neither file nor piles will positively influence the use of

contextual cues.
H4b : The use of files will negatively influence the use of contextual cues.
H5b : The use of digital piles will positively influence the use of contextual cues.
H6b : The use of digital neither file nor piles will positively influence the use of contextual cues.
H7b : The use of digital files will positively influence the use of contextual cues.

Finally, a pile and a neither file nor pile are often implicitly ordered in a chronological order. This is due to the spatial properties of these strategies where the oldest information element lies underneath the more recent ones.

H2c : The use of piles will positively influence the use of time cues.
H3c : The use of neither file nor piles will positively influence the use of time cues.
H5c : The use of digital piles will positively influence the use of time cues.
H6c : The use of digital neither file nor piles will positively influence the use of time cues.

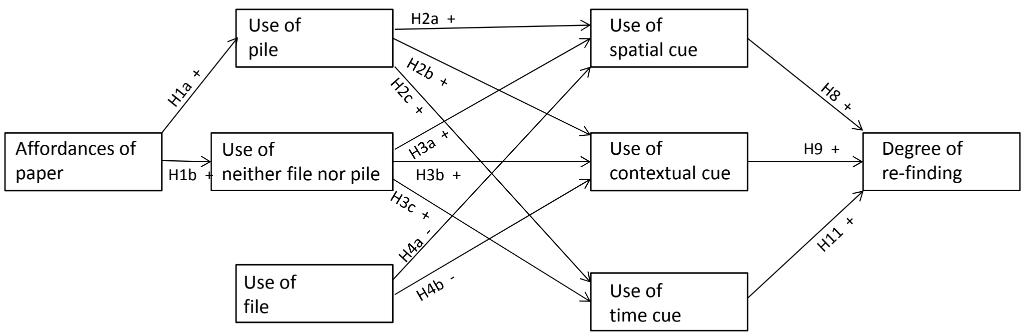


Figure A.2: Conceptual model of the physical space

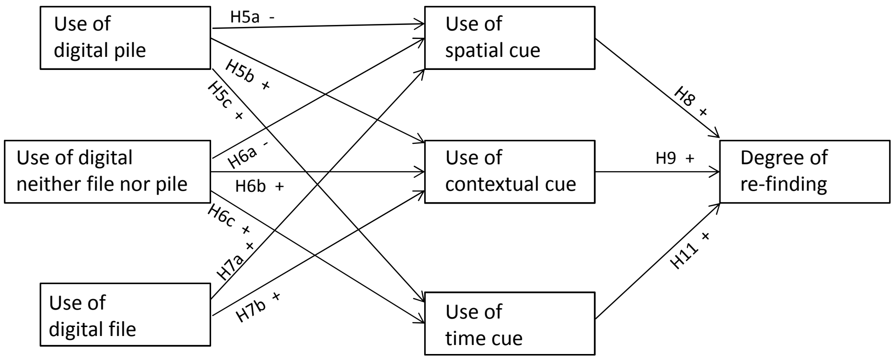


Figure A.3: Conceptual model of the digital space

A.4.3 Cross-Case Hypotheses

The affordances of paper are easily grouping of several papers and easily navigating through grouped papers [65]. In re-finding activities, a reminder may be triggered whereas the spacial arrangement of piles provides a contextual cue. In contrast to physical piles, digital piling does not allow such spatial arrangement. Navigation through digital piles will only display the labels of the digital file and not an overview of the content itself. Therefore, the reminder functionality may be much less than observed in physical piling. By this lack of spatial arrangement and reminder functionality in digital piles, we may hypothesise that they will be less used than physical piles.

H1: The degree of physical pile use is higher than the degree of digital pile use.

The folder strategy has not been well-discussed till now in past research. Nevertheless, we may hypothesise that physical folder use may be more than digital folder use. Because of the possibility to spatially arrange labelled grouped papers and the use of ring binders with unordered content, physical folders may easily be constructed. In digital space, folders may only be constructed by automatically labelled digital files which are placed in a labelled digital folder. This is in contrast to the physical space, where the user has much more opportunities to apply the folder strategy.

H2: The degree of physical folder use is higher than the degree of digital folder use.

The last organisational strategy observed in both spaces is filing. By the spatial restriction of the physical space to apply filing and the unlimited reusability of digital file systems, physical filing may be less used than digital filing.

H3: The degree of physical file use is less than the degree of digital file use.

The digital space may provide better support for metadata integration. It is often easy to annotate content in digital files whereas extra contextual information of digital files is available in file properties which are automatically extracted. In contrast, physical annotations require space in documents such as margins and often additional paper notes need to be created in order to provide metadata for a the document. Automatically extracting contextual information may not be applied. A good example is the creation of labels for filing strategies. In both information spaces, users create long and fuzzy labels to preserve some contextual information of the document or file. By the less spatial restrictions in label length in digital filing strategies, these labels may be longer than in physical filing strategies. Therefore, digital file labels may contain more metadata.

H4: The degree of metadata integration is higher in the digital space than the physical space.

As shown by [40], the digital file system is also used for problem/project decomposition. This is done by constructing subtrees for each project and parts of a project. It may be harder to apply such a structuring in physical file systems since it takes much more effort to create new physical files and re-arrange the filing structure than the copy/paste functionality provided in digital file systems.

H5: The degree of problem/project decomposition is higher in the digital space than the physical space.

We may hypothesise that orienteering is more used in digital information spaces than in physical information spaces. Users mostly apply orienteering in digital space to re-find information in a digital filing strategy [73]. This behaviour is not yet well enquired in the physical space. However, the larger amount of available contextual information in the digital file system, such as longer labels and project decomposition behaviour, may imply a greater use of orienteering than in the physical space.

H6: The degree of orienteering is higher in the digital space than the physical space.

Digital files often contain additional automatically extracted metadata such as timestamps. In physical space users need to do an effort to create such timestamps and integrate them in document annotations. This overhead in the context of a user may indicate that a time cue in re-finding activities is much less used in physical space than in the digital space.

H7: The degree of time cues use is higher in the digital space than the physical space.

Contextual information may be preserved in several organisational strategies. In the physical space the context may be preserved in the spatial arrangement of physical piles whereas this is lacking in digital piling. In contrast, the digital file system provides more possibilities to preserve the context than in physical filing by its affordance of creating longer labels and project decomposition. This leads us to a similar use of contextual cues in both information spaces.

H8: The degree of contextual cues use is the same in the digital space and the physical space.

Cole [20] indicates that physical piles provide much more spatial reference points than a physical file systems. The 3D environment of the physical space implies the construction of spatial references on three axes. In contrast, the digital space is restricted to 2D spatial reference points which implies less efficiency in locating an item than in a 3D environment. Therefore, we may hypothesise that spatial cues in a re-finding activity an more applied in the physical information space than the digital information space.

H9: The degree of spatial cues use is lower in the digital space than the physical space.

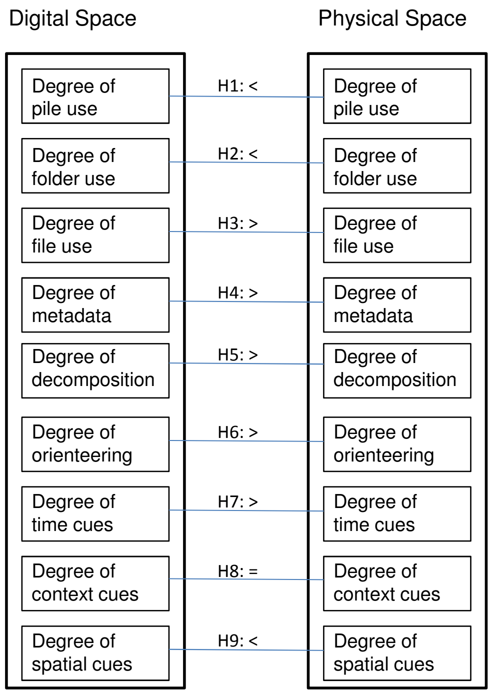


Figure A.4: Conceptual cross-case space model

A.5 Phase 1: Survey

Participants

A case study must be conducted on a representative group of the global context subjects. Because Personal Information Management is a concern of all participants in the society, the community has agreed upon population representativeness by limiting the context of inquiry to knowledge workers. Knowledge workers are seen as a population which uses a large amount of personal information. If the results are significant for this population then they are also significant for less extensive information users. Therefore, we have defined the representative population by users who are professor, post-doctoral researchers, PhD students and university students.

Pilot Enquiry

Results and evaluation available in paper form (strullem@vub.ac.be).

Mapping Hypotheses and Questions

	Hypothesis	Questions
Re-finding	H8	C.5.1, C.2.2, C.2.3, C.2.4
	H9	C.5.1, C.3.1, C.3.2, C.3.3
	H10	C.5.1, C.4.1, C.4.2, C.4.3
In-Case	H1a	A.1.1, A.1.2, A.1.3, A.1.4, A.2.8, C.5.5
	H1b	A.2.8, C.5.5
	H2a	A.1.1, A.1.2, A.1.3, A.1.4, A.2.8, C.4.1
	H3a	C.2.8, C.4.1
	H4a	A.3.1, A.3.2, A.2.8, C.4.4
	H5a	A.1.5, C.4.2, C.4.3
	H6a	A.1.8, C.4.2, C.4.3
	H7a	A.3.4, A.3.5, C.4.2, C.4.3
	H2b	A.1.1, A.1.2, A.1.3, A.1.4, A.2.8, C.3.1, C.3.3, B.1.5, B.2.1
	H3b	C.2.8, C.3.1, C.3.3, B.1.5
	H4b	A.3.1, A.3.2, A.2.8, C.3.1, C.3.2, B.1.5
	H5b	A.1.5, C.3.1, C.3.3, B.1.5
	H6b	A.1.8, C.3.1, C.3.3, B.1.5
	H7b	A.3.4, A.3.5, C.3.1, C.3.2, C.3.3, B.1.5
	H2c	A.1.1, A.1.2, A.1.3, A.1.4, A.2.8, C.2.2, C.2.3, C.2.4
	H3c	C.2.8, C.2.2, C.2.4
	H4c	A.3.1, A.3.2, A.2.8, C.2.2, C.2.4
	H5c	A.1.5, C.2.2, C.2.4
	H6c	A.1.8, C.2.2, C.2.4
	H7c	A.3.4, A.3.5, C.2.2, C.2.4
Cross-Case	H1	A.1.1, A.1.2, A.1.3, A.1.4, A.1.5, A.2.8
	H2	C.1.8, C.2.8
	H3	A.3.1, A.3.2, A.3.4, A.3.5, A.2.8
	H4	B.1.1, B.1.2, B.1.3, B.1.4, B.1.5, B.2.1, B.2.2
	H5	B.2.2, B.2.1
	H6	C.4.1, C.4.2, C.4.3
	H7	C.2.1, C.2.2, C.2.3, C.2.4
	H8	C.3.1, C.3.2, C.3.3
	H9	C.4.1, C.4.2, C.4.3

Table A.3: Mapping hypotheses and questions

Welcome,

This survey takes place in the context of research in Personal Cross-Media Information Management under supervision of Prof. Beat Signer.

The inquiry investigates the daily interaction with information carriers such as paper, books, digital documents and emails.

Thank you for the participation,

Sandra Trullemans

WISE Lab

Vrije Universiteit Brussel

For additional information please contact: Sandra.Trullemans@vub.ac.be

There are 59 questions in this survey

A.0

General information

1 [A.0.1]What is your gender?

Please choose **only one** of the following:

- ○ Female
- ○ Male

2 [A.0.2]Please enter your date of birth.

Please enter a date:

[ ]

3 [A.0.3]In which country do you live?

Please choose **only one** of the following:

- ◯ Belgium
- ◯ Netherlands
- ◯ Switzerland
- ◯ United Kingdom
- ◯ Other ______

4 [A.0.4]What is your current academic position? Please also enter the number of years that you hold this position (in the text field).

Please choose all that apply and provide a comment:

- ☐ Professor ______
- ☐ Postdoc ______
- ☐ PhD student ______
- ☐ Master student ______
- Other: ______ ______

A.1

Use of piles

5 [A.1.1]

To which degree do you have piles of documents on your desk?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

6 [A.1.2]Give the average number of piles of documents on your desk.

Please write your answer here:

7 [A.1.3]

To which degree do you have piles in bookcases or on shelves?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

8 [A.1.4]Give the average number of piles in bookcases or on shelves.

Please write your answer here:

9 [A.1.5]

To which degree do you use digital piles?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

10 [A.1.6]Do you use any tools to create and manage digital piles?

Only answer this question if the following conditions are met:
° Answer was greater than or equal to at question '9 [A.1.5]' (To which degree do you use digital piles? (1 = not at all - 5 = to a high degree))

Please choose **only one** of the following:

- ○ Yes
- ○ No

11 [A.1.7]Can you briefly explain the used tools?

Only answer this question if the following conditions are met:
° Answer was 'Yes' at question '10 [A.1.6]' (Do you use any tools to create and manage digital piles?)

Please write your answer here:

12 [A.1.8]

To which degree do you use labelled digital folders where the containing files have been automatically named without a specific meaning of the name? (e.g. import of pictures from a digital camera)

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

A.2

Use of ring binders, file boxes and letter trays.

13 [A.2.1]

To which degree do you use <u>labelled</u> ring binders?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

14 [A.2.2]

To which degree do you use <u>unlabelled</u> ring binders?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

15 [A.2.3]

To which degree do you use <u>labelled</u> file boxes/folders?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

16 [A.2.4]

To which degree do you use unlabelled file boxes/folders?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- 1
- 2
- 3
- 4
- 5

17 [A.2.5]

To which degree do you use labelled letter trays?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- 1
- 2
- 3
- 4
- 5

18 [A.2.6]

To which degree do you use unlabelled letter trays?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- 1
- 2
- 3
- 4
- 5

19 [A.2.7]

To which degree do you use <u>labelled</u> shelves?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

20 [A.2.8]

Consider only the <u>unlabelled</u> ring binders, file boxes/folders and letter trays with their content. Please specify the level of use for the following ordering strategies.

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Very often
The content is explicitly ordered and each document, note,... is labelled.	○	○	○	○	○
The content is explicitly ordered but the documents, notes,... are not labelled.	○	○	○	○	○
The content is semi-ordered. For example, the content is separated by index tabs but the content for a given index tab is not explicitly ordered.	○	○	○	○	○
The content is not ordered.	○	○	○	○	○

A.3

Use of filing

21 [A.3.1]

To which degree do you use <u>physical</u> classification systems?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

22 [A.3.2]

Give the average number of different <u>physical</u> classification structures you use. For example, one may have a classification structure for student records and a different classification structure for research papers.

Please write your answer here:

23 [A.3.3]Which storage artefacts do you use?

Please choose **all** that apply:

- ☐ file cabinets
- ☐ bookcases
- ☐ ring binders
- ☐ file boxes/folders
- ☐ drawers
- ☐ Other:

24 [A.3.4]

Give the average number of different digital classification structures you use. For example, one may have a classification structure for student records and a different classification structure for research papers.

Please write your answer here:

25 [A.3.5]

How many different digital classification hierarchies do you use? For example, one may use a separate classification hierarchy for files, emails or bookmarks.

Please write your answer here:

26 [A.3.6]Which classification hierarchies do you use?

Only answer this question if the following conditions are met:
° Answer was greater than at question '25 [A.3.5]' (How many different digital classification hierarchies do you use? For example, one may use a separate classification hierarchy for files, emails or bookmarks.)

Please choose **all** that apply:

- ☐ file hierarchy
- ☐ email hierarchy
- ☐ bookmark hierarchy
- ☐ Other:

27 [A.3.7]

To which degree do you experience difficulties in switching between these different hierarchies?

(1 = not at all - 5 = to a high degree)

Only answer this question if the following conditions are met:
° Answer was greater than at question '25 [A.3.5]' (How many different digital classification hierarchies do you use? For example, one may use a separate classification hierarchy for files, emails or bookmarks.)

Please choose **only one** of the following:

- 1
- 2
- 3
- 4
- 5

B.1

Use of metadata

28 [B.1.1]

To which degree do you annotate the following items?

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Very often
documents, books or other physical artefacts	○	○	○	○	○
digital content	○	○	○	○	○

29 [B.1.2]Please set the level of use for the following annotation methods.

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Very often
I annotate directly in paper documents.	○	○	○	○	○
I annotate directly in books.	○	○	○	○	○
I use Post-it notes to annotate physical documents.	○	○	○	○	○
I use loose notes to annotate physical documents.	○	○	○	○	○
I use digital notes to annotate physical documents.	○	○	○	○	○
I use digital notes to annotate digital content.	○	○	○	○	○
I use physical notes to annotate digital content.	○	○	○	○	○

30 [B.1.6]Do you use tools/technologies to link your physical annotations to the digital content?

Only answer this question if the following conditions are met:
° Answer was 'Rarely' or 'Sometimes' at question '29 [B.1.2]' (Please set the level of use for the following annotation methods. (I use physical notes to annotate digital content.)) *and* Answer was 'Rarely' or 'Sometimes' at question '29 [B.1.2]' (Please set the level of use for the following annotation methods. (I use physical notes to annotate digital content.))

Please choose **only one** of the following:

- ○ Yes
- ○ No

31 [B.1.7]Can you briefly explain the used tools/technologies?

Only answer this question if the following conditions are met:
° Answer was 'Yes' at question '30 [B.1.6]' (Do you use tools/technologies to link your physical annotations to the digital content?)

Please write your answer here:

32 [B.1.2.a]Do you use other annotation methods?

Please choose **only one** of the following:

- ○ Yes
- ○ No

33 [B.1.2.b]Can you briefly explain these other annotation methods?

Only answer this question if the following conditions are met:
° Answer was 'Yes' at question '32 [B.1.2.a]' (Do you use other annotation methods?)

Please write your answer here:

34 [B.1.4]

To which degree do you actively make use of the annotations?

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Very often
in documents, books or other physical artefacts	○	○	○	○	○
in digital content	○	○	○	○	○

35 [B.1.3]What is the average length of the labels you create?

Please choose the appropriate response for each item:

	Up to 7 characters	Up to 25 characters	More than 25 characters
in your physical classification systems	○	○	○
in your digital classification systems	○	○	○

36 [B.1.5]For which purposes do you use annotations?

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Very often
I annotate physical documents to better understand the content.	○	○	○	○	○
I annotate digital documents to better understand the content.	○	○	○	○	○
I annotate physical documents to re-find the document.	○	○	○	○	○
I annotate digital documents to re-find the document.	○	○	○	○	○
I annotate physical documents with reminders.	○	○	○	○	○
I annotate digital documents with reminders.	○	○	○	○	○

B.2

Use of decomposition.

37 [B.2.1]

To which degree do you agree with the following statement. *"I arrange piles on my working surface depending on the task I am currently working on."*

(1 = strongly disagree - 5 = strongly agree)

Please choose **only one** of the following:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

38 [B.2.2]How easy can you re-arrange/modify the following organisational structures?

Please choose the appropriate response for each item:

	Very easy	Easy	Moderately	Hard	Very hard
piles on your desk	○	○	○	○	○
your physical classification system (e.g. re-arranging your ring binders for a new project)	○	○	○	○	○
your digital classification system (e.g. modifying your file system for a new project)	○	○	○	○	○

C.1

Use of extra tools

39 [C.1.1]

To which degree do you use extra tools to organise your physical classification systems? This could for example be an index for your physical classification system as used in libraries or the use of digital tools which give support to organise your physical classification system.

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

40 [C.1.2]Can you briefly explain the used tools?

Only answer this question if the following conditions are met:
° Answer was greater than or equal to at question '39 [C.1.1]' (To which degree do you use extra tools to organise your physical classification systems? This could for example be an index for your physical classification system as used in libraries or the use of digital tools which give support to organise your physical classification system. (1 = not at all - 5 = to a high degree))

Please write your answer here:

41 [C.1.3]

To which degree do you use extra tools to organise your digital classification systems?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- 1
- 2
- 3
- 4
- 5

42 [C.1.4]Can you briefly explain the used tools?

Only answer this question if the following conditions are met:
° Answer was greater than or equal to at question '41 [C.1.3]' (To which degree do you use extra tools to organise your digital classification systems? (1 = not at all - 5 = to a high degree))

Please write your answer here:

C.2

Use of time cues

43 [C.2.1]

How often do you use the following items to look up information?

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Very often
your physical agenda or calendar	○	○	○	○	○
your digital agenda or calendar	○	○	○	○	○

44 [C.2.2]

To which degree do you use timestamps (e.g. date/year) as annotation?

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Very often
in documents, books or other physical artefacts	○	○	○	○	○
in digital content	○	○	○	○	○

45 [C.2.4]

To which degree do you re-find information by using timestamps (e.g. date/year)?

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Very often
in documents, books and other physical artefacts	○	○	○	○	○
in digital content	○	○	○	○	○

46 [C.2.3]

To which degree do you use the implicit chronological order in piles?

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

C.3

Use of contextual cues

47 [C.3.1]

To which degree do you re-find information by using annotations?

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Very often
in documents, books or other physical artefacts	○	○	○	○	○
in digital content	○	○	○	○	○

48 [C.3.2]

To which degree do you use the meaning of previously created labels?

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Very often
in your physical classification systems	○	○	○	○	○
in your digital classification systems	○	○	○	○	○

49 [C.3.3]

To which degree do you re-find by using the meaning associated with the documents organised in piles?

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Very often
of piles on your desk	○	○	○	○	○
of piles in bookcases or on shelves	○	○	○	○	○
of your digital piles	○	○	○	○	○

C.4

Use of spatial cues

50 [C.4.1]

To which degree do you re-find information by using the physical location of the artefacts? (e.g. you know the information is in a particular bookcase)

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- 1
- 2
- 3
- 4
- 5

51 [C.4.2]

To which degree do you re-find information by using the digital location of digital content? (e.g. you know it is in a particular digital folder)

(1 = not at all - 5 = to a high degree)

Please choose **only one** of the following:

- 1
- 2
- 3
- 4
- 5

52 [C.4.3]To which degree do you agree with the following statements?

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I prefer to navigate through my digital file system instead of using a desktop search tool.	○	○	○	○	○
I only use a desktop search tool when I cannot re-find the information by navigation.	○	○	○	○	○
I have spatial awareness of where I am in my digital file system.	○	○	○	○	○

C.5

Ease of re-finding

53 [C.5.1]

How easy do you re-find information by using the following hints?

Please choose the appropriate response for each item:

	Very easy	Easy	Moderately	Hard	Very hard
temporal hint	○	○	○	○	○
contextual hint	○	○	○	○	○
spatial hint	○	○	○	○	○

54 [C.5.2]How easy do you re-find information in the following artefacts?

Please choose the appropriate response for each item:

	Very easy	Easy	Moderately	Hard	Very hard
a pile	○	○	○	○	○
unordered folders	○	○	○	○	○
a bookcase	○	○	○	○	○
a physical classification system	○	○	○	○	○
a digital classification system	○	○	○	○	○

55 [C.5.3]How often do you access the following ordering structures?

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Very often
piles on your desk	○	○	○	○	○
piles in a bookcase or on shelves	○	○	○	○	○
ring binders containing non-explicitly ordered content	○	○	○	○	○
ring binders containing explicitly ordered content	○	○	○	○	○
file boxes/folders containing non-explicitly ordered content	○	○	○	○	○
file boxes/folders containing explicitly ordered content	○	○	○	○	○
your physical classification systems	○	○	○	○	○
your digital classification systems	○	○	○	○	○
digital piles	○	○	○	○	○

56 [C.5.4]To which degree do you agree with the following statements?

Please choose the appropriate response for each item:

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
I use too much paper in my daily work activities.	○	○	○	○	○
I normally only access about 30% of the previously stored digital and physical information.	○	○	○	○	○

57 [C.5.5]How easy is it for you to

Please choose the appropriate response for each item:

	Very easy	Easy	Moderately	Hard	Very hard
group physical documents together	○	○	○	○	○
navigate through a group of physical documents	○	○	○	○	○

C.6

58 [C.6.0]Do you prefer to receive the results of this survey?

Please choose **only one** of the following:

- ○ Yes
- ○ No

59 [C.6.1]Please enter your email address below. According to the privacy conditions, your email address will be kept confidential and only be used to provide you with the results of this survey.

Only answer this question if the following conditions are met:
° Answer was 'Yes' at question '58 [C.6.0]' (Do you prefer to receive the results of this survey?)

Please write your answer here:

Thank you for your participation!

Sandra Trullemans

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For additional information please contact: Sandra.Trullemans@vub.ac.be

Please submit by 01/08/2013 – 00:00

Submit your survey.
Thank you for completing this survey.

B

Vereiste Nederlandstalige samenvatting

Reeds lange tijd consumeren mensen een grote hoeveelheid aan informatie voor persoonlijke doeleinden. Dagelijks ontvangen, opslaan en hergebruiken we informatie. Desondanks de goed ontwikkelde opslagcapaciteit van veel gebruikte technologieën zoals laptops, ontbreekt het ons om gemakkelijk informatie te organiseren. Digitaal zijn we het gebruik van hiërarchische boom structuren in bestandssystemen en het bureaublad gewoon. Daarnaast, wordt er gebruik gemaakt van gelijkaardige organisatie structuren in de fysieke wereld zoals archiefkasten en bureaus. Deze voorgenoemde voorbeelden zijn de twee meest voorkomende organisatie gedragingen namelijk classificatie en stappelen welke formeel beschreven werden door Malone [51]. Een classificatie system kan enkel expliciet geëtiketteerde elementen bevatten welke een expliciete rangorder dienen te hebben. Daarnaast, worden stapels gekenmerkt door het includeren van niet-geëtiketteerde documenten welke niet expliciet gerangschikt mogen zijn. Het probleem dat aangekaart werd in dit afstudeerwerk, is dat gebruikers ook andere organisatie structuren gebruiken dan classificatie en stapels. Een voorbeeld is een geëtiketteerde ringmap waar niet gerangschikte documenten in zitten. Deze structuur kan niet benoemd worden als classificatie of stapels door de voorgenoemde formele definitie. Verder is er al sinds de jaren zestig erkent dat gebruikers regelmatig weinig of geen moeite doen om informatie te organiseren doordat het enige cognitieve belasting en tijd vergt. Hierdoor vinden we geregeld niet de juiste informatie terug en wordt terugvinden een hele opgave. Het verbeteren van organisatie activiteiten en het terugvinden van persoonlijke informatie is het onderzoeksonderwerp van Persoonlijk Informatie Beheer (PIB).

Verschillende onderzoekers hebben reeds prototypes ontwikkeld die het toestaan de gebruiker informatie te organiseren en terug te vinden op eenzelfde manier als het menselijk geheugen. Toch gebruiken we nog steeds het digitale bestandssysteem en vele onder ons ondervinden nog steeds moeilijkheden met het terugvinden van fysieke voorwerpen. Om meer inzicht te verkrijgen in deze observatie van huidig informatie gedrag en de ontbrekende formele beschrijving van organisatie strategieën naast classificatie en stapels, is er in dit afstudeerwerk een gebruikersstudie gedaan. Tegengesteld aan voorafgaande gebruikersstudies wordt er in onze studie vooral gekeken naar de verschillen en afhankelijkheden tussen de digitale en fysieke informatie omgeving. De resultaten tonen aan dat gebruikers de drie organisatie strategieën onafhankelijk van elkaar gebruiken en dit in dezelfde maten in beide informatie omgevingen. Ook hebben we kunnen vaststellen dat iedere strategie in elke informatie omgeving leidt tot een ander gebruik van hints in het terugvinden van informatie fragmenten. Zo wordt tijdens een zoek activiteit in fysieke stapels vooral gebruik gemaakt van ruimtelijke en contextuele hints. In tegenstaande tot fysieke stapels, wordt er in digitale stapels vooral beroep gedaan op enkel contextuele hints. Naast deze ontwerp principes hebben we een matrix gedefinieerd om een gebruikersgedrag te kunnen definiëren. Door de onafhankelijkheid van het gebruik van de drie organisatie strategieën in beide informatie omgevingen, kunnen we een gebruikersgedrag definiëren door de graad van gebruik voor elk van de strategieën te bepalen. Hierdoor wordt een gebruiker niet meer gecategoriseerd in classificators of stapelers als in voorafgaand onderzoek maar door een gebruikersprofiel. De fundamentele uitkom van deze bevindingen hebben het mogelijk gemaakt om een theoretisch model te beschrijven omtrent crossmediale PIB activiteiten. In dit model wordt er aangemerkt dat elke PIB activiteit (i.e. houden, organiseren en terugvinden) contextueel beïnvloed wordt en dat de contextuele factoren van groot belang zijn in de effectiviteit van terugvind activiteiten.

Naast de descriptieve en theoretische bijdragen presenteren we het Informatie Linking en Interactie raamwerk (ILI). Het doel van dit raamwerk is het aanreiken van een system waar huidig organisatie gedrag technologisch ondersteund kan worden. Dit kan in de praktijk uitmonden tot augmentaties van huidige organisatie strategieën zoals fysieke stapels. Daarnaast, moet het raamwerk ook de mogelijkheid bieden om innovatieve gebruikersinterfaces te ontwikkelen die het toestaan om informatie fragmenten te organiseren en tergu te vinden op eenzelfde manier als het menselijk geheugen. ILI is gebaseerd op het Resource-Selector-Link (RSL) hypermedia metamodel en biedt de mogelijkheid om digitale alsook fysieke media maar eveneens geselecteerde gebieden in deze media te organiseren door het aanmaken van links tussen media elementen en semantisch gedefinieerde concepten. De voornaamste bijdrage bevindt zich in het toestaan van het uitdrukken van een zekere context relevantie voor ieder informatie deeltje. Ook geven we de gebruiker de mogelijkheid om de relevantie van de relatie tussen twee informatie deeltjes te laten definiëren voor verscheidene contexten. Naast de functionaliteit om informatie deeltjes te linken voorzien we ook een interactie laag. Deze laag voorziet een basis voor de vele gebruikersinterfaces. Dit leidt ons naar een uitbreidbaar en gebruikersgericht raamwerk in plaats van een geïsoleerd systeem. Als bewijs van toepassing werden er twee gebruikersinterfaces geïmplementeerd namelijk digitale context-aware bureaubladen en een geaugmenteerde boekenkast door het gebruik van LEDs. Het gepresenteerde werk opent vele nieuwe fundamentele onderzoeksvragen in zowel descriptief als theoretisch onderzoek en voorziet een mogelijke basis voor een nieuwe generatie PIB systemen.

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